In the manufacture of this book, the publishers have observed the recommendations of the War Production Board and any variation from previous printings of the same book is the result of this effort to conserve paper and other critical materials as an aid to war effort.

HANDBOOK
OF PLASTICS

By

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Editor of Plastics News Letter, Plastics World and
Plastics Supplement of Thomas' Register

AND

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PREFACE

For some years technical workers in various branches of the plastics industry have expressed a desire for a comprehensive reference work that would treat of the details of the subject in one volume. The authors of this book perceived this need and early in 1940 prepared the original outline of the text at the Cape Cod residence of Carleton Ellis. To test the plan, several sections — notably those on plasticizers, pigments and solvents — were prepared and filed in the library of the Ellis Laboratories. The research staff of the laboratories found an immediate value in the classified lists and when the practical use of the typed sections was definitely established, it was decided to start in earnest on the preparation of the full manuscript.

At this point an idea developed which has proved to be one of the pleasantest and most helpful of the entire project. This was to invite representative technical men in the industry to form an advisory committee to assist and guide the authors in the determination of the contents of the book. The enthusiasm of the response to this invitation is indicated by the list of members of this committee which appears on a following page. However, the list by itself does not indicate fully the nature of the generous and extensive assistance given by the members of this committee and the gratifying encouragement that the authors received from the large manufacturers of plastics. The Handbook will be of substantially greater value to the industry as a result of the advice and suggestions of these men; its contents are to a very real degree the result of the cooperation and advice of key men in the industry.

The book is designed to present exhaustively and yet with proper selection the fundamental basis and technology of the plastics industry. It contains nine major sections; to enumerate these in this preface would be superfluous. It is enough to say that the authors intend that these sections should cover fully the present state of the industry, the physical and chemical properties of plastics, their production, manufacture and finishing, and all of the useful information which anyone working with plastics in any part of the industry or anyone desiring full and complete information on plastics should find in a well organized and thorough treatment of the subject. To achieve this aim has been a stupendous task and the authors are well aware that there are omissions and probably errors. However, the justification for the book can be found in its contents and it is sincerely hoped that it will be a useful and valuable tool that will assist in the development of this dynamic industry.

In January, 1941, when the work on the manuscript was about half finished, Carleton Ellis died. This was a great personal loss as well as a disturbance to the progress of the book.

For about a year, I had worked in close cooperation with Mr. Ellis and during this time had acquired not only respect for his ability and thoroughness,,but affection for him as a friend. I found him always considerate of diverse points of view, and always interested in the value which our work might have for the plastics industry; for it was that industry which was his chief absorption during the last twenty years of his life.

Mrs. Carleton Ellis expressed her desire to have the Handbook completed, following the original plan as closely as possible. At this time Dr. M. H. Bigelow very considerately offered to help. I increased the staff, taking some workers from Ellis Laboratories, and adding others. Renewed requests for assistance sent out to the industry met with prompt and generous response, and as the book goes to press my earnest hope is that Mr. Ellis — meticulous editor that he was — would have been pleased with it.

HERBERT R. SIMONDS

November 15, 1942

CARLETON ELLIS, 1882–1941

While still an undergraduate at Massachusetts Institute of Technology, Carleton Ellis perfected certain commercially successful compositions for removing paint and varnish and thus laid the foundation for a career in chemistry which was to result in the issuance to him of more than 1000 patents. The patent office records show that only two other people ever secured as many.

Soon after graduating, Mr. Ellis, with H. B. Chalmers, started the Ellis Chalmers Company, Boston, a research and manufacturing organization, in which Mr. Ellis worked in many capacities. At different times he was patent attorney for his own developments, a worker in overalls in the factory, and a research chemist.

In 1905 he moved to New York to join the Eldred Process Company, also engaged in research, and in 1907 became president of the Ellis-Foster Company, organized for chemical consulting and research work. In 1909 Mr. Ellis built a laboratory in Montclair, N. J., where he worked during the rest of his life. This laboratory housed the Ellis-Foster Co. as well as a personal company known as the Ellis Laboratories, Inc. The plant grew through the years to include five buildings which housed, in addition to extensive apparatus, a library with few equals in the private research field.

Strangely enough, one of the first items developed by Mr. Ellis in his research work at Montclair was a bone-shaped dog biscuit made from a waste milk product. This was a commercial success from the start.

More recent investigations were almost entirely in the petroleum and synthetic resin fields, although Mr. Ellis was always a man of many hobbies and diverse interests. One particular hobby was the soilless growth of plants, which resulted in the commercial production of a plant hormone and in the publication of a widely read book.

In the early 1920's, Mr. Ellis turned his attention to the cracking of petroleums in the manufacture of gases and discovered the important principle that heating an oil and then allowing it to digest increases the gasoline yield. He perfected this process, now widely used and known as the " tube and tank " process. Other important developments during this period include a process for making higher alcohols and acetone from the cracked gases of petroleum, and various processes for the production of lard and butter substitutes by the hydrogenation of vegetable oils. This led to one of his early important books, " Hydrogenation of Organic Substances."

Another book, written at about this time and called " Chemical Action of Ultra Violet Light," was voted by a committee of the League of Nations to be one of the outstanding books of the year.

Gradually, as Mr. Ellis delved deeper into the chemistry of synthetics, he came to realize that new resins were needed to meet the demands of industry and soon after turning his attention in this direction he discovered a reaction of urea and formaldehyde which became the basis of several patents and several well known products, one being Plaskon, product of the Plaskon Company. Another, Rezyl, made from polybasic acid and polyhydric alcohol, is now manufactured by the American Cyanamid Company.

In 1923, Mr. Ellis wrote the first edition of his monumental work, " The Chemistry of Synthetic Resins." A second and enlarged edition was published in 1935. Mr. Ellis held many honorary and professional positions in chemistry, among which were Recipient of the Edward Longstreth Medal of the Franklin Institute, 1916, Gold Medalist of the Jamestown Exposition, President of the New Jersey Chemical Society, Trustee of the Chemistry Club of New York, and Consultant to the Standard Oil Company.

Following such a record of activity and accomplishment it seemed highly appropriate for the National Manufacturers Association to award him, during the last year of his life, a medal which read:

> " To Carleton Ellis, a modern pioneer on the frontier of American industry, in recognition of distinguished achievement in science which has advanced the American standard of living."

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Wilbur Keegan, formerly director of the Ellis Laboratories at Montclair and now chemist for Sigmund Ullman Division of General Printing Inks, New York, has been associated with the Handbook from its inception.

Helen Frey, one of the young chemists at the Ellis Laboratories, collected and arranged part of the chemical material and also contributed to the preparation of the manuscript.

I also wish to thank Archie J. Weith, Bakelite Corporation, for tireless and painstaking reading of manuscript.

Boonton Molding Company, Tennessee Eastman Corporation, Bakelite Corporation, The American Society for Testing Materials, and the American Institute of Chemical Engineers gave special permission to reprint data. Appreciation is extended to *Chemical and Metallurgical Engineering* and to *Modern Plastics.*

Dr. M. H. Bigelow became co-author after the death of Mr. Ellis.

HERBERT R. SIMONDS

TABLES OF CONTENTS

For convenience in using this handbook it is important to note the arrangement of contents. Two tables are presented here. The first is a brief outline and the second is a detailed listing of entire contents under the various headings. In addition to this an extensive General Index is included at the back of the book. In order to give added usefulness as a handy reference some of the text matter is duplicated in different sections although such duplications of course have been minimized as much as possible.

An example will help explain the arrangement. If the reader desires information on a material, he looks under Part III, Materials. Suppose he wants to know about phenolics. He then finds in its appropriate place a detailed account of phenolics as a material. He learns what it is, what forms it has, and how it is used. However, if he wants to know how it is made he must look in Part IV, Manufacture. Or if he wants to know more about its physical properties than he found in Part III he turns to the complete Physical Properties Table in Part II. And, again, if he wants to know what some of the manufacturers of phenolics say about their trade-marked products he turns to the condensed catalogue section which also is in Part II. Data on molding he will find in Part V, and chemical properties in Part VI. In case of doubt the reader is requested to make full use of the General Index.

OUTLINE TABLE OF CONTENTS

PART I. INTRODUCTION

PART II. PHYSICAL PROPERTIES OF PLASTICS

PART III. MATERIALS

PART IV. MANUFACTURE OF PLASTICS

PART V. PROCESSING AND FABRICATION

PART VI. CHEMISTRY OF PLASTICS

PART VII. APPLICATIONS OF PLASTICS

PART VIII. COMMERCIAL CONSIDERATIONS

CHAPTER PAGE

PART IX. APPENDIX — GLOSSARY — BIBLIOGRAPHY

DETAILED TABLE OF CONTENTS

PART I. INTRODUCTION

PART II. PHYSICAL PROPERTIES OF PLASTICS

PART III. MATERIALS

PART IV. MANUFACTURE OF PLASTICS

PART V. PROCESSING AND FABRICATION

PART VI. CHEMISTRY OF PLASTICS

LIST OF TABLES

APPENDIX

(A.S.T.M. Report)

PART I

Introduction

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CHAPTER I

Survey of the Industry

CHAPTER I

SURVEY OF THE INDUSTRY

Growth. The life of the plastics industry has been short and its growth rapid. Companies producing moldings before the 1920's, such as General Electric, Westinghouse, and Continental Diamond Fibre did so almost entirely for their own consumption. Electrical insulation was the chief market until the demand for silent gearing caused the General Electric Company (and some other companies) to begin manufacturing plastics for other fabricators.

During the past fifteen years the industry has had a surprising expansion, more than twice the rate of steel in its early years; but several factors make it difficult to obtain accurate production statistics covering plastics. Government census classification is unsatisfactory; the system of licensing of patent rights between companies and individuals is complicated; different companies often share the successive steps in the production of a single finished item, and authorities disagree on definitions and on extent of the field.

All available statistics have been gathered, sorted, and edited and the results are presented in the following pages in the form of charts and tables. In addition, data covering sales and organization of the following prominent companies are included.

American Cyanamid Company
Bakelite Corporation (Union Carbide and Carbon Corporation)
Catalin Corporation of America
Celanese Corporation of America
Continental Diamond Fibre Company
Dow Chemical Company
E. I. du Pont de Nemours & Company
Durez Plastics & Chemicals
Eastman Kodak Company
General Electric Company
Hercules Powder Company
Monsanto Chemical Company
Plaskon Company
Röhm & Haas Company
Westinghouse Electric and Manufacturing Company

What Is the Plastics Industry? Just as the backbone of the steel industry is the manufacture of ingots, the backbone of the plastics industry is the manufacture of molding powder. Each of these industries has other products and each has arms reaching out into many associated fields. Many parallels between the two industries may be drawn. Molding powder (and resin), like the ingot, is a sort of reservoir of unfinished material waiting to be processed. From molding powder, rods and shapes may be extruded and moldings may be made. Molding powder is the principal raw material for the molder. But even more important is the laminator who uses resin (an earlier stage of the same plastics material from which the powder is made). Another unit consists of those who use synthetic resins as raw material and make castings instead of moldings.

Some manufacturers, although using large amounts of plastics, keep an identity with other industries; for example, manufacturers of abrasive wheels, brake linings, plywood, printing inks, lacquers, sand paper, and glues.

Consequently, the difficulty of setting any clearly defined limits to the plastics industry is apparent. In briefest terms it consists of a relatively small number of producers (of resins, of powders, and of sheets, rods, and tubes) supplying a relatively large number of molders and other fabricators. The molder may have in his plant several departments such as a die shop, a pilling room, a compression molding department, an injection molding department, an extrusion shop and a finishing room. Other fabricators may use plastics sheets and shapes as a stock material much as the better known steel and wood materials are used.

The breadth of the industry considered in this handbook is best understood from the Table of Contents, but the following list of four important branches may help orient those first approaching the subject.

1. Manufacturers of source materials (fillers, chemicals, etc.).
2. Manufacturers of molding powders, resins and varnishes.
3. Manufacturers of stock forms (sheets, tubes, etc.).
4. Users of molding powders and resins (moldings, laminates, coatings, extruded shapes, etc.).

Statistics which follow indicate the character of each of these four divisions. But in the broad industrial picture of plastics and associated materials there are many activities which cannot be thus classified. Equipment is being designed and manufactured. Synthetic yarns are being spun and processed, and research laboratories are at work in unprecedented eagerness, seeking new plastics which can be made with more easily available raw materials. In almost every major industry, today, some activity will be found which is directly or indirectly connected with plastics and thus any estimate of total extent of the plastics industry must go well beyond the dollars and cents value of materials at any one point in the sequence.

What Is a Plastic? The term plastic is still too young to have an unchallenged definition. In this handbook it is understood to be a synthetic organic material whose chief component is a resinous or cellulose derivative binder. At some stage in its production it is either plastic (capable of being shaped) or liquid (capable of being cast) and at some subsequent stage it assumes a more or less rigid condition. A plastic is either thermosetting (cures or sets under action of heat and cannot be remelted), or is thermoplastic (softens by reheating and can be remelted or remolded). The phenolics and ureas are examples of thermosetting materials; the acetates and vinyls are examples of thermoplastics.

In its common form (molding powder) a plastic has several components such as binder, filler, plasticizer, dyes. The definitions of these and other terms relating to plastics will be found in the glossary starting on page 953.

Many forms of plastics (moldings, shapes, bristles, yarns) are included in this handbook as well as many borderline materials (synthetic rubber, elastomers, natural resins).

Production and Consumption. The flow of materials from producer to consumer is shown in the color charts. The total plastics production in 1941 is estimated at 350,000,000 pounds with a value of $125,000,000. Both amounts are exclusive of fabrics, yarns, and other borderline materials.

The totals given in the color charts, namely, 284,000,000 pounds and 299,000,000 pounds, vary from the foregoing total for the industry in that they are not fully in-

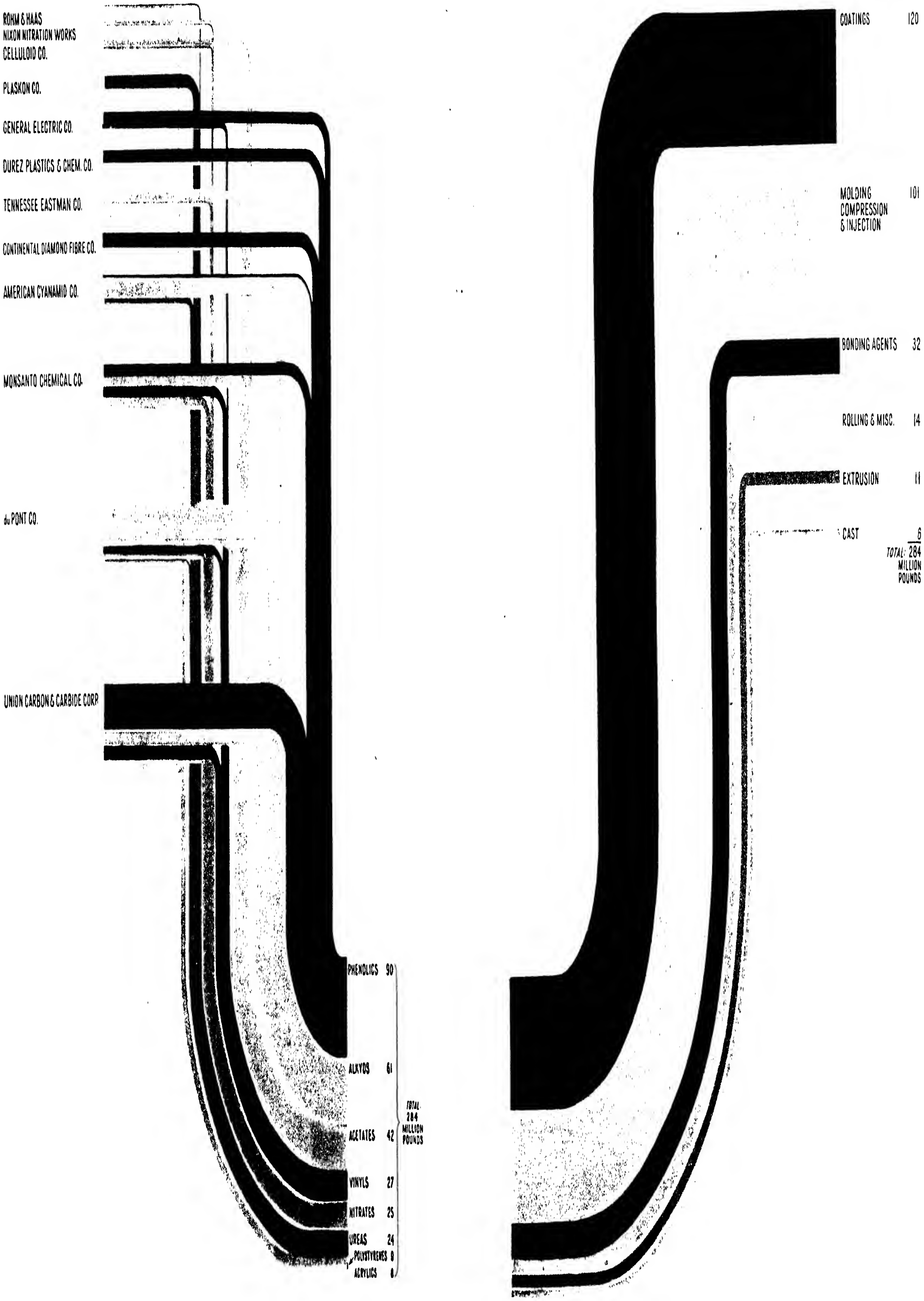
The following charts illustrate the flow of commercial plastics from the producer to the various broad consuming channels in 1941.

●

The colors in chart (A) indicate the various types of plastics which were manufactured by a group of twelve typical companies. The width of each band at the base shows the proportionate production of each type. For instance, the purple band for vinyls has a width corresponding to about 10 percent of the total production or 27,000,000 pounds against a total of 284,000,000 pounds. By following back along the purple band it will be noted that four companies manufactured vinyl plastics in 1941. The branch lines indicate the proportionate amount manufactured by each company.

In chart (B) the color bands indicate consuming channels and have not been broken up to show the individual types of plastics.

Some types of plastics, particularly the allyls, caseins, lignins, melamines, silicones and vinylidene chlorides, are omitted either because of insufficient data or because the types were not in commercial use during the period covered by the chart.


ROHM & HAAS
NIXON NITRATION WORKS
CELLULOID CO.
PLASKON CO.
GENERAL ELECTRIC CO.
DUREZ PLASTICS & CHEM. CO.
TENNESSEE EASTMAN CO.
CONTINENTAL DIAMOND FIBRE CO.
AMERICAN CYANAMID CO.
MONSANTO CHEMICAL CO.
du PONT CO.
UNION CARBON & CARBIDE CORP.
PHENOLICS 90
ALKYDS 61
ACETATES 42
VINYLS 27
NITRATES 25
UREAS 24
POLYSTYRENES 9
ACRYLICS 6
TOTAL 284 MILLION POUNDS
COATINGS 120
MOLDING COMPRESSION & INJECTION 101
BONDING AGENTS 32
ROLLING & MISC. 14
EXTRUSION 11
CAST 6
TOTAL: 284 MILLION POUNDS

(A)

(B)

clusive. The processes indicated might be further broken down to cover kinds of molding and the various uses of bonding agents, such as laminating, plywood bonding and grinding wheel binders, but conflicting data make the omission of such further groups seem advisable.

The 1941 total for cellulose acetate, based on government figures for sheets, rods, tubes, and molding powder, was approximately 37,000,000 pounds. This compares with an estimated 1942 production of 60,000,000 pounds. In 1941, another 35,000,000 pounds probably were produced for yarn and staple fiber. The 1940 dollar volume for borderline products such as rayon, transparent wrapping materials, and synthetic rubber is estimated at $250,000,000.

History. Schonbein discovered nitrocellulose in Basle, Switzerland, in 1846, but made no commercial use of his discovery. However, he sent samples to friends and he wrote some notes which were published to form the foundation for later work.

Other investigators contributing to the development of this new material included Braconnot, Poggendorff, Faraday, and Parkes. But more important than any was John Wesley Hyatt, of this country, noted for his development of roller bearings, who is given chief credit for producing in 1868 the first commercial plastic, Celluloid (nitrocellulose or cellulose nitrate). In 1870, The Albany Dental Plate Co. was organized to handle Celluloid production and sales. But the demand was greater than expected and, in 1871, The Celluloid Manufacturing Co. was formed to take over the growing business. In 1872 this second company was moved from Albany, N. Y., to Newark, N. J., where it has remained ever since. Although slow to realize the full possibilities of the new material, the Newark company must be given credit as the real pioneer in the development of the market for plastics in this country.

Adolf Spiteller of Germany is given credit for the world's second plastic, casein, discovered in 1890, but not introduced commercially in the United States until 1919. The first company marketing casein here was The Aladdinite Co. Other companies in this field are American Plastics Corporation and George Morrell Corporation.

Dr. Leo Baekeland, of Yonkers, N. Y., discovered the first thermosetting plastic, Bakelite resimoid, in 1909. This was a phenol-formaldehyde plastic which, because of its peculiar qualities, stimulated the imagination of manufacturers and thus did more than anything else to bring about the subsequent growth and extension of the industry.

Other names prominently identified with the early development of phenolics are: A. Baeyer, H. Lebach and Otto Röhm of Germany, Redman and Aylsworth of America, and Spill of England. The manufacture of Bakelite products started in Dr. Baekeland's laboratory in 1907. In 1910, The General Bakelite Co. was organized and production gradually increased until 1922 when this company was merged with The Redmanol Chemical Products Co. and The Condensite Co. under the new name, Bakelite Corporation.

The early history of cellulose acetate is somewhat confused. The Celanese Corporation was probably the first producer in this country, but in 1927 it entered a combination with The Celluloid Corporation to produce the first rods and tubes.

One of the important early patents for this plastic was taken out in 1903 by A. Eichengrün and T. Becker. Others who contributed to the development were G. W. Miles, Schützenberger, Cross, Bevan, and the Dreyfus brothers.

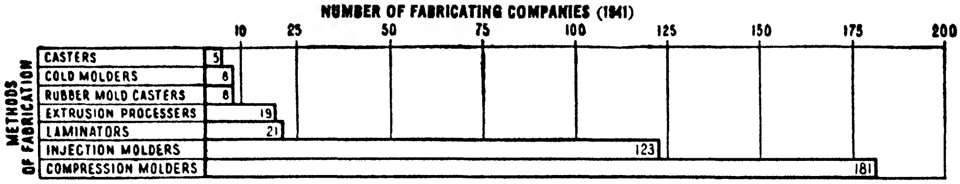


Fig. 1.1 — Number of fabricating companies.

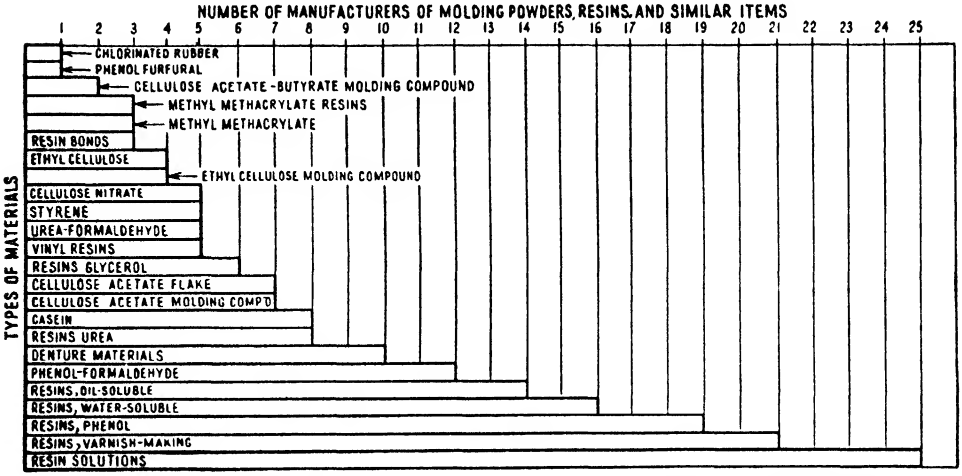


Fig. 1.1*a* — Number of manufacturers of molding powders, resins, and similar items.

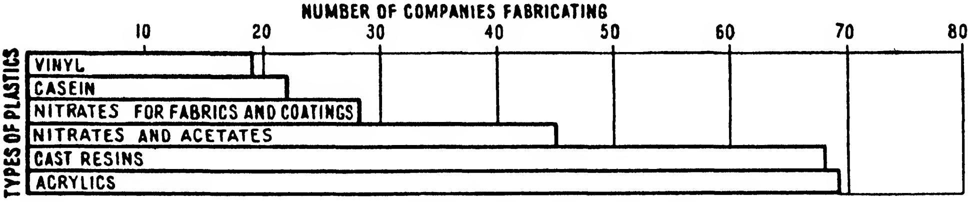


Fig. 1.1*b* — Number of companies fabricating.

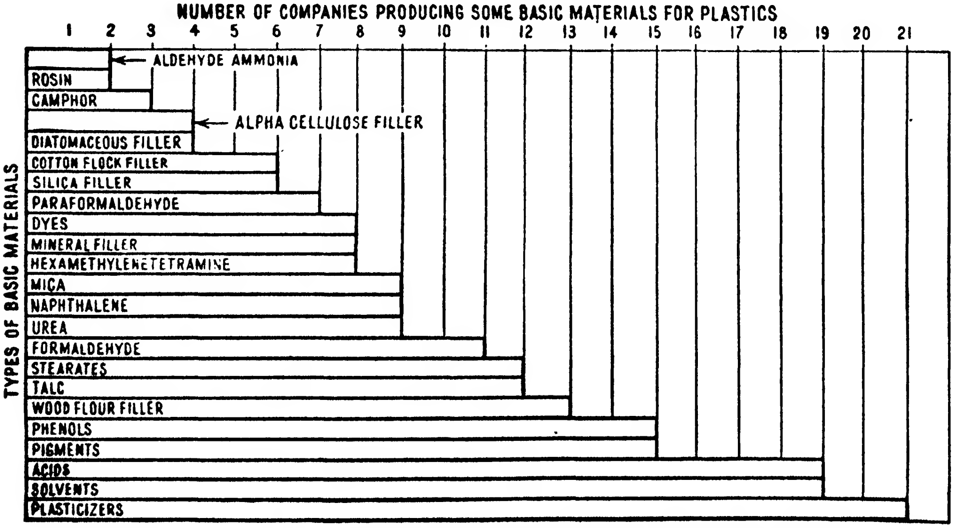


Fig. 1.1*c* — Number of companies producing some basic materials for plastics.

The first acetate molding powder was not marketed until 1929. Safety glass with acetate interlayer came on the market in 1934.

Hans John and Carleton Ellis share honors in the early development of urea-formaldehyde plastics. Fritz Pollak and Kurt Ripper were other contributors to this work. The first American product (Aldur, 1928) was not successful, but a successful urea powder, Beetle, appeared in 1929 and another, Plaskon, in 1931.

In 1928 a new type of cast phenolic, Catalin, appeared on the American market. This was the result of the work of Ostersetzer, Riesenfeld, Pollak, and Pantke.

The vinyl plastics appeared in 1928, but it was not until some years later that the vinyl materials achieved their success as coatings for insulated wire and as safety glass interlayer. Inventors contributing to the development of the vinyls include Lawson, Skirrow, Morrison, Klatte, and Rollett.

The many new types of plastics which have been developed in recent years are described elsewhere and the approximate dates of their appearance are indicated in Fig. 1.2. Some of the research workers associated with these recent developments were: for polystyrene, Simon and Ostromislensky; for acrylic types, Röhm, Neher, Hollander, and Hill; for ethyl cellulose, Leuchs, Lilienfeld, and Dreyfus; for lignin, Phillips, Wiehe, Novotny, and Kendall; for alkyds, Callahan, Arsem, Gibbs, and Conover; for cumarone-indene, Sperr, Darrin, and Miller; for nylon, Carothers.

PROGRESS IN PLASTICS

Approximate Dates When Commercial Products Were Introduced in the United States

1870	Cellulose nitrate (Celluloid)	Sheets, rods, tubes
1909	Phenol-formaldehyde	Castings
1910	Phenol-formaldehyde	Molding powders
1912	Cellulose acetate	Photographic safety film
1918	Casein	Thick sheets and rods
1919	Vinyl acetate polymers	Adhesives
1922	Phenol-formaldehyde	Laminated sheets
1923	Phenol furfurals	Molding powders
1924	Urea-formaldehyde	Cast forms
1927	Cellulose acetate	Sheets, rods, tubes
1928	Vinyl esters	Molding powders, films, sheets
1929	Cellulose acetate	Molding powders
1929	Urea-formaldehyde	Molding powders
1930	Alkyd plastic	Coatings, films
1931	Acrylic esters	Castings, moldings
1931	Phenol-formaldehyde	Modified cast resins
1931	Urea-formaldehyde	Laminated sheets
1933	Cellulose acetate	Injection molding powders
1933	Benzyl cellulose	Sheets, rods, tubes
1934	Celluloid and cellulose acetate	Continuous extruded sheets
1935	Vinyl chloride polymers and mixed polymers	Sheets, rods, powders, films
1936	Ethyl cellulose	Sheets, powders
1936	Methyl methacrylate	Transparent sheets
1937	Lignin plastic	Sheets
1937	Urea-formaldehyde*	Transparent molding powders
1937	Methyl methacrylate	Molding powders

* Experimental in the United States, commercial in England.

FIG. 1.2.

1937	Polystyrene	Powders, castings
1937	Polystyrenes	Transparent molding powders
1937	Cellulose acetate propionate	Powders
1938	Protein (including casein)	Molding powders
1938	Cellulose acetate butyrate	Molding powders
1938	Vinyl butyral	Safety glass filler
1939	Lignin plastic	Molding powders
1939	Methyl cellulose	Coatings, films
1939	Polystyrene	Rods, tubes, shapes
1940	Cellulose acetate butyrate	Continuous shapes by " dry " extrusion
1940	Melamine	Molding powders
1941	Polythene*	Molding powders
1941	Vinylidene chloride	Extruded strip

FIG. 1.2 — (*Continued*)

PRODUCTION AND CONSUMPTION DATA

The following charts, Fig. 1.3 and Fig. 1.3a, cover the manufacture and distribution of molding powders, resins and initial materials rather than finished products. They take a somewhat arbitrary list of companies and, also, a somewhat arbitrary list of types of plastics. For instance, they do not cover the following companies: Durite Plastics, Inc., Makalot Corporation, Marblette Corporation, Catalin Corporation, and others. Also, they do not cover some important plastics as, for instance, butyrates, furfurals, ethyl cellulose plastics, and melamines. Data have been difficult to secure, and the accuracy in connection with the materials and companies omitted seemed insufficiently established to warrant their inclusion. The charts cover resins used for coatings but do not cover the large borderline phase of the industry as typified by nylon and other synthetic yarns, fibers, and films.

1941 ESTIMATED PRODUCTION OF NINE TYPES OF PLASTICS

Types	*Millions of Pounds*
Acetates	43
Acrylics	6
Alkyds	61
Casein	6
Nitrates	25
Phenolics	94
Polystyrenes	9
Ureas	24
Vinyls	27
This table total	295
Other types included in distribution	4
Total of distribution table	299

FIG. 1.3.

1941 CONSUMPTION DISTRIBUTED TO SIX CONSUMING PROCESSES

Process	*Millions of Pounds*
Bonding	35
Casting	7
Coatings, manufacture of	125
Extrusion	12
Molding	105
Rolling (as for safety glass interlayer) and misc.	15
Total	299

FIG. 1.3*a*.

Thirty-two firms making molding powder and resins reported to the government in 1937 and 1939 as follows:

Item	1939	1937
Production in pounds	152,122,000	130,120,000
Per cent increase over previous year	14	—
Value in dollars	29,406,000	—

Another group of smaller plastics manufacturers reported an 18 per cent increase during the same period. This rate of increase (9 per cent a year) was bettered in 1940 and jumped to about 32 per cent in 1941, when war requirements taxed all production facilities.

The following data are based on government reports and manufacturers' estimates.

Kind of Plastic	Plastics Production in Pounds		Unit Price 1940
	1940	1939	
Nitrates	11.915,300	13,373,000	45
Acetates	23,850,000	20,795,000	70
Phenolics and Cresols	91,700,000	77,400,000	31
Urea	21,491,000	15,300,000	39
Polystyrene	4,400,000	3,200,000	52
Methyl Methacrylates	4,570,000	3,000,000	72
Vinyls	22,500,000	14,273,000	76

A Barometer. Acetone is used extensively in the production of rayon and of cellulose acetate plastics. The following table shows its sharply increased consumption in the United States.

Year	*Pounds of Acetone Produced in United States*
1934	42,615,312
1935	56,124,067
1936	64,651,128
1937	68,772,268
1938	77,041,184
1939	100,935,422

Machinery for Plastics. The production of machinery, equipment and supplies for the industry is a large and important item. The tables give an indication of the number of companies in this field and also the variety of equipment necessary to the industry. A description of the principal items will be found in Part IV. Most of the large companies and the Government do extensive testing and research in plastics, and about one hundred industrial designers, other than those in the design departments of the large companies, are working on plastics products.

MOLDING PRESSES IN OPERATION IN THE PLASTICS INDUSTRY, 1941

Compression	12,500
Injection	3,250
Extrusion*	117
Total	15,867

* Dry extrusion type.

FIG. 1.4.

ORGANIZATION AND OPERATION OF MANUFACTURING COMPANIES

KEY

* in tables indicates that the figure has been estimated from available data.
NR indicates no report.

AMERICAN CYANAMID COMPANY

President: W. B. Bell *Home office:* New York, N. Y. *Incorporated:* 1907

In 1916, the company purchased the entire stock of the Ammo-Phosphate Corporation, Warners, N. J. It now has six subsidiaries and one affiliate.

Products: Chemicals for mining, agricultural, and industrial purposes including many source materials for plastics and the following plastics products:

Alkyd resins
Casein
Ureas
Melamines
Phenolic resins

Trade Names:

Akco
Aero Brand Ester Gum
Beetle
Ketonone
Melmac
Phenac
Rezyl
Teglac

Remarks: Investment in plant (large part for plastics) in 1941 was $11,479,800. During 1941, plastics sales moved from seventh position to sixth position among main divisions of the company's products.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	NR	$3,113,909	$6,766,292	$7,800,000*
1940	$72,000,000*	2,531,000	6,629,000	7,000,000*
1934	NR	1,201,000	2,495,000	NR
1931	NR	1,300,000*	400,000*	NR

* Estimated

BAKELITE CORPORATION

Unit of Union Carbide and Carbon Corporation

President: James A. Rafferty *Home office:* New York, N. Y.

Products:

Cellulose acetate (molding materials)
Phenolic (molding materials, laminating varnishes, synthetic resins, and cast products)
Polystyrene (molding materials and film)
Urea (molding materials, resin glues for wood, and synthetic resins for protective coatings)

Trade Names:

Bakelite cellulose acetates
Bakelite phenolics
Bakelite ureas
Bakelite polystyrenes

Remarks: See Union Carbide and Carbon Corp.

CARBIDE AND CARBON CHEMICALS CORPORATION (PLASTICS DIVISION)

Unit of Union Carbide and Carbon Corporation

President: James A. Rafferty *Home office:* New York, N. Y.

Products:

Polyvinyl acetate resins
Polyvinyl chloride resins
Vinyl chloride-acetate resins

Trade Names:

Vinylite
Vinyon
Vinylseal

Remarks: See Union Carbide and Carbon Corp.

CATALIN CORPORATION OF AMERICA

President: William Theile *Home office:* New York, N. Y.

Incorporated in 1929 with manufacturing rights purchased from the American Catalin Company. The company has one affiliate in England, and in 1942 had about 3100 stockholders.

Products:

Cast phenolic resins
Polystyrene

Trade Names:

Aquapearl
Catabond
Catalane
Catalin
Catavar
Loabond
Loalin
Loavar
Opalite
Prystal

Remarks: The company manufactures and sells semi-finished articles in the form of sheets, rods, tubes, and shapes or special castings. The company manufactures a liquid phenolic resin for impregnating wood, paper, cloth, and textiles, also several types of adhesives. A polystyrene molding powder was placed on the market in 1941. In 1940, 4,258,000 pounds of plastics were produced. Plastics production in 1941 is reported as 5,325,078 pounds.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	**$2,345,805**	**$59,758**	**$203,102**	**$2,345,800**
1940	**1,836,374**	**44,500**	**174,727**	**1,836,000**
1939	**1,768,050**	**31,484**	**165,315**	**NR**
1934	**1,214,000**	**6,214**	**223,118**	**1,214,000**
1931	**NR**	**NR**	**1,568**	**NR**

CELANESE CORPORATION OF AMERICA

President: Camille Dreyfus *Home office:* New York, N. Y.

Incorporated in 1918. The principal business of the corporation is the manufacture and sale at wholesale of cellulose acetate yarns, and fabrics containing such yarns under the registered trade mark "Celanese" and under other trade marks owned by the corporation. The corporation is the largest producer of cellulose acetate yarns in the United States. In December 1941 Celluloid Corporation, a former subsidiary, was merged into the corporation. As a result of such merger the corporation now manufactures and sells at wholesale plastic products made from cellulose acetate and cellulose nitrate, and other related products. The plastic and related products are sold under the name of Celanese Celluloid Corporation which was formed in 1941 at the time of the merger.

Plastic and Related Products:

- Cellulose acetate molding material
- Cellulose acetate transparent packaging, wrapping and insulating material
- Cellulose acetate and cellulose nitrate film, sheets, rods and tubes
- Cellulose acetate coated wire screen
- Ethyl cellulose molding material
- Ethyl rubber
- Tricresyl phosphate
- Synthetic pearl essence

Trade Names for Plastics and Related Products: .

- Lumarith
- Celluloid
- Vimlite
- Lumapane
- Lumarith E. C.
- Lumarith E. R.
- H-Scale
- Lindol

Remarks: See also Celanese Celluloid Corporation.

Table of Operations (Giving effect to merger with Celluloid Corporation):

Year	*Sales*	*Research*	*Net Income*	*Plastic Sales*
1941	$71,544,118	NR	$7,911,061	$12,000,000*
1940	50,686,103	NR	6,719,072	NR
1939	41,407,576	NR	6,576,926	NR

* Estimated.

CELANESE CELLULOID CORPORATION

(Subsidiary of Celanese Corporation of America)

President: Camille Dreyfus *Home office:* New York, N. Y.

Incorporated in 1941 at the time of the merger of Celluloid Corporation into the Celanese Corporation of America. This company sells plastics and chemicals formerly produced by Celluloid Corporation and now produced by the Celanese Corporation of America. Celluloid Corporation was incorporated in 1927 as a consolidation of The Celluloid Company and Safety Celluloid Company. The Celluloid Company was incorporated in 1890 as a consolidation of the Celluloid Manufacturing Company with Celluloid Novelty Company, Celluloid Brush Company, American Zylonite Company, United Zylonite Company and the Lithoid Manufacturing Company. The original Celluloid Manufacturing Company was incorporated in 1872.

Products:

- Cellulose acetate molding material
- Cellulose acetate transparent packaging, wrapping and insulating material
- Cellulose acetate and cellulose nitrate film, sheets, rods and tubes
- Cellulose acetate coated wire screen
- Ethyl cellulose molding material
- Ethyl rubber
- Tricresyl phosphate
- Synthetic pearl essence

Trade Names:

- Lumarith
- Celluloid
- Vimlite
- Lumapane
- Lumarith E. C.
- Lumarith E. R.
- H-Scale
- Lindol

Remarks: See also Celanese Corporation of America.

CONTINENTAL DIAMOND FIBRE COMPANY

President: J. P. Wright *Home office:* Newark, Delaware

Incorporated in 1929 to acquire the assets of the Continental Fibre Company, Diamond State Fibre Company, Aleron Company, Glens Mills Paper Company, Diamond Fibre Company, Ltd. of London, La Fibre Diamond, S. A., and the Diamond State Fibre Company, Ltd. of Canada. This, with some modifications, has been done. In addition, in 1930 the company acquired the plant and inventories of the Delaware Hard Fibre Company, the assets and business of the Fibroc Insulation Company and of the Chicago Mica Company. It now owns a controlling interest in the Haveg Corporation.

Products:	*Per cent of total sales*
Vulcanized fiber	33
Molded plastics	25
Laminated plastics (phenolic)	23
Mica (for electrical insulation)	12
Non-competitive Zuciallon	7
Total	100

Trade Names:

Celoron
Diamond
Dilectine
Dilecto
Haveg
Micabond
Vulcoid

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	NR	NR	NR	NR
1940	$7,100,000*	$219,250	$275,000*	$2,500,000*
1939	5,925,000	150,000*	222,610	NR
1934	4,584,000	NR	23,919**	NR
1931	4,362,000	NR	217,313**	NR

* Estimated.

** Deficit after foreign exchange.

DOW CHEMICAL COMPANY

President: W. H. Dow *Home Office:* Midland, Michigan

Incorporated in 1897 as successor to the Dow Process Company. Charter extends to 1957. In 1938, the Great Western Electro-Chemical Company was acquired.

Products over 300, including:

Anilin
Bromides and iodides
Butadiene
Calcium chloride
Carbon
Carbon bisulfide
Insecticides and fungicides
Magnesium metal
  methyl cellulose
Pharmaceutic and aromatic chemicals
Phenol (for plastics)
Plastics —
  ethyl cellulose
  polystyrene
  vinylidene chloride
Styrene (for plastics and synthetic rubber)
Plasticizers
Solvents
Dyes

Trade Names:

Ethocel
Ethocel sheeting
Ethomelt
Ethomulsion
Methocel
Saran
Styron

Remarks: Business developed around the Midland, Michigan, saline deposits which are the most important in the United States. From these the company obtains bromine, chlorine, magnesium, and caustic soda. This company is the leading producer of bromine and magnesium. It manufactures over 300 chemical products. During recent years it has been turning more and more to plastics.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	$46,907,950	$2,262,000	$7,770,547	NR
1940	37,743,000	1,744,000	7,159,000	NR
1934	17,076,000	NR	3,572,000	NR
1931	13,500,000	NR	2,376,000	NR

E. I. DU PONT DE NEMOURS AND COMPANY

Chairman of the Board: Lammot du Pont

President: W. S. Carpenter, Jr.

Home office: Wilmington, Delaware

The Du Pont Company was founded in 1802 for the manufacture of black powder, and until 1880 this was the only commercial product of the company. In that year it began to make nitroglycerin and other high explosives, and this was followed in 1890 by smokeless powder manufacture. In 1904, the company began to branch into other chemical activities, either by acquisition of existing organizations or by developing new processes of its own. This expansion led into new and broader fields, each one related in a general and logical way to the others. In this way the company has grown from a single powder mill to an organization having 80 plants in 25 states, with operations covering virtually the entire scope of the chemical industry.

Principal products:

Acids (sulfuric, muriatic, nitric, sulfamic, etc.)
Alcohols
Ammonia
Cellophane
Ceramic colors
Degreasing solvents
Dyestuffs and other organic chemicals
Electroplating chemicals
Explosives, commercial and military
Fire retardants
Formaldehyde
Neoprene synthetic rubber
Nylon yarn
Paints, varnishes and enamels
Perfume chemicals
Photographic and motion picture film
Plastics —
  cellulose acetate (sheets and molding powder)
  cellulose nitrate (sheets, rods and tubes)
  methyl methacrylate (sheets, rods, tubes and molding powder)
  nylon monofilaments
  polyvinyl acetal (continuous sheeting and flakes)
  polyvinyl acetate (granular, solutions, and emulsions)
  polyvinyl alcohol (powder)
Pyroxylin coated fabrics
Rayon, viscose and acetate
Rubber coated fabrics

Trade Names of Du Pont Plastics:

Butacite (polyvinyl acetal resin)
Lucite (methyl methacrylate resin)
Luciton (methyl methacrylate resin denture material)
Plastacele (cellulose acetate plastic)
Pyralin (cellulose nitrate plastic)

Remarks: This company is one of the large producers of plastics in the country. It began the manufacture of pyroxylin plastics in 1915, following acquisition of assets and business of the Arlington Company. Manufacture of cinematographic film, sometimes regarded as a plastic, began in 1924. Production of pyroxylin plastics was greatly expanded in 1925 following acquisition of assets and business of the Viscoloid Company, and formation of the Du Pont Viscoloid Company, now the Plastics Department. The Celastic Corporation (50 per cent owned by Du Pont and 50 per cent owned by the United Shoe Machinery Company) manufactures colloid-treated fabrics used in box toes, arch supports, and repair of wooden foundry patterns.

Table of operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	$503,352,294	NR	$90,401,470	NR
1940	359,055,000	$14,000,000*	86,945,000	$25,000,000*
1934	179,394,000	NR	46,701,000	NR
1931	NR	NR	53,190,000	NR

* Estimated.

DUREZ PLASTICS AND CHEMICALS

President: Harry M. Dent *Home Office:* North Tonawanda, N. Y.

Incorporated in 1937 and consolidated in 1939 with General Plastics, Inc.

Products:

Phenolic molding compounds and resins
Synthetic phenol
Dichlorbenzols
Higher chlorinated benzols

Plastics Trade Name: Durez

Remarks: In 1939, a $2,000,000 synthetic phenol plant was put in operation. In 1941, $400,000 was allotted for new equipment and buildings. Production in early part of 1942 was at the rate of 20,000,000 pounds per year.

EASTMAN KODAK COMPANY

President: T. J. Hargraves *Home Office:* Rochester, N. Y.

Incorporated in 1901. It now has eighty wholly owned subsidiaries. Some of the more important subsidiaries are Tennessee Eastman Corporation, Eastman Gelatine Corporation, The Recordak Corporation, Distillation Products, Inc., and Canadian Kodak Company, Ltd.

Products:	*Per Cent (1941) of Total Operations*
Photographic supplies, amateur	30
Photographic supplies, professional and commercial	22
Cellulose-acetate products	22
Motion picture film	9
Photographic accessories	6
Chemicals	7
Miscellaneous	4
Total	100

Products of Tennessee Eastman Corporation:

Acetate dyestuffs
Acetic acid and anhydride
Cellulose acetate
Charcoal
Denaturants for ethyl alcohol
Hydroquinone
Manganese salts

Plastics Trade Names:

Eastman acetate sheet
Kodaloid
Kodapak
Tenite I (cellulose acetate molding composition)
Tenite II (cellulose acetate butyrate molding composition)

Remarks: An important division in the plastics field is the Tennessee Eastman Corporation, Kingsport, Tenn. For 1939, Tennessee Eastman Corporation gave its production of cellulose acetate molding powder as 12,000,000 pounds. This was nearly 25 per cent of the total United States production. The Tennessee Eastman Corporation's annual report for 1940 gave its production as 30 per cent greater than 1939. This increase was largely due to demand for Tenite II (cellulose acetate-butyrate) for continuous extrusion.

In 1941, Eastman Kodak Company announced a new film for making patterns, known as Matte Transfer Film, which it claimed would speed production of airplanes.

Table of Operations (figures include those of the Tennessee Eastman Corporation):

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	$181,831,909**	NR	$21,588,790**	$8,000,000*
1940	130,896,000**		20,076,000**	6,000,000*
1939	140,331,000	NR	21,537,000	NR
1934	96,828,000	NR	14,503,000	NR
1931	NR	NR	13,408,000	NR

* Estimated.
** Western Hemisphere operations only.

GENERAL ELECTRIC COMPANY

Chairman: Owen D. Young *President:* Gerard Swope *Home Office:* Schenectady, N. Y.

Incorporated in 1892. Now has forty-two wholly owned subsidiaries and twenty-nine factories.

Products:

Large variety of electrical machinery and supplies
Plastics
  alkyds
  laminates
  molding compounds
  phenolic resins
  varnishes
  miscellaneous

Plastics Trade Names:

Flamenol
Glyptal
Textolite (many kinds of plastics)

Remarks: In 1921, the company had three plastics press operators using 37,000 pounds of compounds per year. In 1941, it had 1800 press operators using 18,000,000 pounds of compound per year.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	$679,333,760	NR	$57,197,499	NR
1940	411,938,000	$15,000,000*	56,241,000	$9,000,000*
1934	104,797,000	NR	19,786,000	NR
1931	263,275,000	NR	40,956,000	NR

* Estimated.

(Plastics sales figures include molded products for customers.)

HERCULES POWDER COMPANY

President: C. A. Higgins *Home Office:* Wilmington, Delaware

Incorporated in 1912 by a decree of the U. S. Supreme Court. Took over a portion of the du Pont business for $13,000,000 in stocks and bonds. There are now five wholly owned subsidiaries and two affiliates.

Products:

Acids
Casein
Cellulose acetate flake
Cellulose nitrate
Ethyl cellulose
Rosin and Resins

Plastics Trade Names:

Abalyn
Hercolyn
Hercose A P
Hercules cellulose acetate
Hercules ethyl cellulose
Vinsol

1940 Plastics Sales:

Type	*Per cent of Total*	*Value*
Acetates	56	$2,128,000
Nitrates (plastics)	34	1,292,000
Casein	8	304,000
Miscellaneous	2	76.000
Total plastics	100	$3,800,000

Remarks: A plant at Parlin, N. J., produces 54,000,000 pounds of cellulose nitrate annually.

The company originally manufactured explosives exclusively. This led to the development of cellulose products, and in 1940, explosives formed but one-third of the company's production.

The company spent about $5,000,000 in 1941 for plant extension. One of the company's most important markets is protective coatings for automobiles, airplanes, and wood surfaces.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	$85,612,000	NR	$6,098,000	NR
1940	52,429,000	$1,114,000	5,807,770	$3,800,000
1934	25,795,409	NR	3,038,000	NR
1931	20,450,411	NR	1,430,538	NR

MONSANTO CHEMICAL COMPANY

President: Edgar M. Queeny *Home Office:* St. Louis, Missouri

Incorporated in 1905. It has one wholly owned subsidiary, Monsanto Chemicals Ltd., and has part ownership in the following: New England Alcohol Company, Shawinigan Resins Corporation, Monsanto Ltd. (of Canada). It took over Fiberloid Corporation, of Springfield, Mass., in 1938. Purchased the Resinox Corporation in 1939.

Products:

Cellulose acetate sheets, rods and tubes
Cellulose nitrate sheets, rods and tubes
Phenolic (molding materials
and cast phenolic)
Vuepak (continuous length film)
Polystyrene
Viny Acetals
Cellulose nitrate flake
Cellulose acetate molding compounds

Plastics Trade Names:

Fibestos
Lustron
Nitron
Opalon
Resinox
Saflex TS (a vulcanizable plastic)
Styramic
Vuepak
Vuelite

Remarks: The Fiberloid Company developed a continuous process of cellulose acetate sheet production and was first to introduce cast phenolic resin for radio cabinets. The company is one of the leading manufacturers of acetate molding powder.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	$70,272,557	$1,488,445	$6,725,225	NR
1940	51,117,000	1,313,145	5,816,000	$10,000,000*
1934	17,543,000	456,316	2,619,000	NR
1931	13,126,000	403,955	1,280,000	NR

* Estimated.

PLASKON COMPANY, INC.

President: James L. Rodgers, Jr. *Home office:* Toledo, Ohio

Incorporated 1931. The name was changed in 1936 from Toledo Synthetic Products to Plaskon Company and in the same year the company consolidated with Unyte Corporation. A 70 per cent interest in Plaskon was acquired in June, 1940, by Libbey-Owens-Ford Glass Company from the Toledo Scale Company for between $2,000,000 and $2,500,000.

Products:

Urea-formaldehyde molding compound
Resin bonds for plywoods, veneers, and laminates
Melamine formaldehyde molding compound
Resins for coatings and paper treatment

Plastics Trade Name: Plaskon

Remarks: Recently the company has done considerable expanding, especially in its research program and in the field of adhesives.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	NR	NR	NR	NR
1940	$7,500,000*	$250,000	$650,000	$7,500,000*

* Estimated.

UNION CARBIDE AND CARBON CORPORATION

President: Benjamine O. Shea *Home office:* New York, N. Y.

Incorporated in 1917 with a perpetual charter. It has twenty-seven wholly owned subsidiaries including the Bakelite Corporation and Carbide and Carbon Chemicals Corp.

Products:

Alloys and metals
Calcium carbide, oxygen, acetylene and other industrial gases;
oxy-acetylene welding and cutting equipment and supplies
Electrodes, carbons, batteries
Synthetic organic chemicals including plastics

Plastics Trade Names:

Bakelite
Vinylite
Vinylseal
Vinyon

Remarks: The company stands between E. I. du Pont de Nemours and Company and Allied Chemical Corporation in size in its field. It has 179 plants, six mines, and six main research units. Bakelite Corporation was purchased for a reported $11,000,000.

The company makes substantial quantities of butadiene (source material for synthetic rubber). The 1941 production of Vinylite is reported as 11,000,000 pounds, and of Bakelite as 41,000,000 pounds.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	NR	NR	$42,041,625	NR
1940	$231,393,000	$5,166,000*	42,247,000	$20,000,000
1934	111,176,000	NR	20,277,000	NR
1931	NR	NR	18,029,000	NR

WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY

President: George H. Bucher *Home office:* East Pittsburgh, Pennsylvania

Incorporated in 1872. It wholly owns four subsidiaries and thirteen unconsolidated companies. Production in the plastics field is limited to laminates.

Plastics Trade Names:

Micarta Moldarta

Remarks: One of the two largest electrical manufacturing companies. Production of Micarta in 1940 exceeded 6,000,000 pounds. Through its affiliate, the Bryant Electric Manufacturing Company, it is a large producer of moldings.

Table of Operations:

Year	*Sales*	*Research*	*Income*	*Plastics Sales*
1941	$369,094,125	NR	$23,117,511	NR
1940	200,000,000*	$5,477,000*	19,000,000*	$7,400,000*
1939	175,071,000	NR	13,854,000	NR
1934	92,158,000	NR	181,000	NR
1931	115,393,000	NR	3,033,000	NR

RECAPITULATION OF COMPANY FIGURES FOR 1940

Company	Company Total Net Sales	Company Total Net Income	Company Total Research	Company Plastics Sales
	$	$	$	$
American Cyanamid	*72,000,000	6,629,000	2,531,000	*7,000,000
Catalin	1,836,374	174,727	44,500	1,836,000
Celanese	50,686,103	6,719,072	—	—
Continental Diamond Fibre	*7,100,000	*275,000	*219,250	*2,500,000
Dow Chemical	37,743,000	7,159,000	1,744,000	—
du Pont de Nemours	359,055,000	86,945,000	*14,000,000	*25,000,000
Eastman Kodak	130,896,000	20,076,000	—	*6,000,000
General Electric	411,938,000	56,241,000	*15,000,000	*9,000,000
Hercules Powder	52,429,000	5,807,770	1,144,000	3,800,000
Monsanto	51,117,000	5,816,000	1,313,145	10,000,000
Plaskon	*7,500,000	650,000	250,000	*7,500,000
Union Carbide	231,393,000	42,247,000	*5,166,000	*20,000,000
Westinghouse	*200,000,000	*19,000,000	*5,477,000	*7,400,000
Total Plastic Sales				100,036,000*

* Estimated figures.

Fig. 1.5.

SOME TYPICAL ITEMS OF EQUIPMENT

Accumulators
Blowers, portable, electric
Buffs
Compressors, air
Controllers, pressure
Controllers, temperature
Dust collectors
Hydraulic valves and fittings
Kettles, resin
Machine tools
Marking devices
Preheating equipment
Presses, compression
Presses, hobbing
Presses, injection molding
Presses, preforming
Pyrometers
Testing apparatus

AVERAGE ANNUAL RESEARCH EXPENDITURES OF LEADING CHEMICAL COMPANIES[1]

	Total Research Personnel	Est. Research Expenditures (Thousands)	Yearly Sales Average 1937–9 (Millions)	Est. Research Expenditures Per Cent of Sales	Per Cent Earned On Invested Capital	
					1935–39	1929–34
du Pont de Nemours	2,680	$10,720	$273.4	3.9	12.7	8.6
Dow Chemical	500	2,000	25.7	7.8	13.5	NR
American Cyanamid	466	1,864	NR	NR	8.0	4.5
Union Carbide	(a) 460	(a) 1,840	(b) 150.0	1.2	12.5	7.7
Hercules Powder	363	1,412	39.5	3.6	10.0	5.6
Monsanto	212	848	36.0	2.4	12.7	10.2
Atlas Powder	54	216	16.3	1.3	6.2	3.2
Comm'l Solvents	51	204	16.7	1.2	8.7	20.1
Allied Chem. and Dyes	NR	—	(b) 160.4	—	9.5	1.8

(a) In addition Bakelite Corp. 1939 had research personnel of 240 persons, and spent about $960,000 for research. Thus total is about 700 workers and $2,800,000. (Union Carbide figures are conservative.)

(b) Average sales for 1937 and 1938 only.

NR No report.

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[1] Prepared by J. V. Sherman and reproduced by special permission.

FIG. 1.6.

LAMINATORS

KEY

1. Sheeting, tubing, rod stock
2. Punching stock
3. Molded-laminated shapes
4. Gears and gear stock
5. Bearings
6. Decorative laminated plastics
7. Translucent laminated sheeting
8. Engraving stock
9. Densified-laminated wood
10. Rubber-laminated sandwich stock

	Trade-Marks	*Types*
Continental-Diamond Fibre Co., Newark, Del.	Dilecto	1, 2, 3, 4, 5, 8, 10
Farlite Division, Farley & Loetscher Manufacturing Company, Dubuque, Iowa	Farlite	2, 3, 6, 8
Formica Insulation Co., Cincinnati, Ohio	Formica	1, 2, 3, 4, 6, 7, 8, 9
Gatke Corporation, Chicago, Ill.	Gatke	3, 4, 5
General Electric Co., Schenectady, N. Y.	Textolite Laminated	1, 2, 3, 4, 6
Mica Insulator Company, Schenectady, N. Y.	Lamicoid	1, 2, 4, 7, 8, 10
Phenolite Division, National Vulcanized Fibre Co., Wilmington, Del.	Phenolite	1, 2, 3, 4, 5, 10
Panelyte Division, St. Regis Paper Company, 230 Park Avenue, New York, N. Y.	Panelyte	1, 2, 3, 4, 5, 6, 8
Richardson Company, Melrose Park, Ill.	Insurok	1, 2, 3, 4, 5, 6, 7, 8
Spaulding Fibre Company, Tonawanda, N. Y.	Spauldite	1, 2, 3, 4, 5, 8
Synthane Corporation, Oaks, Pa.	Synthane	1, 2, 3, 4, 5, 10
Micarta Division, Westinghouse Electric & Manufacturing Company, Trafford, Pa.	Micarta Moldarta	1, 2, 3, 4, 5, 8, 9

FIG. 1.7

MOLDERS

KEY

Symbol	*Type of Molding*	*Symbol*	*Type of Molding*
A	Compression	E	Adhesives
B	Injection	F	Foils
C	Extrusion	G	Cast
D	Laminating	H	Cold Molding

Accurate Molding Corporation, 120 Nassau St., Brooklyn, N. Y.	A
Ace Plastic Novelty Corporation, 476 Jefferson St., Brooklyn, N.Y.	
Ackerman Rubber and Plastic Corporation, 986 East 200 St., Cleveland, Ohio	A
Advance Molding Corporation, 54 West 21 St., New York City	A B
Alden Products Co., 715 Center St., Brockton, Mass.	A
Allied Plastics Corporation, 6243 S. Manhattan Pl., Los Angeles, Cal.	A B
American Hard Rubber Co., 11 Mercer St., New York City	A B
American Household Mfg. Co., 2077 U. S. Highway #1, Rahway, N. J.	
American Insulator Corporation, 1930 Main St., New Freedom, Pa.	A B H
American Luminous Products Co., Huntington Park, Cal.	
American Molded Products Co., 1753 North Honore St., Chicago, Ill.	B
American Molding Co., 16th and Vermont Sts., San Francisco, Cal.	A B C
American Phenolic Corporation, 1250 W. Van Buren St., Chicago, Ill.	B
American Plastics Corporation, Bainbridge, N. Y., or 225 West 34 St., New York City	C
American Products Mfg. Co., New Orleans, La.	
Ampco Mfg. Co., Los Angeles, Cal.	
Anchor Hocking Glass Corporation, Closure Div., 109 N. Broad St., Lancaster, Ohio	
Anchor Cap & Closure Corporation, 22 Queens St., Long Island City, N. Y.	A
Anchor Plastics Corporation, 71–73 Grand Ave., New York City	C
Anfinsen Plastic Molding Co., Aurora, Ill.	A B
Armstrong Cork Co., Glass & Closure Div., 1010 Concord St., Lancaster, Pa.	A B
Athol Comb Co., 261 Fifth Ave., New York City	B
Atlantic Plastics & Metal Parts Co., 2729 or 2730 Grand Ave., Cleveland, Ohio	A B C
Auburn Button Works, Inc., 1930 Canova Ave., Auburn, N. Y.	A B
Automatic Molded Products Co., 40–35 21 St., Long Island City, N. Y.	A
Bachmann Bros., Inc., 1420 E. Erie Ave., Philadelphia, Pa.	B
Baldwin Rubber Co., Peryale & Shephard Sts., Pontiac, Mich.	
Ballard Plastics Corporation, 5300 14 Ave., N. W., Seattle, Wash.	A B
Barber-Coleman Co., 230 Loomis St., Rockford, Ill.	A
Bay Mfg. Co., Div. of Electric Auto-Lite Co., Bay City, Mich.	A B
Bay State Molding Co., 1189 Dorchester Ave., Boston, Mass.	A
Beaman Molded Products Co., 4635 S. E. Hawthorne St., Portland, Ore.	A
Belmar Mfg. Co., 16 Marble St., Canton, Pa.	B
Belmont Molded Plastics, Inc., 400 Pike St., Cincinnati, Ohio	B
Berkander, George F., 891 Broad St., Providence, R. I.	B
The Bolta Co., Lawrence, Mass.	
Boonton Molding Co., 42 Thomason St., Boonton, N. J.	A B
Bowling Green Rubber Co., Hoag & Prospects Sts., Toledo, Ohio	
Breeze Corporations, Inc., 18–38 or 24 So. 6 St., Newark, N. J.	A
Bridgeport Moulded Products, Inc., 304 Myrtle Ave., Bridgeport, Conn.	A B
Bright Plastics, Inc., Dayton, Ohio	
Brill-Monfort Co., Inc., 77 Washington Ave., Brooklyn, N. Y.	A
Bryant Electric Co., Hemco Plastics Div., 1934 Weaver Ave., Bridgeport, Conn.	A B

Fig. 1.8.

Buckley Co., C. E., Leominster, Mass.	
Butterfield, Inc., T. F., 58 Rubber Ave., Naugatuck, Conn.	A B
Button Corporation of America, 49 Dickerson St., Newark, N. J.	A B
Caldwell Products, Inc., 142 West 24 St., New York City	B
California Plastic Molding Co., 1702 East 61 St., Los Angeles, Cal.	A
Cardinal Corporation, 1941 Bauer Ave., Evansville, Ind.	B
Cargo Corporation, 121 N. Broadway, Milwaukee, Wis.	
Celluplastic Corporation, 50 Ave. L., Newark, N. J.	
Central Die Casting & Mfg. Co., Inc., 2935 West 47 St., Chicago, Ill.	A
Chicago, Die Mold Mfg. Co., 1731 Diversey Parkway, Chicago, Ill.	A
Chicago Extruded Plastics, 1209 Webster Ave., Chicago, Ill.	C
Chicago Molded Products Corporation, 1020 North Kolmar Ave., Chicago, Ill.	A B
Cincinnati Molding Co., 2037 Florence St., Cincinnati, Ohio	A
Claremould Plastics Corporation, 117 Edison Place, Newark, N. J.	B
Cleveland Plastics, Inc., 12910 Taft Ave., Cleveland, Ohio	A
Climax Mfg. & Molding Corporation, 315 Reynolds Place, S. W., Canton, Ohio	A
Colt's Patent Fire Arms Mfg. Co., 1935 Van Dyke Ave., Hartford, Conn.	A B H
Columbia Dentoform Corporation, 131 East 23 St., New York City	B
Columbia Protektosite Co., Inc., Carlstadt, N. J.	B
Columbus Plastic Products, Inc., 519 Dublin Ave., Columbus, Ohio	B
Commonwealth Plastics Co., 39 Spruce St., Leominster, Mass.	B
Compo-site, Inc., Paterson, N. J.	
Conklin Pen Co., Toledo, Ohio	
Connecticut Hard Rubber Co., 407 East St., New Haven, Conn.	A
Connecticut Plastic Products Co., 124 North Elm St., Waterbury, Conn.	B
Consolidated Molded Products Corporation, 302 Cherry St., Scranton, Pa.	A B
Continental Diamond Fibre Co., Newark, Del.	D
Coventry Ware Inc., Barberton, Ohio	
Cruver Mfg. Co., 2460 W. Jackson Blvd., Chicago, Ill.	B
Cutler-Hammer, Inc., 315 N. 12 St., Milwaukee, Wis.	A
Daven Co., 160 Summit at Newman St., Newark, N. J.	
Davies Molding Co., Harry, 1356 or 1428 N. Wells St., Chicago, Ill.	A
Davis Manufacturing Co., Plano, Ill.	
Dayton Insulating Molding Co., 418 E. 1st St., Dayton, Ohio	A B
Detroit Macoid Corporation, 12340 Cloverdale Ave., Detroit, Mich.	B C
Detroit Paper Products Corporation, Domme at Bettis St., Detroit, Mich.	D
Diemolding Corporation, Canastota, N. Y.	A B
Dillon-Beck Mfg. Co., Irvington, N. J.	
du Pont de Nemours, E. I., & Co., Inc., Wilmington, Del.	C
Eagle Electric Mfg. Co., Park Ave. & Hall St., Brooklyn, N. Y.	
Eagle Plastic Corporation, 135 Walton St., Brooklyn, N. Y.	A
Eby, Hugh H., Inc., 4704 Stenton Ave., Philadelphia, Pa.	A
Eclipse Moulded Products Co., 5151 N. 32nd St., Milwaukee, Wis.	A
Eclipse Plastic Industries, Milwaukee, Wis.	B
Economy Fuse & Mfg. Co., Greenview Ave. & Diversey Parkway, Chicago, Ill.	A
Emeloid Co., 289–93 Laurel Ave., Arlington, N. J.	B
Erie Plastics Co., 1304 Cranberry St., Erie, Pa.	B
Erie Resistor Corporation, 644 West 12th St., Erie, Pa.	B C
Evelo Mfg. Co., Westfield, N. J.	
Extruded Plastics, Inc., New Canaan Ave., Norwalk, Conn.	C

Fig. 1.8 — (*Continued*)

Fanwood Specialties Co., Scotch Plains, N. J.	
Farlite Division, Farley & Loetscher Mfg. Co., Dubuque, Iowa	D
Federal Tool Corporation, 412 N. Leavitt St., Chicago, Ill.	A
Firestone Tire & Rubber Co., Mitchell & Blizzard Sts., Akron, Ohio	
Firestone Rubber & Latex Products Co., 172 Ferry St., Fall River, Mass.	A B
Formica Insulation Co., 4672 Spring Grove Ave., Cincinnati, Ohio	D
Foster-Grant Co., Inc., Lancaster St., Leominster, Mass.	B
Franklin Plastic & Die Casting Div. Baldwin Laboratories, Inc., Grant St., Franklin, Pa.	A B
Garfield Mfg. Co., Wallington Road, Garfield, N. J.	A
Gatke Corporation, Chicago, Ill.	D
Gemloid Corporation, 79–10 Albion Ave., Elmhurst, L. I., N. Y.	A B
General Button Co., 136 Harrison Ave., Boston, Mass.	
General Electric Co., Plastics Dept., 1 Plastics Ave., Pittsfield, Mass.	A B D H
The General Industries Co., Cleveland & Olive Sts., Elyria, Ohio	A B
General Insulate Co., Inc., 11 New York Ave., Brooklyn, N. Y.	A
General Molding Co., 6300 N. Shelborne St., Philadelphia, Pa.	A
General Products Co., 15 Elbow St., Providence, R. I.	
General Products Co., Mill Bldg., Union Springs, N. Y.	A
General Railway Signal Co., 801 West Ave., Rochester, N. Y.	
Gibbs Mfg., 2411 6 St., Berkeley, Cal.	A
Gits Molding Corporation, 4600 W. Huron St., Chicago, Ill.	B
Globe Tool & Molded Products Co., 1032 Mulberry St., Rockford, Ill.	A
Grigoleit Co., 400 Short St., Decatur, Ill.	A
Gulliksen Mfg. Co., W. M., West Newton, Mass.	A
The Haas Corporation, Mendon, Mich.	
Harbor Island Brass Foundry, 3426 13 St., S. W., Seattle, Wash.	
Haskelite Mfg. Corp., 208 W. Washington St., Chicago, Ill.	
Haveg Corporation, S. Newark, Del.	D
Hill Button Works, Inc., 21–07 40 Ave., Long Island City, N. Y.	
Hopp Press, Inc., 462 W. 34 St., New York City	
Hurst, Inc., 791 Tremont St., Boston, Mass.	A B
Hyde, A. L., Greenloch, N. Y.	A B
Imperial Molded Products Corporation, 2925 W. Harrison St., Chicago, Ill.	A
Industrial Molded Products Co., 2049 or 2035 W. Charleston St., Chicago, Ill.	A
Industrial Plastics Corporation, State Highway #6, Fairfield Rd., Caldwell, N. J.	
Ingwersen, Inc., 1810 Acoma St., Denver, Col.	A
Inland Mfg. Div., General Motors Corporation, Dayton, Ohio	A B
The Injection Molding Co., 3827 Independence Ave., Kansas City, Mo.	B
Injection Molding Corporation, 117 Fourth Ave., New York City	B
Insel Co., The, 430 Schuyler Ave., or Schuyler Ave., foot Quincy St., Arlington, Mass.	A B
Insulating Fabricators, Inc., 12 East 12 St., New York City	
Insulation Mfg. Co., Inc., 15 New York Ave., Brooklyn, N. Y.	A
Insulation Products Co., 504 North Richland St., Pittsburgh, Pa.	A
International Molded Plastics, Inc., 4383 E. or W. 35 St., Cleveland, Ohio	A
Irvington Varnish & Insulation Co., Irvington, N. J.	C
Ivorycraft Co., Inc., Long Island City, N. Y.	
Jamison, H., 71 Sunrise Highway, Freeport, L. I., N. Y.	A B
Johns-Mansville Sales Corporation, 22 E. 40 St., New York City	
Kampa Mfg. Co., Milwaukee, Wis.	
Keasbey & Mattison, Ambler, Pa.	A

Fig. 1.8 — (*Continued*)

Keeler Brass Co., Webb & Beek Sts., or 955 Godfrey Ave., S. W., Grand Rapids, Mich.	A B
Kellogg Switchboard & Supply Co., 6650 So. Cicero Ave., Chicago, Ill.	A
Kem, Inc., 1900 E. Jefferson St., Detroit, Mich.	
Kenilworth Button Mfg. Co., Kenilworth, N. J.	A
Keolyn Plastics Co., 2725 or 2731 N. Pulaski Road, Chicago, Ill.	B
Keyes Fibre Co., Inc., Portland, Me.	A
Keystone Specialty Co., 1370 or 1373½ Cove Ave., Cleveland, Ohio	A
Kilgore Mfg. Co., East Broadway, Westerville, Ohio	A B
Kingman Co., E. B., Leominster, Mass.	B C
Knoedler, Alphonse, & Co., Inc., 31 Division St., Newark, N. J.	
Koken Co., 3400 Morganford Road, St. Louis, Mo.	
Kuhn & Jacob Moulding & Tool Co., 1200 Southard St., Trenton, N. J.	A
Kurz-Kasch Inc., 1417 S. Broadway, Dayton, Ohio	A
Lanfare Molded Products, 1519 Freeman St., Toledo, Ohio	A
Lapin Products, Inc., 200 Varick St., New York City	B C
Lauterbach Co., John, 3627 N. Lawrence St., Philadelphia, Pa.	
Leviton Mfg. Co., 236 Greenpoint Ave., Brooklyn, N. Y.	A
Los Angeles Moulding Co., 1702 East 61 St., Los Angeles, Cal.	
Lowe Co., E. S., Inc., 27 West 20 St., New York City	
Luzerne Rubber Co., Dewey St., Trenton, N. J.	
McDonald & Co., P. F., 17 King Terminal, Boston, Mass.	A B
McDonald Mfg. Co., 548 East 31 St., Los Angeles, Cal.	
Mack Molding Co., Inc., 100 Main St., Wayne, N. J.	A B
Marbello Artcraft Co., Inc., 622 W. Lake St., Chicago, Ill.	
Marks Products Co., Inc., 84 N. 9 St., Brooklyn, N. Y.	
Martindell Molding Co., North Olden at Sixth, Trenton, N. J.	A B
Mason Co., Inc., Thomas, Sunnyside Ave., Stamford, Conn.	B
Meissner Mfg. Co., Mt. Carmel, Ill.	A
Merrigan Plastic Co., 4405 Fruitland Ave., Los Angeles, Cal.	B
Metal Specialty Co., Winston Place, Cincinnati, Ohio	B
Mica Insulator Co., Schenectady, N. Y.	D
Michigan Molded Plastics Inc., G & Baker Sts., Dexter, Mich.	A B C
Mico, Inc., Millerton, N. Y.	A
Midwest Molding & Mfg. Co., 323 or 319 N. Whipple St., Chicago, Ill.	A
Mills Corporation, Elmer E., 814–22 or 812 Van Buren St., Chicago, Ill.	B
Minneapolis Plastic Molding Co., 23rd Ave. So. at 31 St., Minneapolis, Minn.	
Minnesota Plastic Corporation, 411 Broadway, St. Paul, Minn.	B
Modern Plastic Co., 4641 Pacific Blvd., Los Angeles, Cal.	B C
Modern Plastics Corporation, Benton Harbor, Mich.	A B
Molded Insulation Co., 335 E. Price St., Philadelphia, Pa.	A B
Molded Plastics, Inc., 300 Atkins Ave., Neptune, N. J.	A B
Molded Products Co., 4533 West Harrison St., Chicago, Ill.	A
Molded Wood Products Co., Medford, Mass.	H
Molding Corporation of America, 225 Chapman St., Providence, R. I.	A B
Morley Button Mfg. Co., Portsmouth, N. H.	
Mullen, Coleman J., 50 Church St., New York City	
Multi-Plastics Corporation, 155 North Vermont Ave., Los Angeles, Cal.	B C
Multi-Products Tool Co., 119 Sussex Ave., Newark, N. J.	
Mundet Cork Corporation, 1939 Thomas St., Hillside, N. J.	
National Lock Co., 7 St. & 18 Ave., Rockford, Ill.	A B G
National Organ Supply Co., 1617 Cascade Ave., Erie, Pa.	A B
National Plastic Products Co., 6527 Russel Ave., Detroit, Mich.	

Fig. 1.8 — (*Continued*)

National Plastics Inc., 2330 McCalla Ave., Knoxville, Tenn.	A B
National Vulcanized Fibre Co., Wilmington, Del.	D
New England Novelty Co., Leominster, Mass.	C
New Plastic Corporation, 1917 Sycamore St., Hollywood, Cal.	
New Products Corporation, Benton Harbor, Mich.	A
Niagara Insul-Bake Specialty Co., Inc., 483 Delaware Ave., Albany, N. Y.	A
Norris Plastics Co., 655 South Erie St., Massilon, Ohio	A B
Northern Industrial Chemical Co., 11 Elkins St., Boston, Mass.	A B
Northwest Plastics, Inc., 2233 University Ave., St. Paul, Minn.	A
Norton Laboratories, Inc., 1035 Mill St., Lockport, N. Y.	A B
Novel Products Co., 97 E. Houston St., New York City	C
Ohio Plastics Co., Frazeysburg, Ohio	B
Oris Mfg. Co., Thomaston, Conn.	A
O'Shei, B. F., 170 Florida St., or 2671 Main St., Buffalo, N. Y.	
Owens-Illinois Glass Co., Closure Div., Toledo, Ohio	A F
Pacific Plastic & Mfg. Co., Inc., 5446 Carlton Way, Hollywood, Cal.	B
Panelyte Div., St. Regis Paper Co., 230 Park Ave., New York City. Factory: Trenton, N. J.	D
Paragon Molding Co., Maritime Building, Seattle, Wash.	A
Patent Button Co. of Tennessee, Inc., Knoxville, Tenn.	A
Paulis, Inc., H., 215 E. Washington Blvd., Los Angeles, Cal.	A B
Peerless Molded Plastics, Inc., 401 Hamilton St., Toledo, Ohio	A B
Peerless, Moulded, Inc., Teaneck, N. J.	
Phenolite Div., National Vulcanized Fibre Co., Wilmington, Del.	D
Phoenix Metal Corp., Clinton, Mass.	A
Pierce Plastics, Bay City, Mich.	C
Pittsburgh Plastics Co., Inc., P. O. Box 523, New Kensington, Pa.	A
Place Co., Roland P., Midland, Mich.	A
Plano Molding & Machine Co., Plano, Ill.	A B
Plastex Trim Corp., 402 Mt. Vermon Ave., Columbus, Ohio	C
Plastic & Die Cast Products Corporation, 1010 E. 62 St., Los Angeles, Cal.	
Plastic Jewelry, Inc., 10–15 46 Ave., Long Island City, N. Y.	A B
Plastic Molded Arts, Inc., 2912 Atlantic Ave., Brooklyn, N. Y.	A B
Plastic Molding Corporation, 610 Baymiller St., Cincinnati, Ohio	A B
Plastic Parts Co., 40 Clifford Ave., Providence, R. I.	A
Plastic Products, Inc., 415 Lexington Ave., New York City	A B H
Plastic-Ware Inc., 238–240 William St., New York City	A
Plastic Molding Corporation, 1939 Anderson St., Sandy Hook, Conn.	A
Plastics Inc., 813 Main St., Bradley Beach, N. J.	A B
Plastics, Inc., 20 Chicago Ave., St. Paul, Minn.	A B
Plastik, Inc., 791 Tremont St., Boston, Mass.	A B
Plastimold, Inc., (formerly Associated Attleboro Manufacturers) Attleboro, Mass.	A
Poinsettia, Inc., Pitman, New Jersey	A
Potter & Brumfield Mfg. Co., Inc. Prince & Gibson Sts., Princeton, Ind.	
Premier Die Cutting Co., Attleboro, Mass.	
Prime Plastic Mfg. Co., 403 Bedford Ave., Brooklyn, N. Y.	
Pyro Plastics Co., Westfield, N. J.	B
Quintard and McIlhiney, Saxtons River, Vermont	A
R & R Plastics Products Co., West Springfield, Mass.	
Rathbun Molding Corporation, 1939 Rathbun St., Salamanca, N. Y.	A
Raymond Laboratories, Inc., 261 E. 5 St., St. Paul, Minn.	
Recto Molded Products, Inc., B&O RR & Appleton St., Cincinnati, Ohio	A B
Reinhold Co., F. E., 7001 McKinley St., Los Angeles, Cal.	A
Remler Co., Ltd., 2101 Bryant St., San Francisco, Cal.	A B
Resistoflex Co., 37 Plansoen St., Belleville, N. J.	

FIG. 1.8 — (*Continued*)

Rex Products Corporation, 302 Fifth Ave., New York City	
Rex Co., Inc., The, 51 Landsdowne St., Cambridge, Mass.	C
Reynolds Spring Co., Molded Plastics Div., Thomas St., Cambridge, Ohio	A B
Rhode Island Molding Works, 16 Manhasset St., Cranston, R. I.	A B
Richardson Co., The, 27th St. at Lake St., Melrose Park (Chicago), Ill.; also 3529 20 St., Indianapolis, Ind.	A B D
Rochester Button Co., The, 300 State St., Rochester, N. Y.	
Royal Molding Co., Inc., 69 Gordon Ave., Providence, R. I.	A
St. Louis Plastic Moulding Co., Div. Quick Point Pencil Co., 3500 North Florissant Ave., St. Louis, Mo.	B
Salz Bros., Inc., 44 W. 28 St., New York City	A B
Sandee Mfg. Co., 3945 N. Western Ave., Chicago, Ill.	C
Scott Mfg. Co., Inc., George S., Plantsville, Conn.	A
Screw Machine Specialties Co., Grand Haven, Mich.	
Seamless Rubber Co., New Haven, Conn.	
Shaw Insulator Co., Irvington, N. J.	A B C
Sheller Mfg. Co., Portland, Ind.	A
Shepherd Son & Co., J. H., 1820 East Ave., Elyria, Ohio	B
Shields Mfg. Co., Tampa, Fla.	
Siemon Co., Bridgeport, Conn.	A
Sinko Tool & Mfg. Co., 351 N. Crawford Ave., Chicago, Ill.	A B
Sobenite, Inc., South Bend, Ind.	B
Spaulding Fibre Co., Tonawanda, N. Y.	D
Southern Plastics Co., 906–8 Main St., Columbia, S. C.	C
Specialty Insulation Mfg. Co., 55 Center Ave., Hoosick Falls, N. Y.	A
Standard Cap & Molding Co., 307 S. Eaton St., Baltimore, Md.	A
Standard Plastics Co., 16 State St., Attleboro, Mass.	A B
Standard Plastics Co., 1281 Riverside Drive, Los Angeles, Cal.	
Standard Products Co., Boulevard Bldg., Detroit, Mich.	
Standard Pyroxoloid Corporation, Leominster, Mass.	B
Sterling Injection Molding, Inc., 277 Military Rd., Buffalo, N. Y.	B
Sterling Plastics Co., 6 Garden St., Newark, N. J.	A B
Stokes Rubber Co., Jos., 220 Webster St., Trenton, N. J.	A B
Superior Plastics Co., 643 N. Kedzie Ave., Chicago, Ill.	B
Swedlow Aeroplastics Corporation, Glendale, Cal.	
Synthane Corporation, Highland Ave., Oaks, Pa.	D
Synthetic Molded Products, Inc., Wakefield, R. I.	A
Synthetic Plastics Co., 88 St. Francis St., Newark, N. J.	A C
Synvar Corporation, Wilmington, Del.	E
Tech-Art Plastics, Inc., 36 Ave. & 41 St., Long Island City, N. Y.	
Terkelsen Machine Co., 326 A St., Boston, Mass.	A
Ther Electric & Machine Works, 17 S. Jefferson St., Chicago, Ill.	
Thermo-Plastics Div., Standard Products Co., St. Clair, Mich.	B C
Tilton & Cook Co., Leominster, Mass.	B
Transilux Molding Corporation, New Haven, Conn.	
Trimm Mfg. Co., Ltd., 1770 W. Berteau Ave., Chicago, Ill.	
Trojan, Inc., Troy, N. Y.	B
Tupper Co., Earl S., Leominster, Mass.	A B
Union Insulating Co., Parkersburg, W. Va.	A
Union Plastic Co., 1941 Long Ave., Hillside, N. J.	
United Comb & Novelty Co., Leominster, Mass.	A B
United States Plastic Corporation, Leominster, Mass.	A B
United States Plywood Corporation, 46 St. & 12 Ave., New York City	D E
Universal Molded Products Co., Bristol, Va., or Orlando, Fla.	D
Universal Plastics Corporation, 235 Jersey Ave., New Brunswick, N. J.	A B
Valley Molding Co., 48 Jefferson Ave., Waterbury, Conn.	A

Fig. 1.8 — *(Continued)*

Van Norman Molding Co., 6441 South State St., Chicago, Ill.	A
Victor Mfg. & Gasket Co., 1059 S. Menard St., Chicago, Ill.	A
Victor Metal Products Corporation, 198 Diamond St., Brooklyn, N. Y.	A
Victory Molding Co., 147-7 St., Leominster, Mass.	A B
Vivian Allied Plastics Corporation, 110 W. 27 St., New York City	B
Vichek Tool Co., Plastics Div., E. 87 & Koster St., Cleveland, Ohio	A B
Voges Mfg. Co., Ozone Park, L. I., N. Y.	A
Vulcanized Rubber Co., The, 2 E. 29 St., New York City	A B
Ward Plastic & Rubber Co., Rochester, Mich.	A B
Warren Plastic Corporation, 1941 Myers St., Warren, Pa.	A B
Waterbury Button Co., The, Waterbury, Conn.	A B
Watertown Mfg. Co., 100 Echo Lake Road, Watertown, Conn.	A B
Werner, R. D., Co., 320 Second Ave., New York City	C
Western Plastic Molding Co., 1139 East 105 St. or 335 East 58 St., Los Angeles, Cal.	
Westinghouse Electric & Mfg. Co., Micarta Div., Trafford, Pa.	D
Wheeling Stamping Co., Wheeling, W. Va.	A
White Dental Mfg. Co., SS., Ind. Div., 10 East 40 St., Dept. T., New York City	A B
Windman Bros., 3325 Union Pacific Ave., Los Angeles, Cal.	A
Woodruff Co., The, 185 Clark St., Auburn, N. Y.	A
Worcester Moulded Plastics Co., Worcester, Mass.	A B
Zenith Plastics, Inc., 1011 Power Ave., Cleveland, Ohio	A
Ziwel Plastics Corporation, 1434 N. Walnut St., Dover, Ohio	A B

FIG. 1.8 — *(Continued)*

PART II

Physical Properties of Plastics

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CHAPTER II
Tables of Properties of Plastics

CHAPTER III
Test Methods for Physical Properties

CHAPTER IV
Plastics Catalogues

CHAPTER II

TABLES OF PROPERTIES OF PLASTICS

In this chapter the properties of common plastics compounds are enumerated. The plastics are grouped according to general types in the following manner:

Thermosetting Plastics:

- Table 1. Phenol-Formaldehyde and Phenol-Furfural Compounds
  - Phenol-Formaldehyde Compounds
    - Molded
      - No Filler
      - Wood Flour Filler
      - Mineral Filler
      - Fabric Filler
    - Laminated
      - Paper Base
      - Cotton Fabric Base
      - Asbestos Cloth Base
      - Glass Fabric Base
    - Cast
  - Phenol-Furfural Compounds
    - Molded
      - Wood Flour Filler
      - Mineral Filler
      - Fabric Filler

- Table 2. Urea-Formaldehyde and Melamine-Formaldehyde Compounds
  - Urea-Formaldehyde Compounds
    - Molded
      - Alpha-Cellulose Filler
      - Wood Filler (sold in England)
  - Melamine-Formaldehyde Compounds
    - Molded
      - Mineral Filler
      - Cellulose Filler

Thermoplastic Plastics:

- Table 3. Vinyl Resins and Polystyrene Plastics
  - Vinyl Resins
    - Polyvinyl Chloride Acetate
      - Molded
        - No Filler
        - Filler
    - Polyvinyl Chloride
      - Molded — Plasticized
    - Polyvinyl Acetate
      - Molded
    - Polyvinyl Acetal (Aldehyde Reaction Products)
      - Molded
    - Vinylidene Chloride
      - Molded
    - Polyvinyl Alcohol
      - Molded
  - Polystyrene Plastics
    - Molded
  - Films, rods, tubes and shapes

- Table 4. Methyl Methacrylate Plastics
  - Cast
  - Molded

- Table 5. Nylon Plastics
  - Molded

- Table 6. Cellulose Derivative Plastics
  - Cellulose Nitrate
  - Cellulose Acetate
    - Transparent
    - Pigmented
    - High Acetyl Transparent
  - Cellulose Acetate Butyrate
  - Ethyl Cellulose

Miscellaneous:

- Table 7. Miscellaneous Compounds
  - Casein
  - Lignin
  - Rubber Compounds
    - Hard Rubber
    - Chlorinated Rubber (Parlon — Tornesit)
    - Organic Polysulfide (Thiokol)
  - Cold Molded Compounds
    - Refractory (Inorganic)
    - Non-Refractory (Organic)
  - Shellac

Properties of Plastics Compared:

- Table 8.
  - Tensile Strength
  - Modulus of Elasticity

Properties of Plastics Compared:
- Table 8 (*Continued*)
  - Compressive Strength
  - Flexural Strength
  - Impact Strength
  - Hardness
  - Thermal Conductivity
  - Specific Heat
  - Thermal Expansivity
  - Safe Top Operating Temperature
  - Volume Resistivity
  - Dielectric Strength
  - Dielectric Constant
  - Power Factor
  - Moisture Absorption
  - Flammability

Not all the known plastics nor all their available forms are listed. In many cases those forms, such as extruded fibers or resin coatings, are described elsewhere in appropriate sections of the book. For each type of plastic the range of properties of commercially available compounds is given in the charts.

For other information covering physical properties, see general Index.

TABLE 1

Properties	Phenol-formaldehyde Compounds									Phenol-furfural Compounds		
	Molded				Laminated				Cast	Molded		
	No Filler	Wood Flour Filler	Mineral Filler	Fabric Filler	Paper Base	Cotton Fabric Base	Asbestos Cloth Base	Glass Fabric Base		Wood Flour Filler	Mineral Filler	Fabric Filler
Specific Properties												
✓ Specific gravity	1.28	1.25–1.52	1.59–2.09	1.3–1.4	1.3–1.4	1.3–1.4	1.55–1.80	1.4–1.6	1.27–1.33	1.3–1.4	1.6–2.0	1.3–1.4
Specific volume, cu. in. per lb.	21.7	22.2–18.2	16.4–13.3	20.2–19.8	21.3–20.4	21.3–20.4	17.8–15.0	19.7–17.3	23.0–20.0	21.3–19.8	17.3–13.9	21.3–19.8
Clarity	Transparent to translucent	Opaque	Opaque	Opaque	Opaque	Opaque	Opaque	Opaque	Transparent to opaque	Opaque	Opaque	Opaque
Color possibilities	All colors, mostly dark shades	Medium to dark shades, mottles	Dark shades	Dark shades	Medium to dark shades	Dark shades	Dark shades	Medium to dark shades	All colors, light to dark	Dark shades	Black brown	Black brown
Refractive index	1.56–1.70	—	—	—	—	—	—	—	1.46–1.70	—	—	—
Light transmission, per cent	—	—	—	—	—	—	—	—	70–92 1/8 in. — 40-watt source	—	—	—
Thermal Properties												
Specific heat, cal. per ° C. per gram	0.33–0.36	0.35–0.36	0.25–0.35	0.30–0.35	0.30–0.40	0.30–0.40	—	—	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4
Thermal expansion, 10^{-5} per ° C.	2–3	3.7–7.5	2.5–4	2–6	1.7–2.5	1.7–3.0	1.7–2.5	—	2.8	3.0	2.0	—
Thermal conductivity, 10^{-4} cal. per sec. per sq. cm. per ° C. per cm.	3–4	4–12	8–20	3–6	5–8	5–8	5–8	—	3–5	3.5–5	10–20	5.0–8.0
Softening point, ° F.	None	None	None	None	None	None	None	None	176–212	Chars 450	Chars 450	—
Distortion under heat, ° F.	240–260	240–285	—	—	> 320	> 320	> 320	320	—	—	—	—
Resistance to continuous heat, ° F.	250	250–450	450	230–350	212–400	212–350	400–450	480	160	—	—	—
Burning rate	Very low	Very low	Nil	Very low	Very low	Very low	Nil	Nil	Very low	—	—	—
Mechanical Properties												
Tensile strength, lb. per sq. in.	6000–9000	4000–11,000	4000–10,000	6500–12,000	7000–18,000	8000–15,000	7000–12,000	14,000–20,000	3000–8000	—	—	—

TABLE 1 (*Continued*)

Properties	Phenol-formaldehyde Compounds									Phenol-furfural Compounds		
	Molded				Laminated				Cast	Molded		
	No Filler	Wood Flour Filler	Mineral Filler	Fabric Filler	Paper Base	Cotton Fabric Base	Asbestos Cloth Base	Glass Fabric Base		Wood Flour Filler	Mineral Filler	Fabric Filler
Elongation, per cent	—	—	—	—	—	—	—	—	—	—	—	—
Modulus of elasticity, lb. per sq. in. $\times 10^5$	7–10	10–15	10–45	7–12	4–20	3.5–15	3.5–15	10–20	3–10	10–25	10–45	7–12
✓ **Compressive strength, lb per sq. in.**	—	16,000–36,000	18,000–36,000	20,000–32,000	20,000–40,000	30,000–44,000	18,000–45,000	42,000–47,000	10,000–30,000	28,000–36,000	24,000–36,000	26,000–30,000
Flexural strength, lb. per sq. in.	12,000–17,000	8000–15,000	8000–20,000	10,000–13,000	13,000–30,000	13,000–30,000	10,000–35,000	20,000–27,000	7000–15,000	10,000–16,000	8000–14,000	10,000–16,000
✓ **Impact strength, ft.-lb. energy to break ½ by ½ in. bar C = Charpy I = Izod**	0.32–0.40 I	0 20–0.56 I	0.22–0.72 I	0.8–4.8 I	0.6–7.6 I	1.4–15 I	1.8–11 I	5.0–6.5 I	0.1–0.4 I	0.30–0.56 I (50 kg.)	0.32–0 74 I	1.20–4.60 I
Hardness, Brinell (2.5-mm. ball; 25-kg. load)	10–50	30–45	—	32–40	24–40	30–45	35–45	—	30–45	35–40 (50 kg.)	44–46 (50 kg.)	30–35 (50 kg.)
Hardness, Rockwell	M80–M130	M100–M125	M85–M120	M85–M110	M70–M120	M70–M120	M70–M110	M105–M110	M80–M130	B65–75	B54–62	B65–75
Electrical Properties												
Volume resistivity, ohm-cm. (50% relative humidity) at 25° C.	$(1\text{–}5) \times 10^{12}$	10^{10}–10^{12}	10^{9}–10^{11}	10^{9}–10^{11}	10^{10}–10^{13}	10^{10}–10^{12}	—	—	10^{9}–10^{14}	10^{10}–10^{12}	10^{9}–10^{11}	10^{9}–10^{11}
at 30° C.	10^{10}–10^{13}	10^{10}	10–1000 × 10^{10} (mica filler)	10^{10}	10^{10}–10^{12}	10^{9}–10^{10}	—	—	—	—	—	—
✓ Dielectric strength, 60 cycles Short time volts per mil	400–600	300–500	250–400	150–450	400–1000	150–600	60–150	450–650	300–450	400–600	200–500	200–500
Step by step volts per mil	250–350	200–350	200–400	100–350	250–600	150–400	50–125	—	250–350	—	—	—

TABLE 1 (*Continued*)

Properties	Phenol-formaldehyde Compounds									Phenol-furfural Compounds		
	Molded				Laminated				Cast	Molded		
	No Filler	Wood Flour Filler	Mineral Filler	Fabric Filler	Paper Base	Cotton Fabric Base	Asbestos Cloth Base	Glass Fabric Base		Wood Flour Filler	Mineral Filler	Fabric Filler
Dielectric constant												
60 cycles	5–6	5–12	5–20	5–10	—	—	—	—	5–10	—	—	—
10^3 cycles	4–5	4–8	4.5–20	4.5–6	—	—	—	—	4.5–8	4–8	4.5–20	4.5–6
10^6 cycles	4.5–5	4.5–8	4.5–20	4.5–6	3 6–5.5	4.5–7	7.5	3.7–4.5	5–8	6–7.5	5–18	5–7.5
Radio frequencies	4.5–7.0	4.5–8 Long life	—	4.5–7.0	4.5–8	4.5–7	—	—	4.5–7.0	—	—	—
Power factor												
60 cycles	0.05–0 10	0.04–0.30	0 10–0.30	0.08–0 30	—	—	—	—	0.025–0.20	—	—	—
10^3 cycles	0.025–0.06	0.04–0.15	0.10–0.15	0 08–0.20	—	—	—	—	0.005–0.08	0.04–0.15	0.1–0.15	0.08–0.20
10^6 cycles	0 015–0 04	0 035–0.1	0.005–0.10	0.04–0.10	0.02–0.08	0.02–0.08	0.15	0.01–0.02	0.01–0.045	0.035–0.1	0.04–0.1	0.035–0.1
Radio frequencies	0.005–0.05	0.01–0.1	0.1–0 2 (Mica filler)	0.05–0.1	0.015–0.05	0.02–0.08	—	—	0.005–0.05	0.01–0.06	—	0.05–0.08
Physical-Chemical Properties												
Effect of light	Exposure to ultra-violet lowers surface resistance and darkens light colors	Exposure to ultra-violet lowers surface resistance and darkens light colors	Exposure to ultra-violet lowers surface resistance and darkens light colors	Exposure to ultra-violet lowers surface resistance and darkens light colors	Lowers surface resistance	Lowers surface resistance	Lowers surface resistance	Lowers surface resistance	Causes surface discoloration	Prolonged exposure darkens light colors	Prolonged exposure darkens light colors	Prolonged exposure darkens light colors
Effect of aging	None	None	None	None	Improves mechanical and electrical properties	Improves mechanical and electrical properties	Improves mechanical and electrical properties	Improves mechanical and electrical properties	Hardens slightly	Improves mechanical and electrical properties	Improves mechanical and electrical properties	Improves mechanical and electrical properties
Effect of water												
Cold	No change to slight absorption	None	Very resistant	Variable	Slight deterioration on long immersion	Slight deterioration on long immersion	Slight deterioration on long immersion	Slight effect	None	Slight deterioration on long immersion	Very resistant	Slight deterioration on long immersion
Hot	Some materials swell and soften	Reduces insulation value	—	—	Effects are more rapid	Effects are more rapid	Effects are more rapid	—	Withstands intermittent washing	Effects are more rapid	Very resistant	Effects are more rapid

TABLE 1 (*Continued*)

Properties	Phenol-formaldehyde Compounds									Phenol-furfural Compounds		
	Molded				Laminated				Cast	Molded		
	No Filler	Wood Flour Filler	Mineral Filler	Fabric Filler	Paper Base	Cotton Fabric Base	Asbestos Cloth Base	Glass Fabric Base		Wood Flour Filler	Mineral Filler	Fabric Filler
Water absorption, per cent (24 hr.)	0.1–0.2	0.2–0.9	0.01–0.3	0.6–2.5	0.3–9.0	0.3–9.0	0.3–2.0	0.3–0.5	0.01–0.5	0.3–0.6	0.01–0.15	0.8–1.4
Effect of acids												
Weak	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids	None to slight, depending on acids
Strong	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect	Decomposed by oxidizing acids; reducing and organic acids have slight effect
Effect of alkalies												
Weak	Slight	Slight to marked, depending on alkalinity	Slight to marked, depending on alkalinity	Slight to marked, depending on alkalinity	Slight to marked, depending on alkalinity	Slight to marked, depending on alkalinity	Slight to marked, depending on alkalinity	Slight to marked, depending on alkalinity	Slight to marked, depending on alkalinity	Slowly softened, depending on alkalinity	Slowly softened, depending on alkalinity	Slowly softened, depending on alkalinity
Strong	Decompose	Decompose	Decompose	Decompose	Decompose	Decompose	Decompose	Decompose	Decompose	Decompose	Decompose	Decompose
Effect of organic solvents	None	None on bleed-proof materials	None on bleed-proof materials	None on bleed-proof materials	None on bleed-proof materials	None on bleed-proof materials	None on bleed-proof materials	None on bleed-proof materials	None	None on bleed-proof materials	None on bleed-proof materials	None on bleed-proof materials
Effect of metal inserts	Inert	Inert	Inert	Inert	Inert	Inert	Inert	Inert	Inert	Inert	Inert	Inert
Molding Properties												
Molding qualities	Fair	Excellent	Excellent	Good to fair	—	—	—	—	—	Excellent	Excellent	Good to fair
Compression molding temperature, °F.	300–340	280–360	270–350	270–360	250–350	250–360	300–350	275–350	—	330–400	330–360	330–360

TABLE 1 (*Continued*)

Properties	Phenol-formaldehyde Compounds									Phenol-furfural Compounds		
	Molded				Laminated				Cast	Molded		
	No Filler	Wood Flour Filler	Mineral Filler	Fabric Filler	Paper Base	Cotton Fabric Base	Asbestos Cloth Base	Glass Fabric Base		Wood Flour Filler	Mineral Filler	Fabric Filler
Compression molding pressure, lb. per sq. in.	2000–5000	2000–4500	2000–4000	3000–8000	1000–3000	1000–3000	1000–3000*	1000–3000	1000–3000	1000–3000	1000–3000	1000–3000
Injection molding temperature, °F.	—	275–375	275–350	—	—	—	—	—	—	250–290	250–290	250–290
Injection molding pressure, lb. per sq. in.	—	2000–10,000	2000–10,000	—	—	—	—	—	—	300–5000	300–5000	300–5000
Bulk factor ratio of volume loose powder to volume solid	2.0–2.6	2.2–2.8	2.0–6.0	3.0–11.0	1.5–3.0	1.5–3.0	1.6	—	—	2.5–3.0	2.5–6.0	4.0–15.0
Mold shrinkage, in. per in.	0.009–0.011	0.006–0.010	0.002–0.006	0.003–0.007	—	—	—	—	—	0.005–0.009	0.002–0.006	0.0025–0.006
Tendency to cold flow (Bell Telephone Lab. Cold Flow Test)	0.4%	0.4%	0.4%	0.4%	None	None	None	None	10%	None	None	None
Tendency to unmold	None	None	None	None	None	None	None	None	Very slight	None	None	None

* Most of the cast material is made without pressure.

TABLE 2. PROPERTIES OF UREA AND MELAMINE COMPOUNDS

Properties	Molded	
	Urea-formaldehyde Compounds	Melamine-formaldehyde Compounds
	Alpha-cellulose Filler	Mineral Filler
Specific Properties		
Specific gravity	1.45–1.52	1.76–1.98
Specific volume, cu. in. per lb.	19.1–18.5	—
Clarity	Translucent to opaque	Translucent to opaque
Color possibilities	Unlimited, complete range of standard shades	Range of colors possible
Refractive index	1.54–1.56	—
Light transmission, per cent	65 (unpigmented, 0.040 in. thickness)	—
Thermal Properties		
Specific heat, cal. per ° C. per gram	0.4	—
Thermal expansion, 10^{-5} per ° C.	2.5–3.0	—
Thermal conductivity, 10^{-4} cal. per sec. per sq. cm. per ° C. per cm.	7.1	—
Softening point, ° F.	None	None
Distortion under heat, ° F.	230–280	250–300
Resistance to continuous heat, ° F.	170	300–400
Burning rate	Very low	Approximately nil
Mechanical Properties		
Tensile strength, lb. per sq. in.	5000–13,000	5942 (one test)
Elongation, per cent	—	—
Modulus of elasticity, lb. per sq. in. $\times 10^6$ (Flexore)	12–15	12–15
Compressive strength, lb. per sq. in.	20,000–35,000	—
Flexural strength, lb. per sq. in.	10,000–16,000	8820–9925
Impact strength, ft. lb. energy to break a ½ by ½ in. bar. C = Charpy; I = Izod	0.15–0.32 I 1.2–1.7 C	0.273–0.360 I
Hardness, Brinell (2.5-mm. ball, 25-kg. load)	48–54 10-mm. ball; 50-kg. load	—
Hardness, Rockwell	M110–M130	—
Electrical Properties		
Volume resistivity, ohm–cm. (50% relative humidity and 25 ° C.)	2.8×10^{13}	—
Dielectric strength, 60 cycles	400–550	340–410 (100 ° C.); 415–464 (25 ° C.)
Short time volts per mil		
Step by step volts per mil	300–385	—
Dielectric constant		
60 cycles	7.0–8.75	8.2–11.5
10^3 cycles	6.4–8.75	—
10^6 cycles	6.3–7.75	—
Radio frequencies	—	—
Power factor		
60 cycles	0.039–0.10	0.11–0.165
10^3 cycles	0.035–0.055	—
10^6 cycles	0.027–0.039	—
Radio frequencies	—	—

TABLE 2 (*Continued*)

Properties	Molded	
	Urea-formaldehyde Compounds	Melamine-formaldehyde Compounds
	Alpha-cellulose Filler	Mineral Filler
Physical-Chemical Properties		
Effect of light	Natural color unaffected	—
Effect of aging	Hardens slightly	—
Effect of water		
Cold	Absorbs water slightly	Slight
Hot	Boiling water results in surface checking	More resistant than ureas
Water absorption, per cent (24 hr.)	1–3	0.15–0.3 (48 hr.)
Effect of acids		
Weak	Fair resistance	None
Strong	Decompose or attack surface	Slight
Effect of alkalies		
Weak	None on bleed-proof materials	None
Strong	Decompose	Slight
Effect of organic solvents	Resistant to oils and greases	—
Effect of metal inserts	Inert	Inert
Molding Properties		
Molding qualities	Excellent	Excellent
Compression molding temperature range, °F.	275–340	300–320
Compression molding pressure, lb. per sq. in.	2000–8000	1500–4000
Injection molding temperature, °F.	—	300–320*
Injection molding pressure, lb. per sq. in.	—	—
Bulk factor (volume loose powder per volume solid)	2.5–3.0	—
Mold shrinkage, in. per in.	0.006–0.011	6.0–6.6 (mil. per in.)
Tendency to unmold	—	—
Tendency to cold flow	None to slight	—

* Transfer molding recommended.

TABLE 3

Properties	Vinyl Resins							Polystyrene Plastics
	Polyvinyl Chloride Acetate		Polyvinyl Chloride	Polyvinyl Acetate	Polyvinyl Acetal (Aldehyde Reaction Products)	Vinylidene Chloride	Polyvinyl Alcohol	
	Molded No Filler	Molded Filler	Molded Plasticized	Molded	Molded	Molded	Molded	Molded
Specific Properties								
Specific gravity	1.34–1.37	1.35–2.50	1.2–1.6	1.191	1.107–1.25	1.6–1.75	1.259	1.054–1.070
Specific volume, cu. in. per lb.	20.7–20.4	20.5–11.1	23.0–17.3	—	25	17.3–15.8	—	26.3–25.9
Clarity	Transparent to opaque	Transparent to opaque	Transparent to opaque	Transparent to opaque	Transparent to translucent	Transparent to opaque	Transparent to opaque	Transparent to opaque
Color possibilities	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
Refractive index	1.53	—	1.544	1.466	1.488–1.50	1.60–1.63	—	1.59
Light transmission, per cent	—	—	—	—	85.–90.5 (.135 in thickness)	—	—	90 (0.1 in.) thickness
Thermal Properties								
Specific heat, cal. per °C. per gram	0.244	Depends on filler	0.32–0.51	—	—	0.32	—	0.32
Thermal expansion, 10^{-5} per °C.	6.9	Depends on filler	Varies with plasticizer	—	—	—	—	6–8
Thermal conductivity, 10^{-4} cal. per sec. per sq. cm. per °C. per cm.	3.95	Depends on filler	3.9–4.0	—	—	2.2	5	1.9–3.2
Softening point °F.	140–150	140–158	Varies with plasticizer	—	140–158	200–325	—	190–230
Distortion under heat, °F.	140–150	140–160	—	100	116–140	150–200	—	170–180
Resistance to continuous heat, °F.	Darkens at 300	Darkens at 300	190–212	Easily softened	200	160–200	250–285	150–170
Burning rate	Non-flammable	Non-flammable	Slow	Slow	Slow	Nil	Low	Moderate
Mechanical Properties								
Tensile strength, lb. per sq. in.	8000–10,000	6000–12,000	500–9000	5000	2500–8500	5000–12,000 up to 40,000 extruded	2100 up to 5200 extruded	5000–9000

TABLE 3 (*Continued*)

Properties	Vinyl Resins							Polystyrene Plastics
	Polyvinyl Chloride Acetate		Polyvinyl Chloride	Polyvinyl Acetate	Polyvinyl Acetal (Aldehyde Reaction Products)	Vinylidene Chloride	Polyvinyl Alcohol	
	Molded No Filler	Molded Filler	Molded Plasticized	Molded	Molded	Molded	Molded	Molded
Elongation, per cent	—	—	2–500	—	20–500	10–40	213–445	1–5
Modulus of elasticity, lb. per sq. in. × 10^5	3.5–4.1	3.5–8.5	—	—	—	0.8–1.7	—	1.7–7.0
Compressive strength, lb. per sq. in.	10,000–12,000	—	—	—	—	—	—	11,500–13,500
Flexural strength, lb. per sq. in.	12,000–14,000	7500–12,000	-	-	-	15,000–17,000	—	6000–19,000
Impact strength, ft.-lb. energy to break ½ by 12 in. bar	0.2–0.6 I	0.1–0.7 I	—	—	0.44–0.60 I	1–4 I	—	0.2–0.6 I
Hardness, Brinell (2.5-mm. ball; 25-kg. load)	12–15	15–25	30–100 (Shore)	—	—	—	—	20–30
Hardness, Rockwell	—	—	—	—	—	—	—	M85–M93
Electrical Properties								
Volume resistivity, ohm-cm. (50% relative humidity; 25° C.)	> 10^{14}	10^{11}	(0.8–2.6) × 10^{14}	—	—	10^{14}–10^{16}	—	10^{15}–10^{19}
Dielectric strength, 60 cycles								
Short time volts per mil	400–650	Depends on filler	600–2000	—	—	500–2500	610–1070	500–700 (⅛ in. thickness)
Step by step volts per mil	400–500		350	—	—	—	—	500–525
Dielectric constant								
60 cycles	3.2–3.6	4.7	6.5–12	2.7–6.1	—	3–5	—	2.5–2.7
10^3 cycles	3.2–3.4	4.7	5.0–6.0	—	—	3–5	—	2.5–2.7
10^6 cycles	3.0–3.4	4.0	—	—	—	3–5	—	2.5–2.8
Radio frequencies	4.0	5.0	—	—	—	—	—	2.96

TABLE 3 (*Continued*)

Properties	Vinyl Resins							Polystyrene Plastics
	Polyvinyl Chlorid Acetate		Polyvinyl Chloride	Polyvinyl Acetate	Polyvinyl Acetal (Aldehyde Reaction Products)	Vinylidene Chloride	Polyvinyl Alcohol	
	Molded No Filler	Molded Filler	Molded Plasticized	Molded	Molded	Molded	Molded	Molded
Power factor								
60 cycles	0.01–0.04	0.02–0.15	0.08–0.12	0 025–0.070?	—	0.03–0.08	—	0.0001–0.0002
10^3 cycles	0.014–0.02	0.012–0.15	0.10–0.16	—	—	0.03–0.15	—	0.0001–0.0002
10^6 cycles	0.01–0.02	0.02–0.065	—	—	—	0.03–0.05	—	0.0001–0.0004
Radio frequencies	0.018	0.02–0.065	–	—	—	—	—	0.0015–0.002
Physical-Chemical Properties								
Effect of light	Darkens on prolonged intense exposure	Darkens on prolonged intense exposure	None	None	Very slight	Slight	None	Yellows slightly
Effect of aging	Strength affected	Unaffected	Unaffected	Unaffected	Slight	Strengthens	Some decrease in tensile strength and slight shrinkage	Slight effect
Effect of water								
Cold	None	None	None	Swells, becomes leathery and pliable	—	—	Some grades are soluble; some resistant	None
Hot	Softens	Softens	Softens	—	—	—	—	None
Water absorption, per cent (24 hr.)	0.05–0.15	0.15–4.0	0.05	2 (144 hr.)	3–10	None	—	None
Effect of acids								
Weak	None	Dependent on filler	None	None	Affected	None	None	None
Strong	None	—	None	Affected	Affected	None	Attacked	Discolor
Effect of alkalies								
Weak	None	Dependent on filler	None	None	None	None	None	None
Strong	None	—	None	Affected	Affected	None	Attacked	None

TABLE 3 (*Continued*)

Properties	Vinyl Resins							Polystyrene Plastics
	Polyvinyl Chloride Acetate		Polyvinyl Chloride	Polyvinyl Acetate	Polyvinyl Acetal (Aldehyde Reaction Products)	Vinylidene Chloride	Polyvinyl Alcohol	
	Molded No Filler	Molded Filler	Molded Plasticized	Molded	Molded	Molded	Molded	Molded
Effect of organic solvents	Soluble in ketones and esters; swell in aromatic hydrocarbons; resist alcohols, aliphatic hydrocarbons and oils. Dissolve in carbon disulfide and chlorinated hydrocarbons.	Soluble in ketones and esters; swell in aromatic hydrocarbons; resist alcohols, aliphatic hydrocarbons and oils.	Soluble in ketones and esters; withstand most oils except gasoline	Soluble in most alcohols, ketones, esters, ether alcohols, and chlorinated hydrocarbons; insoluble in water, turpentine, vegetable and mineral oils.	Soluble in alcohol, toluene, acetone, methanol, ethanol, isopropanol, butanol, and Cellosolve; swelled by ketones, aromatic hydrocarbons, many esters and chlorinated hydrocarbons.	Highly resistant	Resistant to chlorinated hydrocarbons, aliphatic and aromatic ketones, but not in mixtures involving water, glycerol or alcohol.	Soluble in aromatic and chlorinated hydrocarbons.
Effect of metal inserts	Inert	Inert	Inert	Inert	Inert	Inert	—	Inert
Molding Properties								
Molding qualities	Good	Excellent	Good	Poor	Good	Excellent	Good	Excellent
Compression molding temperature, °F.	270–290	280–370	220–350	—	225–275	220–350	—	275–350
Compression molding pressure, lb. per sq. in.	1500–2000	2000–2500	500–1000	—	1000–2000	500–5000	—	300–5000
Injection molding temperature, °F.	280–300	—	—	—	180–212 (extrusion)	300–400	—	300–500
Injection molding pressure, lb. per sq. in.	3000–30,000	—	—	—	50–150 (extrusion)	10,000–30,000	—	3000–30,000
Bulk factor, volume loose powder per volume solid	2.0	1.5–3.5	—	—	—	2	—	2.0–2.5
Mold shrinkage, in. per in.	0.001	0.001	0.016	—	—	0.004–0.008	—	0.002–0.008
Tendency to unmold	None	None	None	—	—	—	—	Slight
Tendency to cold flow	Slight	Very slight	Slight	—	—	Slight	63%	Slight

TABLE 4

Properties	Methyl Methacrylate	
	Cast	Molded
Specific Properties		
Specific gravity	1.18–1.20	1.16–1.20
Specific volume, cu. in. per lb.	23.4–23.0	23.8–23.0
Clarity	Transparent to opaque	Transparent to opaque
Color possibilities	Unlimited	Unlimited
Refractive index	1.48–1.50	1.48–1.52
Light transmission, per cent	88–92	90–95
Thermal Properties		
Specific heat, cal. per °C. per gram	0.35–0.40	0.35–0.50
Thermal expansion, 10^{-5} per °C.	8	7–9
Thermal conductivity, 10^{-4} cal. per sec. per sq. cm. per °C. per cm.	1–10	1–10
Softening point, °F.	140–240	140–230
Distortion under heat, °F.	150	120–165
Resistance to continuous heat, °F.	140–160	120–190
Burning rate	Slow	Slow
Mechanical Properties		
Tensile strength, lb. per sq. in.	7000–8000	4000–12,000
Elongation, per cent	1–5	5–15
Modulus of elasticity, lb. per sq. in. $\times 10^5$	4–6	6
Compressive strength, lb. per sq. in.	10,000–13,000	8000–15,000
Flexural strength, lb. per sq. in.	14,000–16,000	9000–15,000
Impact strength, ft.-lb. energy to break ½ by ½ in. bar C = Charpy; I = Izod	0.3–0.5 C 0.2–0.4 I	0.2–0.3 C 0.2–0.4 I
Hardness, Brinell (10-mm. ball; 500-kg. load)	18–20	17–20
Hardness, Rockwell	M85–M105	M60–M90
Electrical Properties		
Volume resistivity, ohm-cm. (50% relative humidity) at 25° C	10^{15}	10^{16}
Dielectric strength, 60 cycles		
Short time volts per mil	500	500
Step by step volts per mil	400	400
Dielectric constant		
60 cycles	3.4–3.6	3.0–3.7
10^3 cycles	3.0–3.2	3.0–3.5
10^6 cycles	2.7–3.2	3.1–3.3
Radio frequencies	—	—
Power factor		
60 cycles	0.05–0.06	0.05–0.08
10^3 cycles	0.04–0.07	0.06–0.07
10^6 cycles	0.015–0.025	0.015–0.03
Radio frequencies	—	0.02

TABLE 4 (*Continued*)

Properties	Methyl Methacrylate	
	Cast	Molded
Physical-Chemical Properties		
Effect of light	Very slight	Very slight
Effect of aging	Becomes slightly harder	Becomes slightly harder
Effect of water		
Cold	None	None
Hot	—	—
Water absorption, per cent (24 hr.)	0.3	0.3–0.5 (48 hr.)
Effects of acids		
Weak	Very slight	Very slight
Strong	Oxidizing acids decompose	Oxidizing acids decompose
Effect of alkalies		
Weak	Very slight	Very slight
Strong	Very slight	Very slight
Effect of organic solvents	Attacked by ketones, esters, aromatic and chlorinated hydrocarbons	Attacked by ketones, esters, aromatic and chlorinated hydrocarbons
Effect of metal inserts	Inert	Inert
Molding Properties		
Molding qualities	—	Excellent
Compression molding, temperature °F.	—	280–360
Compression molding pressure, lb. per sq. in.	—	1000–4000
Injection molding temperature, °F.	—	325–450
Injection molding pressure, lb. per sq. in.	—	5000–30,000
Bulk factor, ratio of volume loose powder to volume solid	—	1.6–2.4
Mold shrinkage, in. per in.	—	0.001–0.006
Tendency to cold flow	Slight	Slight
Tendency to unmold	Slight	—

TABLE 5

Properties	Nylon
	Molded
Specific Properties	
Specific gravity	1.06–1.19
Specific volume, cu. in. per lb.	26.0–23.2
Clarity	Translucent to opaque
Color possibilities	Wide range available
Refractive index	1.53–1.55
Light transmission, per cent	—
Thermal Properties	
Specific heat, cal. per °C. per gram	0.55
Thermal expansion, 10^{-5} per °C.	10
Thermal conductivity, 10^{-4} cal. per sec. per sq. cm. per °C. per cm.	—
Softening point, °F.	450–485
Distortion under heat, °F.	—
Resistance to continuous heat, °F.	—
Burning rate	Very low
Mechanical Properties	
Tensile strength, lb. per sq. in.	5000–9000
Elongation, per cent	30–35
Modulus of elasticity, lb. per sq. in. × 10^5	4.5
Compressive strength, lb. per sq. in.	—
Flexural strength, lb. per sq. in.	10,000–15,000
Impact strength, ft.-lb. energy to break ½ by ½ in. bar. C = Charpy; I = Izod	—
Hardness, Brinell (10 mm. ball; 500-kg. load)	—
Hardness, Rockwell	L95–L100
Electrical Properties	
Volume resistivity, ohm–cm. (50% relative humidity) at 25° C.	10^{13}
Dielectric strength, 60 cycles	
Short time volts per mil	—
Step by step volts per mil	—
Dielectric constant	
60 cycles	3.2
10^3 cycles	3.3
10^6 cycles	3.6
Radio frequencies	—
Power factor	
60 cycles	0.010
10^3 cycles	0.015
10^6 cycles	0.022
Radio frequencies	—
Physical-Chemical Properties	
Effect of light	Slight
Effect of aging	Tensile strength reduced. Surface appearance also changed.

TABLE 5 (*Continued*)

Properties	Nylon
	Molded
Effect of water	
Cold	—
Hot	—
Water absorption, per cent (24 hr.)	—
Effect of acids	
Weak	Slight
Strong	Oxidizing acids attack
Effect of alkalies	
Weak	Slight to marked
Strong	Decompose
Effect of organic solvents	Resistant to most common solvents
Effect of metal inserts	Inert
Molding Properties	
Molding qualities	Fair
Compression molding temperature, °F.	—
Compression molding pressure, lb. per sq. in.	—
Injection molding temperature, °F.	400–500
Injection molding pressure, lb. per sq. in.	1500
Bulk factor, ratio of volume loose powder to volume solid	—
Mold shrinkage, in. per in.	—
Tendency to cold flow	—
Tendency to unmold	—

TABLE 6. PROPERTIES OF CELLULOSE DERIVATIVE PLASTICS

Properties	Cellulose Nitrate	Cellulose Acetate			Cellulose Acetate Butyrate	Ethyl Cellulose
		Transparent	Pigmented	High Acetyl Transparent		
Specific Properties						
Specific gravity	1.35–1.60	1.27–1.32	1.37–1.56	1.27–1.32	1.14–1.22	1.10–1.25
Specific volume, cu. in. per lb.	20.5–17.3	21.5–20.2	17.8–12.9	21.5–20.2	24.3–22.8	25–22
Clarity	Transparent to opaque	Transparent	Translucent to opaque	Transparent	Transparent to opaque	Transparent to opaque
Color possibilities	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
Refractive index	1.46–1.50	1.47–1.51	Varies	1.47	1.47–1.48	1.47
Light transmission, per cent	—	80–90	—	—	—	—
Thermal Properties						
Specific heat, cal. per °C. per gram	0.34–0.38	0.4–0.5	0.35–0.5	0.35–0.45	0.3–0.4	0.25–0.40
Thermal expansion, 10^{-5} per °C.	12–16	1.56–1.64 ($\times 10^{-4}$)	1.02–1.5 ($\times 10^{-4}$)	5–9 ($\times 10^{-4}$)	11–16	10–14
Thermal conductivity, 10^{-4} cal. per sec. per sq. cm. per °C. per cm.	3.1–5.1	5.4	5.3–8.7	5–9	4.5–7.8	5.6
Softening point, °F.	160–195 (Decomposes at 272 in 30 minutes)	115–230	145–374	—	140–250	210–270
Distortion under heat, °F.	110–150	—	—	130–212	115–215	130–150
Resistance to continuous heat, °F.	140	140–180	140–180	150–250	140–250	140–200
Burning rate	Very high	Slow	Slow	Slow	Slow	Slow
Mechanical Properties						
Tensile strength, lb. per sq. in.	4900–10,000	2800–9500	3000–9500	4500–8000	2500–7500	6000–8500
Elongation, per cent	10–40	15–35	2.5–30	5–35	8–82	10–40
Modulus of elasticity, lb. per sq. in. × 10^5	2–3.9	2.0–3.5	2.0–3.5	2.0–3.6	2.0–3.5	2–4
Compressive strength, lb. per sq. in.	20,000–30,000	4000–12,000	11,000–16,000	—	7500–22,000	10,000–12,000
Flexural strength, lb. per sq. in.	8000–10,000	5000–15,000	5000–15,000	4500–12,000	2800–13,000	9000–10,000
Impact strength, ft.-lb. energy to break ½ by ½ in. bar. C = Charpy; I = Izod	3–12 C —	3.2–5.2 C 0.5–1.2 I	2.2–4.5 C 0.17–0.6 I	1.5–3.5 C —	0.8–5.5 I —	2–5 I —
Hardness, Brinell (2.5-mm. ball; 25-kg. load)	7–20 (10 kg.)	6–11	6–11	6–15 (10 kg.)	6–12	—
Hardness, Rockwell	M25–M60	M20–M60	M20–M60	M20–M35	M25–M55	M25–M55
Electrical Properties						
Volume resistivity, ohm-cm. (50% relative humidity) at 25° C.	(2–30) × 10^{10}	—	—	—	(0.7–1.4) × 10^{12}	10^{16}
Dielectric strength, 60 cycles, volts per mil	600–1200	300–500	250–500	350–500	250–400	1500
Dielectric constant						
60 cycles	6.7–8.8	4–5.0	4–5.0	4.4–5.5	3.5–6.4	2.7
10^3 cycles	—	—	—	—	—	2.5–3.5
10^6 cycles	6.15	—	—	—	3.2–6.2	2.0–3.0
Radio frequencies	—	—	—	—	—	—

TABLE 6 (*Continued*)

Properties	Cellulose Nitrate	Cellulose Acetate			Cellulose Acetate Butyrate	Ethyl Cellulose
		Transparent	Pigmented	High Acetyl Transparent		
Power factor						
60 cycles	0.06–0.145	0.015–0.025	—	0.01–0.02	0.01–0.06	0.007
10^3 cycles	—	—	—	—	0.01–0.06	0.005–0.025
10^6 cycles	0.075–0.097	—	—	—	0.01–0.05	0.007–0.028
Radio frequencies	—	—	—	—	—	—
Physical-Chemical Properties						
Effect of light	Yellows and decomposes on long exposure; becomes brittle	Slight	Slight; some colors fade	Slight	Slight	Slight
Effect of aging	Slight hardening	Slight	Slight	Slight	Slight	Slight
Water absorption, per cent (24 hr.)	0.6–3.0	1.4–2.0 (96 hr.)	1.4–2.0 (96 hr.)	0.95–1.2 (96 hr.)	1.2–2.0	1.25 (48 hr.)
Effect of acids						
Weak	Slight	Slight	Slight	Slight	Slight	Slight
Strong	Decompose	Decompose	Decompose	Decompose	Decompose	Decompose
Effect of alkalies						
Weak	Slight	Slight	Slight	Slight	Slight	None
Strong	Decompose	Decompose	Decompose	Decompose	Decompose	None
Effect of organic solvents	Soluble in ketones and esters; softened or slightly soluble in acohol; little affected by hydrocarbons	Soluble in ketones and esters; softened or slightly soluble in alcohol; little affected by hydrocarbons	Soluble in ketones and esters; softened or slightly soluble in alcohol; little affected by hydrocarbons	Soluble in ketones and esters; softened or slightly soluble in alcohol; little affected by hydrocarbons	Soluble in ketones and esters; softened or slightly soluble in alcohol; little affected by hydrocarbons	Widely soluble
Effect of metal inserts	—	Inert	Inert	Inert	Inert	Inert
Molding Properties						
Molding qualities	Good	Excellent	Excellent	Good	Excellent	Excellent
Compression molding temperature,* °F.	185–250	275–285	300–310	320–370	250–350	320–360
Compression molding pressure, lb. per sq. in.	2000–5000	2000–5000	2000–5000	2000–5000	1500–5000	1000–5000
Injection molding temperature, °F.	—	335–365	360–390	380–440	300–440	380–425
Injection molding pressure, lb. per sq. in.	—	10,000–20,000	10,000–20,000	10,000–20,000	8000–30,000	3000–30,000
Bulk factor, ratio of volume loose powder to volume sold	—	2.0–2.8	2.0–2.8	2.0–2.8	2.0–2.4	2.2–2.5
Mold shrinkage, in. per in.	—	0.0025–0.0045	—	—	0.002–0.009	0.004–0.007
Tendency to cold flow	Slight	Slight	Slight	Slight	Slight	Slight

TABLE 7. MISCELLANEOUS COMPOUNDS

Properties	Casein	Lignin	Rubber Compounds			Cold Molded Compounds		Shellac
			Hard Rubber	Chlorinated Rubber (Parlon-Tornesit)	Organic Polysulfide (Thiokol)	Refractory (Inorganic)	Non-Refractory (Organic)	
Specific Properties								
Specific gravity	1.35	1.45	1.12–1.80	1.5–1.65	1.54–1.55	1.80–1.90	1.85–2.20	1.1–2.7
Specific volume, cu. in. per lb.	20.5	19.1	24.7–15.4	18.5–16.9	18.0–17.8	15.4–14.5	14.0–13.9	25.2–10.3
Clarity	Translucent to opaque	Opaque	Opaque	Translucent to opaque	Opaque	Opaque	Opaque	Opaque
Color possibilities	Unlimited	Limited to dark shades	Limited to dark shades	Light to dark shades	Black only	Gray and dark shades	Dark shades only	Limited, no pastels
Thermal Properties								
Specific heat, cal. per °C. per gram	—	—	0.33	0.37–0.43	—	—	—	—
Thermal expansion	8.0	2.1–2.4	8.0	12–13	—	—	—	—
Thermal conductivity, 10^{-4} cal. per sec. per sq. cm. per °C. per cm.	—	—	3.2	3.0	—	—	—	—
Softening point, °F.	200	None	150–190	175–320	265	—	—	150
Distortion under heat, °F.	—	—	—	140	—	—	—	—
Resistance to continuous heat, °F.	—	—	130–160	Decomposes above 250	150–200	1300	500	150–190
Burning rate	Very low	Slow	Medium	Nil	Slow	Nil	Nil	High
Mechanical Properties								
Tensile strength, lb. per sq. in.	7600	9000–10,000	4000–10,000	2700–5000	1500–1700	—	—	900–2000
Elongation, per cent	—	—	2–15	0.52–4	150–400	—	—	—
Modulus of elasticity, lb. per sq. in. × 10^5	5.1–5.7	15–20	5.3	1–5	—	—	—	5–6
Compressive strength, lb. per sq. in.	—	25,000–35,000	8000–12,000	—	—	16,000	15,000	10,000–17,000
Flexural strength, lb. per sq. in.	—	15,000–20,000	8000–15,000	9000–16,000	—	6000	7500	—
Impact strength, ft.-lb. energy to break ½ by ½ in. bar C = Charpy; I = Izod	1.0 I	0.7–0.8 I	0.5 I	0.14–2.8 I	—	0.4 C	0.4 C	2.6–2.9 I
Hardness, Brinell (2.5-mm. ball, 25-kg. load)	23	—	31	—	—	—	—	—
Hardness, Rockwell	—	M110–M112	—	—	—	—	—	—

TABLE 7 (*Continued*)

Properties	Casein	Lignin	Rubber Compounds			Cold Molded Compounds		Shellac
			Hard Rubber	Chlorinated Rubber (Parlon-Tornesit)	Organic Polysulfide (Thiokol)	Refractory (Inorganic)	Non-Refractory (Organic)	
Electrical Properties								
Volume resistivity, ohm-cm. (50% relative humidity and 25°C)	—		10^{12}–10^{15}	2.5×10^{13}	—	—	1.3×10^{12}	1.8×10^{9}
Dielectric strength, 60 cycles. Short time volts per mil	400–700	300–400	250–900	2300	500	—	85	100–600
Step by step volts per mil	425	300–400	—	—	—	—		—
Dielectric constant								
60 cycles	—	—	2.8	3.0	7.5	—	15.0	3–4
10^3 cycles	—	—	2.8–3.4	3.1	—	—	—	4–5
10^6 cycles	6.15–6.8	—	3.0	—	—	—	6.0	—
Radio frequencies	—	—	3.0	—	—	—	—	—
Power factor								
60 cycles	—	—	—	0.003	0.55	—	0.20	0.004–0.04
10^3 cycles	—	—	0.003–0.008	0.0015–0.003	—	—	—	0.05
10^6 cycles	0.052	—	0.003–0.008	—	—	—	0.07	—
Radio frequencies	—	—	—	—	—	—	—	—
Physical-Chemical Properties								
Effect of light	Colors may fade	Slight	Discolor; disintegrates after exposure to ultra-violet	Discolor and become brittle	Unaffected	—	—	None
Effect of aging	Hardens slightly, becomes drier	None	None	Becomes slightly brittle	Slight	—	—	None
Effect of water	Softens slowly	—	Slight	Varies with composition	Resistant	—	—	—
Water absorption, per cent (24 hr.)	7–14	0.75	0.02	0.1–0.3	0.04	0.5–15	1.5	—
Effect of acids								
Weak	Resistant	Slight effect	Resistant	Resistant	Resistant	Decompose	Slight effect	Decompose
Strong	Decompose	Oxidizing acids attack	Oxidizing acids attack	Resistant	Oxidizing acids attack	Decompose	Decompose	Decompose

TABLE 7 (*Continued*)

Properties	Casein	Lignin	Rubber Compounds			Cold Molded Compounds		Shellac
			Hard Rubber	Chlorinated Rubber (Parlon-Tornesit)	Organic Polysulfide (Thiokol)	Refractory (Inorganic)	Non-Refractory (Organic)	
Effect of alkalies								
Weak	Soften	Slight effect	Resistant	Resistant	Resistant	Resistant	Decompose	Decompose
Strong	Decompose	Decompose	Resistant	Resistant	Slight effect	Resistant	Decompose	Decompose
Effect of organic solvents	Resistant	Slight effect	Attacked by alcohol, acetone, carbon disulfide, ether and boiling turpentine; softens in mineral oil, naphtha and aniline	Soluble in aromatic hydrocarbons; attacked by ketones, esters, animal and vegetable oils	Resistant to most	Resistant	Attacked by some	Attacked by some
Effect of metal inserts	—	—	—	—	—	—	—	—
Molding Properties								
Molding qualities	Poor	Good	Fair	Fair	Good	Fair	Fair	Good
Compression molding temperature, °F.	200–225	365	285–350	200–380	240–300	—	—	240
Compression molding pressure, lb. per sq. in.	2000–2500	1500–2000	1200–1800	2000–5000	500–5000	400–12,000	400–12,000	1000–1200
Injection molding temperature, °F.	—	1500–2000	180–220	310–400	—	—	—	180–260
Injection molding pressure, lb. per sq. in.	—	—	2000–5000	—	—	—	—	1000–1200
Bulk factor, ratio volume loose powder to volume solid	—	—	4–6	2–3	2.5–3	3.5	2.5	2–3
Mold shrinkage, in. per in.	—	—	—	—	0.015–0.02	None	0.022	0.002
Tendency to unmold	—	—	—	None	—	—	—	—
Tendency to cold flow	—	—	—	None	Some	—	—	Slight

TABLE 8. PROPERTIES OF PLASTICS COMPARED[1]

KEY

Acetate — Cellulose Acetate
Butyrate — Cellulose Acetate Butyrate
C. M. Org. — Cold Molded Organic
C. M. Inorg. — Cold Molded Inorganic
Cast Phen. — Cast Phenolic
Ethyl Cell. — Ethyl Cellulose
Fab. Phen. — Fabric Filled Phenolic
Lam. Phen. — Laminated Phenolic
Min. Phen. — Mineral-filled Phenolic
Nitrate — Cellulose Nitrate
Styrene — Polystyrene
Trans. Phen. — Transparent Phenolic
W. F. Phen. — Wood Flour Filled Phenolic

Items are listed in order of excellence on a scale from 1 to 19, number 1 being highest. Whenever two items have equal rating they are given the same number.

Tensile Strength. The pulling force in pounds necessary to break a given sample, divided by the area of the cross section in square inches. Figures given are in thousands of pounds.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Nylon	10.0	30.0	50.0	7. Fab. Phen.	6.5	7.3	8.0
2. Lam. Phen.	7.0	12.5	18.0	8. Acetate	3.5	7.0	10.0
3. Cast Phen.	6.0	9.0	12.0	8. Styrene		7.0	
3. Vinyl		9.0		8. Hard Rubber	4.0	7.0	10.0
3. Lignin		9.0		9. Urea	5.5	6.25	7.0
4. W. F. Phen.	6.0	8.5	11.0	10. Butyrate	2.8	5.2	7.5
5. Min. Phen.	5.0	7.5	10.0	11. Acrylate	4.0	5.0	6.0
5. Casein		7.5		12. C. M. Org.		2.0	
5. Ethyl Cell.	6.0	7.5	9.0	13. Shellac	0.9	1.5	2.0
5. Nitrate	5.0	7.5	10.0	14. C. M. Inorg.		1.2	
6. Trans. Phen.	6.0	7.4	8.5				

Modulus of Elasticity. The quotient obtained by dividing the stress per square inch by the elongation in 1 inch caused by this stress.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Min. Phen.	10.0	22.5	45.0	12. Hard Rubber		5.3	
2. Lignin	15.0	17.5	20.0	13. C. M. Org.		5.0	
3. Urea		16.0		13. C. M. Inorg.		5.0	
4. Melamine	12.0	13.5	15.0	14. Nylon		4.5	
5. W. F. Phen.	10.0	12.5	15.0	15. Styrene		4.0	
6. Lam. Phen.	4.0	12.0	20.0	16. Vinyl	3.5	3.8	4.1
7. Cast Phen.	5.0	10.0	15.0	17. Nitrate	2.0	3.0	4.0
8. Fab. Phen.	7.0	9.5	12.0	17. Ethyl Cell.	2.0	3.0	4.0
9. Trans. Phen.	7.0	8.5	10.0	18. Aceate	2.0	2.8	3.5
10. Acrylate		6.0		18. Butyrate	2.0	2.8	3.5
11. Casein	5.1	5.4	5.7				

Compressive Strength. The crushing load at failure of piece divided by the number of square inches of resisting surface. Figures given are thousands of pounds.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Lam. Phen.	20.0	30.0	40.0	8. C. M. Inorg.		16.0	
2. Lignin		28		9. Butyrate	8.5	15.8	22.5
3. Min. Phen.	18.0	27.0	36.0	10. Styrene		13.0	
4. Fab. Phen.	20.0	26.0	32.0	11. Acrylate	10.0	12.5	15.0
4. W. F. Phen.	16.0	26.0	36.0	12. C. M. Org.		12.0	
5. Cast Phen.	15.0	22.5	30.0	13. Ethyl Cell.		11.0	
6. Urea	20.0	22.0	24.0	13. Vinyl		11.0	
7. Acetate	11.0	19.0	27.0	13. Hard Rubber		11.0	

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[1] Reproduced by permission of the Boonton Molding Company. (Figures differ slightly from other tables.)

TABLE 8 (*Continued*)

Flexural Strength. The pressure in pounds necessary to break a given sample when applied to the center of the sample which has been supported at its ends. Figures in thousands of pounds.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Lignin		17		7. Vinyl	10	11.5	13
2. Styrene	14	16.5	19	7. Fab. Phen.	10	11.5	13
2. Lam. Phen.	13	16.5	20	7. W. F. Phen.	8	11.5	15
3. Trans. Phen.	12	14.5	17	8. Acetate	5	10.5	16
3. Melamine	10	14.5	19	9. Nitrate		9.0	
4. Nylon		14		9. Ethyl Cell.		9.0	
4. Min. Phen.	8	14	20	10. Butyrate	4	8.5	13
5. Acrylate	12	13	14	11. C. M. Org.	5.3	6.3	7.5
6. Cast Phen.	10	12	14	12. C. M. Inorg.		6.0	

Impact Strength. The mechanical energy absorbed by a standard test piece during fracture by a blow from a pendulum hammer.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Lam. Phen.	0.6	7.8	15.0	9. Lignin		0.7	
2. Nitrate	2.0	5.0	8.0	10. Hard Rubber		0.5	
3. Butyrate	0.8	3.2	5.5	11. Min. Phen.	0.22	0.47	0.72
4. Fab. Phen.	0.8	2.6	4.8	12. C. M. Inorg.		0.40	
5. Acetate	0.7	2.4	4.2	12. C. M. Org.		0.40	
6. Cast Phen.	0.6	1.2	1.8	13. W. F. Phen.	0.20	0.38	0.56
6. Ethyl Cell.	0.6	1.2	1.8	14. Acrylate	0.25	0.37	0.50
7. Casein		1.0		15. Trans. Phen.	0.32	0.36	0.40
7. Styrene	0.8	1.0	1.2	16. Urea	0.30	0.33	0.36
8. Vinyl	0.2	0.8	1.4	17 Melamine	0.28	0.30	0.32

Hardness: Brinell. The ratio of the pressure on a sphere used to indent the material to be tested to the area of the spherical indentation produced. Arranged in order of increasing hardness.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Urea	48.0	51.0	54.0	6. Casein		23.0	
2. Cast Phen.	30.0	37.5	45.0	7. Vinyl	15.0	20.0	25.0
2. W. F. Phen.	30.0	37.5	45.0	8. Acrylate		18.0	
3. Lam. Phen.	24.0	32.0	40.0	9. Acetate	8.0	11.5	15.0
4. Hard Rubber		31.0		10. Butyrate		10.0	
5. Styrene	20.0	25.0	30.0				

Thermal Conductivity is the time rate of the transfer of heat by conduction, through unit thickness, across unit area for unit difference in temperature.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Styrene		1.9		5. Ethyl Cell.		5.6	
2. Hard Rubber		3.2		6. Butyrate	4.5	6.1	7.8
3. Fab. Phen.	3.0	4.0	5.0	7. Lam. Phen.	5.0	6.5	8.0
3. Cast Phen.	3.0	4.0	5.0	8. Acetate	5.4	7.1	8.7
3. Vinyl		4.0		8. Urea		7.1	
4. Nitrate	3.1	4.1	5.1	9. W. F. Phen.	4.0	8.1	12.2
5. Acrylate	4.3	5.6	6.8	10. Min. Phen.	8.0	14.0	20.0

TABLE 8 (*Continued*)

Specific Heat of a substance is the ratio of its thermal capacity to that of water at 15 degrees C.

	Low	*Av.*	*High*
1. Vinyl		0.244	
2. Min. Phen.	0.25	0.30	0.35
3. Styrene		0.32	
4. Ethyl Cell.	0.25	0.325	0.40
4. Fab. Phen.	0.30	0.325	0.35
5. Hard Rubber		0.33	
6. Lam. Phen.	0.30	0.35	0.40
6. Cast Phen.	0.30	0.35	0.40
6. W. F. Phen.		0.35	
6. Acetate	0.31	0.35	0.39
6. Butyrate		0.35	
7. Nitrate	0.34	0.36	0.38
8. Urea		0.40	
9. Acrylate		0.45	
10. Nylon		0.55	

Thermal Expansivity (Coefficient of Expansion): The increase in length per unit length per degree C. rise in temperature.

	Low	*Av.*	*High*
1. Lignin		2.1	
2. Lam. Phen.	1.7	2.3	3.0
3. Urea	2.5	2.8	3.0
3. Cast Phen.		2.8	
4. Min. Phen.	2.5	3.8	4.0
5. Fab. Phen.	2.0	4.0	6.0
6. W. F. Phen.	3.7	5.6	7.5
7. Vinyl		6.9	
8. Styrene		2.1	
9. Acrylate	7.0	8.0	9.0
9. Casein		8.0	
9. Hard Rubber		8.0	
10. Ethyl Cell.	10.0	12.0	14.0
11. Butyrate	11.0	13.5	16.0
12. Nitrate	12.0	14.0	16.0
13. Acetate	14.0	15.0	16.0

Safe Top Operating Temperature in degrees F.

	Low	*Av.*	*High*
1. C. M. Inorg.		1300	
2. C. M. Org.		500	
3. Nylon		400	
3. Min. Phen.		400	
4. Casein		350	
5. W. F. Phen.		300	
5. Fab. Phen.	250	300	350
6. Lam. Phen.	212	256	300
7. Trans. Phen.		250	
8. Melamine		210	
9. Styrene	155	177	200
10. Shellac	150	175	190
11. Urea		170	
11. Butyrate	140	170	200
12. Cast Phen.		160	
12. Acetate	140	160	180
12. Ethyl Cell.	140	160	180
13. Nitrate		140	
14. Acrylate	120	130	140
14. Hard Rubber		130	
14. Vinyl		130	

Volume Resistivity. The resistance in ohms between opposite faces of a centimer cube of the material; is in the order of millions of ohms.

	Low	*Av.*	*High*
1. Styrene		18.0	
2. Acrylate		15.0	
2. Ethyl Cell.		15.0	
3. Hard Rubber	12.0	13.5	15.0
4. Nylon		13.0	
4. Urea		13.0	
5. Acetate		12.0	
5. Butyrate		12.0	
5. Trans. Phen.		12.0	
6. Cast Phen.	9.0	11.5	14.0
7. Lam. Phen.		11.0	
7. Vinyl		11.0	
7. W. F. Phen.	10.0	11.0	12.0
8. Nitrate		10.0	
8. Fab. Phen.	9.0	10.0	11.0
8. Min. Phen.	9.0	10.0	11.0

TABLE 8 (*Continued*)

Dielectric Strength. The voltage that will rupture or puncture the material in question when placed between electrodes of a given size. (Instantaneous.)

Dielectric tests are usually made at commercial frequencies, i.e., 60 cycles. The results will vary with the thickness tested. The thinner the section the higher the electrical gradient.

Puncture voltage in volts per mil thickness is usually given in tables.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Ethyl Cell.		1500		11. W. F. Phen.	300	400	500
2. Hard Rubber	1000	1250	1500	12. Acetate	350	375	400
3. Nitrate	600	900	1200	12. Fab. Phen.	300	375	450
4. Lam. Phen.	400	850	1300	13. Cast Phen.	300	350	400
5. Urea	500	600	700	14. Butyrate	250	325	400
6. Casein	400	550	700	15. Melamine		321	
7. Styrene		500		16. Lignin		300	
8. Acrylate		480		17. Shellac	100	250	400
9. Min. Phen.		475		18. C. M. Inorg.		100	
10. Vinyl	400	450	500	19. C. M. Org.		85	

Dielectric Constant. The ratio between the capacity of a condenser with a given dielectric and the same capacity with air as a dielectric.

DIELECTRIC CONSTANT 60 CYCLES

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Styrene		2.6		8. Acetate	4.9	5.6	6.2
2. Hard Rubber		2.8		9. Cast Phen.	4.5	5.7	7.0
3. Nylon		3.2		10. Nitrate	6.7	7.0	7.3
4. Acrylate	3.0	4.5	6.0	11. Fab. Phen.	5.0	7.5	10.0
5. Vinyl		4.7		12. W. F. Phen.	5.0	8.5	12.0
6. Butyrate	3.6	5.0	6.4	12. Urea		8.5	
7. Min. Phen.		5.5		13. Melamine	5.0	12.5	20.0
7. Trans. Phen.		5.5		14. C. M. Org.		15.0	

DIELECTRIC CONSTANT 10^6 CYCLES

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Ethyl Cell.	2.0	2.5	3.0	9. Butyrate	3.2	4.7	6.2
2. Styrene		2.6		10. Min. Phen.		5.0	
3. Hard Rubber		3.0		11. C. M. Org.		6.0	
4. Acrylate		3.2		11. Cast Phen.	5.0	6.0	7.0
5. Nylon		3.6		12. Nitrate		6.2	
6. Vinyl		4.0		13. W. F. Phen.	4.5	6.3	8.0
7. Acetate	4.0	4.5	5.0	14. Casein		6.8	
7. Trans. Phen.		4.5		15. Urea		7.8	
8. Lam. Phen.	3.6	4.6	5.5				

Power Factor. In a perfect condenser the current leads the voltage by ninety degrees. When a loss takes place in the insulation, the absorbed current which produces heat throws the ninety degree relation out according to the proportion of current absorbed by the dielectric. The Power Factor is a direct percentage measurement of the power lost. Measurements are usually made at million cycle frequencies.

TABLE 8 *(Continued)*

POWER FACTOR 60 CYCLES

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Styrene		0.0001		8. Acrylate		0.050	
2. Ethyl Cell.		0.007		9. Trans. Phen.		0.060	
3. Nylon		0.010		10. Urea	0.06	0.080	0.100
4. Vinyl		0.0143		11. Nitrate	0.062	0.106	0.150
5. Melamine		0.016		12. Cast Phen.	0.025	0.113	0.200
6. Min. Phen.		0.025		13. W. F. Phen.	0.040	0.170	0.300
6. Acetate	0.010	0.025	0.040	14. Fab. Phen.	0.080	0.190	0.300
7. Butyrate	0.010	0.035	0.060	15. C. M. Org.		0.200	

POWER FACTOR 10^6 CYCLES

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Styrene		0.0001		10. Lam. Phen.	0.02	0.035	0.05
2. Min. Phen.	0.005	0.005	0.100	11. Urea	0.036	0.037	0.039
3. Hard Rubber	0.003	0.0055	0.008	12. Vinyl	0.02	0.043	0.065
4. Ethyl Cell.	0.007	0.0185	0.030	12. Acetate	0.035	0.043	0.060
5. Trans. Phen.		0.019		13. W. F. Phen.	0.040	0.170	0.300
6. Acrylate		0.020		14. Casein		0.052	
7. Nylon		0.022		15. Fab. Phen.	0.04	0.07	0.100
8. Cast Phen.	0.01	0.027	0.045	15. C. M. Org.		0.07	
9. Butyrate	0.010	0.030	0.050	16. Nitrate	0.074	0.087	0.100

Moisture Absorption. The percentages by weight of water absorbed by a sample immersed in water. Depends on area exposed.

	Low	*Av.*	*High*		*Low*	*Av.*	*High*
1. Styrene		0.00		10. Lam. Phen.	0.5	1.25	2.0
2. Hard Rubber		0.02		10. Ethyl Cell.		1.25	
3. Vinyl	0.05	0.10	0.15	11. Nitrate	1.0	1.5	2.0
3. Tran. Phen.		0.10		11. C. M. Org.		1.5	
4. Min. Phen.	0.01	0.16	0.30	12. Butyrate	1.2	1.6	2.0
5. Cast Phen.	0.01	0.26	0.30	13. Nitrate	0.6	1.8	3.0
6. W. F. Phen.	0.2	0.4	0.6	14. Urea	1.0	2.0	3.0
6. Melamine	0.2	0.4	0.6	15. Acetate	1.4	2.1	2.8
7. Acrylate		0.5		16. Casein	4.0	7.0	10.0
8. Lignin		0.75		17. C. M. Inorg.	0.5	7.5	15.0
9. Fab. Phen.	1.0	1.15	1.3	18. Nylon		7.6	

Flammability is based on the time a given piece will continue to support a flame after having been held in a Bunsen burner for a fixed period. The first material listed supports flame the least number of seconds.

Phenolic — Heat Resistant
Phenolic — Low Loss
Phenolic — Acid and Alkali Resistant
Phenolic — Wood Flour
Phenolic — Shock Resistant
Urea
Polystyrene
Acetate

CHAPTER III

TEST METHODS FOR PHYSICAL PROPERTIES

TESTING VITAL TO PLASTICS INDUSTRY

Tests were originally a checkup on materials that had been produced to specification. They were conducted in a direct way, almost like dropping a china plate to see if it would break. But such tests admitted too many variables, because no two people will drop a plate in the same way and no two surfaces upon which a plate drops are of the same composition. Thus machines, apparatus, and a technique and standards of procedure had to be developed.

Standardization of methods of testing is relatively simple, but the interpretation of results, which is the reason for testing, is difficult and often not well done. At technical society meetings where tentative standards are set up, they are discussed sometimes for years among consumers, producers, and technical men until they receive full acceptance at which point they may be obsolete and have to be revised. In spite of the relative inefficiency of the slow consideration and round robin letters, a broad compromise is often reached that can form a basis for testing procedure and interpretation.

Standard tests are not intended to simulate service conditions, but because of the uncontrollable variables in service, prescribed laboratory conditions for standard specimens have been found to be the best method for controlling quality. A machined and polished fatigue test specimen does not represent service conditions, but it provides uniform conditions for determining endurance limit. A notched bar impact specimen does not represent actual practice, but it gives a standard law for a test under fixed conditions. Few purely axial tensile stresses are encountered in service, but much can be read from tensile test data to serve as guideposts of quality. A critical study of stress-strain diagrams offers the best possibilities for interpretations of characteristics of a material, even as difficult a material as plastics.

The procedure for most any testing follows logical steps from raw material to finished product. The airplane offers an excellent example.

First there is the laboratory acceptance test of materials to ensure good physical pedigree, such as endurance limit, creep limit, tensile, impact and chemical properties, hardness, effect of temperature and corrosion. Then follow static tests of the finished product with strain gauges for the analysis of stress distribution, and comparison with the mathematical analysis. Lastly there are service tests under dynamic conditions with strain gauges again, flight tests, and oscillographic records.

QUALITY FACTORS

Physical properties of moldings are influenced by: (1) degree of compression during molding; (2) freedom from bubbles and pinholes; (3) thickness of section; (4) types of molding (thermosetting materials, molded by transfer, are usually denser than some materials molded by compression, and thus may be expected to be stronger); and (5) design of the mold (the mechanics of flow and the rate of cooling have an effect on the physical properties of the molded plastics).

High density gives a stronger molding. The thicker the molded section, the more difficult it is to obtain a non-porous piece, and the user, in his tests, may expect strengths above standard with thin sections, and below standard with thick sections.

In the case of thermoplastic materials, physical characteristics differ with compression molding as against injection molding. With cellulose acetate, for instance, the following differences usually apply: (This implies flow characteristics suited to the pressure. Soft material molds poorly under extreme pressure.)

Injection Molding	*Compression Molding*
Softer surface	Higher tensile strength
Higher impact strength	Higher softening temperature

A high molding pressure, other things being equal, is more favorable to the production of good parts than low molding pressure.

Degree of cure of thermosetting materials affects the quality of the molded product. Undercured thermosetting materials are weak and lack resistance to solvents. Ureas deteriorate on overcure. The molding cycle must be carefully regulated to prevent this condition. In most instances a longer cure at lower temperatures gives a better molding. Phenolics are not affected by overcure except in aggravated cases where the filler (e.g., cellulose) deteriorates on long heating.

All plastics absorb measurable amounts of moisture. Moist or dry conditions therefore may change the physical properties. The effect is especially pronounced on electrical properties. Tests, therefore, should be made on moisture-conditioned specimens. For example, the following conditioning procedures have been adopted by various authorities:

1. As received[1]
2. After 96 hr. in 70 per cent relative humidity at 25° C. (77° F.)[1]
3. After 24-hr. bake at 105° C. to 110° C. (221° F. to 230° F.)[1]
4. After 48 hr. in a desiccator at 25° C. (77° F.)
5. After 48-hr. immersion in water at 50° C. (122° F.)[1]
6. After 6-hr. immersion in boiling water[1]

MOLDING POWDERS

For test purposes, samples of the powder are taken from at least 10 per cent of the drums represented by the manufacturer's run or batch number. The powder should be removed from a point about 3 in. below the surface. Samples taken from the surface may show an unduly high proportion of coarse particles and may also be higher in moisture content than the bulk of the material. The portions of powder removed from drums are blended and stored in a sealed metal or glass container to prevent changes in moisture content during storage. The following tests are important to the molder in determining suitability of a powder.

[1] U. S. Navy Specifications 17P4, November, 1936.

Bulk Factor. The bulk factor of a molding power is defined as the ratio of the volume of a unit weight of powder to the volume of the same weight of the material in molded form. It is equal to the ratio of the specific gravity of the molded material to the apparent density of the unmolded powder (A.S.T.M. D392–38). This ratio — the bulk factor — is ordinarily from 2.0 to 2.5:1 for general purpose phenolic materials. The bulk factor may go as high as 10:1 for high impact cellulose filled materials which tend to be fluffy. Many molds obviously cannot be operated with a powder load if the bulk factor of the powder is too high. The apparent density of the powder is ordinarily measured by flowing the powder through a funnel into a cup of 100 cc. capacity, leveling and weighing the contents of the cup. The apparent density is taken as the weight in gm. per cc.

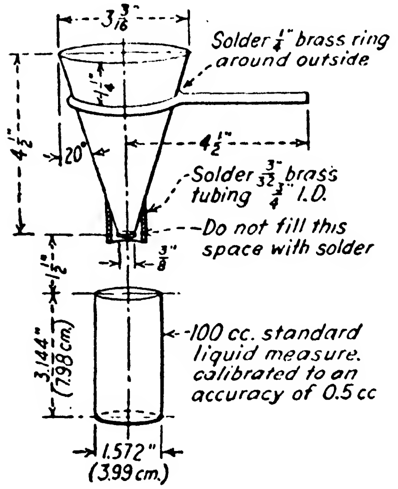

Fig. 3.1 — Apparatus for apparent density test.

Specific Gravity of the Molded Piece. Specific gravity of the molded piece is a property of price interest to the custom molder in cost estimation since he buys molding powder by the pound, but usually sells his finished product by the piece. A suitable method for determining the specific gravity is described in detail under A.S.T.M. D71–27.

Specific gravity is expressed as the ratio of the weight in air of a given volume of material at a stated temperature, usually at 25° C. (77° F.) to that of an equal volume of water at the stated temperature.

Values vary from about 1.05 for unfilled styrol resins to about 2.0 for highly mineral filled phenolic resins.

Pourability of Powders. With certain molding powders, notably those of high bulk factor (3.0 or more), it is difficult to feed the powder through the hoppers and into the dies of tableting or preforming machines to obtain preforms of uniform weight. To measure this property of pourability a sample of material proportional in weight to its molded specific gravity is allowed to flow through a funnel and the efflux time is measured. Powders which do not flow properly in this special test do not usually preform well without special feeders. So-called general purpose materials usually flow readily in this test and are easily preformed.

For special equipment such as automatic molding machines manufacturers supply compounds having controlled particle size and fines content.

Grain Size of Powders. *Sieve Method.* Sieve analysis of molding powder is of value in detecting contamination with foreign material. It also ensures against the presence of unduly large particles or excess of fines which may interfere with preforming or injection molding operations. The test may be run with sieves of various sizes. Molding powders are usually ground to pass 12- to 140-mesh and it is usually sufficient to measure the amount retained on 12-mesh, the amount retained on 140-mesh and the percentage of fines passing 140-mesh. Compounds for injection molding and extrusion molding are ground about 4-mesh.

Moisture Content of Powders. The moldability of many compounds is directly affected by the moisture content. With ureas this is doubly important, since there may be present a certain amount of free moisture due to the hygroscopicity nature of the compound itself and there may be a certain amount of loosely combined moisture, resulting from partial condensation of the urea and formaldehyde. Any method to determine moisture must differentiate beween the two.

For determining free moisture, the compound is weighed into a flat dish and placed over a desiccant such as sulfuric acid for 24 hr. at 100° F. It is again weighed and the loss expressed as a percentage.

For determination of the total water content, free and loosely combined, the following procedure is followed:

Xylol Method

Two hundred and fifty gram xylol is refluxed to dryness in a Sterling-Bidwell Moisture Apparatus. (See Fig. 3.2.) When cool, the apparatus is disassembled and the condenser and receiving tube are cleaned and dried with acetone. The sample, 25 gm. molding material, is added to the distilling flask and the apparatus is reassembled. The sample is then refluxed for 3 hr.[2] and the number of ml. of water is read in the graduated receiving tube.

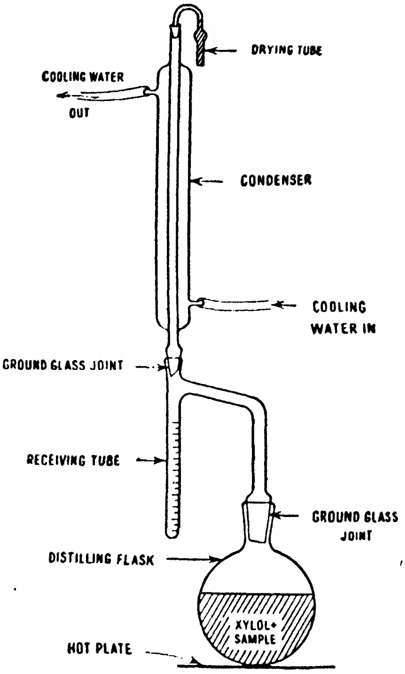

FIG. 3.2 — Sterling-Bidwell moisture apparatus.

Calculations:

$$\text{Per cent total water} = \frac{\text{Ml water in receiving tube}}{\text{Sample wt.}} \times 100$$

MOLDED MATERIAL A.S.T.M. D618-41T

Conditioning of Plastics for Testing Purposes. It is essential to condition plastics test specimens prior to testing to eradicate previous effects caused by unusual temperature and humidity conditions. The following procedure is considered satisfactory for all plastics.

Scope. The purpose of this procedure is to establish standard times, temperatures and relative humidities to be used in the pre-treatment of plastics prior to testing, as well as in the actual testing of such plastics where their physical properties are subject to rapid change as a result of changes in atmospheric conditions. The method shall be applied to all plastics or electrical insulating materials, except where other methods of conditioning are definitely specified as part of specific test procedures.

Classification of Materials for Test. Materials to be tested should be arbitrarily

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[2] Reflux sample over oil bath or electric hot plate.

classified " R " (rapid) or " S " (slow) on the basis of the rapidity with which their physical properties vary with changes in atmospheric humidity at 25° C. (77° F.).

Any material which, during the period of time required for the completion of a test, changes sufficiently in mechanical properties to affect the numerical results of the impact test by 10 per cent as a result of changes in humidity shall be classified as a type " R " material. The specimens shall be subjected to the type " S " detailed procedure, and the humidity change shall consist of removing the material from the anhydrous calcium chloride desiccator and holding it at a relative humidity of 50 per cent for 15 min., as outlined in the detailed procedure which follows. In establishing this classification, impact tests on the material shall be run within 15 sec. after removal from the desiccator used in the " S " conditioning method, and a similar test shall be run within 15 min. after removal from the said desiccator, during which 15 min. the material shall be held in an atmosphere at 50 per cent relative humidity. If the results differ by 10 per cent or more, the material shall be classified as type " R."

While some properties are practically unaffected by changes in atmospheric humidity, it is known that, for most physical properties, cellulose derivatives and some polyvinyl acetal resins are sufficiently affected by humidity to throw them into the " R " classification, whereas plastics manufactured from methyl methacrylate, phenol-formaldehyde, or urea-formaldehyde are so slowly affected by atmospheric changes that they would fall into the " S " classification.

Apparatus.

(a) *For Type " S " Materials.*

A circulating air oven which may be maintained at a temperature of 50° ± 3° C. (122° ± 5.4° F.).

Suitable desiccators containing anhydrous calcium chloride for cooling specimens to testing temperature. The desiccant should be renewed frequently.

(b) *For Type " R " Materials.*

A room, of sufficient size for the running of desired tests, which is maintained at a temperature of 25° ± 1° C. (77° ± 2° F.) and a relative humidity of 50 ± 2 per cent.

Procedure.

(a) *Type " S " Material.*

Type " S " specimens should be pre-conditioned for a period of 48 hr. in the circulating air oven at a temperature of 50° ± 3° C. (122 ± 5.4° F.). They should be removed from the oven, cooled in a desiccator over anhydrous calcium chloride for a period of at least 16 hr. prior to the actual running of the test. A definite time interval, previously decided upon by cooperating laboratories, should be allowed to elapse between removal of the specimens from the desiccator and the application of force applied in the test. The test may be run at room atmospheric conditions.

(b) *Type " R " Material.*

Specimens should be pre-conditioned for 48 hr. in a room at relative humidity of 50 ± 2 per cent at 25° ± 1° C. (77° ± 2° F.) prior to testing. The actual test itself should be run in the same room at the same atmospheric conditions.

If, because of lack of equipment, type " R " materials must be tested after conditioning by the " S " procedure, the effect of the time elapsing between removal from the desiccator and actual testing must be established.

If type " S " materials are distorted or otherwise affected by the type " S " conditioning methods, they may be run by the type " R " procedure. If the specimens are over 0.25 in. in thickness and/or are suspected of having been subjected to excessive humidity, the time of conditioning should be extended to 96 hr.

Report. In reporting results, the type of pre-conditioning used and the atmospheric conditions under which the test was run should be clearly stated.

Determining Relative Humidity. *Sling Psychrometer, Approved Instrument.* The sling psychrometer shall be the standard instrument for measuring relative humidity, and for calibrating all other humidity measuring instruments. The sling psychrometer shall conform to the following requirements:

Thermometers. Two mercury thermometers, stem graduated in degrees Fahrenheit or finer, matched to within 0.25° F. throughout the range used.[3]

Wet Bulb Covering. The bulb of the wet bulb thermometer shall be completely covered with a close fitting fabric of mercerized cotton, silk or other soft unsized material, preferably tubular knitted. This material shall be kept clean and free from all foreign substances likely to affect the absorption or evaporation of moisture.

Alternate Instruments. (a) Except in the case of dispute, other wet and dry bulb psychrometers may be used which have provision for maintaining a definite movement of air across the sensitive elements of the thermometers, provided their indications have been proved equivalent to those of a standard sling psychrometer within the permissible limits of accuracy.

(b) Except in the case of dispute, various types of absorption hygrometers (preferably those containing human hair) may be used, provided they are carefully calibrated at sufficiently frequent intervals to agree with indications of a standard sling psychrometer within the allowable limits of accuracy.

Procedure. (a) *Preparing Instrument.* The covering of the wet bulb shall be thoroughly moistened with water, preferably distilled water at approximately room temperature. A small bottle will serve as a convenient water container. If new or dry through disuse, several minutes may be required for complete saturation of the fabric. Touching the fabric with the fingers, which may deposit oil or dirt, should be avoided. The dry bulb shall be maintained absolutely dry.

(b) *Swinging Instrument.* The handle of the psychrometer shall be grasped and the instrument whirled, preferably in a vertical plane, with sufficient rapidity to give the wet bulb a velocity of from 10 to 20 ft. per sec. The purpose of whirling is effectively to expose the thermometer to the action of the air until the minimum wet bulb temperature is indicated. Whirling shall be continued for a minimum of 30 sec. if the mercury bulbs are thin, and for about 60 sec. if they are thick. The operator should preferably stand facing the air current, and avoid locations where proximity to machinery, direct heat from the sun or other sources would have undue influence.

(c) *Reading Instrument.* Immediately after whirling the instrument the thermometers shall be read quickly. It is usually preferable to read the wet bulb first. For commercial accuracy, readings shall be made to the nearest 0.5° F. Greater accuracy may be secured by reading to the nearest 0.25° F. or closer. The hands, face and other warm objects shall be kept as far as possible from the mercury bulbs while the thermometers are being read.

(d) *Check Readings.* For purposes of checking, the instrument shall again be whirled for about 20 sec. and another reading made. If necessary, this shall be continued until

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[3] Thin mercury bulbs have the advantage of sensitivity, requiring less time for swinging and giving quicker response to changes in atmospheric conditions.

two successive readings agree. If atmospheric conditions are fluctuating, it may be desirable to obtain several readings in order to secure an average. It will not be necessary to rewet the covering on the wet bulb so long as the fabric remains visibly damp.

(e) If the wet bulb temperature is below freezing, special care and patience are necessary in making an observation. As the moisture on the wet bulb begins to freeze, its temperature becomes 32° F. and remains so until freezing is completed. The temperature of the ice-covered bulb will then slowly descend until the true minimum is reached. Several minutes may be required to secure a correct reading in such a case.

Calculation. (a) Subtract the wet bulb reading from the dry. The difference is the "wet bulb depression." Knowing the temperature and the wet bulb depression, the relative humidity may be calculated from the following basic formula:[4]

$$e = e' - 0.00367P(t - t')\left(1 + \frac{t' - 32}{1571}\right)$$

where:

e = actual vapor pressure of the atmosphere in inches of mercury,
e' = saturated or maximum vapor pressure at temperature t' in inches of mercury,[5]
P = barometric pressure in inches of mercury,[6]
t = dry bulb temperature in degrees Fahrenheit, and
t' = wet bulb temperature as shown by the sling psychrometer in degrees Fahrenheit.

Relative humidity may be calculated from the relation:
where:

$$\text{Relative humidity, per cent} = \frac{100e}{E}$$

E = saturated or maximum vapor pressure[7] at temperature t.

(b) For determining relative humidity from psychometric observations within the normal temperature range, 0° to 112° F., and for normal barometric pressure, 29 to 31 in., reference may for convenience be made to tables,[8] charts, calculating devices, etc., provided they agree with the basic formula within the permissible limits of accuracy.

Accuracy. Distinction shall be made between the degree of accuracy satisfactory for ordinary commercial testing and that required of the laboratory technician.

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[4] The basic formula is that deduced by Mr. Ferrel. It is found in the Smithsonian Meteorological Tables and in Report No. 235 of the Weather Bureau, Department of Agriculture, 1915.

[5] See Smithsonian Meteorological Tables for table of saturated vapor pressures.

[6] *Effect of the Barometer.* Except for precise scientific measurements, changes in barometric pressure in any given locality are of negligible importance as affecting the accuracy of psychrometric humidity observations. Consequently, in locations at or near the sea level (within 1000 ft. elevation) no consideration need be given to the height of the barometer. In the case of tests made at high altitudes or under conditions of excessive plenum, special tables should be used. A set of tables for various barometric pressures may be found in Report No. 234 of the U. S. Weather Bureau.

[7] See Smithsonian Meteorological Tables for table of saturated vapor pressures.

[8] A Psychrometric Humidity Table in a form found to be most convenient for use appears in "Proceedings," A.S.T.M., Vol. 31, Part 1, p. 567 (1931); also in "A.S.T.M. Standards on Textile Materials," p. 233, October, 1939, available as a separate publication.

Commercial Testing. For ordinary commercial testing, measured relative humidity shall not be more than 2 per cent above or below the relative humidity indicated by a standard sling psychrometer properly operated.

Laboratory Testing. For close laboratory testing, or in case of dispute, measured relative humidity shall not be more than 1 per cent above or below the relative humidity indicated by a standard sling psychrometer properly operated.[9]

Impact Strength. This is a measure of the resistance to breakage of the molded plastic when struck a single blow under specific conditions. Briefly the test is made by allowing a pendulum to strike and break the specimen at the bottom of its swing. The amplitude of the upward swing as compared with that of a free swing where no specimen is broken measures the energy absorbed in breaking the specimen. It is this energy expressed in ft.-lb. that is reported, either as such for the specimen in question, or as calculated for 1 inch of width.

Two types of equipment for this test are widely used, the Charpy and the Izod, each of the pendulum type.

The Charpy test uses a specimen ½ in. by any dimension of ½ in. or less agreed upon as representative of the cross section in which the particular material is to be used. For all specimens having one dimension less than ½ in., the notch when used shall be cut in the narrower side. For all compression molded specimens the notch shall be in the side parallel to the direction of application of the molding pressure. For sheet material, the thickness shall be the thickness of the sheet except that it shall not exceed ½ in. If so, it shall be machined down to ½ in. When the individual specimens are less than ½ in. thick, the test specimen may be a composite consisting of a number of individual thin specimens aggregating as nearly as possible ½ in. in thickness. They shall be tested edgewise. In the Charpy test the specimen rests on two supports and is broken by a blow delivered midway between the supports.

In the Izod method the specimen is held as a vertical cantilever beam. It is broken by a blow delivered at a fixed distance from the edge of the specimen clamp. The test requires a notched specimen in all cases. The notch is put into the narrow side and is intended to produce a standard degree of stress concentration.

For very thin materials, the test specimen may be a composite consisting of a number of individual specimens aggregating as nearly as possible ½ in. in thickness. See the detailed A.S.T.M. method which follows.

Proposed Methods of Test for Impact Resistance of Plastics and Electrical Insulating Materials

A.S.T.M. D256-41T

Scope. (a) These methods are intended to determine the relative susceptibility to fracture by shock of plastics materials and electrical insulating materials as indicated by the energy expended by a standard pendulum type impact machine in breaking a standard specimen in one blow.

(b) There are two types of pendulum impact machines and related methods of test which use different specimens and differ in the method of holding and striking the specimen. Each specimen and method has characteristics which may dictate its use.

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[9] Under ordinary conditions, 1 per cent error in relative humidity corresponds to approximately 0.25° F. error in wet bulb depression.

Results by the different methods cannot be directly compared because impact values determined by the two methods may be numerically different.

(c) Method A is the Cantilever Beam Method or Izod type test in which the specimen is held as a cantilever beam (usually vertical) and is broken by a blow delivered at a fixed distance from the edge of the specimen clamp. The test requires a notched specimen in all cases. The notch is intended to produce a standard degree of stress concentration.

(d) Method B is the Simple Beam Method or Charpy type test in which the specimen is supported as a simple beam (usually horizontal) and is broken by a blow delivered midway between the supports. In this test the specimen may be either plain or notched as required by the characteristics of the material tested.

I. *Method A*

Cantilever Beam Method (*Izod Type Test*)

Apparatus. (a) The machine for Method A shall be of the pendulum type as shown in Fig. 3.3, of rigid construction and accurate to within 0.01 ft.-lb. for readings of less than 1 ft.-lb. and to within 1 per cent for higher values. Accurate correction shall be made for friction and windage losses.

(b) The dimensions of the machine shall be such that the center of percussion of the striker[10] is at the striking edge.

(c) The pendulum shall be released from such a position that the linear velocity of the striking edge at the instant of impact shall be approximately 11 ft. per sec., which is that corresponding to an initial elevation of the striking edge of 2 ft.

(d) The striking edge of the pendulum shall be a circular cylindrical surface of 1/32 in. radius, with its axis horizontal. The cylindrical surface shall be, when the pendulum is hanging free, tangent to the specimen in a line 0.866 in. above the top surface of the vise. The pendulum above the cylindrical portion of the striking edge shall be recessed or inclined at a suitable angle so that there is no chance of its coming in contact with the specimen during the break.

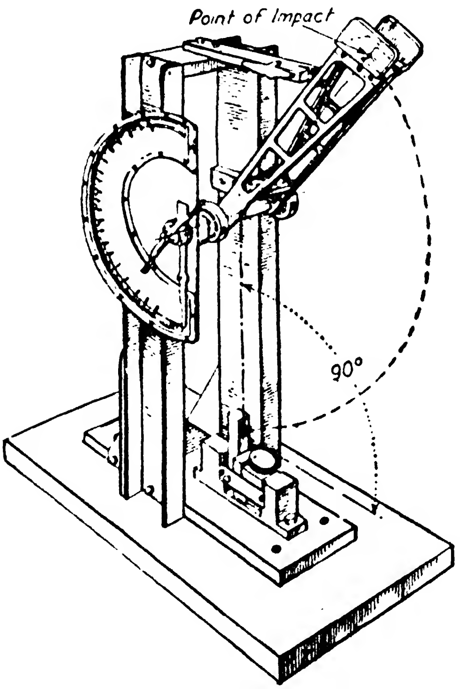

FIG. 3.3 — Cantilever beam (Izod) impact machine.

(e) Means shall be provided for clamping the specimen rigidly in position with the edges of the supporting surfaces at 90° angles.

(f) Means shall be provided for determining the " impact value " of the specimen

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[10] The distance from the axis of support to the center of percussion, l, may be determined experimentally from the period of oscillation of the pendulum through a small angle by means of the expression $l = 0.81P^2$, where P is the time in seconds of a complete swing (to and fro).

which is the energy expended by the machine in breaking the specimen. This value is equal to the difference between the energy in the pendulum blow and the energy remaining in the pendulum after breaking the specimen, after suitable correction has been made for windage and friction.

Test Specimen. (a) The test specimen shall conform to the dimensions shown in Fig. 3.4 except as modified by paragraphs (b), (c) and (d) below. To ensure duplication of the correct contour of the specified notch all specimens shall be notched with a special formed milling cutter or equivalent means and in such manner that the bottom of the notch is smooth, straight and free from scratches.

(b) For molded material[11] the specimen shall be ½ in. by any dimension of ½ in. or less agreed upon as representative of the cross section in which the particular material is to be used. For all specimens having one dimension less than ½ in., the notch shall be cut in the narrower side. For all compression molded specimens the notch shall be in the side parallel to the direction of application of the molding pressure.

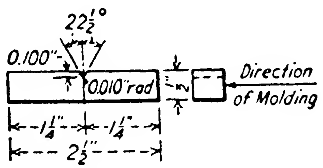

FIG. 3.4 — Cantilever beam (Izod) impact test specimen.

(c) For sheet material the thickness shall be the thickness of the sheet except that it shall not exceed ½ in. Sheet material thicker than ½ in. shall be machined down to ½ in. Sheet material when thicker than ½ in. may be tested either edgewise or flatwise, as specified and may be cut from the sheet either lengthwise or crosswise as specified.[12] When tested flatwise, the notch shall be made in the original surface.

(d) When the individual specimen is less than ½ in. in thickness, the test specimen may be a composite specimen consisting of a number of individual thin specimens aggregating as nearly as possible ½ in. in thickness. They shall all be accurately aligned with each other and shall be tested edgewise. Single specimens less than ½ in. in thickness may be used provided the width is sufficient for firm, accurate clamping and the impact value of the material is sufficiently high to be accurately determined by a machine of the capacity used.

Preconditioning Test Specimens. (a) Specimens shall be preconditioned and tested in accordance with Tentative Methods of Test for Preconditioning Plastics and Electrical Insulating Materials.

Procedure. (a) At least five individual determinations of impact value shall be made under the conditions prescribed under section (a) Preconditioning of Specimens.

(b) The test specimen shall be rigidly clamped with the center line of the notch on

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[11] The type of mold used to produce test specimens has an effect on the results obtained. Co-operating laboratories should, therefore, agree upon standard molds per D551–39T and upon molding procedure to obtain concordant results.

[12] In referring to the cutting of the specimens of laminated sheet materials and the application of the load, the following descriptions of terms apply:

Flatwise — Load applied to the flat side of the original sheet or plate.
Edgewise — Load applied to the edge of the original sheet or plate.
Lengthwise — In the direction of the length of the sheet.
Crosswise — In the direction at right angles to the direction of the length of the sheet.

NOTE: When the sheet has the same length and width, one dimension shall arbitrarily be designated as the *A* direction and the other as the *B* direction.

the level of the top of the clamping surface[13] and the blow shall be struck on the notched side.

(c) When a composite specimen is used the individual members shall be held closely in contact and accurately aligned with each other when clamped.[13]

Report. (a) A statement indicating the size of specimen, the method of test and type of preconditioning used and, for sheet materials, the direction of testing and whether the specimens were cut lengthwise or crosswise from the sheet.

(b) The value of energy expended in breaking each individual specimen expressed in ft.-lb. per in. of notch, determined by dividing the energy in ft.-lb. expended in the individual test by the actual dimension in inches along the notch of the specimen broken in each test, whether a single or a composite specimen was used; and

(c) The average of the values given in paragraph (b) the average thickness of the individual specimen and the number of such specimens broken in each operation of the machine.

II. *Method B*

Simple Beam Method (Charpy Type Test)

Apparatus. (a) The machine for Method B shall be of the pendulum type, as shown in Fig. 3.5, of rigid construction and accurate to within 0.01 ft.-lb. for readings of less than 1 ft.-lb. and to within 1 per cent for higher values. Accurate correction shall be made for friction and windage losses.

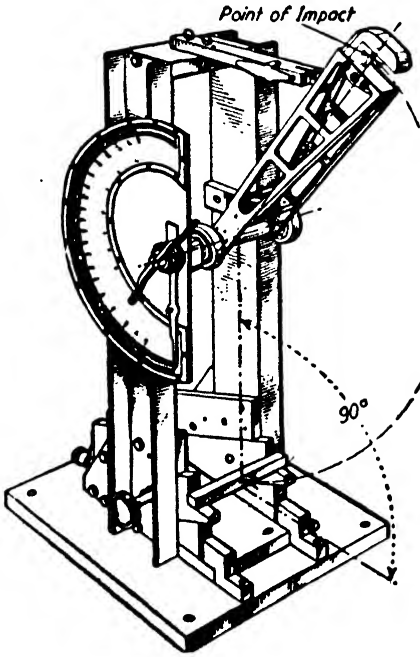

FIG. 3.5 — Simple beam (Charpy) impact machine.

(b) The dimensions of the machine shall be such that the center of percussion of the striker[10] is at the point of impact, that is, the center of the striking edge.

(c) The pendulum shall be released from such a position that the linear velocity of the center of the striking edge (center of percussion) at the instant of impact shall be approximately 11 ft. per sec., which is that corresponding to an initial elevation of this point of 2 ft.

(d) The striking edge of the pendulum shall be tapered to have an included angle of 45° and shall be rounded to a radius of 0.125 in. It shall be so aligned that in the case of rectangular specimens it will make contact across the full width of the specimen.

(e) The test specimen shall be supported against two rigid blocks in such a position that its center of gravity shall lie on a tangent to the arc of travel of the center of percussion of the pendulum drawn at the position of impact. The edges of the blocks shall be rounded to a radius of 0.125 in. and the points of support shall be 4 in. apart.

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[13] It is recommended that a jig or template be used to locate the specimen in the jaws as specified.

(f) Means shall be provided for determining the impact value, which is the energy expended by the machine in breaking the specimen. This value is equal to the difference between the energy in the pendulum blow and the energy remaining in the pendulum after breaking the specimen, after suitable correction has been made for friction and windage.

Test Specimen. (a) For materials other than ceramic materials the test specimen shall conform to the dimensions shown in Fig. 3.6, except as modified by paragraphs (b), (c), and (d) below. The notch, when used, shall be milled with a special formed milling cutter or machined by other equivalent means to ensure duplication of correct contour and in such manner that the bottom of the resulting notch is smooth, straight, and free from scratches.

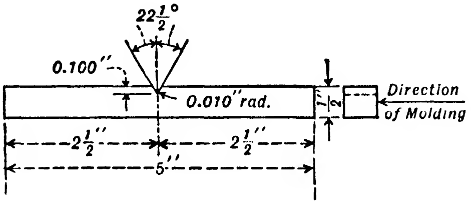

FIG. 3.6 — Simple beam (Charpy) impact test specimen.
Thickness in accordance with text.

(b) For molded material[11] the specimen shall be ½ in. by any dimensions of ½ in. or less agreed upon as representative of the cross section in which the particular material is to be used. For all specimens having one dimension less than ½ in., the notch when used shall be cut in the narrower side. For all compression molded specimens the notch shall be in the side parallel to the direction of application of the molding pressure.

(c) For sheet material the thickness shall be the thickness of the sheet except that it shall not exceed ½ in. Sheet material thicker than ½ in. shall be machined down to ½ in. Sheet material when thicker than ½ in. may be tested either edgewise or flatwise, as specified and may be cut from the sheet either lengthwise or crosswise as specified.[12] When tested flatwise, the notch when used shall be made in the original surface.

(d) When the individual specimen is less than ½ in. in thickness, the test specimen may be a composite specimen consisting of a number of individual thin specimens aggregating as nearly as possible ½ in. in thickness. They shall all be accurately aligned with each other and shall be tested edgewise. Single specimens less than ½ in. in thickness may be used provided the width is sufficient to ensure stability during the test and the impact value of the material is sufficiently high to be accurately determined by a machine of the capacity used.

(e) For *ceramic* materials, the specimen shall be an unnotched cylinder 6 in. in length. The diameter shall be 0.5 in., 0.75 in., or 1.125 in., whichever value is comparable to that of the finished product.

Preconditioning Test Specimens. (a) Except for ceramic materials, specimens shall be preconditioned and tested in accordance with Tentative Methods of Test for Preconditioning Plastics and Electrical Insulating Materials.

Procedure. (a) At least five individual determinations of impact value shall be made under the conditions prescribed under section (a) Preconditioning of Specimens.

(b) The test specimen shall be supported against the steel blocks so that the blow will be struck at the center of the specimen and on the side opposite the notch for notched specimens.

(c) When a composite specimen is used the individual members shall be closely in contact and accurately aligned with each other. It is recommended that a jig be used to ensure alignment of notches.

Report. The report of the test shall include the following:

(a) A statement indicating the size of specimen, the method of test and type of preconditioning used and, for sheet materials, the direction of testing, and whether the specimens were cut lengthwise or crosswise from the sheet.

(b) For ceramic materials the energy expended in breaking each individual specimen expressed directly and for other materials the value of energy expended in breaking each individual specimen expressed in ft.-lb. per in. of notch, or per in. of width of the face of the specimen against which the hammer strikes determined by dividing the energy in ft.-lb. expended in the individual test by the actual dimension in inches along the notch or face of the specimen broken in each test, whether a single or a composite specimen was used, and

(c) The average of the values given in paragraph (b), the average thickness or diameter of the individual specimen, and the number of such specimens broken in each operation of the machine.

Compression Strength. This property, relatively, is of small interest because failure is apt to occur more from impact, flexural or tensile stresses than from compression.

In principle, the test determines the crushing force required to obtain rupture and results are calculated and expressed on a lb. per sq. in. basis. The test specimens vary with the nature of the product.

Details of the method may be found under the following A.S.T.M. designation, D48-41T.

Proposed Test

Scope. This method of test is intended for the determination of the maximum compressive strength which an electrical insulating material is capable of developing. This test is intended for molded plastics, laminated tubes, sheet and plate materials and round rods. Any existing method covering the testing of a given material should be consulted for special details applying to it.[14]

Apparatus. Any standard type of testing machine may be used provided it is accurate to within 1 per cent of the lowest load for which it is used. One end of the specimen shall bear upon an accurately centered spherical bearing block located wherever practicable at the top. The metal bearing plates shall be directly in contact with the ends of the specimen.

Test Specimens. Test specimens shall be such as are specified for the particular material tested. A primary requirement for all test specimens is that the ends be flat and perpendicular to their axis. In general the dimensions are as follows:

Molded Materials — A cylinder having a height of 1.25 in. and a diameter of 1.125 in.

Laminated Tubes — The diameter of the tube.

Sheet and Plate — One-inch cube for sheets 1 in. thick or over. For sheets less than

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[14] In the case of a material which fails in compression by a shattering fracture, the compressive strength has a very definite value. In the case of materials which do not fail in compression by a shattering fracture, the value obtained for compressive strength is of arbitrary value depending upon the degree of distortion which is regarded as indicating complete failure of the material.

1 in. thick specimens shall consist of a pile of sheets 1 in. square with a minimum number of layers to produce a height of at least 1 in.

Round Rods — The diameter of the rod.

Conditioning. Unless otherwise specified, test specimens shall be preconditioned and tested in accordance with tentative methods of tests for preconditioning plastics and electrical insulating material.

Procedure. (a) Five conditioned specimens shall be tested at room temperature or at other temperatures as specified.

(b) The crosshead speed of the testing machine shall be such that the load can be accurately weighed, but shall not exceed 0.050 in. per min. when the machine is running idle.

(c) Molded materials shall be tested with the load applied on the ends of the specimen.

(d) Laminated tubes shall be tested axially with the load applied perpendicular to the faces or ends of the specimen. Specimen shall also be tested diametrically with the load applied perpendicular to the tangent at the point of application.

(e) Rods shall be tested with the load applied perpendicular to the faces or ends of the specimen.

(f) Sheet and plate materials shall be tested with specimen turned both flatwise and edgewise, and cut both crosswise and lengthwise of the sheet.

Report. The report shall include the following:

(a) The significant dimensions of each specimen in inches measured to the nearest 0.001 in. and the direction of cutting and loading for sheet and plate specimens. Thickness is the thickness of sheet or plate, or the dimension parallel to the application of molding pressure for molded specimens.

(b) The load on each specimen in pounds at the first sign of failure and the direction of application of the load.

(c) The ultimate compressive strength in lb. per sq. in. for molded materials and sheets and plates calculated from the measured area before the load is applied and for rods and tubes calculated from the measured area before the load is applied and for rods and tubes calculated from the data obtained on the application of the load perpendicular to the face of the specimen.

(d) The rate at which the load was applied.

(e) Any condition of specimen or test which has not been standardized for the material.

Tensile Strength. The force required to rupture in tension. Results are calculated and expressed in lb. per sq. in. of cross-sectional area.

For molded materials and laminated sheets, the figure eight type test piece is used. For laminated tubes a 12-in. specimen is used. Finally, in the case of laminated rods, the specimens are 12 in. in length, and where the diameter is ¼ in. or over, the center is turned down to the same width and depth as in the case of the tubes. Details of the methods appear in the following A.S.T.M. tests, D638-41T and D48-41T.

Proposed Test

Scope. These methods are intended for use in determining the comparative tensile properties of organic plastics in the form of test specimens of standard shapes and when tested under defined conditions of pretreatment, temperature, humidity, and testing machine speed (1)[15], (2).

The test specimen may be compression — or injection-molded into its final form or it may be machined from sheets, slabs, plates, or similar shapes prepared by any suitable method (3), (4).

Definition of Terms. (5).

(a) *Ultimate* (*or Tensile*) *Strength* is the tensile load per unit area of original cross section, within the gauge boundaries, required to break a test specimen of the type and in the manner herein described. It is expressed in lb. per sq. in.

(b) *Extension* is the change in length produced in a longitudinal section of a test specimen, measured between fixed gauge points on the specimen, by a tensile load. It is expressed in inches.

(c) *Unit Extension* is the ratio of the *Extension* to the length of the measured elongating section of the test specimen, i.e., the change in length per unit original length. It is expressed as a dimensionless ratio.

(d) *Strain* is synonymous with *Unit Extension.*

(e) *Per Cent Elongation* is the *Extension* recorded at the moment of rupture of the specimen expressed as a percentage of the original length of the measured elongating section.

(f) *Mean Rate of Stressing* is defined, for report purposes, as the tensile load, in lb. per sq. in. of original cross section, carried by the test specimen at the moment when the strain is 0.02 divided by the time in seconds required for the attainment of this tensile load and this strain, measured from the beginning of application of the load. It is expressed in lb. per sq. in. per sec.

Apparatus. The apparatus shall be of the constant-rate-of-crosshead-movement type and shall comprise essentially the following:

(a) A fixed, essentially stationary member carrying one grip.

(b) A movable member carrying a second grip.

(c) A drive mechanism for imparting to the movable member (b) a uniform, controlled velocity with respect to the stationary member (a). The velocity must be regulated for each material as specified under Sec. 8.

(d) A suitable load-indicating mechanism capable of showing the total tensile load carried by the test specimen when held by the grips attached, respectively, to the stationary member (a) and the movable member (b). This mechanism should be essentially free from inertia lag at the specified rate of testing and should indicate the load with an accuracy of ± one per cent or better. The accuracy of the testing machine must be verified in accordance with A.S.T.M. Designation E4–36.

(e) Grips for holding the test specimens between the fixed member (a) and the movable member (b). These must be of the self-centering type, i.e., they must be attached to (a) and (b), respectively, in such a way that they will move freely into alignment as soon as any load is applied, so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly. The test specimen must be held in such a way that slippage relative to the grips is prevented in so far as this is physically possible.

(f) A suitable instrument for determining the distance between two fixed points on

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[15] Numbers in parentheses refer to similarly numbered paragraphs in Appendix A, pp. 78–79.

the test specimen at any time during the test. It is desirable, but not essential that this instrument automatically record this distance (or any change in it) as a function of the load on the test specimen or of the time elapsed from the start of the test. This instrument should be essentially free of inertia lag at the specified rate of loading, and must be accurate to ± 1 per cent or better.

(g) Fixed member (a), movable member (b), drive mechanism (c), and grips (e) must be constructed of such materials and in such proportions that the total elastic longitudinal strain of the system constituted by these parts does not exceed 1 per cent of the total longitudinal strain between the two gauge marks on the test specimen at any time during the test and at any load up to the rated capacity of the machine.

(h) Suitable micrometers, reading to at least 0.001 in., for measuring the width and thickness of the test specimens, must be provided.

(i) A circulating air oven, adjusted to 50° ± 3° C. (122° ± 5° F.), and desiccators containing anhydrous calcium chloride (or other suitable desiccant) are required for conditioning some materials.

(j) The actual testing must be carried out in an atmosphere maintained at 25° ± 1° C. (77 ± 2° F.) and 50 ± 2 per cent relative humidity.

Classification of Materials. For simplification, plastic materials are arbitrarily divided into four groups on the basis of two criteria, i.e., (a) ductility, and (b) rate of response to variations of atmospheric temperature and humidity.

(a) With respect to ductility, plastic materials are subdivided into two groups, namely: (i) " Low." Those materials whose ultimate per cent elongation is not greater than 5 per cent; (ii) " High." Those materials whose ultimate per cent elongation is greater than 5 per cent.

(b) With respect to rate of response to changes in atmospheric environment, plastic materials are subdivided into two groups on the basis of their behavior in the impact test (6). See Impact Test, p. 12.

" R " (Rapid.) Those materials which, as a result of variations in atmospheric humidity or temperature, change sufficiently in impact strength, during the period of time required for completion of a tensile test, to affect numerical test results by 10 per cent.

" S " (Slow.) Those materials whose impact strength is so slowly affected by variations of atmospheric humidity or temperature that numerical test results do not change by as much as 10 per cent during the period of time required for completion of a tensile test.

Combination of the above classifications produces the following subdivision of plastic materials:

Type A: " Low " and " Rapid." Those materials whose ultimate per cent elongation is not greater than 5 per cent and whose impact strength, as a result of variations in atmospheric humidity or temperature, changes sufficiently during the period of time required for a tensile test, to affect numerical test results by 10 per cent.

Type B: " Low " and " Slow." Those materials whose ultimate per cent elongation is not greater than 5 per cent and whose impact strength is so slowly affected by variations of atmospheric humidity or temperature that numerical test results do not change by as much as 10 per cent during the period of time required for completion of a tensile test.

Type C: " High " and " Rapid." Those materials whose ultimate per cent elongation is greater than 5 per cent and whose impact strength, as a result of variations in atmospheric humidity or temperature, changes sufficiently during the period of time required for tensile test, to affect numerical test results by 10 per cent.

Type D: " High " and " Slow." Those materials whose ultimate per cent elongation is greater than 5 per cent and whose impact strength is so slowly affected by variations of atmospheric humidity or temperature that numerical test results do not change by as much as 10 per cent during the period of time required for completion of a tensile test.

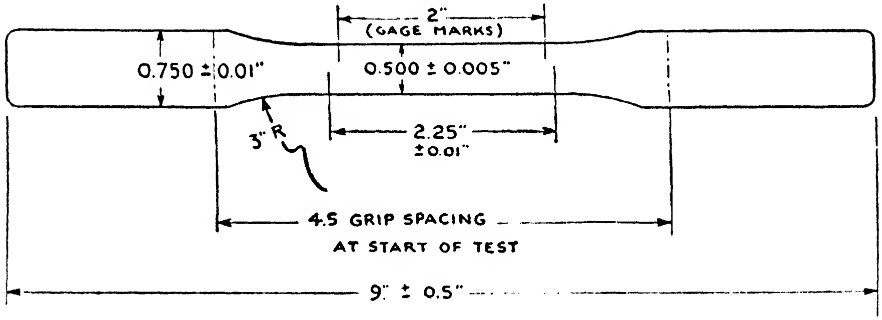


Fig. 3.7 — Tensile test specimen, type 1.

Note — Thickness should be 0.125 in. for molded specimens and for other specimens wherever possible when specimens are machined from sheet materials. Thicknesses may be the thickness of the sheet provided this does not exceed 0.5 in.

Test Specimens and Grips. Two types of test specimens are shown in Figs. 3.7 and 3.8. Type 1 is intended primarily for testing materials in sheet, plate, slab, or similar form, from which the test specimen must be shaped by machining operations. However, this specimen may also be prepared by compression-molding or injection-molding of the material to be tested. Type 2 is intended primarily for testing molding materials from which the test specimens are formed by injection-molding. However, it may also be compression-molded or machined from sheets, plates, slabs, etc.

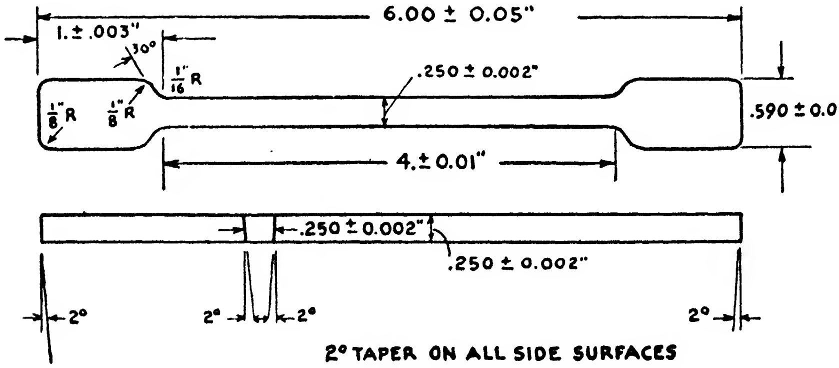


Fig. 3.8 — Tensile test specimen, type 2.

Grips of the form shown in Fig 3.9, which grip the test specimen at the shoulders, are best used with the Type 2 specimen (7). For the Type 1 specimen, grips whose surfaces are deeply scored with a pattern similar to that of a coarse single-cut file, the separations being about 3/32 in. apart and about 1/16 in. deep, have been found most satisfactory for materials of Types A, B, C, and D. In testing materials which may be suspected of anisotropy, duplicate sets of test specimens must be prepared having their long axes respectively parallel with and normal to the suspected direction of anisotropy.

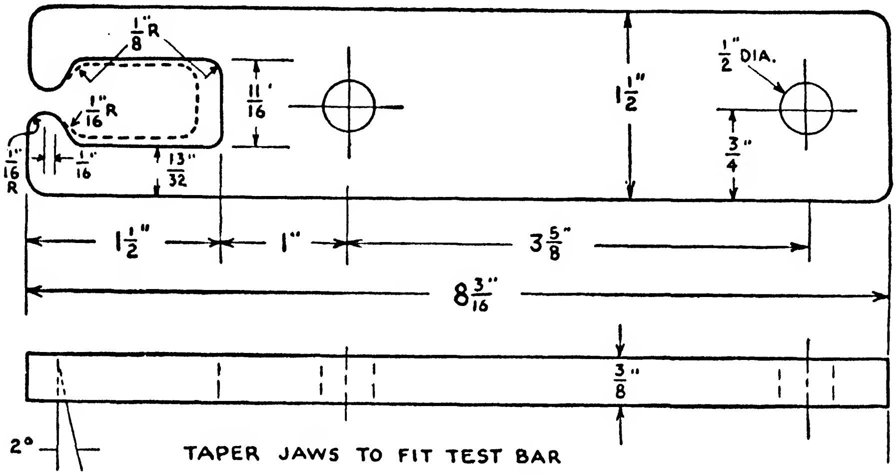


FIG. 3.9 — Tensile test grip for type 2 specimen.

All surfaces of the specimens must be free from visible flaws, scratches or imperfections. Marks left by coarse machining operations must be carefully removed with a fine file and the filed surfaces must then be smoothed up with abrasive paper (No. 00 or finer). The finishing file strokes or sanding strokes must be made in a direction parallel to the long axis of the test specimen. All flash must be removed from molded specimens, taking great care not to disturb the molded surfaces (8). If it is necessary to place gauge marks on the specimen, this should be done with a soft, fine, wax crayon or with India ink. Gauge marks must not be scratched into the surface of the specimen with a sharp instrument, because this causes weakness and premature fracture as a result of concentrations of stresses.

Conditioning. (a) Plastic materials are arbitrarily classified as " R " (rapid) or " S " (slow) on the basis of the rapidity with which their impact strength varies with changes in atmospheric humidity and temperature. While some properties are practically unaffected by changes in atmospheric humidity and temperature, it is known that the tensile properties of cellulose derivatives and of some polyvinyl acetal resins are sufficiently affected, either by humidity or temperature changes, to throw them into the " R " classification, whereas plastics manufactured from polystyrene, methacrylic acid esters, phenol-formaldehyde or urea-formaldehyde are so slowly affected by atmospheric changes that they generally fall into the " S " classification.

Referring to Sec. 4, materials classified as Types A and C are considered to belong to the " R " group, while materials classified as Types B and D are considered to belong to the " S " group.

(b) *Detailed Conditioning Procedures.*

Types A and C ("R" group). Specimens should be preconditioned for 14 days in an enclosure maintained at 25° ± 1° C. (77° ± 2° F.) and 50 ± 2 per cent relative humidity prior to testing. The actual tests should be run in the same enclosure at the same atmospheric conditions (9).

Types B and D ("S" group). Specimens should be preconditioned for a period of 48 hr. in a circulating air oven at a temperature of 50° ± 3° C. (122° ± 5° F.). They should then be removed from the oven, cooled in a desiccator over anhydrous calcium chloride (or an equivalent desiccant) for a period of at least 16 hr. prior to actual performance of the test. The test should be run in an enclosure maintained at 25° ± 1° C. (77° ± 2° F.) and 50 ± 2 per cent relative humidity. A definite time interval, previously decided upon by cooperating laboratories, should be allowed to elapse between removal of the specimens from the desiccator and the application of load in the test.

Alternatives. When it is necessary to evaluate, under comparable conditions, a series of materials, some of which belong in the "S" group and some of which belong in the "R" group, all of the materials should be conditioned by either the "S" procedure or the "R" procedure. Comparison of a series of results obtained by combinations of "S" and "R" conditioning procedures should not be attempted (10). If group "S" materials are distorted or otherwise adversely affected by the group "S" conditioning methods, they may be run by the group "R" procedure.

Number of Test Specimens. (a) At least five specimens shall be tested for each sample in the case of isotropic materials.

(b) Ten specimens, five normal to and five parallel with the principal axis of anisotropy, shall be tested for each sample in case of anistropic materials.

(c) Results on specimens which break at some obvious fortuitous flaw or which do not break between the predetermined gauge marks shall be discarded and retests made, unless such flaws constitute a variable whose effect it is desired to study.

(d) Results on specimens which deviate from the mean value of all tests by more than five times the average deviation from the mean value of all tests shall be discarded and retests made, unless the degree of variability is a factor which is being studied.

Testing Speed. Testing speed is defined as the velocity of separation of the two crossheads (or grips) of the machine when running idle (under no load). This velocity must be uniform and within ± 5 per cent of the stated value.

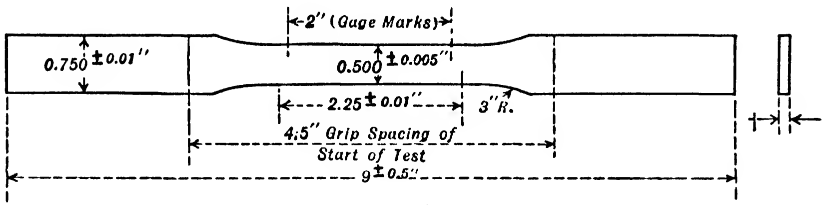
(a) *Types A and B.* These materials, defined as "low" ductility, are to be tested at a speed of 0.05 in. per min.

(b) *Types C and D.* These materials, defined as "high" ductility are to be tested at a speed of 0.25 in. per min.

(c) *Alternatives.* When it is necessary to evaluate, under comparable conditions, a series of materials some of which are of Type A or B and some of which are of Type C or D, it is suggested that duplicate sets be run, one at 0.05 in. per min. and one at 0.25 in. per min. In any event, all members of such series should be tested at the same speeds.

Procedure. (a) Measure the width and thickness of the specimen to the nearest 0.001 in., at several points (3 to 4) along its length. Record the minimum value found.

(b) Place the test specimen in the grips of the testing machine, taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine. With Type 1 specimens, allow at least ¼ in. between the ends of the gripping surfaces and the extreme shoulders of the test specimen. The ends of the gripping surfaces should thus be 4.5 in. apart at the start of the test. Tighten the grips evenly and firmly to the degree necessary to prevent slippage of the specimen during the test but not to the point where the specimen would be crushed. (If the Type 2 specimen is used with the grips shown in Fig. 3.11 no tightening is necessary.)



NOTE — THE THICKNESS "t" SHOULD BE 0.125" FOR MOLDED SPECIMENS AND FOR OTHER SPECIMENS WHEREVER POSSIBLE. WHEN SPECIMENS ARE MACHINED FROM SHEET MATERIALS, THICKNESS MAY BE THE THICKNESS OF THE SHEET, PROVIDED THIS DOES NOT EXCEED 0.5."

FIG. 3.10 — Plastics: tension specimen.

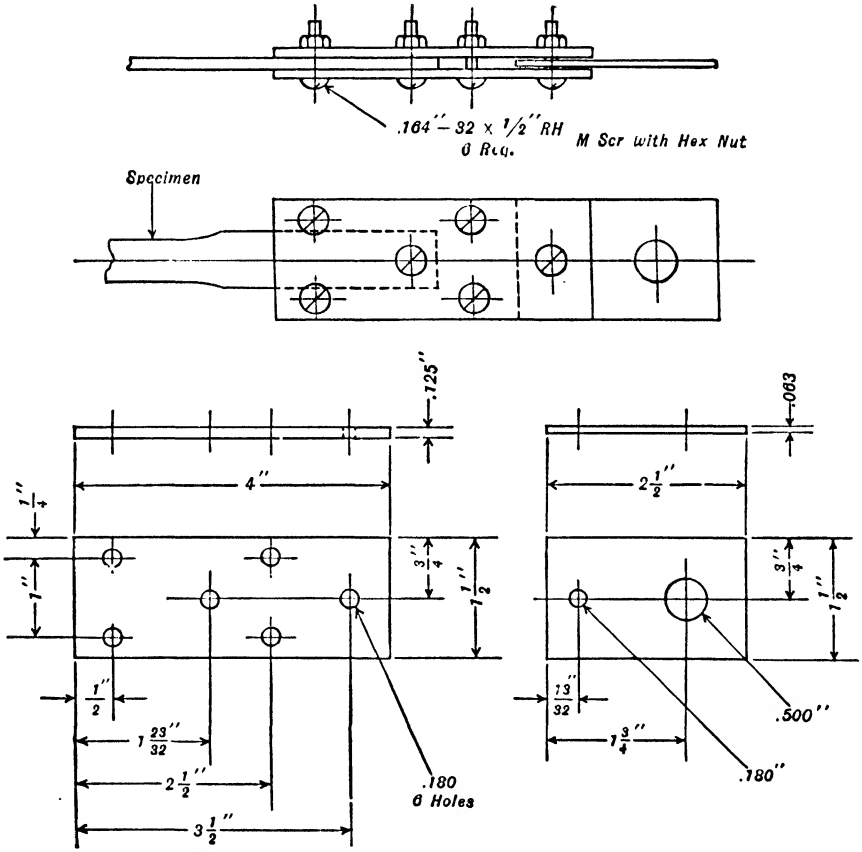


FIG. 3.11 — Plastics: long-time tension test-specimen grip.

(c) Set the speed control at the desired value and start the machine. Allow the machine to run at the desired speed until the specimen breaks. Record the maximum load carried by the piece during the test (usually this will be the load at the point of break).

(d) Record the load carried by the specimen when the strain reaches 0.02 and the time elapsed from the start of test until this point is reached.

Calculations.

(a) *Ultimate (or Tensile) Strength* shall be calculated by dividing the maximum (or breaking) load in lb. by the original minimum cross-sectional area of the specimen in sq. in. It is reported in lb. per sq. in. Retain three significant figures.

(b) *Ultimate Per Cent Elongation* shall be calculated by dividing the ultimate elongation by the original distance between gauge marks and multiplying by 100. It is reported in per cent. Retain two significant figures.

(c) *Mean Rate of Stressing* shall be calculated by dividing the tensile load carried by the specimen when the strain reaches 0.02 by the original minimum cross-sectional area of the specimen, and then dividing this result by the time in seconds, measured from the beginning of the test, required to attain this tensile load and strain. It is reported in lb. per sq. in. per sec. Retain three significant figures.

(d) For each series of tests, calculate the arithmetic mean of all values obtained. Report this as the " average " result for the particular value in question. Retain two significant figures.

(e) Calculate the deviation of each value from the " average " value and determine the arithmetic mean of these deviations. Report this as the " Average Deviation " of the particular series of results. Retain two significant figures.

Report. The report shall include the following:

(a) Complete identification of the material tested, including type, source, manufacturer's code numbers, form, principal dimensions, previous history, etc.

(b) Method of preparing test specimens.

(c) Type of test specimen and dimensions.

(d) Conditioning procedure used.

(e) Atmospheric conditions in test room.

(f) Number of specimens tested.

(g) Testing speed.

(h) Mean rate of stressing as defined above.

(i) Ultimate (or Tensile) Strength, average value and average deviation.

(j) Ultimate per cent elongation, average value and average deviation.

(k) Date of test.

APPENDIX A.

1. These methods are not well adapted to the testing of plastic materials in the form of thin sheets or films; methods for the testing of such forms are being developed. Neither are these methods particularly suitable for the testing of rubber or rubber-like polymers (elastomers), although the position of such materials as organic plastics is recognized.

2. These methods may be used for testing phenolic resin molded or laminated materials where comparative results are desired. However, where correlation with older

data is an object, such materials should be tested according to the methods described in A.S.T.M. Designation D48–39, entitled "Testing Molded Materials Used for Electrical Insulation," or A.S.T.M. Designation D229–39, entitled "Testing Sheet and Plate Materials Used in Electrical Insulation," respectively.

3. It is realized that one cannot test a material without also testing the method of preparation of that material. Hence, when comparative tests of materials *per se* are desired, the greatest care must be observed to ensure that all samples are prepared in exactly the same way. Similarly, for referee or comparative tests of any given series of samples, care must be taken to secure the maximum degree of uniformity in details of preparation, treatment, and handling.

4. These methods are not intended to be precise physical procedures. It is recognized that the constant-rate-of-crosshead-movement type of test leaves much to be desired from a theoretical standpoint, that wide differences may exist between rate of crosshead movement and rate of strain between gauge marks on the specimen, and that the testing speeds specified disguise important effects characteristic of materials in the plastic state. Further, it is realized that variations in the thicknesses of test specimens, which are permitted by these procedures, produce variations in the surface-volume ratios of such specimens, and that these variations influence the tensile test results. Hence, where directly comparable results are desired, all samples should be of equal thickness. Special additional tests should be used where more precise physical data are needed.

5. A more complete definition of terms and symbols relating to the tensile testing of plastics and related materials is given in Appendix B.

6. It is recognized that this basis of classification is a very arbitrary one and that behavior in the impact test is not necessarily a criterion of behavior in the tensile test. The classification has, however, been adopted by a joint action of A.S.T.M. Committee D–9 and D–20.

7. These grips must be applied with caution on Type 2 specimens of Classes C and D (Sec. 4), making certain that shear at the shoulders does not occur.

8. Before testing, all transparent specimens should be given a polariscopic inspection and those which show a typical or concentrated strain patterns should be rejected unless these "initial" strains constitute a variable whose effect it is desired to study.

9. In cases of extreme urgency, where the 14-day conditioning period is intolerable, the conditioning may be reduced to a minimum of 48 hr.

10. If, because of lack of equipment, group "R" materials must be tested after conditioning by the "S" procedure, the effect of the time elapsing between removal from the desiccator and completion of the actual test must be established.

APPENDIX B.

Definitions of Terms Relating to Tensile Testing of Plastics.

1. *Ultimate (or Tensile) Strength* is the tensile load per unit area of original cross section, within the gauge boundaries, required to break a test specimen. ("Tensile load" is interpreted to mean the maximum tensile load sustained by the specimen during the test, whether or not this coincides with the tensile load at the moment of rupture.) It is expressed in lb. per sq. in.

2. ***True Ultimate (or Tensile) Strength*** is the tensile load per unit of minimum cross-

sectional area within the gauge boundaries, measured at the moment of rupture, required to break a test specimen. It is expressed in lb. per sq. in.

3. *Tensile Stress* is the tensile load per unit of original cross-sectional area within the gauge boundaries carried by the test specimen at any given moment. It is expressed in lb. per sq. in.

4. *True Tensile Stress* is the tensile load per unit of minimum cross-sectional area within the gauge boundaries carried by the test specimen at any given moment. It is expressed in lb. per sq. in.

5. *Extension* is the change in length produced in a longitudinal section of a test specimen, measured between fixed gauge points on the specimen, by a tensile load. It is expressed in inches.

6. *Unit Extension* is the ratio of the extension to the length of the measured elongating section of the best specimen, i.e., the change in length per unit original length. It is expressed as a dimensionless ratio.

7. *Longitudinal Tensile Strain* (or simply *Strain*) is synonymous with *Unit Extension.*

8. *Ultimate Extension* is the extension recorded at the moment of rupture of the test specimen.

9. *Ultimate Unit Extension* is the unit extension recorded at the moment of rupture of the test specimen.

10. *Ultimate Longitudinal Strain* (or simply *Ultimate Strain*) is synonymous with *Ultimate Unit Extension.*

11. *Per Cent Ultimate Extension* is the *Ultimate Extension* expressed as a percentage of the original length of the measured elongating section. It is equal to the *Ultimate Unit Extension* multiplied by 100.

12. *Per Cent Elongation* is synonymous with *Per Cent Ultimate Extension.*

13. *Nominal Reduction in Area* is the difference between the original cross-sectional area of the test specimen and the cross-sectional area measured at the point of rupture after breaking the specimen in tension. It is expressed in sq. in.

14. *Nominal Unit Reduction in Area* is the ratio of the nominal reduction in area to the original cross-sectional area of the test specimen, i.e., the nominal reduction in area per unit original cross-sectional area. It is expressed as a dimensionless ratio.

15. *Nominal Per Cent Reduction in Area* is the nominal reduction in area expressed as a percentage of the original cross-sectional area of the specimen. It is equal to the *Nominal Unit Reduction in Area* multiplied by 100.

16. *True Reduction in Area* is the difference between the original cross-sectional area of the test specimen and the minimum cross-sectional area within the gauge boundaries at the moment of rupture in tension. It is expressed in sq. in.

17. *True Unit Reduction in Area* is the ratio of the true reduction in area to the original cross-sectional area of the test specimen; i.e., the true reduction in area per unit original cross-sectional area. It is expressed as a dimensionless ratio.

18. *True Per Cent Reduction in Area* is the true reduction in area expressed as a percentage of the original cross-sectional area of the specimen. It is equal to the *True Unit Reduction in Area* multiplied by 100.

19. *Tensile Stress-Strain Curve* is the curve obtained by plotting *Tensile Stresses* as

ordinates against corresponding *Longitudinal Tensile Strains* (*Unit Extensions*) as abscissae for the entire course of a tensile test.

20. *True Tensile Stress-Strain Curve* is the curve obtained by plotting *True Tensile Stresses* as ordinate against corresponding *Longitudinal Tensile Strains* (*Unit Extensions*) as abscissae for the entire course of a tensile test.

21. *Plastic Yield Stress* is the first stress asymptote on the stress-strain curve (whether nominal or true stress should be stated) at which the slope of the curve becomes zero, i.e., where the tangent to the curve becomes horizontal, when the test is conducted on a machine having a constant rate of crosshead movement.

22. *Rate of Loading* is the variation in tensile load carried by the specimen per unit time. It is expressed in lb. per sec.

23. *Rate of Stressing* is the variation in tensile stress per unit time. It is expressed in lb. per sq. in. per sec.

24. *True Rate of Stressing* is the variation in true tensile stress per unit time. It is expressed in lb. per sq. in. per sec.[16]

25. *Mean Rate of Stressing* is defined, for report purposes, as the *Tensile Stress* at which the *Unit Extension* (*strain*) is 0.02 divided by the time required for the attainment of this stress, measured from the beginning of load application. It is expressed in lb. per sq. in. per sec.

26. *Mean True Rate of Stressing* is defined, for report purposes, as the *True Tensile Stress* at which the *Unit Extension* (*strain*) is 0.02 divided by the time required for the attainment of this true stress, measured from the beginning of load application. It is expressed in lb. per sq. in. per sec.

27. *Rate of Straining* is the variation in longitudinal tensile strain per unit of time. Note that it is not synonymous with rate of crosshead movement.

28. *Symbols.* The following symbols may be used for the above terms:

W = Weight load.
ΔW = Increment of weight load.
L = Distance between gauge marks at any time.
L_0 = Original distance between gauge marks.
L_u = Distance between gauge marks at moment of rupture.

$$\Delta L \left\{ \begin{array}{l} = \text{Increment of distance between gauge marks.} \\ = \text{Extension.} \end{array} \right.$$

A = Minimum cross-sectional area at any time.
A_0 = Original cross-sectional area.
ΔA = Increment of cross-sectional area.
A_u = Cross-sectional area at point of rupture, measured after breaking specimen.
A_t = Cross-sectional area at point of rupture, measured at the moment of rupture.
t = Time.
Δt = Increment of time.

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[16] At the nominal plastic yield stress, the instantaneous nominal rate of stressing becomes zero, but the instantaneous true rate of stressing may continue to have a positive value if the cross-sectional area is decreasing.

σ = Tensile stress.
σ_t = True tensile stress.
σ_u = Ultimate (or tensile) strength.
σ_{ut} = True ultimate (or tensile) strength.
ϵ = Unit extension.
= Strain.
ϵ_u = Ultimate unit extension.
= Ultimate strain.
% El. = Per cent elongation.
= Per cent ultimate extension.
P.Y.S. = Plastic yield stress (nominal).
P.Y.S.$_t$ = Plastic yield stress (true).

29. Relations between these various terms may be defined as follows:

$$\sigma = \frac{W}{A_o}$$

$$\sigma_t = \frac{W}{A}$$

$$\sigma_u = \frac{W}{A_o} \quad \text{(where } W \text{ is breaking load)}$$

$$\sigma_{ut} = \frac{W}{A} \quad \text{(where } W \text{ is breaking load)}$$

$$\epsilon = \frac{L}{L_o} = \frac{L - L_o}{L_o}$$

$$\epsilon_u = \frac{L_u - L_o}{L_o}$$

$$\% \text{ El.} = \frac{L_u - L_o}{L_o} \times 100$$

$$= \epsilon_u \times 100$$

$$\text{Nominal reduction in area} = A_o - A_u$$

$$\text{Nominal unit reduction in area} = \frac{A_o - A_u}{A_o}$$

$$\text{Nominal per cent reduction in area} = \frac{A_o - A_u}{A_o} \times 100$$

$$\text{True reduction in area} = A_o - A_t$$

$$\text{True unit reduction in area} = \frac{A_o - A_t}{A_o}$$

$$\text{True per cent reduction in area} = \frac{A_o - A_t}{A_o} \times 100$$

$$\text{Rate of loading} = \frac{\Delta W}{\Delta t}$$

$$\text{Rate of stressing} = \frac{\Delta\sigma}{\Delta t} = \frac{\dfrac{\Delta W}{A_o}}{\Delta t}$$

$$\text{True rate of stressing} = \frac{\Delta\sigma t}{\Delta t} = \frac{\dfrac{\Delta W}{A}}{\Delta t}$$

$$\text{Rate of straining} = \frac{\Delta\epsilon}{\Delta t} = \frac{\dfrac{\Delta L}{L_o}}{\Delta t}$$

For the special case where the volume of the test specimen does not change during the test, the following relations hold:

$$\sigma_t = \sigma(1 + \epsilon) = \sigma\left(\frac{L}{L_o}\right)$$

$$\sigma_{ut} = \sigma_u(1 + \epsilon_u) = \sigma_u\left(\frac{L_u}{L_o}\right)$$

$$A = \frac{A_o}{(1 + \epsilon)}$$

Flexural Strength. This determination is to evaluate the resistance to bending stresses.

The determination is made on a ½ by ½ by 5 in. specimen. The specimen is supported at two points 4 in. apart in the case of a standard molded bar, but in the case of a sheet material when tested in the flatwise direction, the points of support are brought closer together depending on the thickness of the specimen. Force is applied from above at a point midway between the points of support and is increased until rupture occurs. The force required to produce rupture is converted to maximum fiber stress from the following formula:

$$S = \frac{3FD}{2WT^2}$$

where

S = the maximum fiber stress
F = the force applied
D = the distance between the points of support
W = the width of the specimen tested
T = the thickness of the specimen tested.

The rate at which the force is applied and the deflection at rupture are also recorded.

Fatigue Strength. The fatigue strength of plastics and resin bonded plywood, now under consideration by A.S.T.M., is outlined as follows:

Proposed Test[17]

Scope. This method covers the determination of the effect of repetitions of stress on a plastic[18] material as determined by a fixed-cantilever type of testing machine designed to produce the same maximum deflection of the specimen in each cycle.

Note. Since the characteristics which render a material resistant to fatigue are not completely known, and since the effect of such factors as the variations in shape of specimen, type of testing machine, and conditions of test (speed of machine, temperature of specimen, and atmospheric temperature and relative humidity), etc., are not completely known, the details considered herein concern those factors known to have important influences. Since other factors equally as important may in the future be discovered, the recommended details of the method are largely advisory in nature.

Definitions of Terms.

Fatigue (Progressive Fracture): The phenomenon of the progressive fracture of a material by means of a crack which begins and spreads under the action of repeated cycles of stress.

Fatigue Strength (S_F): The maximum amplitude of an alternating stress cycle, expressed in pounds per square inch, which will not cause fracture of the material for a given number of cycles of alternating stress. The corresponding number of cycles of stress must be stated.[19] If the term is used without further qualification, it is understood that the stress cycle is such as to produce a complete reversal of stress (from tension to compression). See Fig. 3.12a. When the stress cycle does not produce complete reversal of stress the mean stress of the cycle must also be stated. Note that in this case the fatigue strength is not the maximum stress in the cycle, Fig. 3.12, b, c, d.

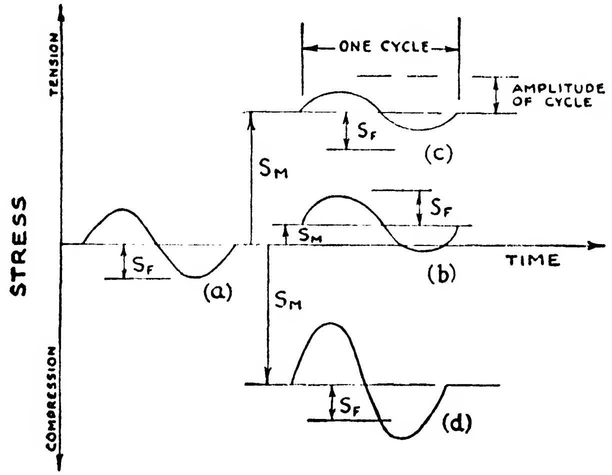

FIG. 3.12 — These curves illustrate cycle variations in fatigue testing.

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[17] Prepared by Section C on Fatigue and Repeated Impact Tests of Plastics, W. N. Findley, Chairman, for Sub-committee I on Strength, of Committee D20 on Plastics, of the American Society for Testing Materials.

[18] This method may also be applied to plastic impregnated wood and plastic bonded plywood.

[19] For some plastics and some metals the fatigue strength remains constant beyond a certain number of cycles of stress. That is, below a certain value of alternating stress the material does not fracture for an indefinitely large number of cycles of stress. The corresponding value of fatigue strength is commonly known as the Endurance Limit.

Note. Unfortunately in the literature on fatigue of metals the terms endurance limit, endurance strength and fatigue limit have been used loosely and interchangeably. They have been used to refer to the *maximum stress* in a stress cycle below which no evidence of fracture can be detected after a very large number of cycles of loading.

The same terms have also been used to refer to the maximum stress in a stress cycle which would cause fracture after an arbitrarily selected number of cycles. This definition has been used in tests of metals for applications in which the number of repetitions of maximum loading in the life of the structure was expected to be relatively small.

Mean Stress (S_M): The algebraic mean between the maximum and minimum stress produced in a material during an alternating cycle of stress. When used in conjunction with the fatigue strength the term mean stress denotes the mean stress for which the stated fatigue strength was determined. The sign of the mean stress, whether tension (+) or compression (−), must be stated. The mean stress is used together with the fatigue strength to define the range of variation of stress in the stress cycle for which the fatigue strength was determined. The mean stress of a cycle is important because in general the fatigue strength of a given material will depend upon the magnitude of the mean stress. Thus it is necessary to specify both the fatigue strength and the mean stress.

Figure 3.12 shows stress versus time curves for one cycle of stress with different combinations of mean stress S_M and superimposed alternating stress. The alternating stress cycle shown has an amplitude equal to the fatigue strength S_F.

In Fig. 3.12a the fatigue strength is S_F, the mean stress is zero, and the maximum tension equals the maximum compression.

In Fig. 3.12b, c, d, the mean stress S_M is not zero. In Fig. 3.12b the cycle of stress produces a maximum tension greater than the maximum compression. In Fig. 1c all values of stress in the cycle are tension. In Fig. 3.12d all values of stress in the cycle are compression.

Note. Another way of defining the range of variation of stress in a stress cycle is to use the "range ratio." The ratio has been defined as the ratio of the (numerical) minimum stress to the maximum for any cycle. Thus the range ratio and the fatigue strength must be stated to define the range of variation of stress in the stress cycle for which the fatigue strength was determined. See Report of the Research Committee on Fatigue of Metals, Proc. A.S.T.M., Vol. 30, p. 260, 1930.

Fatigue Ratio. The ratio of fatigue strength for cycles of completely reversed stress to the static tensile strength of the material as determined by the A.S.T.M. tentative method D638–41T.

Testing Machine.[20] The machine to be used with this method is a fixed-cantilever, repeated constant-deflection type fatigue machine. It is a machine in which the specimen, Fig. 3.13 (A) is a cantilever beam held in a vise (B) at one end (M) and bent by a concentrated load applied to a holder (J) fastened to the other end. The bending is accomplished by a connecting rod (C) driven by a variable eccentric (D) mounted on a shaft. The shaft is rotated at constant speed by a motor (E). The vise may be set in the plane of the eccentric so that the beam will be deflected the same amount on either side of the neutral position (completely reversed stress) or the vise may be set so that the deflection is greater on one side than on the other (mean stress not zero).

A counter (K) is geared to the shaft so as to record the number of cycles. A suitable

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[20] See "Classification of Fatigue Testing Machines," Appendix C, p. 92.

mechanically or electrically operated cut-off switch (*L*) is provided to stop the machine when the specimen fractures.

A diagram of the holder (*J*) for the free end of the specimen is shown in Fig. 3.14. This holder should be proportioned in such a way as to place the center of percussion of the oscillating portion of the specimen and holder at the wrist pin (*F*) and should have as little mass as possible in order to minimize inertia effects. It is necessary, for some materials, to use rubber gaskets in the grips to prevent failure at the grip due to stress concentration and chafing.

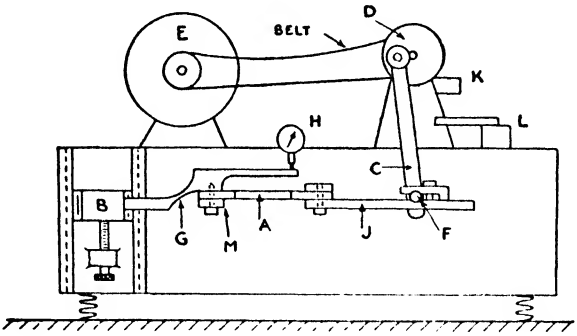

Fig. 3.13 — Fatigue machine.

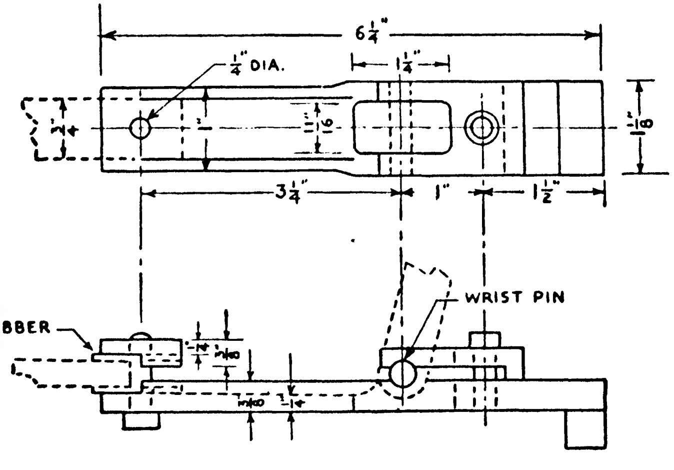

Fig. 3.14 — Grip.

The vise of the machine illustrated in Fig. 3.13 contains a dynamometer[21] for measuring the load on the specimen. The dynamometer consists of a reduced section (*G*) which acts as a spring, and a dial gauge (*H*) which measures the deflection of the spring when the specimen is deflected.

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[21] Another form of this machine does not contain a separate dynamometer but uses the specimen as a dynamometer. In this case a dial is used to measure the deflection of the specimen under a known load, preferably the load which is repeatedly applied to the specimen. This requires a separate calibration for each specimen. The result obtained is very nearly identical to that obtained with a dynamometer.

Possibilities and Limitations. (a) The fatigue test is inherently a time-consuming test and not convenient for acceptance testing. Its primary function is in the evaluation of fatigue strength of materials and determination of data for design.

(b) The type of machine considered here is suitable for determining the fatigue strength of both notched and unnotched specimens for any value of mean stress in *tension.*

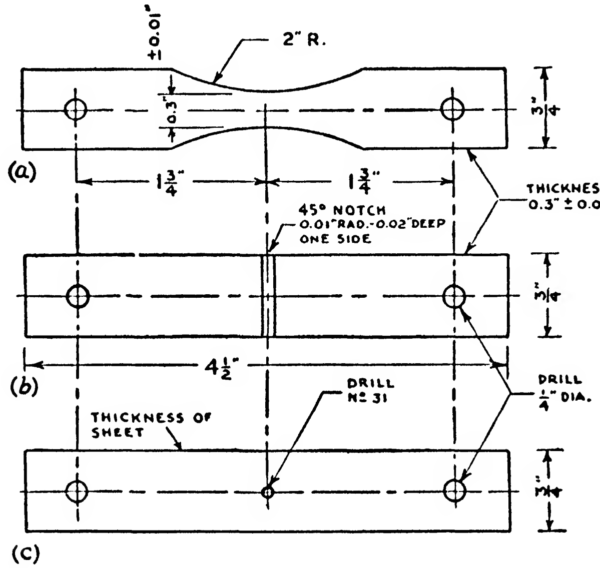

FIG. 3.15 — Specimens.

Specimens notched on one side as in Fig. 3.15b may be used to determine the notched fatigue strength for any value of mean stress either tension or compression. It should be mentioned that for material (such as cellulose acetate) which creeps rapidly the effect of a mean stress other than zero is to cause relaxation so that the stress cycle tends to approach the condition of complete reversal of stress.

(c) The notched specimen is used to determine the effect of a notch of standard dimension upon the fatigue strength of the material. The notch herein defined as " standard " is shown in Fig. 3.15b. The notch (a transverse hole) shown in Fig. 3.15c may be used for thin sheet and material such as plywood for which the continuity of the material would be altered by the V-notch.

Other notches have been proposed to replace those shown in Figs. 3.15b and 3.15c but experimental evidence of their suitability is at present lacking.

In any plastic part there are likely to be changes in cross section, such as fillets, holes, screw threads and the like, at which the state of stress is complex (a combination of normal and/or shearing stresses in more than one direction) and at which the maximum value of stress is greater than that computed by formulas such as $s = Mc/I$. It is known that the effect of a certain type of notch in reducing the fatigue strength of one material may be more severe than in another material; the use of a " standard " notch in a fatigue test is therefore desirable as a means of evaluating the sensitivity of a material to the effect of a stress raiser.

(d) In the application of the following test recommendations it is assumed that test specimens of a given material are comparable and truly representative of the material. Departure from this assumption may introduce discrepancies as great as, if not greater than, those due to departure from details of procedure outlined in this method of test.

Specimens. (1). *For evaluation of the resistance of a material to repeated loading:* (a) Unnotched specimen: The specimen shown in Fig. 3.15a is used for determining the fatigue strength of the material. The radius of the scalloped sides is 2 in.[22] and the minimum cross section is a 0.3-in. sq. The radius is formed by milling, using a very sharp cutter and such combination of speed and feed as will give a good finish with a minimum of heating of the specimen. The test section must be polished with successively finer emery paper, finishing with No. 00 to remove all scratches and tool marks. The final polishing must be lengthwise of the specimen because even small scratches transverse to the direction of tensile stress tend to lower the fatigue strength. In order to avoid heating, all polishing must be done either by hand or with light pressure on a slowly revolving sanding drum. Care must be taken to avoid rounding the corners.

(b) Notched specimen: The notched specimen is used to determine the effect of a standard notch in reducing the fatigue strength. The dimensions of the notched specimen are shown in Fig. 3.15b. The notch must be formed by milling or shaping in such a way that the notch has dimensions indicated and is free from scratches. After machining, all edges of the specimen should be smoothed to remove burrs.

2. *For evaluation of the fatigue strength of thin*[23] *sheets:* (a) Unnotched specimen: The specimen and method of preparation are as described in 1(a) except that the thickness of the specimen is that of the sheet to be tested.

(b) Notched specimen: The specimen used for determining the notch sensitivity of thin sheets is shown in Fig. 3.14c. The notch consists of a transverse hole drilled with a sharp No. 31 drill — 0.120 in. in diameter. The specimen should be polished in the region of the hole before the hole is drilled and all burrs removed after drilling. No attempt should be made to polish the inside of the hole.

Conditioning. (a) All specimens must be conditioned for 14 days in the atmosphere of the enclosure in which the tests are to be conducted.

(b) Tests must be performed in a room maintained at a constant temperature of 77° F. ± 2° and relative humidity of 50 per cent ± 2 per cent except when it is desired to evaluate the effect of high or low temperature or relative humidity on the endurance limit. Under all circumstances the temperature and relative humidity of the test atmosphere must be stated.

Temperature of Specimen. Since the mechanical properties of many plastics change rapidly with small changes in temperature, and since heat is generated as a result of

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[22] With a cantilever specimen the maximum stress does not occur exactly at the minimum section, but slightly farther from the point of loading (F). However, with a moment arm of 5 in. and a specimen with a radius of 2 in. this discrepancy is small enough to be neglected.

[23] For the purposes of this test a thin sheet is defined as a sheet less than 0.3 in. thick or a material for which the ratio of the modulus of elasticity to the endurance limit is less than 100. The reason for these restrictions is that thin sheets and materials having a low modulus of elasticity are bent so much under the required loads that the fatigue specimen cannot (in the deflected position) be considered a straight beam and hence the equation $s = Mc/I$ is not accurate. One should be cautioned that the holder (Fig. 3.14) may not be satisfactory for very thin sheet due to the inertia forces set up by the vibration.

the rapid flexing of the specimen in fatigue, the air velocity over the specimen must be known. In order to ensure uniformity of test conditions all tests must be conducted in " still " air (average air velocity less than 50 ft. per min.). The temperature at the high stress region of the specimen must be measured and recorded for a specimen operating at the fatigue strength in still air. This temperature is measured by means of a thermocouple attached to the specimen by a $\frac{1}{8}$-in. wide strip of cellulose tape.

Speed of Testing Machine. The speed used in conducting the tests must be 1720 cycles ± 25 cycles of stress per minute except when it is desired to determine the effect of speed of testing. The speed of testing must be stated in any case.

Procedure. Calibration of Dynamometer. The dynamometer must be calibrated occasionally by using a dummy specimen disconnecting the connecting rod at (F), hanging known weights from the wrist pin (F), and noting the corresponding reading of the dial (H). The load in pounds is then plotted against the corresponding dial reading. A straight line diagram should result. The load corresponding to one division of the dial may then be computed from the slope of the line. This value is the calibration constant of the dynamometer. The calibration constant must give results within 1 per cent of the correct value of load.[24] The dynamometer dial (H) must read zero when a specimen, without holder (J) attached, is fastened to the dynamometer at (M).

Measurements. Measure the minimum section of the specimen to the nearest thousandth of an inch.[24] (For thin sheet, the relative error of measurement of the thickness of the sheet must not exceed $\frac{1}{3}$ per cent.) Then clamp the specimen snugly to the holder (J) and measure the distance, l, from the center of the crankpin to the minimum section of the specimen to the nearest fiftieth of an inch.[24] Clamp the other end of the specimen in the vise and affix the connecting rod to the wrist pin.

Computation. Compute the bending moment M from the flexure formula

$$M = S\frac{I}{C}$$

in which

S is the desired tension or compression stress on the outer (most highly stressed) fiber of the beam — Units-lb. per sq. in.

C is the distance from the neutral surface to the outer fiber. For a rectangular or square cross section (Figs. 3.15a or 3.15c) C equals one-half the depth of the beam — Units-in.

For the notched specimen (Fig. 3.15b) C equals one-half the thickness of the specimen at the root of the notch.

I is the second moment (moment of inertia) of the net area at the minimum section.

$$I = \frac{bh^3}{12} \quad \text{Units-inch}^4$$

For the unnotched specimen (Fig. 3.15a) b is the net width and h the net depth of the minimum section.

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[24] The maximum allowable errors indicated for the above measurements and calibration will ensure a maximum relative error, in the computed stress, less than 3 per cent.

For the V-notched specimen (Fig. 3.15b) b is the width of the specimen and h the thickness of the specimen at the root of the notch.

For the drilled-hole specimen (Fig. 3.15c) b is the width of the specimen minus the diameter of the hole, and h is the depth of the specimen.

Then compute the load (in pounds) to be applied to the beam by dividing the moment M by C, the distance in inches from the crankpin to the minimum section of the specimen. The reading of the dynamometer dial corresponding to this load is determined from the dynamometer constant mentioned above.

Adjustment of Machine. To produce complete reversal of stress first adjust the position of the vise so that the specimen is undeflected when the variable-throw crank is at mid-stroke. Then adjust the varible-throw crank to produce the load desired on the specimen as indicated by the reading of the dynamometer dial. The load indicated should be the same for both upward and downward deflection and should be equal to that computed above for the desired stress.

To produce an alternating cycle of stress in which the mean stress is different from zero first adjust the variable-throw crank to produce the desired amplitude of the alternating cycle of stress and then with the variable-throw crank of mid-stroke adjust the position of the vise so as to produce a stress equal to the desired mean stress of the cycle.

General. Record the dynamometer readings and revolution counter reading and start the machine. The dynamometer readings must be recorded every 12 to 24 hr. during the life of the specimen. After fracture of each specimen the cross section at fracture and the distance from the fracture to the crankpin must be measured and recorded before the specimen is removed from the holder. If the specimen fractures at a section more than ¼ in. from the minimum section, the data for this specimen shall be marked void.

Plotting and Interpreting Results. Plot a diagram of stress as ordinate against log of the number of cycles required for fracture as abscissa. This diagram is called the *S-N* or stress-cycle diagram. The use of semi-logarithmic paper will facilitate the plotting. Specimens which did not fracture should be indicated by an arrow directed away from the plotted point in the direction of increasing cycles.

When a material shows a knee in the stress-cycle diagram such that the curve gives clear indications that it becomes asymptotic to a horizontal (constant stress) line, it is sufficient to carry the number of cycles far enough beyond the knee to indicate with a good degree of accuracy that the curve becomes asymptotic to a constant stress line. If the curve does not become asymptotic to a constant stress line, the tests must continue until the number of cycles reached is greater than the number of cycles that the material will be expected to withstand in its life. The value of stress correspondence to this number of cycles is reported as the " fatigue strength at —— cycles." (Substitute the maximum number of cycles for which the stress-cycle diagram has been well defined by the tests.)

Corrections. No corrections shall be made to the value of stress computed at the minimum section for fracture away from the minimum section, for the position of the theoretical maximum stress, or for a change in dynamometer reading during the test.

Report. 1. *For evaluation of the fatigue strength of a material:* The report shall contain the following information:

(a) The *fatigue strength at* ...... *cycles of stress* was ...... lb. per sq. in.

(b) The *mean stress* of the cycle was ...... lb. per sq. in tension or compression. (Cross out one.)

(c) The *fatigue ratio* was ....

(d) The maximum *number of cycles* used in the test was ...... cycles.

(e) The *temperature* of the *testing room* was ...... deg. F. and

(f) The *relative humidity* of the *testing room* was ...... per cent.

(g) The *temperature of the specimen* when operating at the fatigue strength was ...... deg. F.

(h) The *preconditioning* used was ...... hours at ...... deg. F. and ...... relative humidity.

(i) The type of testing *machine* was ....

(j) The *speed* (number of cycles per minute) of the testing machine was ......

(k) A description of the material tested is: name ......, manufacturer ......, code number ......, date of manufacture ......, type of molding ......, thickness of sample ....

(l) The *dates* of test are ....

2. *For evaluation of the fatigue strength of a notched material:* The report shall contain items 1(b) through 1(l) above and:

(a′) The *fatigue strength* at ...... *cycles of stress* of a standard *notched* specimen was ...... lb. per sq. in.

3. *For evaluation of the fatigue strength of thin sheet:*[8] The report shall contain items 1(b) through 1(l) and:

(a″) The *fatigue strength* at ...... cycles of stress for a sheet of ...... in. thickness was ...... lb. per sq. in.

4. *For evaluation of the fatigue strength of notched thin sheet:* The report shall contain items 1(b) through 1(l) above and:

(a‴) The *fatigue strength* at ...... *cycles of stress* of a specimen with *transverse hole* was ...... lb. per sq. in.

Precautions Necessary in Applying Results. (1) So little is known about the relationship between service and fatigue tests of plastics that generous factors of safety should be used in design.

(2) One should be cautioned to make sure whether it is failure from fatigue that is the prime danger or failure from other causes such as creep, yielding, fracture under a single loading, or others.

(3) For plastics which are subject to creep at the temperature of testing (this probably includes all plastics at room temperature) a fatigue test, in which the mean stress is not zero, is accompanied by either creep or relaxation depending on the type of testing machine used. Relaxation of stress will occur for the type of machine considered herein. As a result of this relaxation the range of stress tends to approach the condition of complete reversal of stress as time goes on. The magnitude of the effect that relaxation would have on the result obtained will depend upon the rate at which relaxation takes place and upon the time required for the endurance limit to be reached. The rate at which relaxation takes place will depend upon the material and the magnitude of the mean stress of the cycle.

Long-time Tension. Long-time tension stresses of plastics are tested by the following tentative A.S.T.M. method:

Test for Long-time Tension

Scope. This recommended practice covers the determination of the amount of extension of plastic materials, due to the combined effects of tensile stress, time, temperature and relative humidity, when tested in the form of specimens of standard shape.

APPENDIX C.

Classification of Fatigue Testing Machines

1. *Direct stress* (tension and/or compression): (a) Repeated axial loading by alternating magnetic field or by inertia vibration.

(b) Repeated axial deformation by means of connecting rod or cam.

2. *Flexural stress:* (a) Repeated loading by: (1) Rotating cantilever loaded by weight or spring. (2) Fixed cantilever loaded by magnetic or inertia vibrator. (3) Rotating beam in pure bending loaded by spring or weights.

(b) Repeated deflection: (1) Fixed cantilever, repeated constant-deflection.

3. *Torsional stress:* (a) Repeated angular torque by: (1) Inertia vibrator.

(b) Repeated angular twist by: (1) Cam or connecting rod action on a torque arm.

APPENDIX D.

Suggested form of data sheet for repeated flexural fatigue test of plastics:

FATIGUE OF PLASTICS

Material ......

Date ...... Test made by ...... on fixed-cantilever, repeated-deflection type Fatigue Testing Machine, No. ...... Speed ...... cycles per min.

Specimen ...... Width, b ...... in. Height, h ...... in. $I/c = bh^2/6 =$ ...... in.^{3}

Amplitude of alternating stress in cycle ...... lb. per sq. in.

Mean stress of cycle ...... lb. per sq. in.

Moment at minimum section ...... in. lb.

Arm to minimum section, l ...... in.

Load ...... lb. or ...... div. on dynamometer

Cross section of specimen at fracture b ...... in. h ...... in.

Dist. C. line con. rod pin to fracture, l ...... in.

Final reading rev. counter ......

Initial reading rev. counter ......

Cycles for fracture ......

Initial weight of specimen......gm. Room temperature......°F.

Final weight of specimen ...... gm. Room relative humidity ......%

Specimen temp. ...... °F.

Remarks:

NOTE 1. The recommended details of this test are largely advisory since the characteristics of a plastic as to its resistance to extension are not well known.

NOTE 2. For reference or comparative tests of any given series of materials or specimens care must be taken to secure the maximum degree of uniformity in details of preparation, treatment and handling.

Definition of Terms

(a) An ultimate or (tensile) strength for a plastic material is the tensile load per unit area of original cross-section, expressed in pounds per square inch, required to break within the gauge boundaries a test specimen as described in D638–41T. (Tension Testing of Plastics.)

(b) Elongation is the change in length expressed in inches produced by a tensile load on a longitudinal section of a test specimen measured between fixed gauge points on the specimen.

Apparatus. (a) *Testing Machine:* Any simple suspension device by means of which a predetermined load accurately measured to within 1 per cent may be applied in tension as dead weight loading or by the use of a simple lever system. The test system should be as free from vibration as possible.

(b) *Grips:* Grips for holding the test specimens. Grips of the form shown in Fig. 3.9 are satisfactory. These grips may be made from any noncorrosive metal.

(c) *Extensometer:* A suitable instrument for determining the distance between two fixed points on the test specimen gauge length at any time during test. Dividers may be used as it is essential not to disturb the original position of the specimen to obtain the change in position of the fixed lines on the gauge length. A cathetometer or electrical resistance device will yield more accurate results wherever these can be employed.

Classifications of Materials. Plastic materials shall be arbitrarily divided into four groups on the basis of ductility and rate of response to variations in atmospheric temperature and humidity.

Class A: " Low " and " Rapid." Those materials whose ultimate percentage elongation as determined by D638–41T is 5 per cent or less, and whose impact strength as the result of variations in atmospheric humidity or temperature changes sufficiently during the period of time required for the completion of a tension test to affect numerical test results by 10 per cent.

Class B: " Low " and " Slow." Those materials whose ultimate percentage elongation as determined by D638–41T is 5 per cent or less and whose impact strength is so slowly affected by variations of atmospheric humidity or temperature that numerical test results do not change by as much as 10 per cent during the period of time required for completion of a tension test.

Class C: " High " and " Rapid." Those materials whose ultimate percentage elongation as determined by D638–41T is over 5 per cent, and whose impact strength as the result of variations in atmospheric humidity or temperature changes sufficiently during the time required for completion of a tension test to affect numerical test results by 10 per cent.

Class D: " High " and " Slow." Those materials whose ultimate percentage elongation as determined by D638–41T is over 5 per cent and whose impact strength is so slowly affected by variations in atmospheric humidity or temperature that numerical test results do not change by as much as 10 per cent during the period of time required for completion of a tension test.

NOTE. It is recognized that this basis of classification is a very arbitrary one and that behavior in the impact test is not necessarily the criterion of the behavior in the tension test. The classification has, however, been adopted by a joint action of Committee D-9 on Electrical Insulating Materials and Committee D-20 on Plastics and is retained here until such time as a more suitable classification can be developed.

Specimens. (a) The test specimens shall conform to the dimensions as shown in Fig. 3.10. The specimen may be injection or compression molded or machined from sheets, plates, slabs, etc.

(b) In testing materials that may be suspected of anisotropy, duplicate sets of test specimens shall be prepared having their long axis respectively parallel with and normal to the respective direction of anisotropy.

(c) All surfaces of the specimens shall be free from visible flares, imperfections or scratches. Marks left by coarse machining operations shall be carefully removed with a fine file and the filed surfaces shall then be smoothed with abrasive paper (No. 00 or finer). The finishing file strokes or sanding strokes shall be made in a direction parallel to the long axis of the test specimen. All flares shall be removed from molded specimens taking great care not to disturb the molding surfaces.

NOTE. Before testing, all transparent specimens should be given a polariscope inspection and those which show a typical or concentrated strain patterns should be rejected unless these "initial" strains constitute a variable whose effect it is desired to study.

(d) Gauge mark areas should be placed on the specimen with china marking pencil, soft fine crayon, or with India ink. Gauge marks shall be scratched in the markings only with care to avoid injuring the surface of the specimen because this may cause erroneous results as the result of concentrations of stresses.

Number of Test Specimens. (a) At least three specimens shall be tested for each sample in the case of isotropic materials.

(b) Six specimens, three normal and three parallel with the principal axis of anisotropy, shall be tested for each sample in the case of anisotropic materials.

(c) Specimens that fracture at some obvious fortuitous flaw or that do not break between the predetermined gauge mark shall be discarded and another specimen substituted.

Conditioning of Test Specimens. Test specimens from Classes A and C should be allowed to approach test conditions by remaining in the test room prior to test for at least four days. Test specimens from Classes B and D should be allowed to approach test conditions by remaining in the test room prior to test for at least one day.

Procedure. (a) The specimens shall preferably be tested in an atmosphere maintained at 25 ± 1 C. (77 ± 2 F.) and 50 ± 2 per cent relative humidity.

(b) The test specimen shall be placed in the grips of the testing system taking care not to apply too much tightening pressure but enough to prevent slippage. The metal flap which is part of the testing grip should not be tightened too much in order to enable the load to be axially distributed.

(c) Throughout the duration of the test observations of extension should be made at sufficiently frequent intervals to define an extension-time curve.

(d) After unloading a certain amount of prolonged plastic recovery may occur in addition to the elastic recovery. This plastic recovery may be recorded.

(e) The tensile stresses used may be any percentage of the ultimate tensile strength or fixed load agreed upon between the supplier and consumer.

Plotting of Results. (a) Extension-time curves may be plotted on semi-log paper with time as the abscissa and unit extension as the ordinate. Many useful relationships may be obtained from such a curve such as the ratio of per cent extension to a constant number of hours or the time required to produce a definite per cent extension.

(b) For each series of tests the arithmetic means of all ultimate extension values obtained shall be calculated to three significant figures and recorded as the average result for the particular values in question.

(c) The deviation of each value from the average value shall be calculated and the arithmetic means of these deviations determined. This value shall be recorded to three significant figures as the average deviation of the particular series of results.

Report. The report shall include the following:

(a) Date of test.
(b) The complete identity of the material tested, including type, source, manufacturer's code numbers, forms, principal dimensions and previous history.
(c) Dimensions of the test specimen.
(d) The number of specimens tested.
(e) The method of preparing test specimens.
(f) Tensile load applied to test specimen.
(g) The preconditioning procedure used.
(h) Atmospheric conditions during test.
(i) Average ultimate per cent extension at an agreed upon time.

Modulus of Elasticity. The elastic modulus of a material is defined as the ratio of the increment of unit stress to the increment of unit deformation within the elastic limit. If the deformation and stress are progressively measured during the loading and breaking of the tensile specimen, the modulus may be calculated directly. Similar observations may be made during the breaking of a flexural test specimen and the modulus may be calculated from the formula.

$$\text{Modulus of elasticity} = \frac{(P_1 - P_2)l^3}{4bd^3(f_1 - f_2)}$$

or

$$\text{Modulus of elasticity} = \frac{(P_1 - P_2)l^3}{4^8(f_1 - f_2)I}$$

P = Load in middle
l = Length of bar
f_1 = At load of P_1 deflection
f_2 = At load of P_2 deflection
b = Depth of bar
d^3 = Thickness
I = Moment of Inertia

The first formula is used when breaking a standard ½ by ½ by 5 in. test specimen. The second formula is one used for general application of a simple beam with load applied in center. In the calculation of any modulus the appropriate portion of the stress strain curve should be taken as these curves do not always obey Hooke's Law.

Thermal Conductivity. Plastics have a low thermal conductivity compared to metals. The pleasing feel of ordinary molded plastic objects is due in part to this property. Thermal conductivity is much affected by the type of filler used. When mineral fillers are present, the thermal conductivity is considerably higher than when organic fillers or no fillers are used. Typical thermal conductivity values are given in the table:

Copper	0.72	B.t.u. per sq. ft. per sec. per ° F. per in.
Aluminum	0.40	
Steel	0.08	
Cork	0.00057	
Plastics	0.00024 to 0.0010	

A tentative method for determination of thermal conductivity is given in A.S.T.M. D325–31T. Test specimens are flat sheets approximately 10 in. sq. and ½ in. thickness.

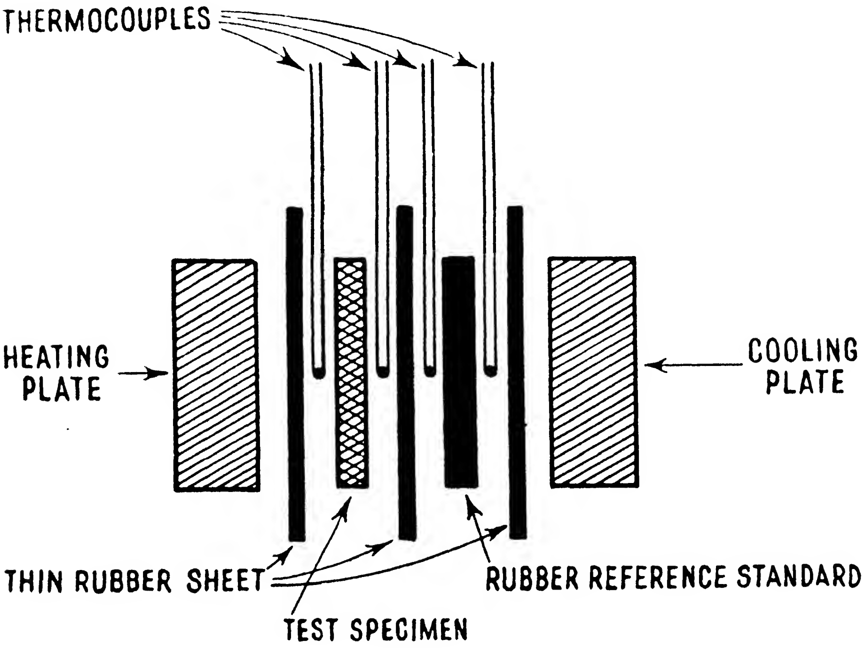

FIG. 3.16 — Thermal conductivity test.

The specimen is placed in series with a reference material of known thermal conductivity between a heating plate and a cooling plate as shown in the diagram.

The heating plate and cooling plates are maintained at constant temperatures, and temperatures which are recorded by means of thermocouples at the interfaces.

$$k = k_r \frac{D}{D_r} \times \frac{t_r}{t}$$

k = conductivity of test specimen
k_r = conductivity of standard of reference
D = thickness of test specimen
D_r = thickness of standard of reference
t = temperature gradient across test specimen
t_r = temperature gradient across standard of reference

Shrinkage. This property is the difference in linear dimension between the mold at room temperature and the molded piece at room temperature, calculated and reported as inches per inch of molded piece.

The values are of some assistance to the mold designer, but because this property varies with different types of molds and with different molding conditions, its value is limited. It serves as an index of relative uniformity between successive runs of a particular compound.

A method for the determination of " shrinkage " based on the ½ by ½ by 5 in. molded bar specimen is described in detail in the following A.S.T.M. method.

Measuring Shrinkage

A.S.T.M. D-551-39T

Samples shall be taken in accordance with the standard methods for sampling molding powders. See page 59.

The apparatus shall consist of a standard single-bar or five-bar single-cavity mold. See section on standard molds.

Test specimens shall be ½ by ½ by 5 in. bars.

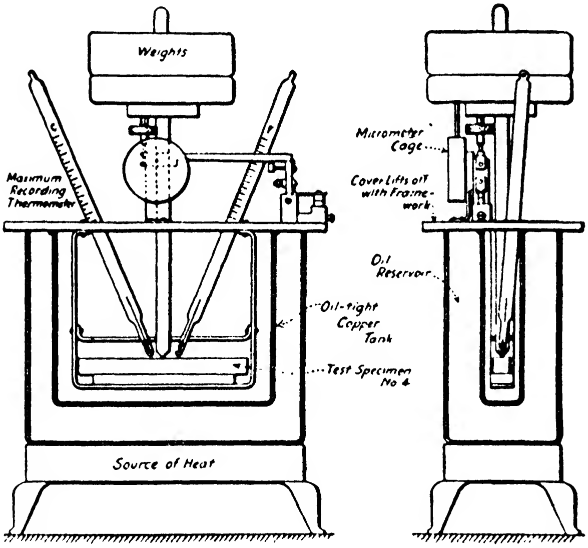

Fig. 3.17 — Machine for temperature tests.

Procedure. For thermoplastics, load requisite amount of granular material at room temperature into mold at room temperature and press at 3000 to 5000 lb. per sq. in. at 250° to 265° F. for 5 to 10 min. Cool, discharge, and measure at room temperature not less than 16 or more than 25 hr. later.

For phenolics, load mold at 300° to 310° F. with requisite quantity of material at room temperature and press at 3000 to 5000 lb. per sq. in. Discharge hot after 6 min. and measure at room temperature not less than 16 or more than 24 hr. later.

For ureas, load mold at 285° to 290° F. with requisite quantity of material at room temperature and mold at 3000 to 5000 lb. per sq. in. Breathe mold for 5 sec. after 5 to

15 sec. Discharge hot after 8 min. Measure not less than 16 or more than 24 hr. later.

Report shrinkage as the difference between the mold dimension and that of the molded piece; and as shrinkage in in. per in.

Distortion Under Heat. (a) The purpose of this test is to evaluate the tendency of the various molded electrical insulators to soften with heat.

In principle, it is the determination of the temperature at which a stress of 5.5 lb. will produce a deflection of 10 mils. when that stress is applied to the top of a horizontal ½ by ½ by 5 in. molded bar at a point midway between two supports spaced 4 in. apart. The temperature is raised at a uniform rate of 1° C. (2° F.) per 2 min. Testing apparatus is shown in Fig. 3.17.

(b) *Deformation of Plastics under Load at Elevated Temperatures.*

Tentative Test

A.S.T.M. D 621–41 T

Scope. This method is intended to apply to the deformation under compression of all classes of non-metallic sheet and molded materials intended for structural and insulating uses, and of all commercial thicknesses.

Definition. The word deformation is used herein in the broad sense to cover dimensional change due almost entirely to flow, and dimensional change comprising a combination of flow and shrinkage due to loss of water or other volatiles. Methyl methacrylate and polystyrene are examples of materials in the former class. Cellulose acetate, cellulose aceto-butyrate, phenol fiber and vulcanized fiber are examples in the latter.

Principle. The principle of the method is essentially that of the parallel place — constant force system whereby a test specimen is conditioned, if necessary, and is then placed between the parallel plates of a constant force device and the change in thickness observed over a period of 24 hr. at a temperature of 50° C. (122° F.), unless otherwise specified.

Apparatus. (a) The machine shall be capable of exerting a constant force of 1000 lb. ± 1 per cent between the parallel anvils of the machine, which shall be arranged so they can be brought into contact with the specimen before the load is applied. A machine devised for this test is shown in Fig. 3.18.

(b) One of the anvils of the machine should preferably be self-aligning and shall, in order that the load may be applied evenly over the face of the specimen, be arranged so that the specimen is accurately centered and the resultant of the load is through its center. The machine shall also be equipped with a dial gauge or the equivalent capable of measuring the relative movement of the faces to 0.001 in. or better.

(c) An oven shall be provided to contain the machine and maintain it at 50° ± 0.5° C. (122° ± 1° F.) during the test except for the short period at the beginning when opening the door may have caused a drop in temperature.

(d) An oven for preconditioning the specimens for 4 hr. at 65 ± 3° C. (150° ± 5° F.).

(e) A chamber for conditioning, capable of maintaining a relative humidity of 90 ± 2 per cent at 35° ±1° C. (95° ± 2° F.) for 68 hr.

Procedure. The procedure common to all materials is as follows:

(a) The specimen at room temperature shall be placed between the faces of the machine and both faces brought into contact with it. The load shall then be applied without shock and the initial reading taken as soon as the full load is upon the specimen.

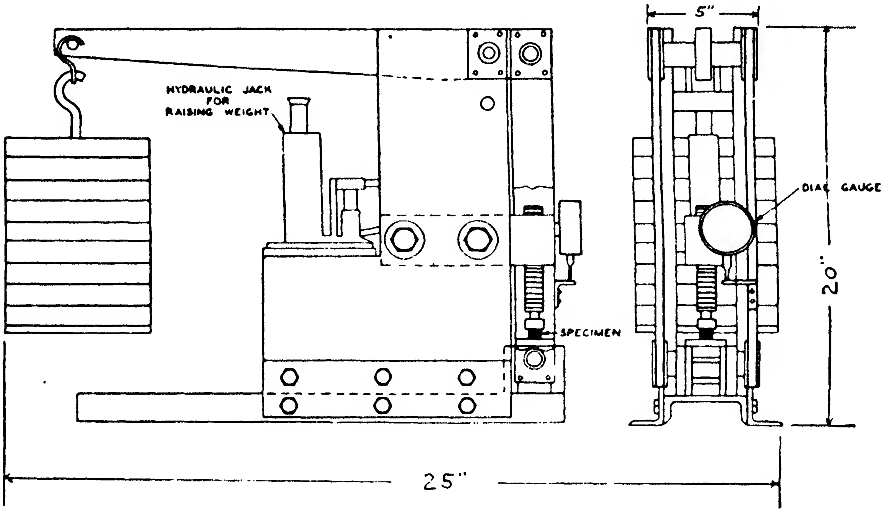

FIG. 3.18 — Machine for heat distortion tests.

This point is made manifest by a sudden slowing of the rate of travel of the gauge. A second reading is taken at the conclusion of 24 hr.

(b) The per cent change in height of the specimen after 24 hr. shall be taken as its deformation. This may be computed by means of the formula:

$$\text{Deformation} = \frac{\text{Change in height in mils in 24 hr.} \times 100}{\text{Original height in mils}}$$

Specimens. A. The test specimen shall be a ½-in. cube, either solid or composite. Materials over ½-in. in thickness shall be reduced to ½-in. and thinner materials shall be piled up with the total height as near to ½-in. as possible. The squares of the pileup shall be accurately aligned in all cases. Specimens made from the standard ½ by ½ by 5 in. test bar shall be tested in the direction of molding.

B. (a) The specimens for materials made in large sheets such as phenol fiber, where moisture absorption characteristics may vary over the entire surface shall be prepared in accordance with the sampling method given below which averages the effect over the sheet by selecting squares comprising the specimen in such a manner that each square represents the same proportional part of the entire area of the sheet.

(b) The specimen shall be selected from the whole sheet by cutting a strip ½-in. wide from the sheet, parallel to the two long edges if the sheet is not square or parallel to any two if it is square, midway between them and extending from the edge to the center of the sheet. If quarter sheets are used, the strip shall be taken from the edge corresponding to the center to edge section of the original whole sheet.

(c) The strip shall be divided into 8 equal parts numbered 1 to 8 beginning with the piece corresponding to the edge of the sheet. The squares to form the pileup shall be taken from these pieces. If the whole piece is not used, the squares shall be taken from the end which was originally nearest the edge of the sheet. If any piece is insufficient for the number of squares required, a second strip shall be cut adjacent to the first one, cut into pieces, and the required number of squares taken from the appropriate pieces. The number of squares to be taken from each piece is given below:

TABLE 9

Thickness in Inches	Total Number of Squares	Number of Piece							
		1	2	3	4	5	6	7	8
		Number of squares to be cut from each piece							
1/64	24	5	5	5	3	2	2	2	–
1/32	12	3	2	2	2	1	1	1	–
3/64	8	2	2	1	1	1	–	1	–
1/16	6	1	1	1	1	1		1	–
3/32	4	1	1	1	–	1	–	–	–
1/8	3	1	–	1	1	–	–	–	–
3/16	2	1	–	–	1	–	–	–	–
3/8	1	–	–	1	–	–	–	–	–

Note. In case of thicknesses not included in the above table, the pileup shall be made according to the method for nearest thickness given in the table. In case the thickness is mid-way between two adjacent values in the table, the pileup should be made according to the instructions for the thinner material.

Conditioning. (a) Before testing, the specimens shall be preconditioned for 4 hr. at 65° ± 3° C. (150° ± 5° F.) and then conditioned for 68 hr. at 90 ± 2 per cent relative humidity at 35° ± 1° C. (95° ± 2° F.) unless otherwise specified. They shall be supported during conditioning upon a $\frac{1}{8}$-in. mesh wire screen or the equivalent in order to permit access of the atmosphere to all specimens.

(b) The test temperature, that is, the temperature of the enclosure containing the testing apparatus shall be maintained at 50° ± 0.5° C. (122° ± 1° F.) unless otherwise specified.

(c) In any case where it is definitely established that the material is not affected by moisture, the preconditioning and conditioning may be omitted.

Testing. (a) Immediately upon removal from the conditioning atmosphere, the specimens shall be placed in the machine. Where composite specimens are used care shall be taken to insure that the squares are well aligned.

(b) The load shall be applied without shock and as soon as the abrupt change in the rate of travel of the dial indicates that the load is on the pileup, the dial shall be read. Another reading shall be made at the end of 24 hr. The original height shall be obtained by measuring the specimen after it is removed from the testing machine and adding to this the total deformation read on the dial.

Report. The report shall include the following:

(a) Original height of specimen in mils.

(b) Thickness of components in mils where a composite specimen is used.

(c) Deformation in 24 hr. in mils.

(d) Flow and/or flow and shrinkage in per cent of original height.

Resistance to Heat. Various plastics react differently to heat; some distort, others opacify, and some shrink. To test for heat resistance, the following method is suggested.

Proposed Test

Scope. This method is designed to apply to hot molded plastics, plastic sheet or laminated materials.

Specimen. The specimen shall be one agreed upon as satisfactory to the parties concerned.

Apparatus.

A. The exposure device shall be of such a nature that the following conditions are maintained:

1. Three specimens shall be exposed in a separate chamber.
2. The chamber shall have a cubical capacity approximately 15 times the volume of the specimen.
3. The specimen shall be suspended in the chamber in such a manner that it does not approach the walls closer than ¼-in.
4. The entering air shall be sufficient to replace that within the chamber approximately once per minute, and at the point of entry shall not blow directly on the specimen.

B. Testing devices for determination of physical properties before or after exposure to heat shall be those approved by the A.S.T.M. for the property reported.

Method.

(a) *Conditioning of Specimen.* Three specimens shall be conditioned for 24 hr. at 50° C. (122° F.), cooled in a desiccator to room temperature, weighed, and tested.

(b) *Exposure.* Three specimens of identical composition shall be exposed in a separate chamber under the conditions listed under " Apparatus A " for a period of 48 hr., and another set for one week at a temperature well below that to which experience indicates the plastic is resistant.

Samples removed from exposure shall be cooled to room temperature in a desiccator, weighed, observed, and tested.

Exposure and testing in triplicate as described above shall be made at temperatures increasing in 25° C. (45° F.) steps until failure occurs.

Report. This shall include observations of any change in form, color or surface appearance. It shall show per cent change in length, and the plastic shall be said to be permanent at the maximum temperature at which this does not exceed 1 per cent of that of the conditioned specimen.

By arrangement between supplier and user permanence may be stated as a function of reduction of elongation or strength by submitting the proper specimen to this test procedure.

Flammability of Plastics. Most plastics, being derived from organic materials, will burn. There are some notable exceptions to this rule. Materials containing halogen in the molecule (such as vinyl-chloride polymer) and compositions containing large amounts of halogenated plasticizers or phosphoric acid esters are quite fire resistant. Conversely, cellulose nitrate plastics burn readily unless formulated with flame-resistant plasticizers.

A tentative method for the determination of the flammability of plastics in sheet form follows:

Proposed Test (Sheets and Films)

A.S.T.M. D 568–40 T

Scope. This method is intended primarily to determine the flammability of plastic materials in thin sheet or film form. It is not designed for determinations of the rate of burning of molded or laminated materials in a thickness greater than 0.050 in.

Apparatus. (a) These tests shall be made in a shield made from sheet metal, or other fire-resistant material, in the form of an open top, rectangular chamber 12 in. wide, 12 in. deep and 30 in. high. The shield shall be constructed in such a manner that there is a ventilating opening approximately 1 in. high around the bottom. It shall be constructed with a viewing window in one side of the shield of sufficient size and in such a position that the entire length of the test piece under test may be observed. Because of danger due to breaking glass it may be necessary to use heat resistant glass for this viewing window. One side of the shield shall be hinged so that the shield may be readily opened and closed to facilitate the mounting and ignition of the test specimen.

(b) There shall be provided a spring type of paper clamp for holding the test specimen in position. This holding clamp shall be mounted rigidly to the shield in such a manner that the test specimen is centered within the shield facing the viewing window.

(c) There shall be provided a pyroxylin plastic fusee material in 0.010 ± 0.001 in. thickness. The fusee material shall be made from pyroxylin having a nitrogen content of 11.0 ± 0.10 per cent and containing 25 per cent camphor. This material shall be cut into 1-in. squares for test purposes.

Test Specimens. The test specimens shall consist of not less than 6 strips 1 by 12.5 in. cut from sheets of each of the materials being tested.

Procedure. (a) The 1-in. square piece of fusee material shall be affixed by means of acetone to one end of the test strip, giving an overlap of ¼ in. In some cases it may be necessary to dry under slight pressure or to use a stapling device to fasten the fusee to the test strip. After drying for 2 hr., exposed to the air at 25° ± 3° C. (77° ± 5° F.), the strip shall be hung vertically by means of the supporting clamp in approximately the center of the testing chamber. The fusee shall be at the lower end of the test strip. The strip shall be clamped in such a manner that 12 in. of the strip is exposed below the clamp. The test chamber shall be placed in a hood with the ventilating fan turned off at the time of test.

(b) The square of fusee material shall be ignited by means of a safety match and the door of the shield shall be closed immediately.[25] The time required for the flame either to extinguish itself or to burn the test strip completely shall be determined by means of a stop watch, or timer, started at the instant of ignition of the fusee. The area of the test strip which is burned or charred shall be measured to the nearest ¼ sq. in. If the material melts and drops from the strip the area melted shall be included in the

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[25] It should be noted that for some materials the products of burning are toxic and care should be taken to guard the operator from the effects of these toxic gases. The ventilating fan in the hood under which the test is performed should be turned on immediately after the test is completed to draw out any irritating products of the test.

burned area. The charred portion which drops off when touched with the fingers or in handling shall also be included in the burned area.

(c) The test specimen shall be marked into squares ½ in. on a side before the test is started. This marking may be done by any convenient means provided the markings are still visible on the unburned portion of the test specimen after the test is completed. The markings may be used for estimating the amount of material burned.

(d) Another convenient method which may be used for measuring the burned area in the case of materials which do not stretch under test is to have a scale 12 in. long by 1 in. wide ruled with lines into squares ½ in. on a side. The partially burned test pieces may be laid over this scale and the amount of burned material estimated by means of the area of the scale left exposed.

Report. The report shall include the following:

(a) The thickness of the material.
(b) The length of time in seconds that the material continues to burn.
(c) The area in square inches of the test strip burned.

Proposed Test (Other Than Films)

Apparatus.

(a) Hood free from air currents.
(b) Laboratory ringstand and two clamps.
(c) Bunsen burner or equivalent.
(d) Bunsen burner gauze 20-mesh 5 by 5 in.
(e) Stop watch.

Test Specimen. Pieces 6 by ½ in. by thickness as supplied.

Procedure. Scribe two lines 4 in. apart on specimen. Clamp specimen at one end to ringstand with its longitudinal axis horizontal and its transverse axis inclined at 45° to the horizontal. The gauze shall be clamped horizontally ¼ in. below the test piece, with test bar protruding beyond edge of gauze ½ in. (See Fig. 3.19.)

A gas flame ½ to ¾ in. high is just placed at the free end of specimen. After 30 sec. the flame is removed. The time is measured from the point where the flame reaches the first mark until it reaches the second mark. If sample does not continue to burn after removal of flame it is reported as self-extinguishing; otherwise report is made of burning in inches per minute.

Additional Test. In addition to the tests for flammability sponsored by the A.S.T.M. tests exist in certain agencies of the United States Government. These follow:

Air Corps Specification

No. 12025B 10-19-40

F–7. ***Rate of Burning.*** The test shall be conducted in a location protected from air currents. A conditioned sample of the plastic 0.5 by 6 in. shall be clamped in a support at one end with the longitudinal axis of the strip horizontal and the transverse axis inclined at 45° to the horizontal. Lines are marked on the sample at distances of 1 and 4 in. from the free end. An alcohol lamp or gas burner with a flame 0.5 to 0.75 in. in height is placed under the free end of the strip adjusted so that the flame tip is just in contact with the sample. At the end of 30 sec. the flame is removed and the sample allowed to burn. A stop watch is started when the flame reaches the 1-in. mark and

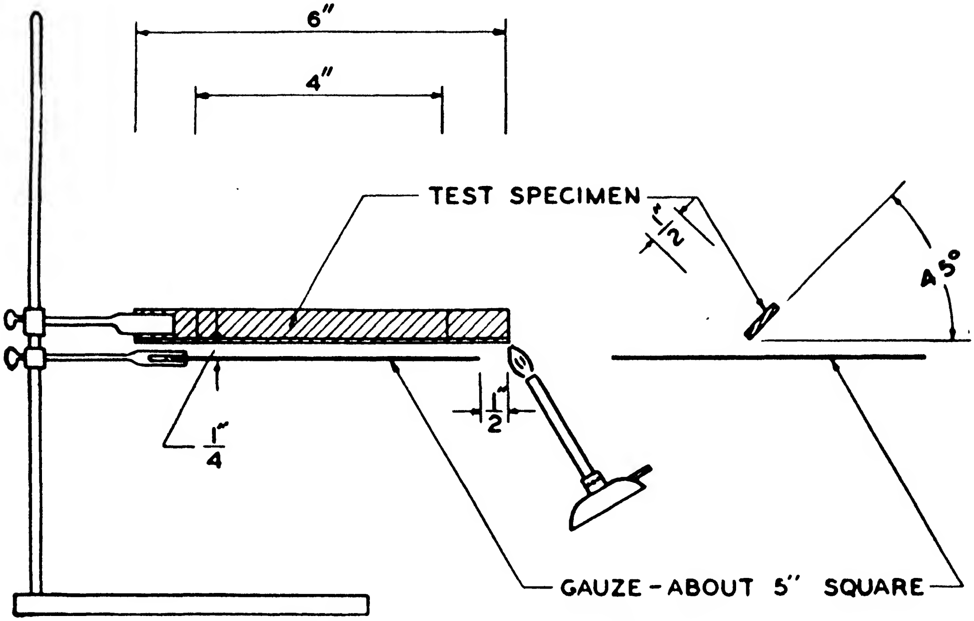

FIG. 3.19 -- Apparatus for flammability test.

the time observed when the flame reaches the 4-in. mark. In case the plastic does not continue burning the lamp shall be placed under the free end for a second period of 30 sec. immediately following the extinction of the flame. If the plastic does not continue burning to reach the 4-in. mark after the second ignition, the sample shall be reported as self-extinguishing.

Navy Aeronautical Specifications

F–3e. *Flammability.* A specimen ½ by 5 in. shall be clamped at one end in a rigid support so that the longitudinal axis of the specimen is horizontal and the transverse axis is inclined at 45° to the horizontal. Lines shall be drawn across the specimen at ½ in. intervals starting from the free end. An alcohol lamp or gas burner with a flame ½ to ¾ in. in height shall be placed under the free end of the specimen so adjusted that the flame tip is just in contact with the material under test. A stop watch shall be started when the flame is placed in contact with the specimen. At the end of 10 sec. the flame shall be removed and the specimen allowed to burn. The rate of burning shall be recorded and reported quantitatively.

Modified A.S.T.M. Test (Bureau of Standards Only)

A 3-mm. hole is drilled in the specimen ¼ in. from one end. The specimen is hung vertically on a rod clamped in a ringstand. A 1½ to 2 in. flame from a horizontal Bunsen burner is held against the bottom of the bar for 30 sec., and the bar allowed to burn until it melts from the rod or extinguished itself. The melted or charred portion is included in the burned area. When specimens will not burn after the flame is removed, the flame is immediately applied for 30 sec. more. Some specimens will not burn without a flame underneath. For such materials a flame is applied until it falls from the rod.

Underwriters' Laboratory Test

Test specimens in the form of strips 6 in. long and ¼ in. wide, or having a cross-sectional area of 1/16 sq. in., are cut from the sheet samples. The test specimens are hung vertically in an enclosure designed to prevent drafts. A ¾ in. high test flame[26] is applied in the lower end of the specimen. The duration of application of the test flame, the length of time that the specimen burns, and the height of its flame are recorded. Any afterglow is also noted.

Index of Refraction. Plastics vary considerably in refractive index, and measurement of this property often affords a clue to the identity of a material. Convenient procedures for the determination of refractive indices of transparent plastic materials are given in the following A.S.T.M. method.

Refractometric Method

A.S.T.M. D–542–40T

Apparatus.

(a) An Abbé refractometer or its equivalent.
(b) A source of white light.
(c) Suitable contacting liquid.

Test Specimen. A slab 0.25 by 0.5 in., plane and polished on one face, and similarly finished on a second surface perpendicular to first.

Procedure. The specimen is placed against the refractometer prism using a suitable contacting liquid; remove hinged illuminating prism if necessary. The usual method of determining the refractor index of liquids shall be followed. Suitable liquids are:

α-Bromnaphthalene	phenolic types cellulose acetate or nitrate types vinyl types
Sat. sol. $ZnCl_2$ (acidic)	acrylic types
Sat. sol. potassium mercury oxide (Rohrbach's sol.)	styrene types

Microscopic Method

Apparatus. Compound microscope of at least 200 magnifications complete with means of measuring tube extension to 0.001 in.

Test Specimen. A slab 0.25 by 0.5 in. or any specimen thin enough so that both parallel faces may be brought into focus.

Procedure. The bottom face is brought into focus and the tube reading noted. The upper face shall be brought into focus and the difference in the tube positions is the apparent thickness of the piece.

Report. The refractive index shall be computed by dividing the actual thickness by the apparent thickness.

Diffusion of Light by Translucent Plastics. Plastics are excellent light diffusers and as such are used in the lighting field for the manufacture of indirect and semi-indirect

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[26] Dimensions of test flame approximately the same as those of the flame of a common strike-on-box match.

luminaries. The following test is suggested for the measurement of light diffusability of plastics.

Tentative Test

A.S.T.M. D 636–41 T

Scope. (a) This method of test is designed to differentiate the relative ability to diffuse light among plastics which scatter incident light to an appreciable extent (diffusion). It is not successfully applicable to the measurement of low ranges of scattering (haze), which are associated with slight departures from optical clarity.

(b) An instrument and procedure are described for measuring the reflective and transmissive diffusion of a beam of light by a flat plastic sample whose face is essentially normal to the beam axis, with numerical means for rating the scattering or diffusion in terms of a theoretically perfect light scattering surface or medium.

Apparatus.

(a) The apparatus employed shall be a goniophotometer the axes of whose active elements operate in a horizontal plane which passes through the center of the sample. The active elements shall consist of a light source and optical system so oriented as to illuminate the sample face at its center, a sample holder which locates the plastic normally to the light beam axis [except as modified by paragraph (b)], a photosensitive receptor fixed to a radius arm which has the vertical axis of the sample face as its center of rotation, a galvanometer for indicating the current flow in the receptor circuit, and an enclosure or other means for excluding extraneous light.

These units shall be combined into one instrument in accord with the following requirements:

(b) *Angle of Illumination of Sample Face.* The axis of the light beam shall meet the center of the sample face normally except in the horizontal plane, where it shall be displaced three degrees in a counterclockwise direction. This angle allows the receptor element to intercept the center of any specularly reflected component from the sample, without interfering with the beam leaving the source.

(c) *Angular Spread of Light Beam.* The light beam shall be suitably controlled so that its divergence shall not exceed six degrees.

(d) *Characteristics of Light Source and Receptor.* The light source shall be of incandescent tungsten operating at a temperature between 2800° and 3000° Kelvin, or any other source which approximates closely the color temperature of a tungsten filament at the above temperature.

The receptor shall have a spectral sensitivity proportional to the luminosity function of the standard I.C.I. observer.

In lieu of the above, equivalent source-receptor combinations may be used.[27]

(e) *Specifications for Receptor Unit.* The receptor unit shall consist of a movable arm which carries at its outer and the photocell held vertically facing the center. The movable arms shall be of sufficient length so that the photocell may just intercept the center of any specularly reflected component without interfering with the beam leaving

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[27] A T-8, 100-watt projection lamp, operating at its rated voltage, combined with a Photox barrier-layer photocell approximates the specified source-receptor combination. Any other combination that will give the same results as the standard is also considered equivalent.

the source. The photocell surface shall be covered by a mask containing a vertical slot which subtends two degrees at the center of rotation.

The receptor unit shall be rotable about the sample through two quadrants from an angle of three degrees clockwise from normal to the sample face (center of specularly reflected beam) through 174°, when the cell will be diametrically opposite the light source.

WARNING. At no time should the photocell be exposed to excessive light intensity. For barrier-layer cells a safe maximum should be maintained by limiting the current output to 100 microamperes per sq. in. of exposed photosensitive surface. This limit may be observed by covering the cell opening with a neutral filter when necessary, which should then remain in place for the complete test (reflective and/or transmissive). A neutral gray photographic negative is convenient.

(f) *Instrument Enclosure and Baffling.* The instrument may be contained in its own light tight enclosure or may be operated in a darkened room with black walls, similar to a photographic darkroom. In the latter case the operator shall wear dark clothing, or stand behind the photocell, or both. The interior of any enclosure and all included instrument parts shall be painted a flat optical black.

While making measurements of diffusion by transmission it is necessary to shield the photocell from scattered light originating in the first, or reflection quadrant by a baffle, not more than 1/16 in. thick and of suitable height, separating the two quadrants. This baffle shall be of such a length that the photocell just clears the outside end, and may be raised off the instrument base to sufficient height to allow the receptor arm to pass underneath. Both of these openings shall be covered by a loose flap of black opaque cloth or felt.

At the point where the baffle passes over the center of rotation of the receptor arm a circular hole shall be cut through, against the back of which the sample face shall be placed. The diameter of the hole shall be 2 in. greater than that of the centered light beam.

(g) *Galvanometer.* A galvanometer of suitable sensitivity[28] shall be employed in conjunction with the photocell for indicating the magnitude of current flow. The receptor-galvanometer circuit shall be calibrated[29] to obtain a relationship between light incident on the sensitive surface and the corresponding current generated.

Preparation and Measurement of Samples. (a) The samples shall be prepared in the customary manner peculiar to their various physical properties (e.g., compression molding, laminating, injection molding, casting, etc.).

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[28] With a barrier-layer cell, a suitable galvanometer is one having a sensitivity of about 0.05 μa per mm. and a period of about 2 sec. This may be shunted by a resistance to reduce its sensitivity when measuring highly reflective or transmissive materials. If a galvanometer of 300 ohms or less internal resistance is employed with the barrier-layer type cell, an essentially linear response is obtained between light flux and current. A calibration should be made in any case, however, with and without any shunt that may be used.

[29] Figure 3.20 is a sketch of several views of an instrument devised by Dows and Baumgartner ["Two Photovoltaic Cell Photometers for Measurement of Light Distribution," Dows and Baumgartner. *Trans. I.E.S.*, **30**, 6 (1935).] which has been modified to satisfy the foregoing requirements. It is a double-quadrant goniophotometer embodying a light source containing a T-8 100-watt projection lamp, a photocell on a radius arm which is rotated by means of a geared shafting brought out to the front panel, toggle switches and a galvanometer. The instrument is enclosed in a sheet-metal body with an optical black interior.

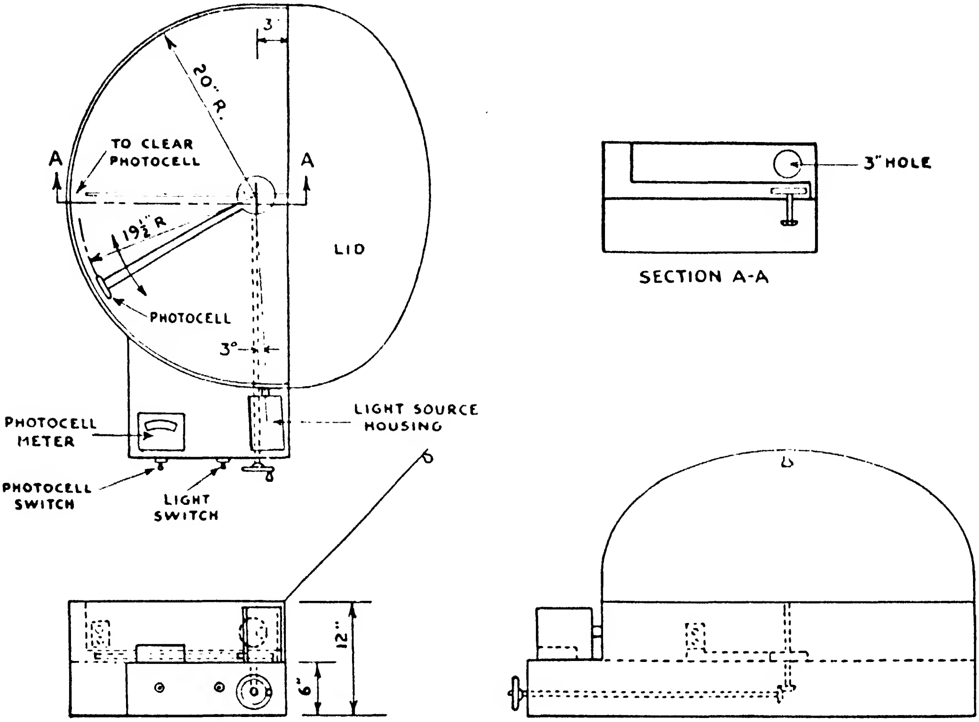

FIG. 3.20 — Dows-Baumgartner double quadrant reflectometer.

(b) The surfaces of such samples shall be essentially flat for purposes of measurement except that, if the surface is configurated, the envelope of such configurations must be flat. If diffusion by transmission is to be measured, the second surface, or envelope thereof, shall be parallel to the first.

(c) The thickness of the sample shall be 0.050 ± 0.005 in. for comparison purposes. If the surface is configurated this restriction shall not hold, but the structure and depth of the configurations shall be noted. Other thicknesses may be employed, but only when necessary.

(d) At least ten units of any configurated design shall be capable of location within the area of the beam of incident light.

(e) The sample shall be sufficiently large to cover the sample hole in the instrument completely.

(f) In making a measurement, the sample is positioned against the rear surface of the quadrant-separating baffle, covering the hole, and the light is turned on. The photocell is positioned to give a full-scale or maximum reading on the galvanometer, at or near the specular angle, and any fluctuation or fatigue is noted. Fluctuation shall not exceed ±2.5 per cent of the reading after correcting for non-linearity of galvanometer response[30] [Sec. 2 (g)].

(g) Two methods of measurement are available, one (Method A) including the specularly reflected or transmitted componement, the other (Method B) excluding

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[30] Lamp voltage fluctuations may be minimized by employing a voltage-regulating device in the lamp circuit.

it. The angles at which the center of the photocell is positioned to take readings for Method A are tabulated below; for Method B the first and last groups of readings are omitted.

TABLE 10. POSITIONS FOR TAKING BRIGHTNESS READINGS FOR METHOD A

(Including Specular Component)

Group	Readings Made Every	From–To
1*	2°	3 to 15°
2	5°	15 to 45°
3	10°	45 to 85°
4	10°	95 to 135°*
5	5°	135 to 165°
6*	2°	165 to 177°

* Exclude these series of readings for Method B.

(h) At the conclusion of a test by either method, the photocell shall be placed accurately in the starting position and a reading taken on the galvanometer. This final reading shall check that made at the beginning of the test within ±2.5 per cent or the test shall be repeated.

(i) If the sample is patterned or configurated in body or surface texture in a manner which may cause orientation of its diffusive properties, tests shall be made with each of the dissimilar axes of symmetry of the pattern in a vertical position and these positions shall be noted.

Numerical Evaluation of Diffusion. (a) The values of the test shall be plotted as ordinates on Cartesian coordinates, employing the corresponding angle for each value as the abscissa.

(b) A smooth curve shall be drawn through the points and extrapolated to zero at 90 degrees. By means of a planimeter or other sufficiently accurate method the areas under the brightness-distribution curve, separately for reflective and for transmissive determinations (S_r and S_t), shall be valuated in any convenient or arbitrary units, from 3° to 90° and from 90° to 177°, respectively (Method A), or from 15° to 90° and 90° to 165° (Method B).

(c) The area ($S_{\text{max.}}$) included under a horizontal straight line at the maximum brightness reading shall be determined over the same angular extent and in the same units of area. This area is the rectangle which includes the brightness distribution curve for the sample within the angular limits corresponding to Method A or Method B.

For example, D_{ra} and D_{ta}, the reflective and transmissive diffusion values (by Method A), are obtained by finding the ratio of S_{ra} and S_{ta} respectively, to the corresponding S_{max}.

1. $$D_{ra} = \frac{S_{ra}}{S_{\text{max.}\,ra}}$$

2. $$D_{ta} = \frac{S_{ta}}{S_{\text{max.}\,ta}}$$

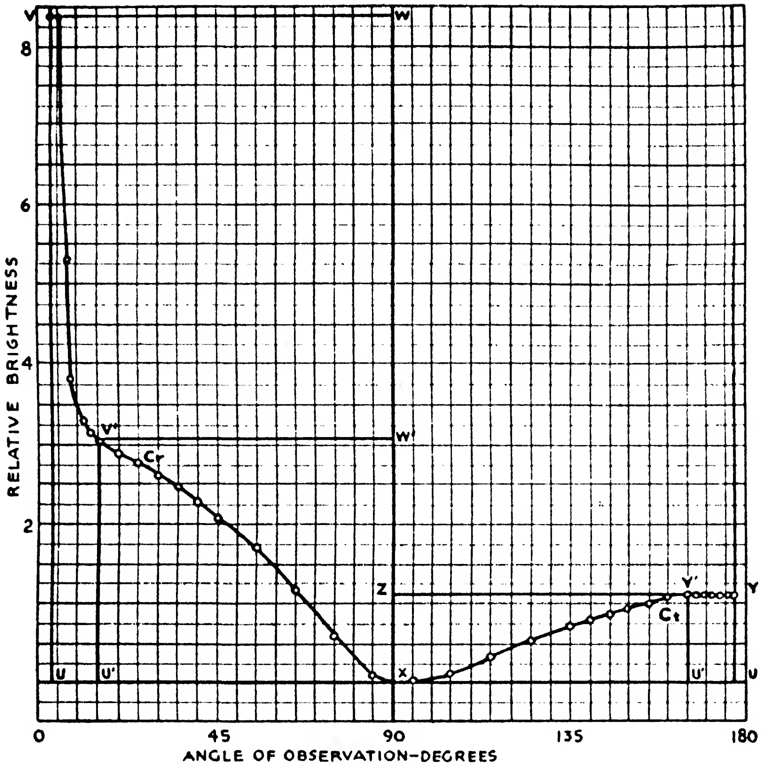

FIG. 3.21 — Brightness distribution curves for typical plastics sample.
C_r—Reflective diffusion curve. C_t—Transmissive diffusion curve.

Example: Arbitrary brightness readings are obtained on a smooth homogeneous plastics sample 0.052 in. thick, as given in Table 11. The relative brightness curves are plotted in Fig. 3.21. Curve C_r is the reflective brightness or diffusion curve, and curve C_t the transmissive diffusion curve. It can be seen that:

1. D_{ra} is evaluated by taking the ratio of the area included within *UVX* to that included within *UVWX*, as denoted by equation 2.
2. Likewise D_{ta} is evaluated by the ratio of areas *UYX:UYZX*; D_{rb}, by *U'V'X:U'V'W'X*; D_{tb}, by *U'Y'X:U'Y'ZX*.

A summation of the areas under the curves gives the following values:

3. For curve C_r, by Method A, area S_{ra} = 91.1 cm.^{2}
4. For curve C_t, by Method A, area S_{ta} = 26.4 cm.^{2}
5. For curve C_r, by Method B, area S_{rb} = 62.1 cm.^{2}
6. For curve C_t, by Method B, area S_{tb} = 19.8 cm.^{2}

The area under the curve for the perfect diffusor ($S_{\text{max.}}$) is:

7. $S_{\text{max}.ra}$ = 365.4 cm.^{2}
8. $S_{\text{max}.ta}$ = 47.9 cm.^{2}
9. $S_{\text{max}.rb}$ = 114.0 cm.^{2}
10. $S_{\text{max}.tb}$ = 41.3 cm.^{2}

The diffusion values for the material are therefore readily determined as follows:

11. $D_{ra} = \dfrac{S_{ra}}{S_{\text{max}.ra}} = \dfrac{91.1}{365.4} = 0.25,$

the reflective diffusing power by Method A (including the specularly reflected component).

12. $D_{ta} = \frac{S_{ta}}{S_{\max.ta}} = \frac{26.4}{47.9} = 0.55$,

the transmissive diffusing power by Method A.

13. $D_{rb} = \frac{S_{rb}}{S_{\max.rb}} = \frac{62.1}{114.0} = 0.55$,

the reflective diffusing power by Method B (excluding the specularly reflected component$_a$.

14. $D_{tb} = \frac{S_{tb}}{S_{\max.tb}} = \frac{19.8}{41.3} = 0.48$,

the transmissive diffusing power by Method B.

TABLE 11. TEST RESULTS FOR TYPICAL PLASTICS SAMPLE 0.052 IN. THICK

Angle of Observation	Galvanometer Deflection	Angle of Observation	Deflection
3	8.40	95	0.01
5	8.40	105	0.10
7	5.30	115	0.33
9	3.82	125	0.52
11	3.28	135	0.70
13	3.15	140	0.78
15′	3.05	145	0.87
20	2.90	150	0.94
25	2.80	155	1.01
30	2.65	160	1.06
35	2.46	165	1.09
40	2.31	167	1.10
45	2.10	169	1.10
55	1.71	171	1.10
65	1 16	173	1.10
85	0.11	177	1.10

(d) If it is desired to compare graphically the diffusing properties of several samples by means of their light distribution curves, the maximum brightness reading for each sample shall be converted to 100 and the readings at other angles shall be modified in like ratio before plotting the points on Cartesian coordinates. The area under each curve is then proportional to the diffusing power of the sample represented. (Fig. 3.22.)

It can be seen from this example that the choice of one of the two possible methods depends upon whether or not there is a well defined specularly reflected or transmitted component and also, whether or not it is desired to show the over-all diffusing power including this component or to indicate only the light scattering ability of the sample, independent of its surface characteristics. Obviously, for a material having a matte surface, there is little value in using Method A when the simpler Method B will give almost the same result. Likewise Method B is to be preferred in transmissive diffusion measurements on a highly diffusive material.

Report. (a) The report shall give the diffusion values for transmission and reflection, as required, as a decimal.

(b) D_r and D_t shall be given to the nearest 0.05 above 0.50, to the nearest 0.02 from 0.25 to 0.50 and to the nearest 0.01 below 0.25.

(c) The thickness of sample shall be given to the nearest 0.001 in. except as noted on page 108 for special and configurated materials, when the necessary dimensions and configurations shall be fully described.

(d) The physical condition of one or both surfaces, depending on whether a determination is made only for D_r, or whether both D_r and D_t are measured, shall be described by one of the following terms: polished, smooth, matte, grained, pebbled, configurated.

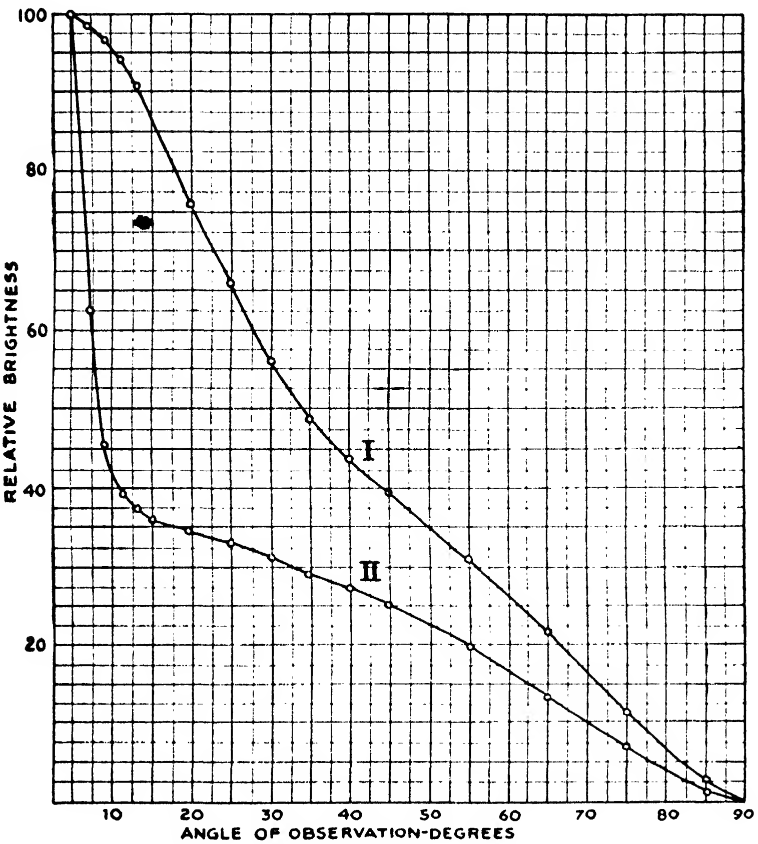

Fig. 3.22 — Graphical comparison of reflective diffusion curves for plastics sample.

I — Distribution with sanded surface, Dra = 0.44

II — Distribution with glossy surface, Dra = 0.25

(e) If any of the last three descriptive terms apply, more than one set of results shall be reported, if necessary, orienting the sample surface differently for each test, as described on page 109.

Light Transmission of Transparent Plastics. This test is designed to determine the degree of transparency of clear plastics.

Equipment. Measurements shall be made with an instrument which measures the light transmitted through a test specimen on to a photoelectric cell as a percentage of that which would reach the cell if the test specimen were not present. The frosted lamp light source intensity shall be adjusted so that a current of 100 microamperes is obtained from the photocell.

Specimens. The test specimens specified by the Bureau of Ships, U.S. Navy Dept., 17 P 8 (INT) shall be either a 6 by 6 in. flat plate ⅛ in. thick or a disk 4 in. in diameter by ⅛ in. thick.

Procedure. The specimen undergoing test shall be placed between the light source and photocell so that all light entering the cell must pass through the specimen.[31]

Haze. This test is designed to measure the optical clarity of transparent plastics.

Equipment. The apparatus used to determine haze value shall be a photoelectric or visual photometer having the sensitivity and precision of the Macbeth Illuminometer. A suitable source of an intense parallel beam of light is required.

Specimens. The specimens may be either a 6 × 6 × ⅛ in. plate or 4 × ⅛ in. disk.

Procedure. The specimen shall be placed in the light source (deviation not more than 5°) at an angle of 45° to the direction of the beam. The test illuminometer shall be directed toward the illuminated portion of the specimen along an axis normal to the specimen and passing through the center of the beam at the point of incidence. The background shall be black. A box having a restricted aperture and a matte black interior shall be placed on the axis of the illuminometer behind the specimen at such a distance that the aperture fills the field of the illuminometer. The field of the illuminometer should cover a circular area on the specimen of at least 1 in. diameter and shall be entirely filled with the illuminated portion of the specimen. Precaution shall be taken that scattered light from other objects is not reflected into the illuminometer. The brightness determined by this arrangement shall be considered the intrinsic brightness of the illuminated specimen. The intensity of the transmitted beam shall be determined by measuring the brightness of a white diffusor located at right angles to the specimen and illuminated by the beam immediately after having passed through the specimen. The white diffusor shall be in position only during the determination of the intensity of the beam. The extent of the diffusion surface and the position of the illuminometer along the axis normal to shall be such that the field of the illuminometer is filled. The haze value in per cent shall be the percentage ratio of the intrinsic brightness of the illuminated specimen and the brightness of the white diffusor.

Dielectric Strength. Plastics are relatively poor conductors of electricity as one would expect from their poor heat conductivity and their organic nature. Most plastics with the proper care in compounding and handling can be made into good dielectrics, especially at low frequencies.

The dielectric strength of an insulating material may be defined as the voltage gradient at which electrical failure or breakdown occurs. It is obtained by dividing the breakdown voltage by the thickness of the dielectric test sample between the test electrodes. It is mostly a comparative test because it is affected by the thickness of the test piece, the form and size of the electrodes, the time of application of the voltage, the frequency and wave shape of the voltage, the temperature and the surrounding medium.

Usually the dielectric strength is determined by the short time method outlined, in which the voltage is increased uniformly to breakdown at the rate of 1000 volts per

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[31] This test may be conducted on such an instrument as the Trans-O-Meter. (Westinghouse Electric & Manufacturing Co.)

sec. It may also be determined by the 1 min. step-by-step method, or by an endurance or long-time method. The tests are run at 60 cycles unless otherwise specified. At higher frequencies such as radio frequency, dielectric strengths are as a rule very much lower.

STEP-BY-STEP TEST

Breakdown voltage by short-time method	*Increment of increase of test voltage starting with 50 per cent of short-time method*
25 Kv. or under	1.0 Kv.
25 to 50 Kv.	2.0 Kv.
50 to 100 Kv.	5.0 Kv.
Over 100 Kv.	10.0 Kv.

The test specimens are molded 4-in. disks from ⅛ to ¼ in. thick or cut off of sheet material with sufficient area to prevent flashover. The test is usually run at room temperature, after 48-hr. immersion in water or at some elevated temperature. The tests are run under oil for dielectric materials, but may be tested in air. In either case, the condition should be reported. The electrodes are flat disks 1 in. in diameter with edges rounded to a radius of ⅛ in., except when testing parallel to flat sides when a modified needle gap is used. The voltage necessary for breakdown is obtained from a step up transformer of such a size and design that with the test specimen in the circuit the crest factor of the test voltage does not differ by more than 5 per cent from that of a sinusoidal wave over the upper half of the range of test voltage.

Resistivity Measurements. An electrical insulating material is ordinarily defined as a material which has a high resistivity. The resistivity of a material is defined as the reciprocal of the current passed between two electrodes placed on opposite faces of a centimeter cube of the material when there is unit potential difference between the electrodes, provided the current distribution is uniform throughout the cube, and the time of application of the voltage has been sufficiently long so that the current is constant. This is called volume resistivity. However, this property alone does not determine the suitability of a material as an insulator. Plastics surfaces have an affinity for water and other substances of relatively high conductivity. Hence it is important that a surface measurement be made. The resistance between two opposite edges of a unit square of the surface film is called surface resistivity. Materials which have a high volume resistivity do not necessarily have a high surface resistivity. Insulation resistance is the ratio of the voltage applied to the electrodes to the total current which flows between electrodes which are fastened to or imbedded in an insulation material. It is a combination of surface and volume resistance.

The test specimens for volume and surface resistivity are in the form of either plates or tubes, and for insulation resistance any specimen can be used. In the case of surface resistivity and insulation resistance tests, the specimens are conditioned for 2 or 3 days at a definite temperature and humidity. This should also be done for volume resistivity tests except in such cases where materials are highly affected by moisture. In this latter case volume resistivity measurements would be of little significance. The circuit shown in Fig. 3.23 can be used for making these measurements. The specimen and electrodes shown are for flat specimens but can be easily adapted for tubular specimens and for other insulation resistance specimens.

Arc Resistance. Molded plastics are often used as electrical insulators under conditions where arcing may result. For this, the ureas are very good and phenolics, unless specifically made for arc resisting, are poor. Thermoplastics are limited because of their low softening point.

In order to measure the arc resistance of plastics, the following method has been devised (A.S.T.M. D495–38T). A high voltage, low current a.c. arc, drawn between two tungsten-pointed electrodes resting upon the surface of the material under test is increased at 1-min. intervals until the material fails by becoming conducting. The results are usually reported as current in milliamperes and time in seconds. The time required to reach failure is a measure of the arc resistance of the material.

Figure 3.24 indicates the electrical circuit used for making such a test.

Power Factor and Dielectric Constant. The power factor of a dielectric is a measure of the energy loss in an alternating field. All dielectrics show some loss in such electric fields.

The dielectric constant or specific inductive capacitance is the ratio of the capacitance of a condenser with a given substance as a dielectric to the capacitance of the same condenser with air or a vacuum as a dielectric.

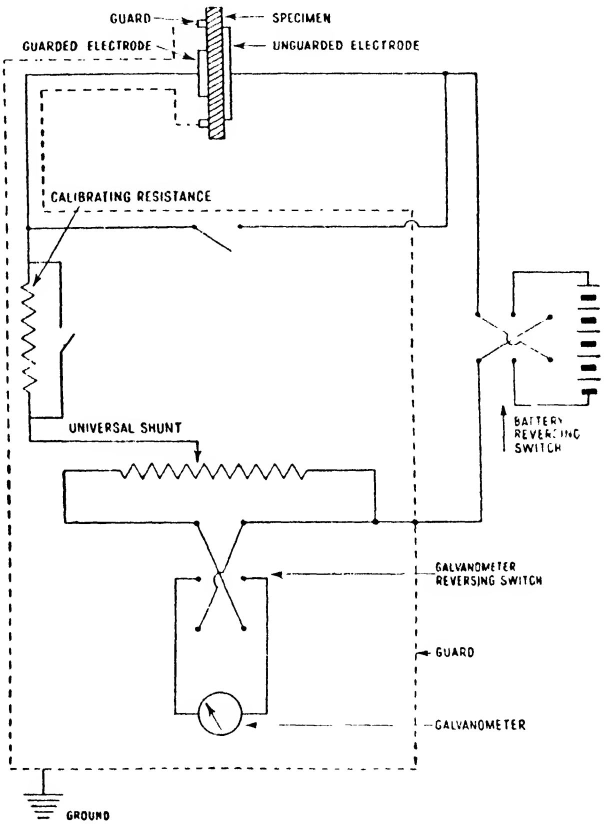

FIG. 3.23 — Circuit for making tests of volume and surface electrical resistivity.

When a sinusoidal alternating voltage is applied to a capacitor, the resulting current will have a small component in phase with the voltage. The angular difference in phase between the voltage and the component is called the dielectric phase angle. The difference between 90 electrical degrees and the phase angle is usually a small angle known as the loss angle. The power factor is the cosine of the phase angle or the sine of the loss angle. The power factor is the fraction of the energy loss and the dielectric constant is a measure of the amount of energy stored in a dielectric; therefore the product of the two is a measure of the actual loss and is known as the loss factor.

The power factor and dielectric constant are usually determined on disks 0.1 to 0.3 in. thick and 6 in. in diameter. Other specimens may be used, but in any case the capacitance of the specimen should not be less than 100 $\mu\mu$f., and since temperature, pressure, and humidity affect dielectric properties, it is essential that specimens for test be suitably conditioned before testing. The power factor and dielectric constants are measured by adaptations of the Wheatstone bridge method or by the substitution method in a resonant circuit, or by the reactance variation method, furnished with a suitable source of power. See A.S.T.M. methods D150-39T.

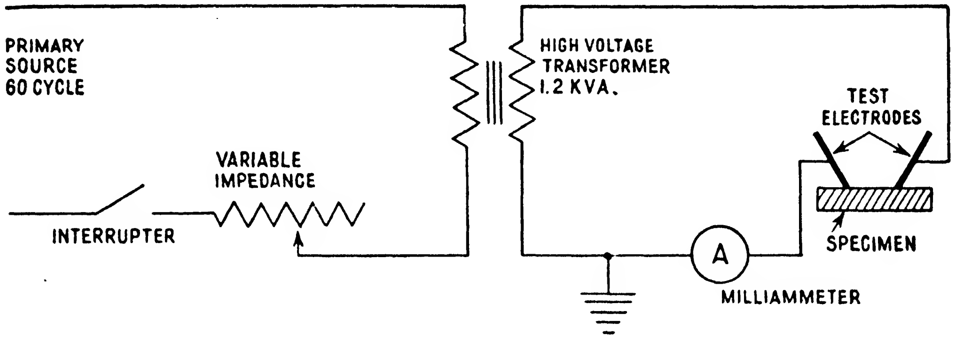

FIG. 3.24 Circuit for arc resistance test.

Resistance to Chemicals. The purpose of this test is to indicate the resistance of plastics to a variety of common chemicals. The following test is recommended.

Tentative Test

A.S.T.M. D543-41T

Apparatus. (a) An accurate chemical balance; (b) containers for test specimen; (c) cabinet held at 77° to 86° F.

Standard Test Reagents.

Sulfuric acid (30% and 3%)
Sodium hydroxide (10% and 1%)
Ethyl alcohol (95% and 50%)
Acetone
Ethyl acetate (C. P.)
Heptane — commercial grade B. P. 90° to 100° C. (194° to 212° F.)
Ethylene dichloride
Carbon tetrachloride
Toluene
Sodium chloride solution (10%)
Distilled water

Supplementary Reagents.

Nitric acid (10%)
Hydrochloric acid (10%)
Acetic acid (5%)
Oleic acid
Ammonium hydroxide (10%)
Sodium carbonate solution (2%)
Hydrogen peroxide solution (3%)

Specimen. Molded compound, a 2-in. diameter disk ⅛ in. thick; laminated materials, a sheet 3 by 1 by ⅛ in.

Procedure. Specimens shall be weighed as received, and measurements of dimensions recorded. Specimens shall be immersed in reagents for seven days at 77° to 86° F.

They shall be washed free of reagents, wiped dry (not rubbed) with a cloth, and weighed.

Report. The report shall indicate any gains or loss in weight, changes in dimension and appearance.

Water Absorption. As the name implies, this test is an index of the susceptibility of the plastic to absorb water upon immersion for definite periods.

Tentative Test[32]

(A.S.T.M. D570–40T)

Scope. This method of test[33] covers the procedure for determining the relative rate of absorption of water by plastics when immersed. The method is intended to apply to the testing of all types of plastics, including case, hot-molded, and cold-molded resinous products, and both homogeneous and laminated plastics in rod and tube form, and in sheets 0.005 in. or greater in thickness.

Apparatus. The apparatus shall consist of the following:

(a) An accurate chemical balance.

(b) An oven capable of maintaining uniform temperatures of 50° ± 3° C. (122° ± 5° F.) and of 105° to 110° C. (221° to 230° F.).

Specimens. (a) The test specimen for molded plastics shall be in the form of a disk 2 in. in diameter and ⅛ in. in thickness. Permissible variations in thickness are ±0.007 in for hot-molded and ± 0.012 in. for cold-molded or cast materials.[34]

(b) The test specimen for sheets shall be in the form of a bar 3 in. in length by 1 in. in width by the thickness of the material. When comparison of absorption values with molded plastics is desired, specimens ⅛ in. in thickness should be used. Permissible variations in thickness of the ⅛ in. thick specimen shall be ±0.008 in. except for asbestos-fabric-base phenolic laminated materials or other materials which have greater standard commercial tolerances.

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[32] The moisture content of a plastic is very intimately related to such properties as electrical insulation resistance, dielectric losses, mechanical strength, appearance, and dimensions. The effect upon these properties of change in moisture content due to water absorption depends largely on the type of exposure (by immersion in water or by exposure to high humidity), shape of the part, and inherent properties of the plastic. With non-homogeneous materials, such as laminated forms, the rate of water absorption may be widely different through each edge and surface. Even for otherwise homogeneous materials, it may be slightly greater through cut edges than through molded surfaces. Consequently, attempts to correlate water absorption with surface area must generally be limited to closely related materials and to similarly shaped specimens. For materials of widely varying density, relation between water absorption values on a volume as well as a weight basis may need to be considered.

[33] The test for rate of water absorption has two chief functions: first, as a guide to the proportion of water absorbed by a material and consequently, in those cases where the relationships between moisture and electrical or mechanical properties, dimensions, or appearance have been determined, as a guide to the effects of exposure to water or humid conditions on such properties; and second, as a control test on the uniformity of a product. This second function is particularly applicable to sheet, rod, and tube forms when the test is made on the finished product.

[34] If there is any oil on the surface of the specimen when received or as a result of machining operations, wash the specimen with a cloth wet with gasoline to remove oil, wipe with a dry cloth, and allow to stand in air for 2 hr. to permit evaporation of the gasoline. If gasoline attacks the plastic, use some suitable solvent or detergent that will evaporate within the 2-hr. period.

(c) The test specimen for rods shall be 1 in. in length for rods 1 in. in diameter or under, and ½ in. in length for larger diameter rods. The diameter of the specimen shall be the diameter of the finished rod.

(d) The test specimen for tubes less than 3 in. in inside diameter shall be the full section of the tube and 1 in. in length. For tubes 3 in. or more in inside diameter, a rectangular specimen shall be cut in 3 in. in length of the circumferential direction of the tube and 1 in. in width lengthwise of the tube.

(e) The test specimens for sheets, rods, and tubes shall be machined, sawed, or sheared from the sample so as to have smooth edges free from cracks. The cut edges shall be made smooth by finishing with No. 0 or finer sandpaper or emery cloth. Sawing, machining, and sandpapering operations shall be slow enough so that the material is not heated appreciably.

(f) The dimensions listed in the following table for the various specimens shall be measured to the nearest 0.001 in. Dimensions not listed shall be measured within ±1/32 in.

TABLE 12. DIMENSIONS FOR TEST SPECIMENS

Type of Specimen	Dimensions to Be Measured to the Nearest 0.001 in.
Molded disk	Thickness
Sheet	Thickness
Rod	Length and diameter
Tube	Inside and outside diameter, and wall thickness

Conditioning. Three specimens shall be weighed individually and then conditioned as follows:

(a) Specimens of materials whose water absorption value would be appreciably affected by temperatures in the neighborhood of 110° C. (230° F.), shall be dried in an oven for 24 hr. at 50° ± 3° C. (122° ± 5° F.), cooled in a desiccator, and immediately reweighed.

NOTE. If a static charge interferes with the weighing, lightly rub the surface of the specimens with a grounded conductor.

(b) Specimens of materials, such as phenolic laminated plastics and other products whose water absorption value has been shown not to be appreciably affected by temperatures up to 110° C. (230° F.), shall be dried in an oven for 1 hr. at 105° to 110° C. (221° to 230° F.).

(c) When data for comparison with absorption values for other plastics are desired, the specimens shall be conditioned in accordance with paragraph (a).

Procedure.

(a) *24-hr. Immersion.* The conditioned specimens shall be placed in a container of distilled water maintained at a temperature of 25° ± 2° C. (77° ± 3° F.), and shall rest on edge and be entirely immersed. At the end of 24 hr., the specimens shall be removed from the water one at a time, all surface water wiped off with a dry cloth, and weighed immediately. If the specimen is 1/16 in. or less in thickness, it shall be put in a weighing bottle immediately after wiping and weighed in the bottle.

(b) *2-hr. Immersion.* For all thicknesses of materials having a relatively high rate of absorption, and for thin specimens of other materials which may show a significant value in 2 hr., the specimens shall be tested as described in paragraph (a) except that the time of immersion shall be reduced to 2 hr.

(c) *Repeated Immersion.*[35] A specimen may be weighed after 2-hr. immersion, replaced in the water, and weighed again after 24 hr.

(d) When data for comparison with absorption values for other plastics are desired, the 24-hr. immersion procedure described in paragraph (a) shall be used.

Reconditioning. When materials are known or suspected to contain any appreciable amount of water-soluble ingredients, the specimens after immersion shall be reconditioned for the same time and temperature as used in the original drying period. They shall then be cooled in a desiccator and immediately reweighed. If the reconditioned weight is lower than the conditioned weight, the difference shall be considered as water-soluble matter lost during the immersion test. For such materials, the water absorption value shall be taken as the sum of the increase in weight on immersion and of the weight of the water-soluble matter.

Calculation and Report. The report shall include the values for each specimen and the average for the three specimens as follows:

(a) Dimensions of the specimens before test, measured in accordance with method on page 118, and reported to the nearest 0.001 in.,

(b) Percentage loss in weight on initial drying, calculated on the basis of the original weight, and the conditioning time and temperature,

(c) The time of immersion,

(d) The percentage increase in weight during immersion calculated to nearest 0.01 per cent as follows:

$$\text{Increase in weight, per cent} = \frac{\text{Wet wt.} - \text{conditioned wt.}}{\text{Conditioned wt.}} \times 100$$

(e) The percentage of soluble matter lost during immersion, if determined, calculated to nearest 0.01 per cent as follows:

$$\text{Soluble matter lost, per cent} = \frac{\text{Conditioned wt.} - \text{reconditioned wt.}^{36}}{\text{Conditioned wt.}} \times 100$$

(f) The percentage of water absorbed in 24 hr. (or in 2 hr.), which is the sum of the values in items (d) and (e), and

(g) Any observations as to warping, cracking, or change in appearance of the specimens.

Hardness. Hardness is a surface characteristic which is of direct interest to users of molded plastics. There are several well-known methods of determining and expressing hardness:

1. Mohs' Scale of Hardness — determined by scratch tests and having a series of standards ranging from 1 for talc to 10 for diamond.

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[35] In using this method the amount of water absorbed in 24 hr. is likely to be less than it would have been had the immersion not been interrupted.

[36] When the weight on reconditioning the specimen after immersion in water exceeds the conditioned weight prior to immersion, report " none " under item (e).

Mohs' Scale

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase
7. Quartz
8. Topaz
9. Corundum
10. Diamond

2. Shore scleroscope method which evaluates the property from the degree of rebound of a steel ball from the surface in question.

3. Brinell ball method which determines the value by pressing a 1-cm. dia. steel ball into the test surface with a force of either 500 kg. or 3000 kg. and expressing the value as kg./sq. mm., obtained by dividing the force applied by the area of the surface of indentation.

4. Rockwell hardness method which evaluates the property by pressing a suitable penetrator into the surface in question and expressing the degree of penetration on an arbitrary inverse scale, such that the higher scale reading indicates a harder surface. The penetrator is either a steel ball (ranging from 1/16 to ½ in.) or in the case of very hard materials, a diamond sphero-conical penetrator. The hardness value expressed must, of course, include the specific penetration used.

The Rockwell method as adapted to sheet plastic materials has been adopted by A.S.T.M. and is as follows:

Rockwell Hardness

A.S.T.M. D229–39

Apparatus. The Rockwell hardness tester shall be used, conforming to the requirements of the Standard Method of Test for Rockwell Hardness of Metallic materials (A.S.T.M. Designation: E 18) of the American Society for Testing Materials.

Specimens. The specimen shall have a minimum thickness of ¼ in. The specimen may be composed of a pileup of several pieces of the material of the same thickness, provided that precaution is taken that the surfaces of the pieces are in contact and not held apart by burrs from saw cuts, etc. The area of the specimens shall be 1 in. sq. if cut from sheet stock or other shape of at least this area.

Note. Conditioning of the specimens of vulcanized fiber is necessary in order to secure consistent results. The procedure for conditioning is under consideration by the committee. In order to secure comparative results, the specimens should be conditioned at the same temperature and humidity.

Procedure. (a) The procedure outlined in Standard Method E 18 shall be followed. The adjustment of speed of load application and the time of application of the major load are of great importance. The machine shall be so adjusted that the major load will be fully applied in from 6 to 8 sec., since a longer time will give an erroneous result due to " creeping " of some materials. It is important that the major load be removed within 1 sec. after the crank handle mechanisms has come to a stop.

(b) For phenolic laminated sheets,[37] a ¼-in. ball penetrator, a minor load of 10 kg., and a major load of 100 kg. shall be used in connection with the red scale. This combination is known as the M scale.

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[37] It should be noted that some materials such as laminated phenolic plates show an appreciable variation in the Rockwell hardness with variation in temperature as small as 15° F.

(c) For vulcanized fiber, a ½-in. ball penetrator, a minor load of 10 kg., and a major load of 60 kg. shall be used. This combination is known as the R scale. The major load shall be removed within 7 to 8 sec. after the handle has been tripped. Care shall be taken that the weight arm does not descend far enough to rest on the lifting link or pin. If the arm rests on the link or pin, the load or penetrator should be changed.

(d) All tests shall be made at a temperature of 25° ± 2° C. (77° ± 3.6° F.).

(e) Care shall be taken that the test is not made so near the edge of the specimen that it will break out when the major load is applied.

(f) The specimen shall be supported in such a manner as to prevent errors due to overhang, when it does not balance itself on the anvil.

(g) The readings shall be taken on the red scale and shall be recorded as follows: Count the number of times the needle passes through zero on the red scale on the application of the major load. Subtract from this the number of times the needle passes through zero upon the removal of this load. If the difference is zero, the reading shall be recorded as over 100. If the difference is 1, the reading shall be recorded as between 0 and 100, and, if the difference is 2, the reading shall be recorded as negative.

Report. The report shall include the following:

(a) The Rockwell hardness number read on the red scale, the major load, and the diameter of the penetrator. The letter M shall precede the Rockwell hardness number for phenolic laminated sheets and the letter R shall precede that for vulcanized fiber.

(b) The total thickness of the specimen.

(c) The number of pieces in a specimen and their average thickness.

(d) The room temperature.

Color Fastness. To determine the color fastness of plastics, the following test is recommended:

Proposed Test of Plastics for Color Fastness to Light

A.S.T.M. D620–41T

Scope. (a) This method is intended to establish a laboratory procedure for evaluating the relative resistance of plastics to change in color when exposed to sunlight. Plastics may change in color because of the action of solar radiation on the dyes or pigments or on the plastic base. The 50-hr. test specified herein has been found to be roughly equivalent to 100 to 200 hr. of exposure to sunlight in Washington, D. C., during the months of August and September between 9:00 A.M. and 4:00 P.M.

(b) This method is not intended to show the resistance of plastics to weathering, that is, continuous exposure of the materials out-of-doors.

Apparatus. The apparatus shall consist of the following:

(a) A General Electric Sunlamp, Model BM 12 or equivalent, equipped with a reflector approximately 15 in. in diameter at the lower rim and an S-1 bulb which has been in use at least 50 hr. and less than 550 hr. The S-1 bulb consists of a combination tungsten-filament mercury-arc inclosed in Corex-D glass which absorbs most of the ultra-violet below 2800 Å. The bulb is rated at 450 watts.

(b) A phonograph turntable, operating at 33 r.p.m. on which is mounted an aluminum disk approximately 17 in. in diameter and 0.1 in. thick. Two sets of 21 brass machine screws and nuts are attached to the disk at holes equally spaced on concentric circles of approximately 3¼ in. and 6 in. radius, respectively. The screws may be size 10, 32 threads to the inch, ½ in. long with fillister head. Brass washers of about ⅝ in. diameter and 0.05 in. thickness are placed over the nuts to support the specimens about 3/16 in. above the surface of the disk. A brass plate about 1 in. square and 0.05 in. thick is fitted over the outer row of screws to cover approximately one-third of the outer portion of the specimen.

Specimen. The test specimen[38] is approximately 2 in. long and 1 in. wide. The material is tested in the thickness as received.

Procedure. The specimens are fastened to the disk by means of the cover plates and nuts. The disk is centered under the S-1 bulb so that the plane of the specimens is 7 in. from the bottom of the bulb. The specimens are rotated under the light for 50 hr. They are then removed from the disk and examined visually for color changes. The test is conducted in a room maintained at 77° ± 2° F. by means of circulating air.

Note. When the apparatus is not confined in a cabinet and the air temperature is 77° F., the temperature of a colorless transparent plastic, ⅛ in. thick, has been found to be approximately 50° C. (122° F.) under the above conditions. The temperature of the specimen was measured by means of a thermocouple inserted immediately after stopping the turntable in a hole bored longitudinally in the plastic. It is undesirable to permit the temperature to go higher than 55° C. (131° F.) as indicated by this test because effects not typical of exposure to sunlight may be produced at higher temperatures. On the other hand, if the test conditions are such that the temperature of the specimens is considerably lower than the 50° C. (122° F.) indicated by the above procedure, the rate of change in color may be considerably retarded. Such an undesirable effect is produced by circulating air directly over the specimens by means of an adjacent fan.

Report. (a) The relative amount of color change of the plastic shall be reported as none, slight,[39] appreciable, or extreme.

(b) The direction of the color change, for example, lighter or darker, and any other noteworthy effect of the exposure to the light on the appearance or condition of the sample shall be reported.

Weathering of Plastics. It is advisable actually to test plastic articles by exposing them to the elements. This is usually accomplished simply by mounting the specimen on racks on factory roofs. Some companies send samples to the West Coast or Florida. A convenient place for testing is operated at Miami, Florida, by the South Florida Test Service (P. O. Box 387). Here reliable experts mount the samples and keep accurate check on the climatic conditions.

CLIMATOLOGICAL DATA AT MIAMI, FLORIDA

General Conditions:

Temperature	(° F.)	*Relative Humidity*	(%)
Mean maximum	80.8	8:00 A. M.	78
Mean minimum	69.2	Noon	66
Mean monthly	75.2	8:00 P. M.	74
Mean daily range	11.0		

Prevailing Wind: East off Atlantic Ocean 8.6 miles per hour

Yearly Precipitation: 60.56 in.

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[38] It is desirable to include a test specimen of known discoloration behavior in each test run in order to guard against the use of a bulb which is defective. A specimen of transparent cellulose nitrate plastic of ⅛ in. thickness has been found to be satisfactory for this purpose.

[39] A slight change is defined here as one which is perceptible with difficulty. An appreciable change is one which is readily perceptible without close examination but is insufficient to alter markedly the original color of the specimen. An extreme change is one which is very obvious and has resulted in a marked alteration of the original color of the specimen.

Sunshine:

Hours per year average	2994	Days without sunshine	6
Percentage possible	67	Average hours per day	7.76

An accelerated test for measuring weathering and one which closely agrees with outdoor tests follows:

Proposed Accelerated Weathering Test

Apparatus. (a) a lamp supplying visible and ultra-violet light; (b) a turntable upon which the test specimens are placed; (c) a cabinet which houses the lamp and turntable; and (d) a fog chamber.

The radiation is supplied by a General Electric Sunlamp, model BM6 equipped with an S-1 bulb or its equivalent. The light source is a mercury arc inclosed in a bulb of special glass which transmits radiation as short as about 2800 Å. The bulb is located at the center of a metal reflector, which is 14½ in. in diameter at the lower rim; the bulb and reflector are attached to an adjustable arm connected to a stand as in a bridge lamp. The lamp is located above the center of the turntable, the height being adjusted so that the lowest point of the bulb is 12 in. from the plane of the specimens.

The wooden cabinet which houses the turntable and light source is 3 ft. high, 2 ft. wide and 2 ft. deep, and its interior is coated with aluminum paint. It is open on one side to permit placing the lamp in position and to allow for ventilation.

The test specimens are carried by an aluminum disk which rests on a phonograph-type turntable. One operating at 33 r.p.m. is preferable. The turntable is mounted on a small box with the disk in a horizontal position. The disk is 20 in. in diameter and 0.10 in. in thickness. The specimens are supported as indicated in the test for light stability on page 122.

Two sets of 21 machine screws and nuts are attached to the disk at holes spaced equidistantly on circles 11¾ and 15¾ in. diameter, respectively. The bolts of one circle are staggered with respect to those of the other so that a sample is supported at its sides between two bolts of the inner ring and the center of its outer edge by a bolt of the outer ring. Each nut is on the top face of the disk and a washer is placed on the nut to hold the sample about 3/16 in. above the disk.

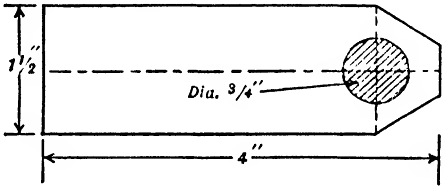

FIG. 3.25 — Sun-lamp apparatus specimen.

The test specimen is 4 in. by 1½ in. with a tapered end. As the intensity of illumination varies along the radius of the disk, it is desirable to measure the haze at similar positions on all test specimens. The haze is measured for a circular area having its center at a distance of 5 in. from the center of the turntable. This area is indicated by the hatched portion of the template.

A mercury thermometer is suspended near the back of the cabinet with its bulb just above the edge of the disk. The temperature is maintained at 35° to 38° C. (95° to 100° F.) by a fan placed outside the cabinet. It has been found that under the foregoing conditions the temperature inside a specimen of transparent plastic as measured by a thermocouple varies from 50° to 55° C. (122° to 131° F.).

The fog chamber is a shallow, well-paraffined wooden box 26 by 23 by 7.5 in., having a loose-fitting lid with a glass window. An enameled pan, which almost covers the bottom of the box, is partly filled with distilled water. A hole is bored in one end of the box and in it is placed the air inlet of an aspirator; the suction tube of the latter dips into the distilled water. The spray from the aspirator is directed against a baffle as high as the fog chamber and about half as wide; the baffle may be any inert material. The specimens are placed on glass rods which bridge the enameled pan and are in the space beyond the baffle. To ensure reasonably uniform condensation, samples are placed in back of the baffle, the space at the ends of the rods and at the edge of the box being avoided.

The radiation and wetting cycles employed for a 24-hr. day are as follows: 2 hr. in the fog chamber, 2 hr. of radiation, 2 hr. in the fog chamber, and the remainder of the day (about 17 hr.) under the sunlamp.

The specimens exposed in the fog apparatus become thoroughly covered with droplets of water on the top surface. This layer of water is not wiped off at any time during the test, but is allowed to dry under the sunlamp. The specimen as it is taken out of the fog chamber is quickly turned over so that the surface with the water on it is on the under side when exposed to the light. When replacing the specimen in the fog chamber, the specimen is turned over again, so that the same surface will always get the moisture deposited upon it. The surface of the specimen, which is turned up during the light cycle and hence receives the direct ultra-violet rays, is wiped off after the second fog cycle each day with lens paper wetted with distilled water and then that surface only is dried with the same type of paper. This is to prevent the deposition of material which would protect the underlying plastic from the action of the ultra-violet light. Haze and light transmission measurements are made on the samples at 200 and 500 hr. before and after cleaning both surfaces with lens paper as described. These time periods are based on light exposure only.

Flow Test Measurements. Thermoplastic resins are tested for flow using the method outlined below. Thermosetting resin flow is not readily measured by any one method and no standard test is available yet.

Tentative Test

(Thermoplastics)

A.S.T.M. D569–40T

Scope. This method of test determines the temperature at which a thermoplastic material attains a specified degree of flow when subjected to a prescribed pressure in a specified extrusion mold for a definite time. Measurements of flow are made at three or more temperatures, and the temperature for the specified flow is obtained by graphic interpolation. The equilibrium state of the material in this test may not be exactly representative of the state in commercial use.

Apparatus. The apparatus for the flow test shall be a constant-force, vertical-orifice type machine[40] consisting essentially of the following:

(a) A vertical orifice ⅛ in. in diameter and 1½ in. in length, into which the material flows. The orifice is machined into a split cone 1 in. in diameter at the base which is clamped into a steam-heated block. A thermometer well 3/16 in. in diameter and 1¼

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[40] Rossi-Peakes flow tester as described in U. S. Patent 2,066,016.

in. in depth is drilled into the split cone. Temperature readings are taken at this point.

(b) A 1¼-in. immersion mercury thermometer having a diameter just under 3/16 in. and a temperature scale of not more than 20° C. (68° F.) per inch of length.

(c) Below the orifice and concentric with it is the charge chamber, ⅜ in. in diameter and ¾ in. in length.

(d) A steam-heated block. Heat is supplied by steam at a line pressure of 90 to 150 lb. per sq. in., passing through an accurate reducing valve; if the line pressure fluctuates too widely, two reducing valves in series may be used. The temperature is controlled by regulating the steam pressure.

(e) A steam-heated ram so arranged that it applied pressure to the charge chamber from the bottom, forcing the material into the orifice. The steam line is so arranged that the steam passes through the reducing valve, the ram, the block, and finally through a suitable trap or small vent.

(f) A mechanical system for applying a net pressure of 1500 lb. per sq. in. to the ram. The pressure system is built so that any pressure up to 3000 lb. per sq. in. may be applied in increments of 100 lb. per sq. in.

(g) Means for measuring the flow of material into the orifice. Measurements shall be accurate to ±0.01 in. The following measuring systems are suitable:

(i) A follower rod, guided by loose bearings in a swing arm, rests on the material in the orifice. A flexible chain attached to the upper part of the follower rod is passed part way around and fastened to the small diameter of a two-step pulley having a three-to-one ratio and mounted on the swing arm. A second flexible chain passing part way around and fastened to the larger diameter is attached to a sliding indicator and a counterweight. The indicator travels over a calibrated scale so that the amount of flow in the orifice is shown on the scale, magnified three times. The weight of the flow-indicating mechanism is such that a pressure of 40 lb. per sq. in. is exerted on the material in the orifice; this, however, is counterbalanced by sufficient additional weight on the pressure system.

(ii) *Optional.* The flow measuring device may be equipped with a time clock, a recording pen, and suitable graph paper with the scale as one axis and time as the other so that the flow behavior over any given time period may be recorded.

Specimens. The test specimens shall be molded of machined cylinders ⅜ in. in diameter and ⅜ in. in height. The height may be obtained by piling up several disks.

Conditioning. (a) *Preferred Method.* Test specimens shall be conditioned at room temperature in a desiccator over anhydrous calcium chloride for 72 hr.

(b) *Alternative Method.* Test specimens shall be conditioned in an oven at 50° C. (122° F.) for 24 hr.

Procedure. (a) A working pressure of 1500 lb. per sq. in. shall be used.

(b) The unit of flow time shall be 2 min. ± 1 sec. as measured with a stop watch or timer.

(c) The test specimens at room temperature shall be inserted in the hot charge chamber and tested immediately.

(d) Between tests, the orifice shall be swabbed with acetone or other suitable solvent to remove any residual plasticizer or lubricant.

(e) Each material shall be tested at three or more temperatures at which the flow will be within the interval of 0.50 to 1.50 in. with at least one measurement above and one below 1 in. Temperatures shall be controlled within ± 0.10° C. (0.18° F.). All temperature measurements shall be made at the split cone after it has come to equilibrium with the block.

Plotting Results. The linear flow shall be plotted against temperature on semi-logarithmic paper. With the flow measurements plotted on the logarithmic coordinate and temperature on the linear coordinate, a straight line will usually result. The temperature at which the flow is exactly 1.0 in. shall be read from the graph and reported as the flow temperature.

Report. The report shall include the following:

(a) A statement indicating the nature of the material tested

(b) Curve of linear flow against temperature.

(c) Temperature at which flow is 1 in.

(d) Report of any unusual behavior of the test specimens such as discoloration, sticking, etc.

(e) Details of conditioning

Plasticity. *Methods of Measuring Plasticity of Phenolic Molding Compounds.*

Flash-type Cup Method. One of the methods used for determining the plasticity of phenolic molding powders was the use of a simple flash-type cup mold as shown in Fig. 3.26. The mold is placed in a hydraulic press equipped with electrically or steam-heated platens. The pressure is supplied preferably by an accumulator system. The procedure is to charge the powder to be tested into the mold cavity and record the time required for the mold to close completely. The mold is of the flash type so that excess material can be forced out of the mold at *A*. A large variety of molds could be used instead of the cup mold illustrated; a multiple-cavity cup or tube-base mold of the flash type is widely used. In this method the number of cavities which can be employed to obtain test pieces properly filled out as determined by measuring the thickness of flash area *A* is recorded as the plasticity of the molding powder. This method of recording plasticity denotes the flow as related to the pressure; and it should be noted that two different test materials could both properly fill the same number of cavities and still have different closing times.

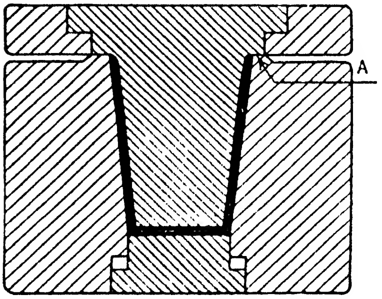

FIG. 3.26 — Flash-type cup mold.

Extrusion Mold Method. The powder charge is placed in mold cavity *A* (see Fig. 3.27), and pressure on the powder is exerted through force *B*. The plastic material flows through orifice *C*, and by measuring the extruded length at definite time intervals, the plasticity of the powder can be graphically represented as shown in Fig. 3.28. By studying plots of this type, it is possible to compare various types of molding powders by noting the following points; the time required for fluxing the powder, the rate of flow as indicated by the slope of the flow line, the over-all time for flow to cease which may be regarded to some extent as the curing rate of the powder, and the over-all extent of flow which may be termed its " fluidity " or " plasticity."

Olsen Bakelite Test Method. Figure 3.29 is a diagram of Tinius Olsen's Bakelite flow tester, as originally described by Peakes. The principle of the operation is the same as that for the extrusion method. The procedure is to place a preform or tablet of the molding powder on ram surface *A* and, by releasing stop *B*, permit the preform to be carried upward into mold cavity *C*. Weights *D* are the source of pressure which causes the plastic material to flow upward in the orifice of split cone *E*. The flow of the material forces follower rod *F* to move and record this movement on chart *G*. A clockwork causes the chart to move at a constant rate, and by combining these two motions, a curve of flow *vs.* time is produced.

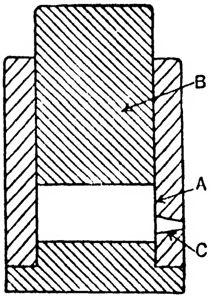

Fig. 3.27 — Extrusion-type mold.

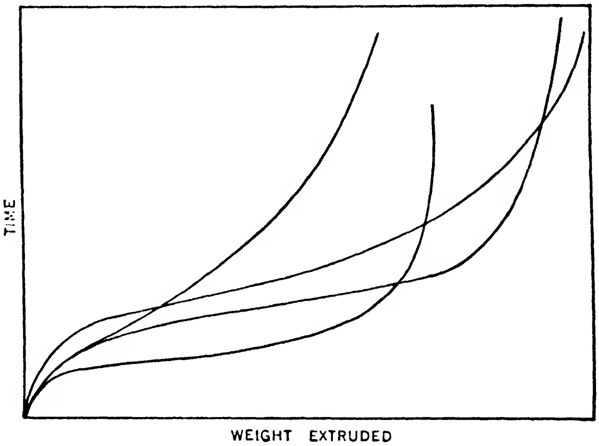

Fig. 3.28 — Typical flow curves for the extrusion mold.

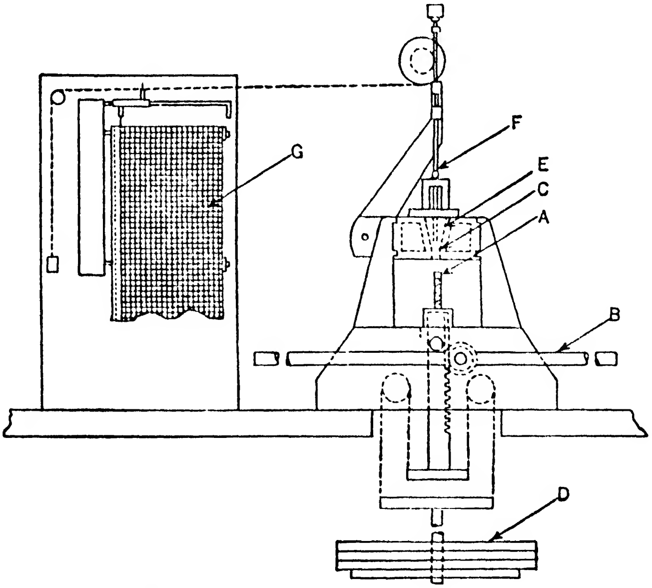

Fig. 3.29 — Bakelite flow tester of Tinius Olsen.

The Multicapillary Plasticity Die.[41] Figure 3.30 shows a cross-sectional view of a mold for determining the plasticity index.

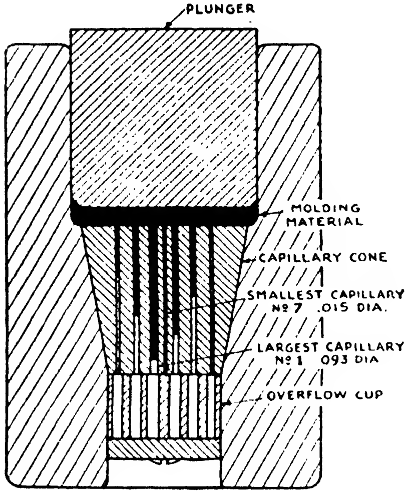

FIG. 3.30 — Mold for determining plasticity index.

Test conditions for the above apparatus:
Charge — 25 gm. Total pressure—4 tons
Ram speed — 30 in. per min.
Time — 5 min.

For *thermosetting* materials the technique for obtaining the test data is as follows: The die shall be heated under pressure between platens with sufficient temperature control to ensure that the die thermometer, at any time during a test, will not read lower than 295° F. nor higher than 305° F. The die is heated assembled except for the plunger which is placed, during the heating period, alongside the die on the lower platen, and in its normal position, that is, with its pressure face down. When a temperature of 300° F. is reached, the press is opened and 25 gm. of the powder under test is poured into the die. The plunger is then entered, the press closed immediately, and the total pressure on the plunger established at 4 tons ± ¼ ton. At the end of a 5-min. period, the press is opened, the mold removed to a bench, and the molded part removed.

The *plasticity index* is determined as follows: After breaking off with the fingers any unmolded powder on the tip, measure the length of each capillary-formed rod and estimate the length to the nearest 0.010 in. Then multiply the length of each rod by its number, the largest being No. 1 and the smallest No. 7. The sum of these products is the plasticity index. In the event that a very soft material is being tested and the larger capillaries overflow in their pots at the base of the capillary cone, weigh the amount of overflow, and, by comparison with the weight of 1 in. of the completed rod from that capillary, calculate the length of the overflow portion, adding this calculated length to the 2-in. rod remaining in the capillary.

For thermosetting materials each determination of the plasticity index shall be based on five moldings and these shall be exclusive of those preliminary runs necessary to remove packing grease, lubricating wax, or the effects of the previous material. Usually not more than three such runs are necessary, and frequently none, depending on the previous history of the mold.

For *thermoplastic* materials the determination of plasticity index is as follows: All conditions are the same as for the thermosetting materials except for temperature. Three or four determinations are made at various temperatures below that necessary to fill all the capillaries. Like the thermosetting materials the flow will come to a complete stop although in some materials there is small additional flow for the duration of the test. The test temperatures are preferably at 15° or 25° F. intervals. For example, for the soft acetates temperatures of 225° to 275° F. will suffice, for the hard acetates 250° to 325° F. At the end of the 5-min. period the die should, while still under

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[41] Bell Telephone Laboratories, Inc.

pressure, be cooled sufficiently to remove the piece. This generally requires a cooling of 50° to 75° F. below test temperature. Ordinarily a single determination, or at most two, will suffice for the thermoplastics at each temperature assuming the die is clean.

When several determinations have been made, a curve is drawn on rectangular paper plotting plasticity index as ordinates and temperature as abscissae. A horizontal line is drawn at the arbitrary plasticity value of 20 and the temperature at where it intercepts the curve is called the plasticity of that material.[42]

Although the index predicts with reasonable certainty the general moldability of materials, it is frequently useful to determine flow time for the engineering study of such influences as moisture content of the powder, grain size, formulation, etc. For this purpose it is satisfactory to mount a dial gauge between the two platens of the press. A stop watch is started at the instant the pressure of 4 tons is reached, and is stopped when the dial gauge comes to rest. This may be called, for convenience, the flow time. If a press can be equipped with a dial gauge, it is recommended that this feature be added.

For all thermosetting materials and for most thermoplastics the dial gauge comes to a complete stop. For some thermoplastics there is an additional minor flow following the initial stop. In these cases both the initial and the total flow times should be recorded.

Color Matching. There are no standard tests for color matching of plastics. In fact the field of color matching is highly controversial and each manufacturer has his own method. There are two general considerations to color matching, one involving the detection of minute differences between two or more consecutive runs of raw material with a view to correcting to a given standard, and the other the general matching of a given plastic to another material, usually textiles, painted surfaces, and the like.

The first problem belongs to the production color department of the manufacturer. The methods used are numerous. A very few companies use the highly technical Hardy recording spectrophotometer. Other companies resort to a visual inspection under actual daylight and couple this with daylight simulating lamps.

The second problem is still more difficult and confusing, and the ultimate decision rests with the customer. With materials having surfaces other than hard, smooth ones, color matching is difficult and the best compromise is to use daylight or a standardized lamp for color comparison.

The performance of color matching tests depends largely upon the source of light, if other than actual daylight is used. Even daylight varies widely and the standard referred to is a slightly overcast northern exposure.

In using artificial sources of daylight, the light should have a color and energy value similar to real daylight, and should be diffused uniformly over a large enough area so that the samples being inspected can be freely moved about.

There are several sources of artificial daylight. One unit incorporates the use of a tungsten lamp having a color temperature of 3000° K. (degrees Kelvin) coupled with a daylight filter which modifies the light temperature to 7400 to 7500° K. The Macbeth Daylighting Corp. of New York produces such units.

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[42] For control purposes, it is frequently sufficient to specify a definite testing temperature, and to give numerical limits within which the plasticity index must fall when the material is tested at that temperature.

High intensity carbon arcs are frequently used. The energy curve of such units incorporating sunshine carbons (National Carbon Co., Cleveland, Ohio) closely resembles that of daylight. Carbon arcs are objectionable due to flicker, high temperatures, short carbon life. To some extent these have been corrected in the newer three-phase lamps put out by National Carbon Co.

Carbon dioxide tubular lamps are also employed.

The latest addition to color matching lights is the daylight fluorescent lamp. If sufficient tubes are used to bring the illumination up to 60 to 80 foot-candles, these tubes give good color matching conditions.

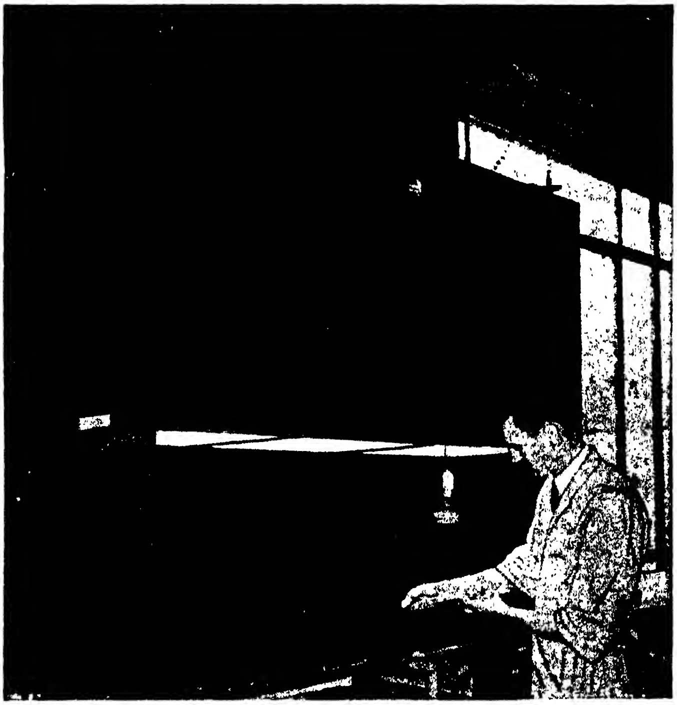


FIG. 3.31 — Color matching in the Ciba Laboratory using Macbeth equipment.

The problem of color matching of plastics is further complicated because many plastic components are not completely light-fast. To ensure uniformity of color from year to year, color standards must be carefully checked against master standards kept in light-fast cabinets. Some attempt has been made to use ceramic color standards for references, but in general, these are opaque and some difficulty has been encountered in using them.

An excellent bibliography on color and color matching can be found in the transactions of the Illuminating Engineering Society, Vol. XXXVI, No. 3, March, 1941.

Degree of Cure (Urea Plastics). Undercured urea plastics undergo hydrolysis or break down into their component parts if exposed to water and cure is measured by the degree of resistance to hydrolysis. To determine this a boiling water test is used as follows:

Boiling Water Test. This test is intended to determine the quality of ordinary, thin section (about 0.070 in.) urea moldings which will not encounter, in service, conditions requiring the best possible cure. Moldings are placed in boiling water for 15 min., and are sufficiently well cured if no chalking or whitening of the surface results. This test is simple but indicative and especially valuable as a comparative test in determining the minimum acceptable curing time at a given temperature for any urea molding.

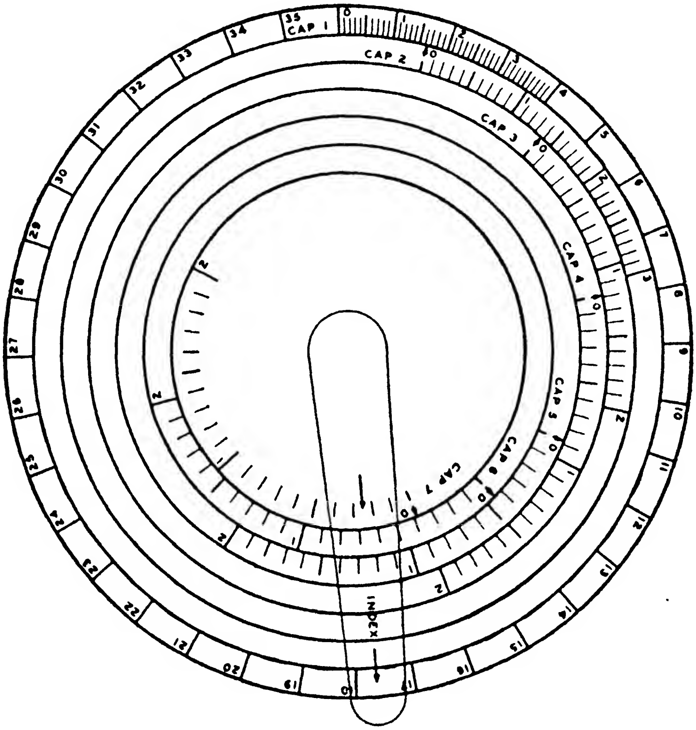


FIG. 3.32 – Type of slide rule used to determine light intensity at different angles.

Water Absorption Test. This quantitative test has been devised to determine the quality of thin section urea moldings, which for one reascn or another, must have the best possible cure. For example, castings which may be expected to be repeatedly in contact with moisture, pieces to be exposed to the elements, or moldings of the greatest possible strength are typical. In preforming this test, the casting is weighed, immersed in boiling water for 15 min., removed and immediately immersed in cold water for 5 min., and then wiped dry and weighed again. The permissible gain in weight is not more than 0.030 gm. per sq. in. of surface, and may be as low as 0.020 gm. per sq. in.

Interpretation of Boiling and Absorption Tests. It must be understood that boiling water causes urea to deteriorate to some degree regardless of the excellence of its cure. Hence the two tests described above should be regarded as comparative, and conclusions should be drawn immediately, rather than from the subsequent cracking of the test pieces on drying out. This is particularly true because the temperature and humidity

TABLE 13. COMPARISON OF SUNLIGHT WITH VARIOUS SOURCES OF ARTIFICIAL LIGHT

Light Source	Intensity—Microwatts/cm.^{2}—Arcs at 1 Meter Distance				Total
	Ultra-violet Not in Sunlight 2300–2900 Å	Ultra-violet in Sunlight 2900–4000 Å	Visible Light 4000–7000 Å	Infra-red 7000–120,000 Å	
1. Clinical sunlight	0	2350 2.5%	35,350 39%	52,900 58%	90600
2. Noon June sunlight — Ohio	0	2400 2.7%	39,700 44%	48,200 53%	90300
	Not in Sunlight Cut Off by Corex D	Wavelengths Present in Sunlight Passed by Corex D, CP			
White Flame Arcs					
3. 6 mm. H.I. W.F. — 40 amp., 25 v., a. c. physicians	25 0.3%	480 6.0%	2340 * (6200) 29.8%	4980 63.6%	7850
4. 3 Phase — 20 amp., 32 v.	30 0.36%	450 5.0%	3100 (7900) 37%	4740 57%	8320
5. 8 mm. M.P. studio 40 amp., 37.5 v., d.c.	35 0.36%	530 5.0%	3680 (9330) 38%	5525 67%	9740
6. ⅞"–½" 60 amp., 50 v., a.c.	125 0.67%	2195 12.0%	5090 27%	11,340 60%	18750
7. 6 mm. H.I. "C" 40 amp., 25 v., a.c.	170 2.3%	470 6.4%	615 8%	6005 83%	7260
Mercury Vapor Arcs					
8. 4.2 amp., 75 v., d.c. — best of lot	62 3.0%	193 10%	240 12%	1447 75%	1942
9. 4.25 amp., 170 v., a.c. — best of lot	163 4.0%	537 13%	458 12%	2732 69%	3980
				7000–17,100 Å	Total to 17,100 Å
10. G.E. Uviarc 3.75 amp., 75 v., d.c.	105 5%	238 12.2%	234 12%	1363 70.3%	1940

	Watts	*Total Radiation*	*40–7000 Å*	*C.P*
6 mm. H.I. W.F.	1.0	1.0	1.0	1.0
3-Phase	1.1	1.06	1.7	1.28
M.P. Studio	1.5	1.23	2.0	1.51

of the atmosphere and the rapidity with which the pieces dry out determine the severity of this subsequent cracking even more than does the degree of cure.

Test for Overcure or Burning (Urea Plastics). *Visual Test.* It is fortunately possible to detect an overcured molding merely by looking at it. Overcure of urea molding compound, either because of too high temperatures or too long a curing time (see Fig.

3.33) results in a burned condition. The resin itself opacifies, rendering the piece chalky and opaque in appearance, and of quite a different color from that of a well cured molding. When the piece is badly burned, blisters result. This condition presents none of the difficulties of undercure because it is so immediately apparent.

Closely related to overcure is the condition of precure, which results when fine powder, or the finer particles of granular material, burn before the mold is closed. The precured particles show up on the surface of the molding as small white spots, which are of course readily detected by the eye. Precure renders the piece valueless only if the appearance of the surface is spoiled; in other words, precure has no bearing on the physical excellence of the piece.

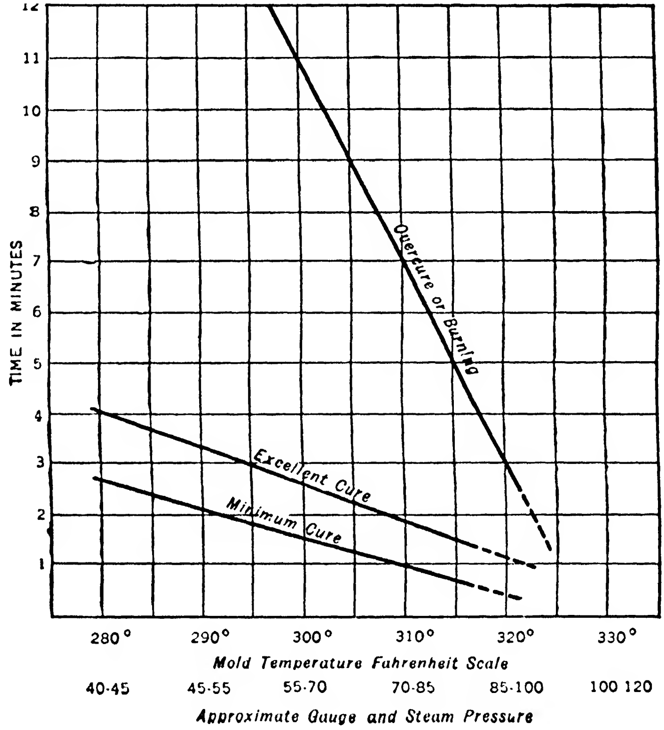


FIG. 3.33 — Cure rate of one urea standard medium compound.

Precure may be eliminated by lowering the temperature of the mold, or closing it more rapidly.

Permanence of Urea Plastics. Several tests are available for determining the permanence of urea plastics. Of all of these tests none surpass testing under actual performance. Accelerated tests are only a fair substitute and then only if coupled with a background of comparative experience.

Some tests used for determining permanence are a baking test, a cyclic test in low and high humidities, and performance in prolonged low humidities. Details of these tests follow:

Baking Test. In testing pieces of heavier cross section, such as door knobs, gear shift balls, thick rods and heavy handles, a baking test is used. Such pieces, if cured too quickly at excessive temperature, or if the mold is closed so rapidly as to allow no time for proper fusion of the material, may on the surface appear to be of excellent quality and yet be only case-hardened. A case-hardened molding consists of a core or layer of unfused or partially fused compound sandwiched in between perfectly cured surfaces.

Case-hardening almost invariable results ultimately in either surface crazing or cracking, and is sure to result in cracking when heavy grinding and buffing operations are required in finishing. Extreme conditions of case-hardening are easily detected by sawing the moldings into halves through the thickest cross section. Properly molded material is uniformly dense throughout the cross section; unfused or improperly fused material is easily detected by the naked eye.

A simple test which does not impair the value of good molds, and yet is more conclusive than the visual examination method, has been devised. The moldings to be tested are merely baked after the finishing operation, in a circulating air oven, at a temperature of 140° F. for from 16 to 24 hr. Pieces which resist this test may be regarded as entirely satisfactory. In fact, they are if anything improved in cure and may safely be used.

Incidentally, very heavy sections of more than 1 in. thickness are not generally advisable. Proper design usually eliminates the necessity for heavy sections, and naturally shows economy in use of material. Too, additional thickness of section over and above that necessary does not give by any means proportionate additional strength.

Inserts. The baking test is applicable and conclusive for moldings containing metal inserts, and should be interpreted precisely as outlined above for application to thick section moldings.

Cyclic Humidity Test. A more complicated comparative test more nearly simulating conditions of use has been devised to determine the resistance of urea moldings to aging. This accelerated test determines the suitability of the castings for service under either ordinary or severe conditions. Test moldings are alternately exposed at 100° F. to an atmosphere of approximately 0 per cent relative humidity for 24 hr., and then to approximately 100 per cent relative humidity for 24 hr., at the same temperature. The test piece is alternately exposed to the low and high humidity at constant temperature until incipient cracking occurs.

This test is comparative in nature and quite severe. Hence the results obtained from each group of moldings to which it is applied must be interpreted on the basis of previous experience rather than against any absolute yardstick. Thus a small button might withstand twelve cycles, while a large radio housing might fail after three cycles and still indicate that satisfactory service could be expected.

The cyclic humidity test requires equipment not usually available in molding establishments. This, plus the fact that results of the test are best interpreted in the light of as wide an experience as possible leads material producers to offer their services and the equipment of their laboratories in determining by this method the quality of any samples submitted.

The following table shows the results obtained on exposing typical urea moldings of varying degrees of cure from the same die to the cyclic humidity test. The results are given in terms of the number of complete cycles necessary to bring on noticeable incipient failure.

TABLE 14. CURE VERSUS RESISTANCE TO CRACKING OF UREA COLOR DISKS

Disks tested at 100° F. for alternate periods of 24 hr. each at 0 per cent relative humidity followed by 100 per cent relative humidity. Results reported as number of complete cycles to cause incipient failure.

Min. Cure	Number of cycles necessary to cause cracking		
	60 lb. steam, 295° F.	75 lb. steam, 305° F.	85 lb. steam, 318° F.
1	1	1	2
1½	1	2	5
2	2	5	6
3	4	6	7
4	—	7	7
5	6	—	6
6	—	—	6
7	7	6	—
8	—	6	—
9	7	—	—

Degree of Cure (Phenolic Plastics). The degree of cure of phenolics is closely related to the bond existent between the phenol and the formaldehyde. A test analagous to the hydrolysis cure test (boiling water test) for urea is the acetone extraction test, which test follows:

Test For Acetone Extraction (Phenolic Plastics)

A.S.T.M. D494–38T

Apparatus. (a) Sieves No. 40 and No. 140, cover and receiver pan.

(b) Extraction apparatus, either type shown in Fig. 3.34 recommended for electric hot plates, or Wiley-Richardson shown in Fig. 3.35 recommended for oil or steam baths. In either case, temperature or rate of extraction must be capable of accurate control.

(c) Drying dishes. Any light weight dish approximately 2½ in. in diameter by 1 to 1½ in. high.

Preparation of Sample.

(a) *Important.* In preparing sample, no heat must be introduced by the sampling equipment; otherwise a pre-cure may result. The smallest possible volume of sample shall be obtained for a unit weight of material. Shavings or particles from drilling, milling, filing, grinding may be used provided they are truly representative of the entire molding giving due consideration to thin and thick cross sections. The sample used shall pass a 40-mesh screen.

Procedure.

Extraction. 3000-gm. sample is weighed into a tared, open-texture, quantitative filter paper (No. 41H Whatman) 5 to 6 in. in diameter, or a standard single thickness extraction thimble approximately 3 by 1 in. Fold either filter paper or thimble so powder cannot float away. Keep samples in desiccator until ready to test.

Place weighed, prepared sample in the syphon and add 50 ml. of C. P. acetone. Start condenser water and adjust heat on syphon until it fills and empties fifteen to twenty times per hr. With this carefully controlled rate, extract for 4 hr. After syphon empties, pour contents into weighing dish, wash out flask into weighing dish three times with least possible amount of acetone.

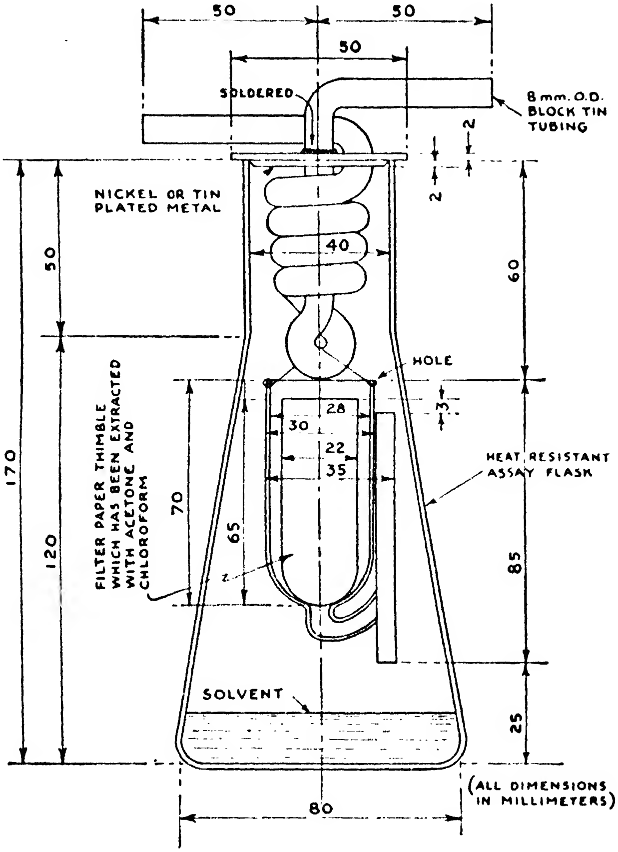


FIG. 3.34 — Acetone extraction apparatus.

Place weighing dish in a well ventilated drying chamber at 50° ± 2° C. (122° ± 3° F.). Dry to constant weight.

Report. Report percentage extractable matter for at least three samples using

$$\text{Acetone extractable water, per cent} = \frac{W - D}{S} \times 100$$

where W = wt. of dish and extract,
D = wt. of dish,
S = wt. of original sample.

Degree of Cure (Laminated Materials). The state of cure of a laminated material can be determined with some degree of success by a water-absorption test. This test is carried out by a standardized procedure using a piece of plate 1 by 3 by 1/16 in.

or ⅛ in. The samples are dried in an oven to remove volatile matter, subsequently placed in water in a controlled temperature bath for 24 to 48 hr., wiped dry and weighed. The increase in weight is a measure of the water absorbed and, to some extent, other things being equal, is a measure of the state of cure.

Still another method which has received some attention is the measurement of insulation resistance through the use of an instrument known as a megger. Specimens are used which have been conditioned by drying at elevated temperatures and then immersed in water at 50° C. (112° F). Conditioning is essential because "as received" material gives high values without regard to important factors, such as resin content. This method is of interest because it is directly related to electrical insulation properties.

Photoelastic Measurements. Transparent plastics are used for models from which measurement by photoplastic means indicates stress-strain concentrations in actual part. The simplest test method involves the use of a polarizer, an analyzer, and a source of light. The equipment is set up as shown in Fig. 3.36. Utilizing polaroid screens, large specimens can be viewed directly without resorting to the use of lens systems and expensive nicol prisms. For a more detailed discussion of photoelastic measurements, see: "Studies in Photoelastic Stress Determination," E. E. Weibel, *Trans. A.S.M.E.*, Vol. 56, 1934; "A Treatise on Photo-

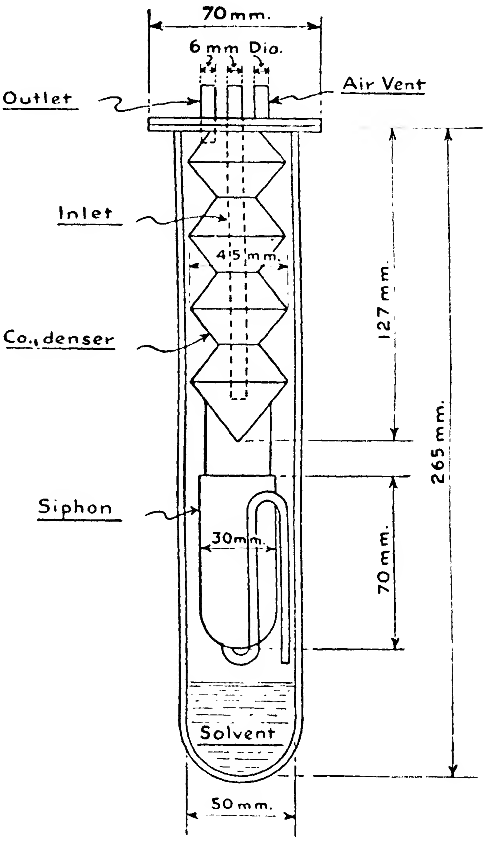


FIG. 3.35 — Acetone extraction apparatus.

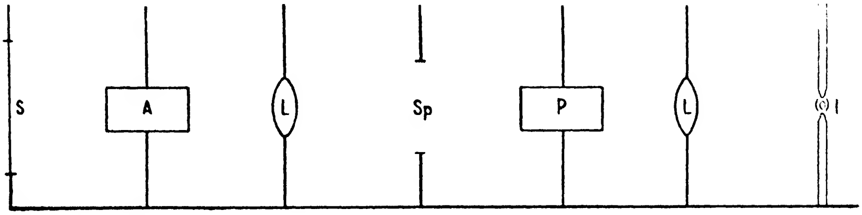


FIG. 3.36 — Photoelastic measurement equipment.

S — Screen
A — Analyzer
L — Specimen
Sp — Specimen
P — Polarizer
L — Light source

elasticity," E. G. Coker and L. N. G. Filon, Macmillan Co., 1931; and "Centrifugal Method of Testing Models," P. B. Bucky, A. G. Solakias, L. S. Baldwin, *Civil Engineering*, May, 1935.

Transparent Plastics — Surface Irregularities and Transparency. A variety of plastics, more particularly thermoplastics, are available in transparent form. Interest centers about the degree of transparency, also surface irregularities. The latter may cause objectionable image distortion. The test for surface irregularities follows:

Tentative Test

A.S.T.M. D637–41T

Apparatus. (a) A good quality lantern slide projector or its equivalent capable of throwing sharp images on a screen 25 ft. distant.

(b) A transparent slide on which have been ruled two very fine black lines at right angles at the center of slide.

(c) A 5 ft. sq. screen. On the screen is ruled a symmetrical cross of seven horizontal and perpendicular lines ½ in. apart.

Test Specimen. A flat sheet of commercial thickness.

Procedure. Test specimen is held in front of projector about 12 in. from lens. Specimen is moved so entire surface is surveyed by beam of light from projector. While moving specimen, screen is watched for any movement of projected cross. The maximum amount and nature of movement of image is noted. This displacement can be reported as a displacement factor, defined as the minimum movement in inches of the image of the cross divided by the displacement in feet from the projector to the screen times 1000.

Plywood Testings. A general trend toward the use of plastics for bonding plywood has called for new tests. Plywood glues for plastics can be classified into two general groups: first, the moisture resistant type which will withstand occasional subjection to thorough soaking in water; second, those which are completely unaffected by prolonged exposure to water.

The moisture resistant type, or general class, is usually tested by soaking 6 by 6 in. squares in water for 4 hr., followed by drying at 100° F. for 20 hr. This constitutes one cycle, which may be repeated any desired number of times depending upon the degree of moisture resistance desired. Failure is evidenced by delamination for more than 2 in. along the edges. Most of the glues used in this type of plywood are subject to attack by fungi and bacteria. Therefore, a test for resistance to fungus attack is usually made.

The Standard Fungus Test. Allow several porous bricks to become saturated with water in a crock, or similar vessel, and adjust the water level so that it is just below the top of the bricks. Place on top of the bricks, in alternate layers, strips of wood ⅛ in. thick by 1 in. wide and slabs of Irish potatoes ⅛ in. thick, to a total of 6 layers each. Maintain the culture at 32° ± 3° C. (90° ± 5° F.) in a dark compartment with free circulation of air, keeping water level constant. After 10 days, remove and rebuild the pile as follows:

Bottom layer	wood strips from first culture
Second layer	potatoes from first culture
Third layer	plywood shear specimen
Fourth layer	potatoes from first culture
Fifth layer	plywood shear specimen
Top layer	potatoes from first culture

Cover tops and sides of the pile with wood strips from the first culture and replace in the compartment, maintaining previous conditions. After 10 days remove plywood specimens and wash. Test for shear strength.

The waterproof types of plywood are usually tested by a slightly different procedure, calling for a more strenuous variation of the soaking test. The Forest Products Laboratory recommends the following:

Three-ply panels are cut in the conventional manner for shear tests (see Shear Tests). The test specimens are soaked in water at room temperature for 16 hr., followed by an 8-hr. bake at 145° F. This cycle is repeated two more times, followed by a 16-hr. soak. The specimens are then sheared while wet, and should show an average of at least 50 per cent failure in the wood. The Forest Products Laboratory does not say that a panel which passes the test will withstand exterior exposure for a specific number of years, but only that for all practical purposes it is satisfactory for use when exposed to exterior atmospheric conditions. It is likewise assumed that during such exposure the glue line may not be protected by paint, etc., on either the face or edge of the panel. A panel glued with an adhesive of low quality may show excellent weathering when so protected.

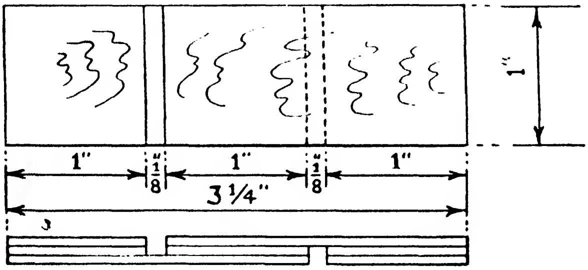


Fig. 3.37 — Shear test specimen.

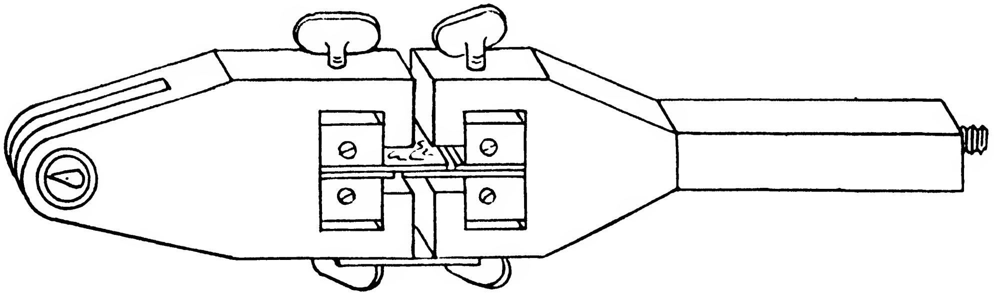


Fig. 3.38 — Shear test grips.

Shear Test. Shear strength tests are conducted on specimen as shown in Fig. 3.37. At least five specimens are tested. The ends of the specimens are gripped in jaws as shown in Fig. 3.38, and the load applied at the rate of 600 to 1000 lb. per min.

In conducting shear tests, the strength to break is not too significant as it depends upon the type of wood used. The per cent of wood failure is, however, a significant figure. In general a minimum of 30 per cent failure is allowed with an average of above 60 per cent wood failure as acceptable.

Specific Gravity of Asphalts and Tar Pitches.

Standard Test

A.S.T.M. D71–27

Scope. This method of test is intended for the determination of the specific gravity of asphalts and tar pitches sufficiently solid to be handled in fragments.

Specific Gravity. The specific gravity of asphalts and tar pitches shall be expressed as the ratio of the weight of a given volume of the material at 77° F. to that of an equal volume of water at the same temperature and shall be expressed thus: specific gravity, 77°/77° F.

Apparatus. The determination of specific gravity shall be made with an analytical balance equipped with a pan straddle or other stationary support.

Specimen. The test specimen shall be a cube of the material measuring approximately ½ in. to the edge. It shall be prepared by melting a small sample of the material by the gentle application of heat, care being exercised to prevent loss by evaporation, and pouring when sufficiently fluid into a ½ in. brass cubical mold, which has been amalgamated with mercury and which is placed on an amalgamated brass plate. Precautions should be taken to prevent the inclusion of air bubbles. The hot material should slightly more than fill the mold and when cool the excess may be cut off with a hot spatula. The specimen shall be removed from the mold when cooled to room temperature.

Procedure. The balance shall first be tared with a piece of fine waxed silk thread sufficiently long to reach from the hook on one of the pan supports to the straddle or rest. The test specimen shall then be attached to the thread, so as to be suspended about 1 in. above the straddle from the hook on the pan support, and weighed to the nearest 0.1 mg. This weight is called a. The specimen, still suspended by the thread, shall then be weighed, to the nearest 0.1 mg., completely immersed in freshly boiled distilled water at 77° ± 1.8° F.), adhering air bubbles being first removed with a fine wire. This weight is called b.

Calculations. The specific gravity of the material shall be calculated from the following formula:

$$\text{Sp. gr.} = \frac{a}{a - b}$$

Accuracy. The limit of accuracy of the test is ± 0.005 specific gravity.

EQUIPMENT FOR TESTING

A.S.T.M. D647–41T

Standard Molds for Molded Electrical Insulation Tests. To promote some semblance of uniformity of tests made on molded electrical insulation, certain types of dies are recommended. The molding procedure, however, is not specified but agreed upon between the parties interested. The molds referred to here are not necessarily intended for general plastics such as urea plastics, thermoplastics, etc., but are designed primarily for phenolics.

Test Specimen Mold — ½ by ½ by 5 in. Molds for ½ by ½ by 5 in. or ½ by ½ by 2½ in. test specimens may be either the single-bar, single-cavity positive mold shown in Fig. 3.39, or the five-bar, single-cavity mold shown in Fig. 3.40. Blueprints of detailed drawings, which are necessary to follow when building either of these molds, are available at a nominal cost from the American Society for Testing Materials, 260 So. Broad Street, Philadelphia, Pa.

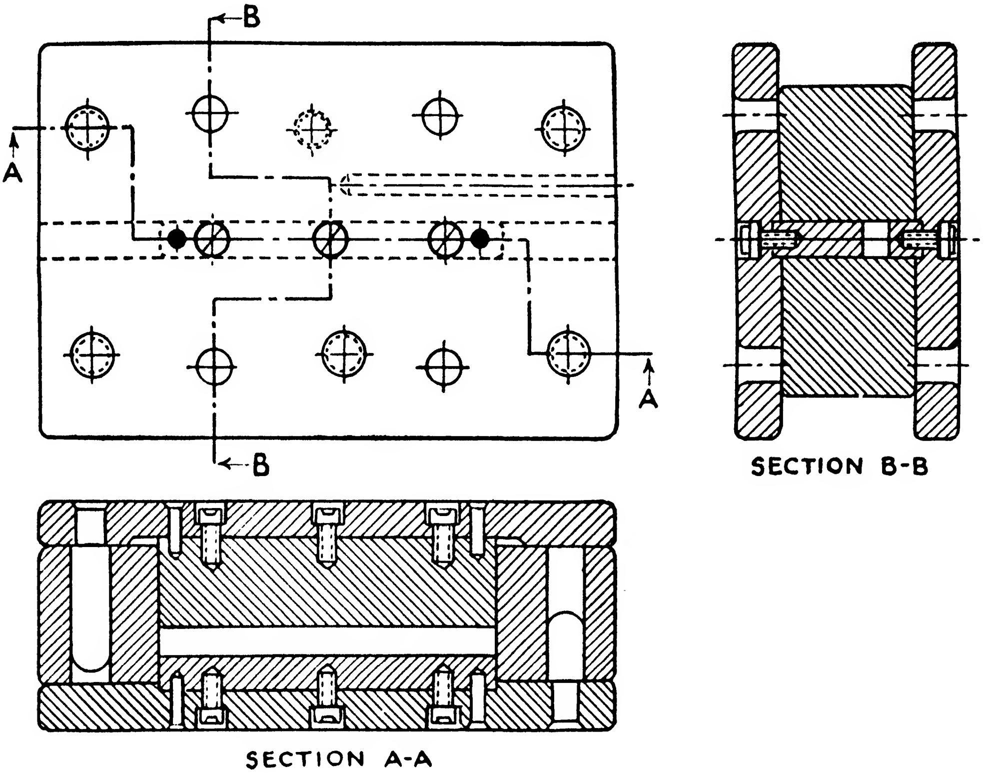


Fig. 3.39 — Single-bar, single-cavity positive mold for ½ in. by ½ in. by 5 in. test specimen. Molds for ½ in. x ½ in. x 5 in. or ½ in. x ½ in. x 2½ in. test specimens may be either the single-bar, single-cavity, positive mold shown in Fig. 3.39, or the five-bar, single-cavity mold shown in Fig. 3.40.

Disk Test Specimen Molds. Molds for 2- or 4-diameter disk test specimens may be of the design and dimensions respectively shown in Fig. 3.41.

Mold for Producing Tensile Test Bar. Three views of this mold are shown in Figs. 3.42, 3.43, and 3.44.

Testing Machines. An important part of the manufacture of plastics is the testing of the molded or cast pieces for impact strength, tensile strength, plasticity, and other qualities. The Tinius Olsen Testing Machine Co. and Baldwin-Southwark of Philadelphia make a number of testing machines which are either especially for the plastics industry or which are applicable to it. Much of this equipment has been used for some

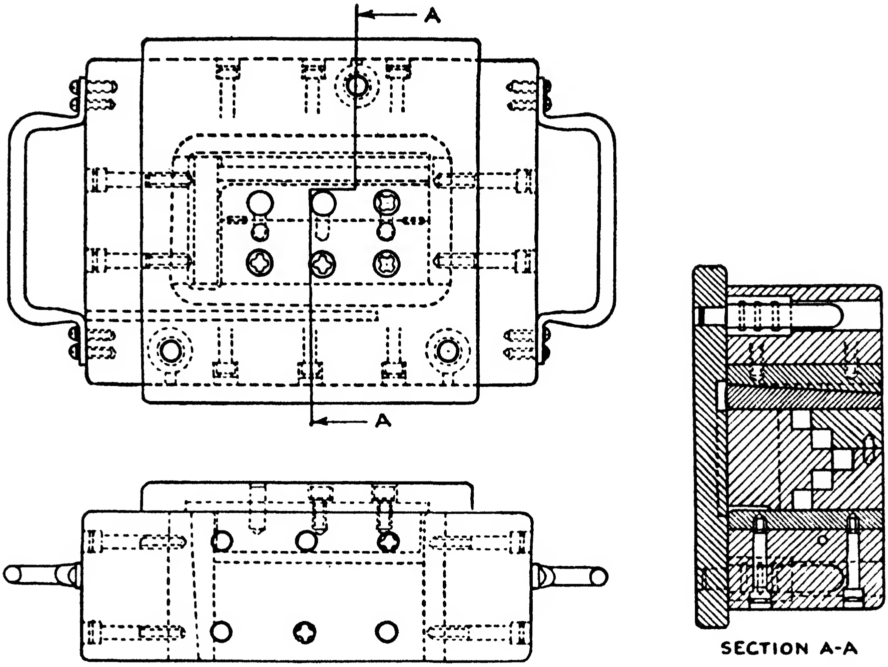


FIG. 3.40 — Five-bar, single-cavity positive mold for ½ in. by ½ in. by 5 in. test specimens.

MOLD FOR	K	L	M
2" DISC	5"	2.032	2.027
4" DISC	7"	4.032	4.027

NOTE: A TOP PLATE MAY BE ADDED IF THE MATERIAL TO BE HANDLED IN THE MOLD IS CONSIDERED TO REQUIRE BREATHING

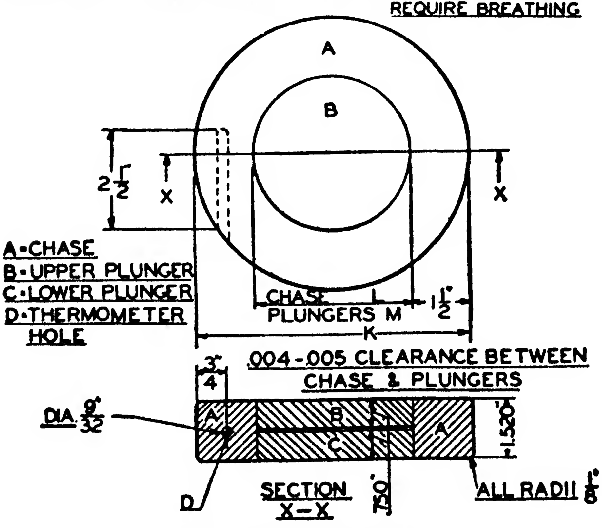


FIG. 3.41 — Disk test specimen mold.

years by various manufacturers and the most important machines are found to be those here listed with their uses and general description.

Universal Testing Machine. This machine can perform tension, compression, and flexure (transverse) tests. A self-indicating lever and pendulum weighing system indicates the load on the test piece and is accurate to ½ of 1 per cent. An autographic recording apparatus, for making a stress-strain curve of the material being tested, is furnished with the machine. The capacity is either 10,000 or 20,000 lb. and the weight of the machine about 1500 lb. The space between the screws is 15 in. and the clearances for test specimens are as follows: tension — 36 in.; compression — 15 in.; flexure — 12 in.

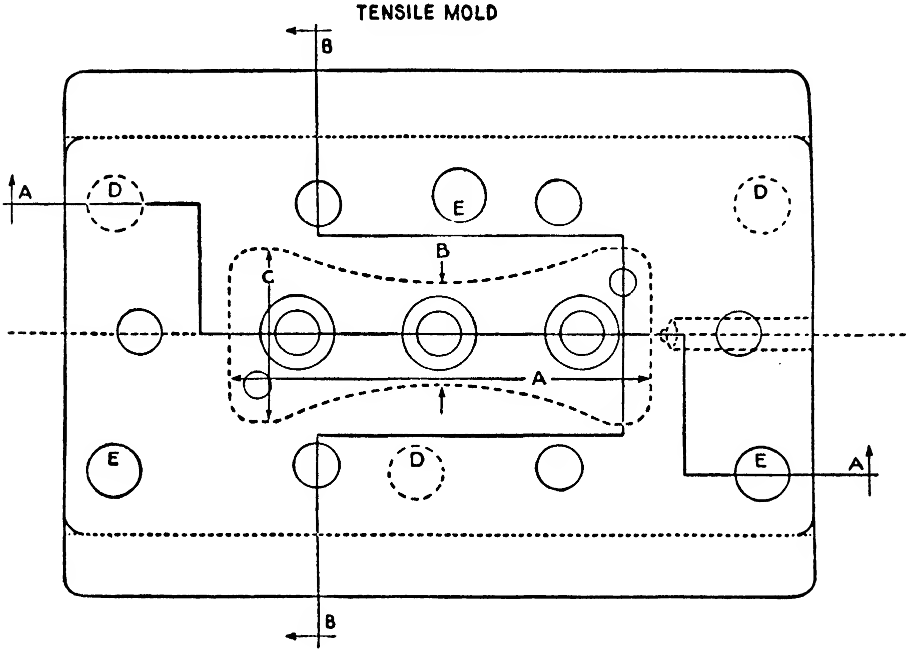


FIG. 3.42 — Mold for producing tensile test bar.

Stiffness Tester. This machine is made in 5 in.-lb. capacity for plastics sheets and rods, and in ½ in.-lb. capacity for thinner sheets and films. In operation, the strip or rod to be tested is clamped at one end and load applied at the other, or free, end. Load is supplied by a 110-volt a. c. motor and is applied at a steady rate, which is important in testing plastics. The maximum specimen width is 1 in. With this machine it is possible to test for comparative bending strength, cold flow, recovery, and to obtain a stress-strain diagram of load and resulting bend angle from 0° to 90°.

Charpy-Izod Impact Testing Machine. This machine, designed especially for indicating the impact strength of molded insulated materials in accordance with the standards of the A.S.T.M. is a sturdy, simple machine. Capacities of 25, 50, and 100 in.-lb. are available with either Charpy or Izod hammers or both. Operation is very simple, a falling hammer on a pendulum arm striking the firmly held test piece, and registering on a large carefully calibrated scale the force necessary for breaking the piece.

Distortion Testing Machine. This piece of equipment is designed to register the amount of distortion of a plastics material under heat. The specimen piece, ½ by ½ by 5 in. is placed on steel supports 4 in. apart with a load of 5.5 lb. applied vertically on top in the center of the piece. By use of a combination of air bath and oil bath plus rheostat control, the temperature can be raised gradually. A sensitive dial gauge then shows the deflection of the piece at the center. When the desired deflection is reached the machine automatically cuts off and a warning light flashes on. This machine is operated by a 110-volt motor and has a thermometer built in for indicating the temperature of the test piece.

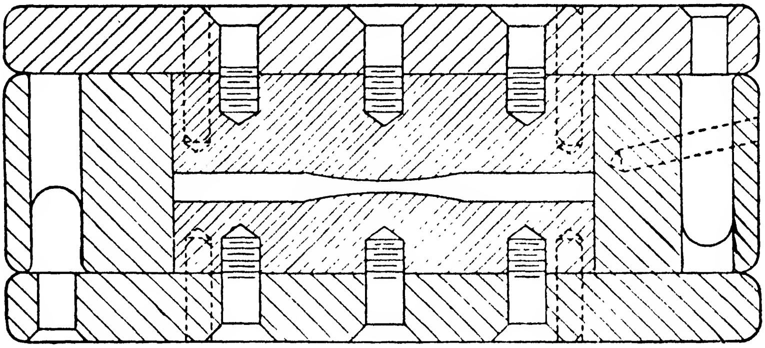


FIG. 3.43 — Tensile mold, longitudinal section.

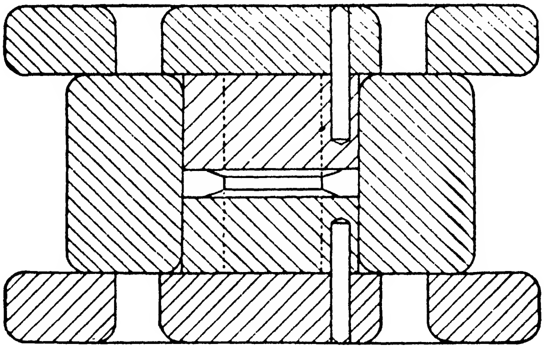
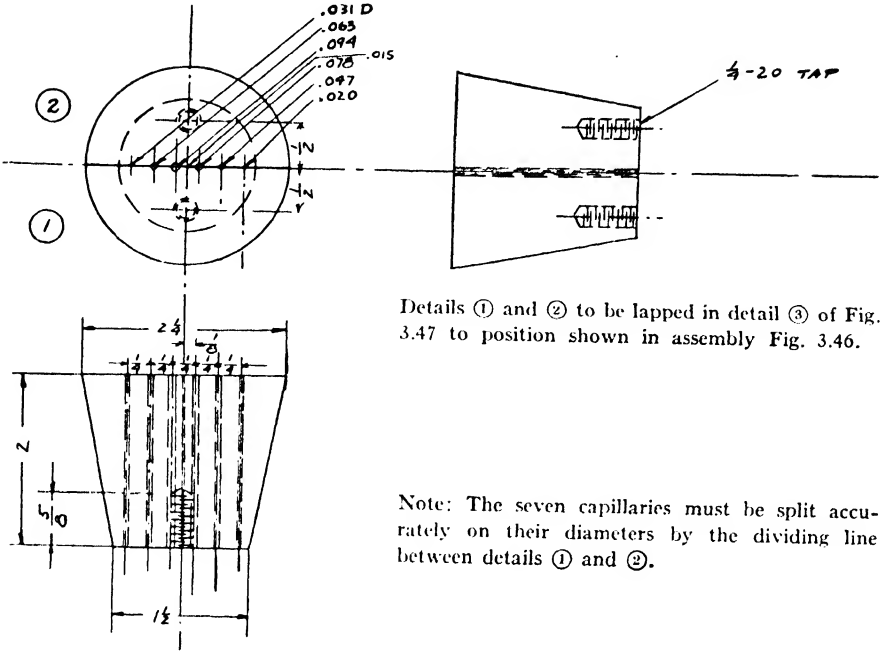


FIG. 3.44 — Tensile mold, cross section.

Flow Testing Machine. This is a machine designed and developed by engineers of the Bakelite Company as a means of indicating the plasticity of phenolic molding compounds. Originally intended for thermosetting plastics it has been found quite as useful for thermoplastics as well.

In operation, material is forced into a split cone orifice under pressure and heat. (Steam heat is used because of ease of control and because results may be calculated on steam pressure.) Load is applied by a steam-heated ram, weighed by a dead load to eliminate errors resulting from friction. An accompanying automatic recording device



Details ① and ② to be lapped in detail ③ of Fig. 3.47 to position shown in assembly Fig. 3.46.

Note: The seven capillaries must be split accurately on their diameters by the dividing line between details ① and ②.

Fig. 3.45 — Plasticity-cure time test mold. (Make of Ketos Steel, harden and grind.)

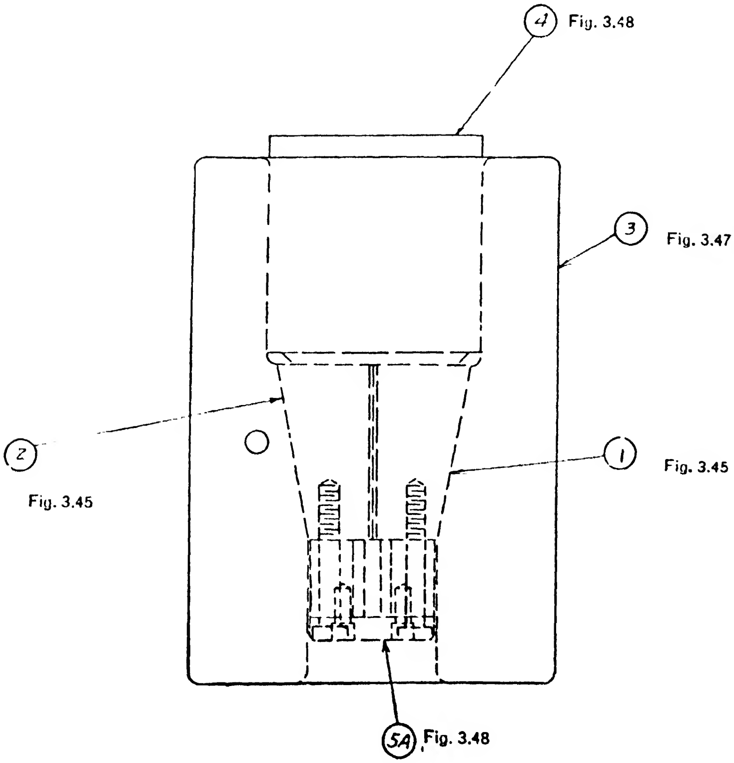


Fig. 3.46 — Plasticity-cure time test mold-assembly.

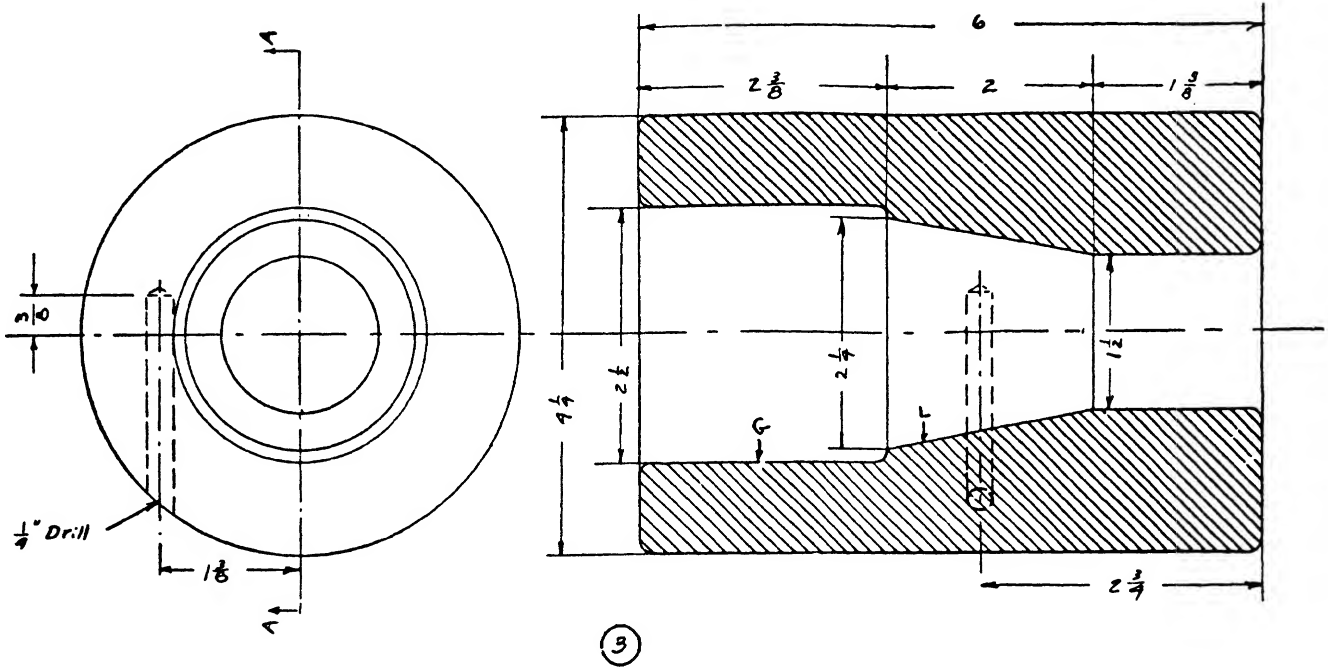


Fig. 3.47 — **Plasticity-cure time test mold.** *Section on AA:* surface marked *G* to be ground. Surface marked *L* to be ground and lapped to fit details ① and ② of Fig. 3.45. All fillets to be of ⅛ in. radii unless otherwise specified. (Make of Ketos Steel, harden and grind.)

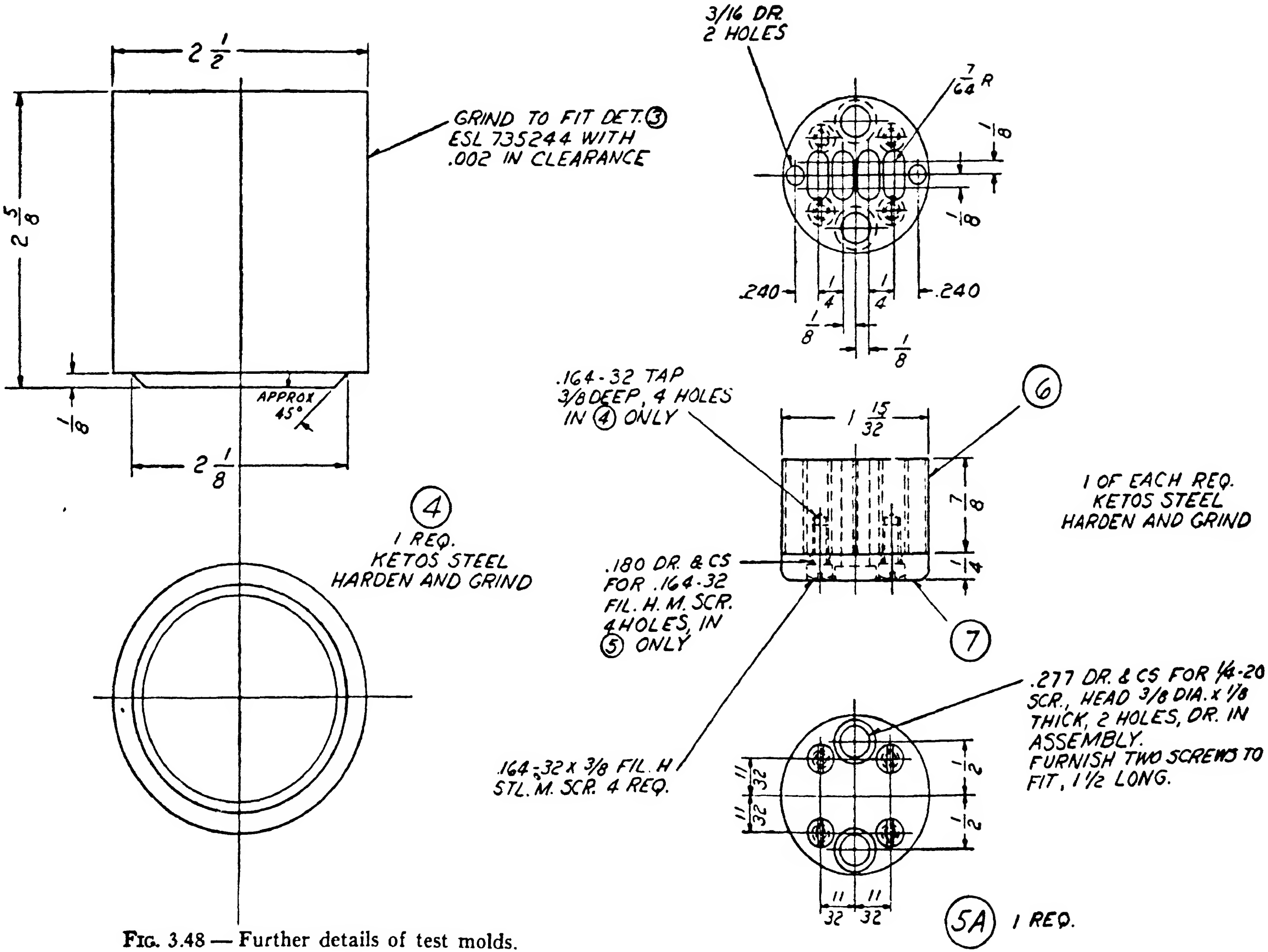


Fig. 3.48 — Further details of test molds.

plots the flow of the material against time. In this way plasticity of many materials may be tested under varying conditions of heat and pressure and an accurate permanent chart of behavior may be kept.

Other Equipment. Tinius Olsen also supplies accessory equipment for use with the Universal Testing Machine and in some cases supplies manufacturers with machines designed primarily for cement and plaster testing, but which have proved useful for plastics materials of certain types.

Brinell hardness testing of articles, plywood testers, and fatigue testers (for molded insulation and dentures) are also available.

The *Dynstat* (Testing Machine Inc.) is a small unit designed to measure the flexural and impact strengths of plastics, also their bending strength. It uses a small specimen, preferably from an actual molding.

The *Impact Testing Machine* (Baldwin-Southwark), complying with A.S.T.M. Standards, was developed especially for molded insulating materials and is used generally in the plastics field. It is best suited to the materials listed here with their strengths.

Hard rubber	0.12 to 0.35 ft.-lb.
Wood flour filled phenol plastics	0.1 to 0.15 ft.-lb.
Cotton flock filled phenol plastics	0.2 to 0.3 ft.-lb.
Phenol fiber — edgewise	0.2 to 0.3 ft.-lb.
Phenol fiber — flatwise	1.0 to 1.2 ft.-lb.
Phenol fabric	1.2 to 1.9 ft.-lb.

The pendulum is made in one piece of welded, streamlined duralumin tubing. Brass weights are attached to the bottom of the head for correct balancing. A chromium-plated scale and an improved release mechanism are also provided.

TABLE 15. CONSTANTS OF IMPACT MACHINE

Length of pendulum	13 in.
Initial elevation of pendulum	24 in.
Effective weight of pendulum	1.0 lb.
Capacity of machine	2000 ft.-lb.
Distance — center of axis to center of percussion	13.010 in.
Accuracy (approx.)	0.001 ft.-lb.

TABLE 16. PHYSICAL TESTS BY THE AMERICAN SOCIETY FOR TESTING MATERIALS

D 392–38	Testing Molding Powders Used in Manufacturing Molded Electrical Insulators
D 348–39	Testing Laminated Tubes Used in Electrical Insulation
D 349–39	Testing Laminated Round Rods Used in Electrical Insulation
D 229–39	Testing Sheet and Plate Materials Used in Electrical Insulation
D 494–38 T	Acetone Extraction of Phenolic Molded or Laminated Products
D 551–39 T	Measuring Shrinkage from Mold Dimensions of Molded Materials Used for Electrical Insulation
D 467–37 T	Phenolic Laminated Sheet for Radio Applications
D 495–38 T	Arc Resistance of Solid Electrical Insulating Materials
D 149–39 T	Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
D 325–31 T	Comparing Thermal Conductivities of Solid Electrical Insulating Materials
D 542–40 T	Index of Refraction of Transparent Organic Plastics
D 570–40 T	Water Absorption of Plastics

TABLE 16. PHYSICAL TESTS BY THE AMERICAN SOCIETY FOR TESTING MATERIALS (*Continued*)

D 618–41 T	Preconditioning Plastics and Electrical Insulating Materials for Testing
D 48–41 T	Testing Molded Materials Used for Electrical Insulation
D 649–41 T	Compressive Strength of Electrical Insulating Materials
D 648–41 T	Distortion under Heat of Molded Electrical Insulating Materials
D 650–41 T	Flexural Strength of Electrical Insulating Materials
D 256–41 T	Impact Resistance of Plastics and Electrical Insulating Materials
D 651–41 T	Tensile Strength of Electrical Insulating Materials
D 616–41 T	Round Phenolic Laminated Tubing for Radio Applications
D 634–41 T	Product Uniformity of Phenolic Laminated Sheets
D 617–41 T	Punching Quality of Phenolic Laminated Sheets
D 374–41 T	Thickness of Solid Electrical Insulation
D 150–41 T	Power Factor and Dielectric Constant of Electrical Insulating Materials
D 620–41 T	Color Fastness of Plastics to Light
D 636–41 T	Diffusion of Light by Plastics
D 621–41 T	Deformation of Plastics under Load at Elevated Temperatures
D 568–41 T	Flammability of Plastics 0.050 in. and under in Thickness
D 645–41 T	Flammability of Plastics over 0.050 in. in Thickness
D 569–41 T	Measuring Flow Temperatures of Thermoplastic Molding Materials
D 543–41 T	Resistance of Plastics to Chemical Reagents
D 637–41 T	Surface Irregularities of Flat Transparent Plastic Sheet
D 638–41 T	Tension Testing of Plastics

NOTE.—A section describing the influence of temperature on the mechanical properties of molded phenolic materials is to be found elsewhere. See index. In this are data showing the variation of the impact, flexural, and tensile strengths with temperature given for molded phenolic compositions containing wood flour, asbestos, macerated fabric, and cord fillers and for a pure resin composition. Impact values between −80° and 250° C. (−112° and 480° F.), flexural values between +80° and 180° C. (+112° and 355° F.) and tensile values between −80° and 230° C. (−112° and 445° F.) are presented. The practical importance of these data are discussed.

CHAPTER IV

PLASTICS CATALOGUES

This chapter contains a group of condensed commercial catalogues of the leading manufacturers of molding powders and synthetic resins. It is included for reference purposes and is almost wholly in the words of the manufacturers themselves. Statements and claims are in general conservative but the reader should keep in mind that they are not the statements and claims of the authors of this book. Where different manufacturers describe the same type of plastic there is unavoidable duplication. To minimize this, arbitrary cuts have been made in some catalogue material. Accordingly the length at which a trade-marked product is discussed bears no relation to the prominence of the product or of the company.

ACRYLIC RESINS

Acryloid[1]

A solution of acrylic resin in organic solvents, Acryloid is clear or pigmented, may be applied with brush or spray gun and may have an air drying or baking finish.

It is used as an adhesive for tough, flexible bond between rubber, glass, wood, metal, and fabric, is especially useful where a transparent joint is required, and is not appreciably affected by weathering or flexing.

Maximum temperature without discoloration is 350° F.

Unaffected by: petroleum, mineral oil, gasoline, greases, salt, photographic solutions. The harder types resist continued boiling water.

Acrysol[2]

Acrysol is an aqueous emulsion of acrylic resin used as adhesive and for coatings that are permanent and flexible and have excellent resistance to chemical reagents.

Its properties are similar to Acryloid.

Crystalite[3]

Crystalite, acrylic resin (methyl methacrylate) thermoplastic molding powder, is available in colors and in a number of forms for compression or injection molding. It is colorless (unless pigmented), weather resistant, shatter resistant, odorless, tasteless.

Unaffected by: water, all concentrations of hydrochloric acid, salt solutions, mineral oil, or animal oils, 50 per cent sodium hydroxide or 50 per cent sulfuric acid at room temperature.

[1,2,3] Rõhm and Haas Company.

Insoluble in: paraffinic and olefinic hydrocarbons, ethers, amines, alkyl monohalides, esters containing more than 10 carbon atoms, formamide.

Soluble in: ketones, lower esters, aromatic hydrocarbons, phenols, aryl propylene dichloride, tetrachloroethylene.

Uses: inspection windows, safety goggle lenses, pen points, pipe bits, gauge glasses, cosmetic containers, jewels, dolls' eyes, trumpet mouthpieces, decorative items, radiator ornaments for automobiles, edge-lighted radio dials, clock dials, speedometer dials, reflector buttons for signs and highway markers, brush backs, dishes, sign letters, boxes, hair-dryer parts (some weigh more than 1 lb. 10 oz., molded by compression).

In general, Crystalite requires slightly higher molding temperatures and pressures than the more familiar cellulose acetate powders, and in injection molding slightly thicker sprues and wider gates.

For injection molding, Crystalite is supplied in the form of granules approximately 5/16 in. in the largest dimension and in a number of stock colors. Compression molders purchase clear Crystalite in the form of fine beads approximately 20- to 60-mesh. Compression Crystalite is also sold in a number of stock colors in 3/32 in. granulation.

For both types of molding, several standard formulas are available offering sufficient variation in properties for all but the most unusual moldings. Plasticizers, which often contribute to the discoloration of other plastics, are not needed to give good molding characteristics to Crystalite. Instead, the proportions of softer or harder acrylic resins may be changed to give improved flow characteristics, higher heat resistance, or other desirable properties.

COMPRESSION MOLDING POWDERS (CRYSTALITE)

Constants (at 30° C.)

Form: Beads
Specific Volume, cu. in. per lb.: 40 to 46
Compression Ratio: 1.7 to 2.0
Apparent Density, gm. per cc.: 0.6 to 0.7
Molding Temperatures, ° F.: 300 to 360
Molding Pressures, lb. per sq. in.: 2000 to 4000

The Molded Material

Specific Gravity: 1.19
Specific Volume, cu. in. per lb.: 23.2
Specific Heat, cal. per ° C. per gm.: 0.4
Mold Shrinkage (cold mold to cold piece), in. per in.: 0.001 to 0.005
Shrinkage after Molding (30 days at 140° F.), in. per in.: 0.001 to 0.006
Thermal Expansion, per ° C.: 8×10^{-5}
Tensile Strength, lb. per sq. in.: 4000 to 6000
Flexural Strength, lb. per sq. in.: 9000 to 12,000
Impact Strength (Charpy Unnotched ½ by ½ in. Bar), ft.-lb.: 1.0 to 2.0
Compressive Strength, lb. per sq. in.: 10,000 to 15,000
Heat Distortion Temperature (A.S.T.M. D48–37), ° F.: 125 to 165
Water Absorption, total immersion 48 hr., % by wt.: 0.4 to 0.5
Room Temperature, equilibrium, % by wt.: 1.4 to 1.7
Burning Rate: Slow
Machining Properties: Excellent
Light Transmission, %: 90 to 92
Refractive Index: 1.49
Dielectric Strength, volts per mil: 500
Dielectric Constant, 60 cycle: 3.0 to 3.1
1000 cycle: 3.3 to 3.5
Power Factor, 60 cycle, %: 6.0 to 6.5
1000 cycle, %: 6.0 to 6.5
Maximum Service Temperature, ° F.: 100 to 140

INJECTION MOLDING POWDERS (CRYSTALITE)

Constants (at 30° C.)

Form: Beads or Granules
Specific Volume, cu. in. per lb.: 31 to 37
Compression Ratio: 2 to 2.4
Apparent Density, gm. per cc.: 0.5 to 0.6
Molding Temperatures, ° F.: 325 to 450
Molding Pressures: Medium to High

The Molded Material

Specific Gravity: 1.18
Specific Volume, cu. in. per lb.: 23.5
Specific Heat, cal. per ° C. per gm.: 0.4
Mold Shrinkage (cold mold to cold piece), in. per in.: 0.004 to 0.006
Shrinkage after Molding, in. per in. (30 days at 140° F.): 0.006 to 0.015
Flexural Strength, lb. per sq. in.: 10,000 to 11,000
Impact Strength, ft.-lb. (Charpy Unnotched ½ by ½ in. Bar): 3 to 4
Heat Distortion Temperature, ° F. (A.S.T.M. D48–37): 125 to 140
Water Absorption, Total Immersion 48 hr., % by wt.: 0.3 to 0.4
Room Temperature, equilibrium. % by wt.: 1.4 to 1.5
Burning Rate: Slow
Machining Properties: Excellent
Light Transmission, %: 90 to 92
Refractive Index: 1.49
Dielectric Strength, volts per mil.: 500
Maximum Service Temperature, ° F.: 120 to 140

Crystolex[4]

Crystolex, an acrylic resin mix for dentures and prosthetic devices, is available in transparent and mottled gum-pink colors.

It is colorless (unless pigmented), strong, color-fast, odorless, tasteless, resistant to mouth acids, and can be molded accurately in plaster mold at 170° F. and at low pressure. It holds its shape indefinitely when properly molded and is completely compatible with mouth tissue.

Uses: Dentures and prosthetic devices.

Plexigum[5]

Plexigum, a viscous solution of acrylic resins in ethylene dichloride, is colorless, weather-resistant and hazefree, has excellent adhesive properties and is unaffected by water, all concentrations of hydrochloric acid, sal solutions, mineral oil, animal oils, or by 50 per cent sodium hydroxide or 50 per cent sulfuric acid at room temperature.

Insoluble in: paraffinic and olefinic hydrocarbons, ethers, amines, alkyl monhalides, esters containing more than 10 carbon atoms, formamide.

Soluble in: ketones, lower esters, aromatic hydrocarbons, phenols, aryl halides, aliphatic acids, chlorohydrins, acetals, chloroform, ethylene, dichloride, propylene dichloride, tetrachloroethylene.

Constants (at 30° C.)

Light Transmission, % (4500–8000 Å.): 92
Index of Refraction: 1.48
Viscosity, sec. (500 gm. wt. 10 rev., Stormer Viscosimeter): 23 to 25

Use: laminating layer for safety glass.

Vernonite[6]

Acrylic resin mix for dentures and prosthetic devices. Colors and properties similar to Crystolex.

[4,5,6] Röhm and Haas Company.

METHYL METHACRYLATE RESINS

Lucite[7]

Lucite is E. I. du Pont de Nemours & Company's registered trade-mark for methyl methacrylate resin.

Polymethyl methacrylate is the resinous polymer of the mobile liquid monomeric methyl methacrylate. This plastic is furnished in the form of sheets, rods, tubes and molding powders.

Cast Sheets meet United States Government Specifications. This means that they are acceptable for transparent airplane enclosures and, therefore, have met requirements far more stringent than those for most commercial uses. The sheets are provided in various thicknesses from 0.060 to 0.250 in. in standard dimensions of

20 in. by 50 in.
28 in. by 54 in.
36 in. by 48 in.
24 in. by 36 in.
36 in. by 36 in.
25 in. by 45 in.
40 in. by 50 in.
28 in. by 30 in.
28 in. by 41 in.
23 in. by 41 in.
30 in. by 30 in.
30 in. by 47 in.
35 in. by 36 in.

and in thicknesses of 0.375 and 0.500 in. in standard sheets of

24 in. by 36 in.
35 in. by 36 in.
20 in. by 50 in.
36 in. by 48 in.

Rectangular sheets of other dimensions up to 45 in. by 65 in. and 50 in. by 80 in. can also be made in thicknesses from 0.100 to 0.250 in. on special order.

Molded Sheets are formed from Lucite molding powder in standard surface dimensions of 20 in. by 25 in. Thicknesses range from ⅛ in. by 2 in.

Round Rods are produced with an unpolished surface in diameters ranging from ¼ in. to 2 in. Rods are supplied up to 48 in. in length. They are also provided with a high surface polish at a slightly greater price.

Square Rods with polished surfaces are made in standard lengths of 25 in. The cross-sectional dimensions available range from ½ in. to 3 in. in steps of ½ in.

Tubes with polished inside surfaces are manufactured in diameters ranging from 1½ in. to 6 in. and in various wall thicknesses. Full length tubes are 52½ in. long. As with round rods, a small charge is added for providing a high outside surface polish.

Blocks and Massive Castings are made up on special order. Blocks are provided in sizes up to 17 in. by 25 in. and in thicknesses above ½ in. with a tolerance on caliper of ± 10 per cent. The surface of blocks is unpolished unless specially ordered. Massive castings of cylindrical shape are manufactured in finished dimensions up to 9 in. in diameter by 9½ in. high. These can be provided either in the rough form or turned and polished.

Constants.

Softening Temperature (cast resin): 80° to 110° C.
(molded resin): 65° to 85° C.
Specific Heat: 0.45
Tensile Strength (lb. per sq. in.): $7\text{–}10 \times 10^3$
Elongation at Rupture (%): 1–5
Modulus of Elasticity (lb. per sq. in.): $5\text{–}6 \times 10^5$

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[7] E. I. du Pont.

Constants — *Continued*

Modulus of Rupture (lb. per sq. in.): 14,000–17,000

Impact Strength, Charpy, Notched Specimens (ft.-lb. per in. of notch): 0.2–0.4

Volume Resistivity, at 30° C. (ohm-cm.) greater than: 10^{15}

Breakdown Voltage, 60 cycles: 450

Dielectric Constant, 60 cycles: 3.6–3.9

Dielectric Constant, 1 megacycle: 2.7–2.8

Power Factor, 60 cycles, %: 6–7

Power Factor, at 1 megacycle, %: 1–1.5

Water Absorption, 24 hr. at 25° C., %: 0.4–0.5

EFFECTS OF SOLVENTS AND CHEMICALS

Good resistance to: weak acids, strong acids, weak alkalis, strong alkalis, alcohols, aliphatic hydrocarbons, mineral oils, animal oils, vegetable oils.

Poor resistance to: ketones, esters, aromatic hydrocarbons.

Typical applications include: airplane cockpit enclosures and cowlings, display fixtures, dentures (registered trade-mark " Lucitone "), illuminated medical and dental instruments, costume jewelry, industrial instruments, exterior and interior automobile fittings, furniture, reflectors, magnifiers, lenses, transparent containers, illuminated signs.

Plexiglas[8]

(*Methyl Methacrylate*)

Plexiglas is a thermoplastic cast acrylic resin (methyl methacrylate) available in range of clear colors, translucent colors and tints, and in sheet sizes up to 45 in. by 65 in. and thicknesses up to 2½ in. It is colorless (unless pigmented), weather resistant, shatter resistant, odorless and tasteless and can be sawed, planed, drilled, or machined like wood or any soft metal. When heated, it can be bent to any curve.

Unaffected by: water, all concentrations of hydrochloric acid, salt solutions, mineral oil, or animal oils, or by 50 per cent sodium hydroxide or 50 per cent sulfuric acid at room temperature.

Insoluble in: paraffinic and olefinic hydrocarbons, ethers, amines, alkyl monohalides, esters containing more than 10 carbon atoms, and formamide.

Soluble in: ketones, lower esters, aromatic hydrocarbons, phenols, aryl halides, aliphatic acids, chlorohydrins, acetals, chloroform, ethylene dichloride, propylene dichloride, tetrachloroethylene.

Uses: transparent sections in aircraft and boats, medical instruments (conducting light to field of operation), furniture, edge-lighted signs, displays and display fixtures, shatter-resistant inspection windows, gauge glasses, transparent exhibition models, testing models, lighting fixtures, jewelry, tableware, safety goggles, unbreakable spectacles, ultra-violet windows.

Constants (at 30° C.)

Light Transmission, %: 91 to 92

Ultra-violet Light Transmission, % down to 350 microns: 90

Refractive Index N_D: 1.488 to 1.489

Dispersion: 0.008

Specific Gravity: 1.18 to 1.19

Hardness Mohs: 2 to 3.

Vickers: 18 to 20

Brinell (500-kg.–10-mm. ball.): 18 to 20

Tensile Strength, lb. per sq. in.: 7000 to 8000

(Elongation of Failure), %: 5 to 15

Flexural Strength, lb. per sq. in.: 14,000 to 16,000

Compressive Strength, lb. per sq. in.: 10,000 to 12,000

Impact Resistance (A.S.T.M. Charpy-Notched Bar), ft.-lb.: 0.3 to 0.5

Modulus of Elasticity, lb. per sq. in.: $4–6 \times 10^5$

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[8] Röhm and Haas Company.

Constants (at 30° C.) — *Continued*

Coefficient of Expansion, ° C.: 8×10^{-5}

Water Absorption by Weight, 24 hr., %: 0.3

48 hr., %: 0.4

500 hr., % (Equilibrium): 1.2

Dielectric Constant, 60 cycles: 3.4 to 3.6

Power Factor, %: 5 to 6

Volume Resistance, ohms. per cm.^{3}: 10^{15}

Dielectric Strength, volts per mil: 500

Scattering Effect: Practically nil

CASEIN

Ameroid

Compression molding of casein powder is still used for buttons and similar items, but some manufacturers are now working directly from the plasticized casein to the finished article. Although injection molding has been used it is not surely a commercially practical method.

The American Plastics Corporation sells its Ameroid (casein) in sheets, rods, disks and other semi-finished forms, which are fabricated into buttons and other articles. This is at present the largest outlay for the material.

Casein plastics can be sawed, drilled, tapped, sanded, ground, polished, slotted, threaded, turned, and in general worked much as horn, bone, brass, rubber, etc. It may be sawed with either a jigsaw, bandsaw, hacksaw, circular saw, or silicon carbide abrasive disk. The abrasive disk when flushed with water gives very satisfactory results.

Drilling may be done with carbon or high-speed twist drills. The drills should have ample clearance and on deep holes the drills should be withdrawn several times in the course of the drilling to avoid overheating and splitting.

Casein plastic rods may be readily turned on hand or automatic screw machines. For turning and milling treat the material about the same as brass.

Punching or blanking may be done by softening the material in hot water or hot oil. The time required for softening depends upon the thickness of the stock. In the case of sheet stock, about 24 hr. per millimeter thickness in room temperature water. Punching is done with a sharp-edged die similar to leather punches. The die should be about 10 per cent oversize as the material expands and the subsequent shrinkage will result in undersize pieces unless the die is oversize.

Grinding: Done with abrasive wheels.

Polishing: In hand polishing or for small quantities, this is usually done by buffing first with wet pumice and then polishing on a clean dry buff with polishing wax. In quantity production the polishing is done in tumbling barrels or with preparations especially prepared for casein plastics with a final polishing being done chemically. This is done with a hypochloride solution which imparts a glaze to the casein plastic articles. When they are dried by warm air they have a high luster.

Dycing: Casein plastics may be dyed with aniline dyes.

CAST PHENOL–FORMALDEHYDE RESIN

Bakelite[9]

Bakelite Cast Resins are pure resins having the consistency of molasses. They are poured into open molds by gravity and *cast* at atmospheric pressure rather than the higher pressures required by moldable plastics. The molds required for casting are

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[9] **Bakelite Corporation.**

inexpensive as compared with molds employed for injection and compression molded products.

Bakelite cast resins are supplied in castings made to special order, and are also furnished in sheet, tube, and rod form, in transparent, translucent, opaque, and variegated colors. Castings are readily machined on ordinary metal-working equipment, and in some instances can be worked like wood. Standard tools, such as lathes, drills, saws, and polishing buffs, are used for finishing the material.

For general utility applications, Bakelite cast resins are available in many stock forms in various sizes, thicknesses, and shapes requiring a minimum amount of finishing and assembling. The exceptional richness and depth of color of cast resins make them particularly suitable for such applications as radio cabinets, cutlery handles, knobs and fittings, brush backs, buttons and buckles, costume jewelry, containers and displayers.

Other types of Bakelite cast resins are available for more highly specialized service. Transparent *chemical-resistant* cast resins are fashioned into laboratory ware, providing the only satisfactory containers and utensils for hydrofluoric acid. *Photoelastic* cast resins have been developed for scientific studies of stresses and strains in structural members under varying load conditions.

Catalin[10]

Catalin is a cast phenol-formaldehyde resin.

In the manufacturing process the proportion of each ingredient, the cooking period, and the curing time vary in accordance with the color and chemical properties desired in the finished material.

The raw ingredients are weighed and poured into pure nickel-lined kettles about 8 or 9 ft. high, having an approximate capacity of 1500 to 1800 lb. of finished resin. The resin, cooked at a comparatively low temperature and dehydrated by vacuum created by individually motor-driven pumps, is agitated from 18 to 20 hr., after which coloring matter is added. The resin is then poured into the molds. The curing period, at about 80° C. (176° F.), varies from 4 to 12 days, depending on the base resin and the purpose for which it is used. White and ivory are cured in the least time (about 4 days), and water-clear and transparent colors require the longest curing time. When the molds are removed from the vulcanizers the castings are ejected and inspected and are immediately ready for shipment and fabrication.

The lead molds for casting rods, cylinders, and special shapes are formed by dipping master steel patterns into molten lead. The lead freezes around the steel and is stripped off to give negative or female molds. These molds are arranged in racks for convenient transportation about the plant, are used but once and then remelted.

In making cast phenolic sheets the liquid resin is poured into a large tin box, rolled into the vulcanizer and allowed to remain until the resin is brought to a curing point where it has the consistency and elasticity of rubber. The block is then removed from the vulcanizer and sliced into sheets of desired thickness with a hydraulic knife. As the sheets curl off the knife, they are piled up, separated only by wax paper, and a heavy weight is placed on top to prevent warping. The stack of sheets is returned to

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[10] **Catalin Corporation.**

the vulcanizer for additional curing which is completed in approximately ten days. Cut sheets have a frosted appearance and must therefore be polished by the fabricator to restore their natural luster and beauty. Fully polished sheets can be made by pouring liquid resin between plates of glass set in a vertical position and properly separated. Sheets so cast acquire the same lustrous, smooth finish as the glass.

Constants

Tensile Strength, lb. per sq. in.: 3000–5000
Flexural Strength, lb. per sq. in.: 7000–12,000
Deflection at Center, in. at breaking load: 0.10 to 0.14
Modulus of Elasticity, lb. per sq. in.: 300,000–375,000
Compressive Strength, lb. per sq. in.: 10,000–18,000
Shear Strength (1 in. diameter plunger), lb. per sq. in.: 6000–6500
Impact Strength (Izod), lb. per sq. in.: 112–212
Impact Strength (Charpy Test Notched Specimen) ft.-lb. per in. of notch: 0.44–0.48
Specific Volume, oz. per cu. in.: 0.751–0.766
Specific Gravity: 1.30–1.33
Hardness (Rockwell B–60 kg. load ⅛-in. steel ball): 30–70
Heat Conductivity, B.t.u. per hr. per ° F., per in. per sq. ft.: 0.7033
Thermal Coefficient of Expansion between minus 15° C. to 22° C.: 0.911 × 10^{-4} and between 22° C. to 100° C.: 0.820 × 10^{-4}
Volume Resistivity, megohm-in.: 0.1 × 10^6 to 1.7 × 10^6
Volume Resistivity after 24 hr. in water, megohm-in.: 0.05 × 10^6 to 0.6 × 10^6
Surface Resistivity, megohm-in.: 1.0 × 10^6 to 6.5 × 10^6
Surface Resistivity, megohm-in., after 24 hr. in water: 0.2 × 10^6–5.0 × 10^6
Dielectric Strength, instantaneous (2 in. diameter, ⅛ in. thick), volts per mil: 300–400
Dielectric Strength Step by Step (2.5 Kv. per step 5 to 6 min.), volts per mil: 250–300
Dielectric Constant, 1 megacycle: 7–9
Dielectric Constant, 10 cycles after 24 hr. immersion in distilled water: 7–9
Power Factor, 1 megacycle, %: 4–6
Water Absorption after 8 days' immersion, gm. per sq. in. of surface: 0.0057–0.0081
Water Absorption after 80 days' immersion, gm. per sq. in. of surface: 0.0132–0.02
Softening Ranges, ° F.: 176–212

Effect of Dry Heat: Withstands up to 160° F. with slight hardening and shrinkage.

Effect of Moist Heat: Withstands up to 160° F. with slight increase in hardness.

Effect of Aging (Indoors): Slight increase in hardness, improves in electrical properties.

Effect of Aging (Outdoors in Sunlight, One Year): Slight increase in hardness, yellowing and fading of nonfast colors. Mechanical and electrical properties not appreciably changed.

Effect of Water (Cold): None.

Effect of Water (Hot): Withstands intermittent washing with hot water. Slight deterioration after 100 hr. complete immersion.

Effect of Weak Acids: None.

Effect of Strong Acids: Slowly attacked.

Effect of Alkali (Weak): Can be washed with soap and soap powders. Slowly softens when immersed in alkaline solutions, showing slight discoloration.

Effect of Alkali (Strong): Slowly attacked.

Effect of Alcohols: Insoluble: Slight swelling in ethyl alcohol after long immersion.

Effect of Ketones: None.

Effect of Esters: None.

Effect of Mineral, Animal or Vegetable Oils: None.
Effect of Hot Flames: Chars but does not support combustion.
Solubility: Insoluble in water, organic solvents and acids. Slightly soluble in alkalis.
Tendency to Cold Flow: None.
Opacity Range: Opaque to transparent, all colors.
Colors: Innumerable.
Forming Qualities: Good.
Machining Qualities: Excellent.

NOTE. Since Catalin is made of several base resins, the ranges in values given represent variations not in any one base but from base to base.

Liquid Catalins

Catavars are laminating varnishes of the heat-hardenable (thermosetting) type. These varnishes have special properties and are best suited for light color work and translucent products.

Laminates produced with these varnishes have a high degree of water and acid resistance, are odorless, possess excellent machining and punching qualities, and are very flexible.

The Catavar varnishes may be used in the standard laminating procedure, as well as in fast curing cycles loading and unloading the presses hot.

Catavar varnishes are soluble in ethyl alcohol, methyl and propyl alcohol, and acetone. They are usually supplied 90 per cent resin and 10 per cent alcohol. They contain from 6 to 20 per cent water, depending on the customer's requirements.

Catabonds are phenol-formaldehyde liquid resins developed for bonding purposes, especially for plywood, cellulose materials, abrasive wheels, etc. They are available in alcohol soluble form as well as in water emulsion form.

Products bonded with Catabond usually show strength factors greater than the product itself. The bond is water resistant, resists fungus attack and may even be boiled in water.

The Catabonds may be extended with various fillers and lend themselves readily for application by roll spreading, spraying or brushing.

Catabonds may be cured in hot plate pressures, such as in the manufacture of plywood, or by the mere application of clamp pressure in drying kilns, such as in the manufacture of wooden airplanes, or without pressure by the application of heat alone, such as in the manufacture of abrasive disks.

Liquid Casting Resin. Catalin is also available in liquid form for casting purposes and may be used in conjunction with acid accelerators for slush molding where the mold consists of latex-lined plaster of Paris.

The casting liquids are available in opaque, translucent, and transparent form. Owing to the high acidity of the accelerator, acid-cured resins are not as stable as the heat-cured resins and are recommended only for uses such as displays where short life (from approximately 6 months to 1 year) is sufficient. These acid-cured resins can be colored only with acid-resisting pigments. Therefore, the color range is also limited.

Catalanes are low-polymer phenol-formaldehyde resins which are water soluble and are especially adaptable for weighting and creaseproofing of felts and textiles.

Owing to their high free phenol and low polymer content, they are only applicable on textiles where light fastness is not important.

Application for Liquid Catalins. 1. Translucent laminated products in various colors including pastels for radio dials, indicators, displays, printed charts and Venetian blinds.

2. Laminated opaque products in light colors including white for table tops, breaker strips and decorative panels. Special features of the products are that they are odorless and hot-water resistant.

3. Bonding resin for bonding abrasive grain for abrasive disks.

4. Waterproofing resin for surface coating and waterproofing various fibrous and cellulose materials.

5. Glue for hot-press manufacture of plywood giving a boiling waterproof, fungus-resistant and weatherproof bond.

6. Bonding resin for granular cork for cork gaskets, cork heels and crown caps.

7. Glue for bonding hard and soft woods at intermediate temperatures, especially suitable for airplane construction.

8. Cements for joining Catalin or phenolic and urea plastics, or urea and phenolic laminates, to themselves or to similar plastics or cellulose materials.

9. Surface finishing wood with hot presses, giving a natural wood appearance with waterproof and solvent-resisting qualities.

10. Impregnating wood and cellulose fibers to render them waterproof.

11. For fast-setting laminated molded forms using paper, felt, sisal and other fibrous materials as a core. Curing is accomplished in 15 sec. and up.

12. For casting in lead and glass molds, using heat for curing.

13. For casting in rubber molds and plaster of Paris rubber-lined molds, using accelerator cured resins.

14. For slush casting in rubber-lined plaster of Paris molds.

15. For creaseproofing, weighing, stiffening and waterproofing textiles and felts.

16. For polish finishing of cloths such as chintz.

17. For embossed surface panels.

Marblette[11]

Marblette is a pure synthetic resin containing no fillers. The fluid resin is poured into open lead molds and then subjected to baking which converts the liquid into a tough solid which is non-inflammable, insoluble, infusible and which can be readily turned, sawed, sanded, drilled, threaded, carved and embossed. A high lasting polish is produced by means of a buffing wheel and rouge or by the tumbling barrel method.

Marblette, produced in all colors, is sold in sheets, rods, tubes, and special shapes in opaque, translucent and transparent form in either plain or mottled effects.

Marblette Crystle is a transparent, water-clear cast phenolic resin.

Prystal[12]

Prystal is a water-clear cast phenol-formaldehyde resin that has properties similar to those of Catalin in all respects with the exception of water resistance. Prystal has somewhat greater water absorption.

[11] Marblette Corporation.

[12] Catalin Corporation.

Prystal has the sparkle of a perfect gem and is furnished in a large selection of delicately transparent pastel shades.

In addition to the mechanical properties of Catalin, Prystal has the following constants:

Light Transmission (1/8-in., 40-watt source) %: 70 to 92.
Ultra-violet Transmission (2800–3200 Å.) %: 18.3.
Index of Refraction: 1.46.

CELLULOSE ACETATES

Lumarith[13]

Lumarith is made from cellulose acetate, plasticizers, dyes and pigments. By varying proportions, compositions that cover a wide range of physical properties are obtained. Since the Lumarith base is practically colorless and transparent, transparent as well as opaque color effects are possible. The range extends from colorless crystal to dense opaque. Multicolored effects also can be made.

Lumarith is thermoplastic and is prepared for either injection or compression molding. It also may be hot swaged and formed in suitable dies. Heat curing periods are unnecessary, and scrap materials may be reworked.

Lumarith is light weight and warm to the touch. It is slow burning, resistant to sunlight, and unaffected by ordinary temperatures. It is resistant to most vegetable and mineral oils but is attacked by acids and alkalies and organic solvents such as the ketones and some esters. Alcohols cause surface spotting. Clear transparent Lumarith transmits ultra-violet light down to a wave length of 290 millimicrons. Lumarith also has excellent dielectric properties.

It is mechanically strong and tough, with high resistance to breakage from impact. For this reason it is practical for thinner cross sections than are recommended for most other types of plastics. Machine operations such as punching, stamping, milling, turning, drilling, sawing, etc., can be performed without chipping.

Lumarith is available in the form of sheets, films, foils, rods and tubes as well as in several types of molding powder. Moldings and stock forms can be machined, printed, embossed or fashioned in many different ways.

Molding powders are classified as follows:

IR. Injection — Regular. Strong, tough, easy flowing, fast setting, low shrinkage and good aging.

Uses: automotive appointments, fountain pens, toiletware, radio bezels.

IN. Injection — Normal. Good finish and welding qualities, low moisture absorption, and good warping resistance.

Uses: automotive appointments, flashlight casings, housings, containers, applications of thin sections.

IS. Injection — Superflow. Fast-molding, quick-setting type.

Uses: bandeaux, bracelets, buckles, buttons, combs, hair ornaments, novelties, toys.

IF. Injection — Free Flow. Good flow for multi-cavity molds, with somewhat greater stiffness and better aging qualities than IS type.

Uses: automobile hardware, combs, cosmetic containers, shaving brush ferrules.

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[13] Plastics Div. of Celanese Corporation of America.

IW. Injection — Welding. Designed for applications where the material must join and weld to itself after flowing around inserts in the course of injection.

Uses: automobile parts, spectacle frames, goggles, bezels, applications requiring inserts.

CR. Compression — Regular. Designed for toughness, aging characteristics and resistance to cold.

Uses: automobile steering wheels, tool handles, toilet seats, automobile hardware.

X. Superior resistance to warpage in hot water or in atmospheres of high temperature and humidity; odorless, tough and has molding characteristics similar to CR grade.

Uses: refrigerator parts, kitchen utensils (to stand dishwashing) bathroom fixtures, soap dishes, tooth brushes, gas masks, radio bezels.

Within each type, proportions can be varied to give different degrees of flow or flow temperatures best suited for a particular mold and molding machine. Flow symbols and flow temperatures are as follows (measured by the Olsen Flow Tester, 1 in. in 2 min. under 1000 lb. per sq. in. pressure):

TABLE 17. FLOW TEMPERATURES

Flow Symbol	Flow Temperature °F.	Flow Symbol	Flow Temperature °F.
H8	365	MS	286
H7	356	S	279
H6	347	S2	272
H5	338	S3	266
H4	329	S4	260
H3	322	S5	254
H2	315	S6	248
H	307	S7	242
MH	300	S8	237

Not all degrees of flow are practical for each type. As a general rule, as the flow temperature decreases, the softening temperature, hardness and tensile strength decrease while the percentage elongation and impact strength of the material increase. As the flow temperature increases the reverse is true.

Molding powders have different grain sizes, chiefly, 1/8, 3/16 and 5/16 in. (screen openings). Grain sizes are remarkably uniform and practically free from fines.

Special compositions can be made for unusual applications. Sheets, films, foils, rods and tubes are available in different formulas for different applications.

Fabricating methods include hot swaging, all kinds of machine operations, creasing, cementing, stretching over wood forms, veneering under heat and pressure, blowing in closed molds by internal fluid pressure, etc. The surface can be printed, lacquered, engraved or decorated in many ways.

Sheets

Size: Standard 20 in. by 50 in.

Thickness: 0.003 up to 1 in. and over.

Colors: Clear transparent to dark opaque in unlimited color; also mottle effects.

Finish: Polished, matte, embossed.

Applications: aircraft cockpit enclosures, lampshades, watch crystals, novelties and toys, shoe heel covers, gas mask lenses and face protectors, display signs, tracing material, instrument dials, toiletware.

Films

Thickness: 0.003 to 0.020 in.

Length: Continuous lengths from 250 to 1200 ft., depending on thickness.

Width: Reels ½ to 42 in. in width.

Color: Clear or colored, transparent up to thickness 0.010 in.

Applications: Photographic and X-ray film base, transparent containers, guide card tabs, storm windows, cold and hot bed frames, electrical insulation.

Foils (Lumarith Protectoid)

Thickness: 0.0007 to 0.002 in.

Lengths: 500 to 4000 ft.

Width: Reels and rolls ½ to 42 in. width.

Color: Clear transparent.

Applications: wrapping material, laminated papers, envelopes, carton and envelope windows, soda straws, electrical wire insulation, laminated slot insulation paper.

Rods and Tubes. Rods in diameter from 0.030 to 1 in. or over. Standard lengths of 60 in. Thin rods in coils of continuous length. In cross sections: circular, rectangular, fluted, irregular.

Tubes in various inside diameter and wall thicknesses.

Color: Clear transparent to dense opaque in all colors, mottle effects.

Applications: moldings, beading, novelties, bracelets, fountain pens, tool handles, webbing for porch and lawn furniture.

Molding Material

(a) Data that are fairly constant for all molding formulations:

Specific Gravity: 1.29
Density, oz./cu. in.: 0.743
Specific Volume, cu. in. per lb.: 21.5
Dielectric Strength, volts per mil, 60 cycles, 50% R.H.: 820–840
Dielectric Strength, volts per mil, 60 cycles, water soaked: 580–630
Volume Resistivity, megohm-cm. × 10^6, 20° C., 50% R.H.: 4.2–6.15
Volume Resistivity, megohm-cm., water soaked: 3500–5100
Dielectric Constant, 60 cycles, 50% R.H.: 5.8–6.0
Dielectric Constant, 550 kilocycles: 4.4–4.6
Power Factor, 60 cycles, 50% R.H.: 4.2–5.8
Power Factor, 550 kilocycles: 3.8–4.2
Specific Heat: 0.43
Thermal Expansion, in. per in. per ° C.: 0.00016
Refractive Index N_D: 1.5
Compression Ratio, Volume of molding compound to molded article: 2.2

Sheets, Rods, and Tubes (*Common type*)

Specific Gravity: 1.27–1.37
Tensile Strength, lb. per sq. in. 4000–11,000
Elongation, %: 20–55
Impact Strength, ft.-lb. per ½ in. sample, Charpy Notched by ½ in.: 0.25–1.0
Brinell Hardness: 6–11
Thermal Conductivity, 10^{-4} cal. per cm.^{2} per ° C. per cm.: 5.4–8.7
Specific Heat, cal. per ° C. per gm.: 0.3–0.4
Thermal Expansion, in per in. per ° C. × 10^{-5}: 14–16
Softening Temperature, ° F.: 140–230
Light Transmission, Total %: 85–92
Dielectric Strength, 0.010 in. gauge — volts per mil.: 1200–1400
Volume Resistivity, megohm-cm. × 10^3: 31.7
Dielectric Constant, 60 cycles: 5.1
Dielectric Constant, 877 kilocycles: 4.2
Power Factor, %, 60 cycles: 2.5
Power Factor, %, 877 kilocycles: 4.2
Burning Rate: Slow to self-extinguishing
Ultra-violet Light Transmission: Transparent to wavelengths down to 290 millimicrons.

(b) Data that change with formulas:

TABLE 18. LUMARITH: CHANGE OF PHYSICAL PROPERTIES

TYPE	IR	IN	IS	IF	IW	CR	Lumarith
	Regular	Normal	Superflow	Free Flow	Welding	Regular	X
Molding Method	Injection	Injection	Injection	Injection	Injection	Compression	Injection
Flow Symbol	H4–S4	H4–S4	H4–S4	H–S6	H4–S	H4–S4	H8–MH
Flow Temperature, ° F.	329–260	329–260	329–260	307–248	329–279	329–260	367–299
Brinell Hardness, kg. per sq. mm.	9.3–3.3	10.9–4.0	12.5–6.0	9.4–3.5	8.7–3.7	10.5–2.8	12.3–6.45
Tensile Strength, lb. per sq. in.	10,600–4000	14,000–5700	14,600–6900 (H3)	13,100–5700	11,200–6700	9700–2200	11,000–5500
Elongation, %	8.5 (H2)–17.7	9.6 (H)–14.3	9.5 (H3)–14.9	7.8 (M)–13.4	7.3–16.8	14–43	9.0–12.0
Impact, strength ft.-lb. per in. Notch, Charpy	1.8–3.06	2.02 (H2)–3.22	1.48 (H2)–2.40	1.58–3.20	1.68–2.66	1.64–3.40	0.51–3.36
Softening Temperature ° F.	201–151 (S2)	212–145	219–158	189 (M)–149	194–144	199–124(S3)	215–154
Mold Shrinkage, %	0.175–0.35(S2)	0.195(H2)–0.44	0.115–0.24	0.13(M)–0.475	0.23–0.33	0.10–0.62	—
Heat Shrinkage, % 48 hr., 140° F.	0.24–1.0	0.23(H2)–0.63	0.09–0.46	0.09(M)–0.64	0.15–0.68	0.12(H)–0.95	0.13–0.34
Water Absorption, %	4.16–3.84	3.22–2.93	3.96–3.51	3.84–3.28	3.63–3.39	4.05–3.69	4.0–2.9
Warpage, degrees	0.63–1.0(MS)	0.25(H2)–0.70	0.37–0.82(M)	0.34(M)–0.83(S4)	0.34–0.80	0.48(H2)–1.20	0.10–0.20
Cold Flow, 1/1000 in., 15 min. at 120° F., 2000 lb. per sq. in. on 1-in. cube	30–104(M)	45(H)–100(M)	15(M)–70	15(M)–100(S4)	13(H)–100(MS)	20(H)–150(S3)	2.5–91.

Films

- Specific Gravity: 1.29–1.33
- Light Transmission, % visible: 92–95
- Index of Refraction: 1.490–1.50
- Tensile Strength, lb. per sq. in.: 9000–11,000
- Elongation, %: 25–40
- Brinell Hardness: 8.5–10.5
- Accelerated Aging Shrinkage, %, 7 days at 120° F.: 0.02–0.10
- Heat Shrinkage, %, 48 hr. at 140° F.: 0.05–0.20
- Humidity Expansion, %, from 0–75% R.H.: 0.2–0.6
- Moisture Absorption, %: 3–4
- Forming Temperature, ° F.: 220–275
- Dielectric Strength, volts per mil, 60 cycles, 50% R.H.: 1500–2400
- Dielectric Strength, volts per mil, after water soaking: 600–1400
- Volume Resistivity, megohm-cm. × 10^6: 26–75
- Volume Resistivity, megohm-cm. × 10^3 (after water soaking): 60–120
- Dielectric Constant, 60 cycles: 4.9–5.1
- Dielectric Constant, 1000 kilocycles: 3.6–3.9
- Power Factor, 60 cycles, %: 1.6
- Power Factor, 1000 kilocycles, %: 4.4–4.7
- Ultra-violet Light Transmission: down to 280 millimicrons.

Foils. Owing to the thin cross sections, tests are difficult to make with accuracy. Results will vary with the conditions of the test and the apparatus used.

(Values cover flexible and rigid types of foils in 0.001 in. thickness.)

- Tensile Strength, lb. per sq. in.: 7000–11,000
- Elongation, %: 9–25
- Specific Gravity: 1.265–1.33
- Mullen Bursting Strength, lb. per sq. in.: 70–100
- Moisture Absorption, %: 0.4–0.6
- Heat Shrinkage, %, 48 hr. at 140° F.: 0.005–1.0
  - 24 hr. at 200° F. (rigid type): 0.5
- Humidity Expansion, %, 0% R.H. to 75% R.H.: 0.2–0.5
- Dielectric Strength, volts per mil, 60 cycles, 50% R.H.: 2300
  - volts per mil after 24 hr. in water: 1700
- Dielectric Constant, 60 cycles, 63% R.H.: 3.6
  - 60 cycles, 100% R.H.: 1.9
  - 620 kilocycles, 63% R.H.: 2.1
  - 620 kilocycles, 100% R.H.: 4.0
- Power Factor, %, 60 cycles, 63% R.H.: 1.8
  - 60 cycles, 100% R.H.: 8.0
  - 620 kilocycles, 63% R.H.: 2.4
  - 620 kilocycles, 100% R.H.: 2.4
- Volume Resistivity, 50% R.H., megohm-cm. × 10^6: 5.0

Aero Quality Lumarith

Aero Quality Lumarith is a cellulose acetate base material specially developed by the Celanese-Celluloid Corporation for aircraft use in such applications as windows, cockpit enclosures, antennae housings, etc. It is characterized by its toughness, high clarity and optical uniformity, its resistance to sunlight and its ability to be heat formed into three-dimensional shapes without surface impairment.

Aero Quality Lumarith does not have the disadvantage of flammability and rapid discoloration and crazing in sunlight that is characteristic of cellulose nitrate plastics. It does have greater toughness and resistance to breakage, which permits the use of thinner gauge sheets, and it has also less optical displacement than other more expensive types of transparent plastics sheets used in aircraft.

Although Aero Quality Lumarith does not have as high a surface hardness as some other types of transparent plastics sheets, still it is more resistant to abrasion, as measured by the relative change in gloss of the transparent sheets before and after abrading with a definite weight of carborundum falling through a definite height.

Aero Quality Lumarith sheets can be heat formed into three-dimensional shapes by heating in an air oven at about 250° F. and forming in a hard wood or metal forming die covered with billiard table felt. The surface of the Lumarith sheet does not become unmolded or impaired by heating at 250° F for 15 to 20 minutes. Usually forming temperature is reached after 4 to 6 minutes heating.

Constants

(Thickness Range 0.060 to 0.125 in.)

Light Transmission,[14] %, as received: 86–92

After 168 hr. accelerated aging under S-1 Sun Lamp: 85–90

Displacement Factor,[14] max.: 6.25

Moisture Absorption,[14] %, 24 hr. immersion: 1.9–3.5

Warpage,[14] in., after 168 hr. under S-1 Lamp: 0.02–0.045

After 24 hr. in water: 0.01–0.03

After 24 hr. in gasoline: 0.01–0.02

Tensile Strength,[14] lb. per sq. in.: 5400–7000

Elongation,[14], 80° F.: 35–50

Elongation, %, 32° F.: 25

Tensile Product at 80° F., min. (Tensile Strength X, % Elongation): 200,000

Flexibility,[14] at 32° F., Flexibility after 168 hr. under S-1 Lamp: No crazing or surface impairment when bent in arc of 5 in. radius circle.

Burning Rate,[14] in. per min., 0.060 in. thickness: 2.5

0.080 in. thickness: 1.13

0.125 in. thickness: 0.72

Specific Gravity: 1.29

Brinell Hardness, kg. per sq. mm. (10-kg. load, 2.5-mm. ball): 8.5

Coefficient of Thermal Expansion (in. per in. per ° C.): 14–16 $\times$ 10^{-5}

Surface Stability under Heat, 15 min. at 250° F.: No surface impairment.

Monsanto Cellulose Acetate[15]

Monsanto supplies various formulas, each having a definite thermal region in which it becomes sufficiently plastic to completely fill the mold cavity. Likewise the chilling temperature varies, but it should be noted that, while with compression molding the die is actually cooled with water, in injection molding the temperature of the die is dependent, in the main, upon the piece being molded.

Molded Sheets or slabs are supplied in the thicknesses of 0.150 to 1.0 in. and in any size up to 21 in. wide and 50 in. long. All colors supplied in the injection type can be duplicated in molded sheets which are commonly used in making blanks for compression molding, especially by molders who operate hand presses.

Symbols for grades of Monsanto cellulose acetate:

VH — very hard
H — hard
MH — medium hard
M — medium
MS — medium soft
S — soft
VS — very soft

In each group, ten divisions are made so that the intermediate formulas can be graduated. For example, there is an MS1, an MS2, an MS3, etc. The position of each

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[14] These values have been determined by methods of testing described in Navy Aeronautical Specification P-41b.

[15] Monsanto Chemical Co.

numeral has been worked out by a mathematical compilation of the active plasticizer content, which progressively becomes softer as the numbers increase.

When a request is received from a customer to match a color, the sample is given an " M " number. When, however, this color is approved by the customer and the material is made in larger scale production, the permanent color number is given to it as well as the correct formula designation.

TABLE 19. MONSANTO COLOR NUMBERS

	Opaque	Translucent	Transparent	Mottles
White (cream) commencing with	1	1001	2001	3001
Red (orange, salmon, coral, cerise, pink) commencing with	101	1101	2101	3201
Yellow (ivory, buff) commencing with	201	1201	2201	3201
Green commencing with	301	1301	2301	3301
Blue commencing with	401	1401	2401	3401
Lavender (purple, orchid) commencing with	501	1501	2501	3501
Brown (tan) commencing with	601	1601	2601	3601
Grey (olive) commencing with	701	1701	2701	3701
Black commencing with	801	——	——	——

Water-clear transparent or crystal run from 2001 to 2099. Shell colors run from 3901 to 3999. Pearl colors commence with 4001. The prefix letter F is used in front of some numbers to indicate Monsanto cellulose acetate slab stock and the prefix letter G is used in front of others to indicate granulations.

Constants

Specific Gravity: 1.27–1.63

Specific Volume, cu. in. per lb.: 21.8–17.0

Weight per Cubic Inch (based on sp. gr. 1.3), lb.: .047

Refractive Index N_D: 1.47–1.5

Compressive Strength, lb. per sq. in.: 11,000–16,000

Tensile Strength, lb. per sq. in.: 4000–5000

Elongation: 10–48%

Flexural Strength, lb. per sq. in.: 5200–8800

Impact Strength, in.-lb., Charpy Notched Specimen, per sq. in.: 3–12

Modulus of Elasticity, lb. per sq. in. × 10^5: 2–4

Impact Strength, in.-lb., Charpy A.S.T.M. No. 4 Unnotched Specimen: Over 100

Brinell Hardness (10-kg. load): 6–7.5

Scratch Resistance, Bierbaum Microcharacter: 5.4–1.2

Molding Material

Type: Thermoplastic

Molding Qualities: Excellent

Compression Molding Temperature, ° F.: 250–350

Compression Molding Pressure, lb. per sq. in.: 500–5000

Injection Molding Temperature, ° F.: 300–500 F.

Injection Molding Pressure, lb. per. sq. in.: 3000–30,000

Compression Ratio: 2–2.8

Tendency to Cold Flow, room temperature: None to very slight

Mold Shrinkage (cold mold to cold piece) Injection, in. per in.: 0.002–0.003

Semi-positive, in. per in.: 0.005–0.007

Flash, in. per in.: 0.008–0.009

Extruding Qualities: Excellent

Molding Methods Applicable: Lends itself readily to all forms of dry molding

Molding Material — ***Continued***

Burning Rate, 0.060-in. thickness: 1.5–2.0 in. per min., slow burning, approved by Underwriters' Laboratories
Thermal Conductivity, 10^{-4} calories per sec. per sq. cm. per ° C. per cm.: 5.4–8.7
Flash Point, ° C.: 530–540
Specific Heat, cal. per ° C. per gm.: 0.3–0.45
Thermal Expansion, 10^{-5} per ° F.: 8–9
10^{-5} per ° C.: 14–16
Resistance to Heat, ° F. (continuous): 140–180
Distortion under Heat, ° F.: 122–155
Softening Point, ° F.: 140–175
Volume Resistivity, ohm-cm. (50% R.H.): $(4.2\text{–}6.2) \times 10^{12}$
Breakdown Voltage, 60 cycles volts/mil (instantaneous): 800–850
Dielectric Constant, 60 cycles: 5.8–6.0
1 megacycle: 4.4–4.7
Power factor, 60 cycles: 0.042–0.58
1 megacycle: 0.038–0.042

Odor: None.

Taste: None.

Effect of Age: Slight hardening.

Effect of Sunlight: Practically none, fades some colors.

Effect of Ultra-violet Light: Slight, fades some colors.

Effect on Metal Inserts: None.

Light Transmission, 0.060 in. gauge, colorless (4000–7000 Å.), %: 85-92.

Effect of Weak Mineral Acids: Slight.

Effect of Strong Acids: Decomposes.

Effect of Weak Alkalies: Slight on short exposure.

Effect of Strong Alkalies: Decomposes.

Water Absorption, 24 hr. immersion, A.S.T.M. method: 1.4–2.0%.

Moisture Transfer, 0.020 in. gauge gm. per sq. meter per day: 35–150.

Soluble in: low molecular weight esters, ketones, hydroxy esters, tetrachlorethane, ethylene dichloride, alcohol mixtures.

Softens in: alcohol, esters.

Swells in: chlorinated hydrocarbons.

Insoluble in: aromatic hydrocarbons, aliphatic hydrocarbons, animal oils, mineral oils, vegetable oils, ethers.

Color: available in an extremely wide variety of transparent, crystal, translucent, pastel and opaque colors, as well as many mottles, pearl and ornamental configurations.

Form: powder and molded slabs.

How to Order

The following information is desirable to avoid errors and consequent disappointment:

Color: A simple designation of color may be sufficient, but if practicable, a sample to be matched should always be supplied. If this is not possible, samples are available from which the exact color and degree of translucence may be selected. When mixtures or mottles are wanted, they should be described as accurately as possible; for example, " Blue white variegation, white predominating, occasional deep blue striations." Colors are numbered when supplied; the number should be used when reordering to ensure an exact match.

Flow: For most applications, medium-soft flow degree is best. It will be furnished unless a different flow is specified. If experimentation has suggested the advisability of a different flow, it should be specified on the order.

Form: The coarseness, or fineness, of the granulation of molding compound is determined by the mesh of the screen through which it will pass. Available standard sizes run from 3/16 to 5/16 in. Unless otherwise specified, 3/16 in. will be furnished.

Application: Particularly on initial orders it is advisable to describe briefly the product to be molded and whether the injection or compression molding process is to be used.

Plastacele[16]

Plastacele is the registered trade-mark for cellulose acetate plastics manufactured by the du Pont Company. Plastacele is available in sheets, rods, and molding powder. Since the molding powder is described in detail in a separate publication, it will be omitted from this description. Sheets are sold on the basis of one standard size, 20 by 50 in., and vary in thickness from 0.025 to 1.000 in. In addition to an unlimited range of transparent, translucent, and opaque colors, special effects are available in mottles and imitation shells.

While the majority of Plastacele sheets are manufactured in the standard PL-5 (like C-7511) composition, the formulation has been modified to give special properties for special uses. PL-7 (like C-7511–7) formulation is more rigid and slower burning than PL-5 but has less impact strength, while the softer PL-9 (like C-10098) is particularly well adapted to swaging and forming where a deep draw is necessary. This composition is recommended for thin sheeting which is to be stitched. A composition with superior weathering properties has been developed for airplane sheeting and the clear transparent C-7517 has been approved by both the U. S. Army Air Corps and the U. S. Navy against the specifications for cellulose acetate base material.

Plastacele cellulose acetate plastic can be cut, sawed, machined, formed, and shaped by methods only slightly different from those used with pyroxylin plastics. An important difference, however, is the preference for dry heat in forming due to the inherent water sensitivity of cellulose acetate plastics in general. If hot water is used as a heating medium because the size of the piece is larger than the available hot plate surface, blushing can be kept to a minimum by the addition of common salt to the solution. This pick-up and loss of moisture with changes in humidity also affects the fabrication of the sheeting in cold, dry weather since the sheeting then becomes somewhat brittle in trimming, blanking or stitching. With air temperatures below 65° F. or low humidity, the stock should always be held for at least 24 hr. prior to working in a room kept at approximately 80° to 90° F. and 55 per cent relative humidity. Moisture absorption causes a linear expansion of the stock and therefore, in mounting cellulose acetate parts in a rigid frame, it is essential to allow for this change in dimension by slotted bolt holes or the like. Humidification of the working area will also help to reduce contamination from surface dirt by reducing the static charge which normally builds up on cellulose acetate sheeting.

Plastacele can be sawed to a smooth edge with a hollow ground saw having about nine teeth to the inch and no set. The saw may be lubricated with oil or water. A more rapid but rougher cut is obtained with a machine cutter of the type of the Unishears. In the latter case as in the case of cutting on the Seybold cutter or in blanking, it is important that the knife edge be kept sharp and the stock warmed as mentioned above. With heavy gauges, the warming should be on a flannel covered hot plate or in an oven at 120° to 240° F. The thermoplastic properties of Plastacele enable the use of the well known press polish operation, whereby a polished, sand blasted or

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[16] E. I. du Pont.

ornamented surface can be transferred to the sheet from an appropriate metal plate by use of heat and pressure. Several of these finishes such as HH polished on both sides, or NN negative on both sides are carried in the standard line.

Plastacele can be composited by heat and pressure and cemented by the use of an active solvent such as acetone. The addition of a high boiling solvent such as ethyl acetate will reduce the tendency to condense moisture and blush in humid weather. Blushing, aside from making the sheet opaque, will also cause poor adhesion.

Plastacele cellulose acetate plastic is much more stable to heat and ultra-violet light than the pyroxylin plastics. Its water sensitivity restricts its use in general, however, to indoor applications. It should be stored flat in a warm, dry place. It should not be stored against radiators, however, since this local heating will cause warping. Warping will also occur on long exposure of the edges of a pile of stock to atmospheric conditions noticeably different from those which existed at the time of packing.

The specific gravity of Plastacele and approximate weight per sheet is given below for various pigment classes and is compared with different woods:

TABLE 20

	Specific Gravity	Approximate Weight per Sheet, pounds	
		0.020	0.100
Transparent and shell	1.30	0.94	5.15
Black pearl, translucent ivory, and white	1.31	0.94	5.18
Cream	1.32	0.95	5.22
Opaque white	1.38	1.00	5.47
White pine	0.43	——	——
Black walnut	0.59	——	——
Live oak	0.87	——	——

Tenite I (Cellulose Acetate) and
Tenite II (Cellulose Acetate Butyrate)[17]

Tenite is made from Eastman cellulose esters, plasticizers, pigments, and dyes. The cellulose esters in Tenite are of the same quality as those in Eastman safety motion-picture film and Eastman acetate rayon. Cellulose acetate and cellulose acetate-butyrate are two of the esters used as Tenite bases, the resulting molding compositions being designated Tenite I and Tenite II, respectively.

The plasticizers in Tenite are organic compounds that are compatible with cellulose esters and serve to impart moldability.

Pigments are employed in Tenite as coloring agents, not as loaders or fillers, and are therefore in relatively minute proportions. The dyes and pigments are the best that can be obtained with respect to stability to light and heat and suitability for use with cellulose ester plastics.

Tenite is supplied in granulation or blanks and is adapted to both compression and injection molding methods. Being thermoplastic, it is molded merely by the applica-

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[17] Tennessee Eastman Corp.

tion of heat and pressure, is set by cooling and undergoes no chemical change in molding.

No process in the manufacture of Tenite requires waiting for aging or curing. This permits prompt shipment in either sample or production quantities, in established or special colors.

General Properties. Tenite has exceptionally high impact strength and articles molded of it are extremely tough, even in thin-walled sections. Objects molded of Tenite may be punched, stamped, drilled, and sawed with ease, and will withstand such assembly operations as the crimping of metal beadings and riveting. Pieces of molded Tenite may be cemented together to make a bond as strong as the material itself.

The hardness of Tenite can be varied within limits, but in general, it is comparable to that of hard rubber, aluminum, or hard oakwood.

Tenite supports combustion with difficulty, burning like hard rubber, fiber wood, or similar substances. Like most materials, natural and synthetic, Tenite is tougher at moderate than at low temperatures.

Tenite is not damaged by contact with most vegetable and mineral oils. Alcohols and some essential aromatic oils will spot the surface of a molded piece. Tenite products should not be subjected to concentrated acids or alkalies.

All cellulose ester molding compositions are somewhat hygroscopic and absorb moisture, depending upon the relative humidity and temperature as well as the formula used. Tenite II absorbs on immersion about the same amount of water as nitrocellulose plastic. This is about one-half as much as that absorbed by cellulose acetate plastic.

Clear transparent Tenite transmits a high percentage of ultra-violet light. A representative formula will transmit 50 per cent ultra-violet at a wavelength of 300 millimicrons and 85 per cent at a wavelength of 360.

Many variations can be made in Tenite formulas in order to accentuate the physical properties desired for particular products. The tabulation on pages 171 and 172 gives the range of physical properties of Tenite in the formulas for the flows regularly supplied. Such all-inclusive figures necessarily show wide limits, and it should be understood that no one formula can have every quality in the same high degree. Specific data on physical properties for each of these formulas and flows are given on request.

Type, Formula, Flow, Color, and Form Supplied

Type: A — Injections; C — Compression.

Formula: Tenite I; Tenite II.

Flow:

H7 — Hard, 7th degree
H6 — Hard, 6th degree
H5 — Hard, 5th degree
H4 — Hard, 4th degree
H3 — Hard, 3rd degree
H2 — Hard, 2nd degree
H — Hard, 1st degree
MH — Medium Hard
M — Medium
MS — Medium Soft

S — Soft, 1st degree
S2 — Soft, 2nd degree
S3 — Soft, 3rd degree
S4 — Soft, 4th degree
S5 — Soft, 5th degree
S6 — Soft, 6th degree
S7 — Soft, 7th degree

Color Classification: Black, regular grade.

Plain colors: Transparent — all colors and crystal, translucent — limited pigment, all colors, opaque — all colors, Special Grade Black.

Variegations: Configurations of mixed colors.

Pearls: Variegated, with iridescent luster, Grade X, Grade XX, Grade XXX, Grade XXXX.

Form: Pellets, ⅛ in. and 3/16 in.; granulation, ⅛ in. to 5/16 in.; blanks and molding sheets, square or rectangular, 5/32 to 1⅜ in. thick, maximum area 20 in. by 25 in.

Properties of Formulas (Tenite I). The *AR formula* is used for ordinary applications that demand no accentuation of certain characteristics, such as impact strength or hardness. Material in this formula is widely used for automotive appointments — window-regulator knobs, dash-control and gearshift knobs, cigar lighters, etc. It is usually supplied in A-MS or A-S flow.

The *CR formula* has extreme toughness even at relatively low temperatures. It is recommended for most compression molding applications. This formula is quite similar to the W, Y, and J formulas in elongation, strength and hardness properties, high impact strength, with moderate tensile, flexural, and compressive strengths and hardness.

The *N formula* in both A and C types has to some extent the welding qualities of the W formula, but with higher tensile and flexural strengths as well as greater hardness. It is somewhat tougher than AR. Owing to the balance between the various physical properties, the N formula gives excellent results in a wide range of uses. It is usually supplied in A-S flow.

The *W formula* in both A and C types has better than average molding qualities, together with extreme toughness, although it sets up relatively slowly in the mold This formula is quite similar to CR, Y, and J formulas in elongation, strength, and hardness properties. The elongation and impact strength are high with moderate tensile, flexural, and compressive strengths and hardness. This formula is especially desirable for articles where the material must join itself (weld) after going around a core in the course of injection. Also, articles molded from this material have better mold finish than any other Tenite I formula. It cannot be supplied in flow greater than A-S2 or C-S6; A-MS and A-S are the flows more generally used.

The *F formula* in both A and C types is similar to the T formula in that it has high flow, sets up quickly in the mold, and shows excellent rigidity in the finished article. It differs from the T formula, however, in that it has moderate toughness, comparing quite favorably with the AR formula in both elongation and impact strength properties. The tensile, flexural, and compressive strengths, as well as hardness, are high. A representative use of such a formula is in the manufacture of combs, where it has adequate flow to fill the fine cross sections and at the same time gives in the finished product relatively stiff and strong comb teeth. The flow most frequently used is A-S3.

The *T formula* in both A and C types is the most free flowing. It provides an extreme of this characteristic in the softer flows, and in the medium and harder flows remarkable rigidity in the finished article. It has, however, the lowest elongation and impact strength. This formula sets up quickest of any in the mold, effecting a very short cycle. It is particularly suited for such items as inlaid name plates and escutcheons, where rigidity is desired and no great resistance to impact is necessary.

The letter *Z* is applied to special formulas of Tenite I.

Properties of Formulas (Tenite II). The *Y formula* in both A and C types has excellent permanence properties, better than average molding qualities and toughness. It shows little shrinkage or dimensional change after long periods of aging, because this formula has the lowest gain in weight with almost no soluble matter lost on 24-hr. immersion in water. Small loss in weight occurs on prolonged aging at somewhat elevated temperatures. This formula is quite similar to the CR, W, and J formulas in elongation, strength and hardness properties. The elongation and impact strength are high, with moderate tensile, flexural and compressive strengths and hardness. Articles molded from this material have excellent finish and seldom require buffing.

The *J formula* in both A and C types is similar to the Y formula. Its low water absorption and low loss of soluble matter during immersion are indicative of its resistance to shrinkage and distortion under varying conditions of warmth and humidity. The outstanding property of J formula is a uniform weld within the molded piece itself which supplies the toughness necessary for the clean removal of gates. The other physical properties including mold finish are generally comparable with those for Y except that Y has somewhat greater rigidity and hardness.

The letter *A* designates special formulas of Tenite II.

Constants

- Specific Gravity, 20°/20°: 1.20–1.37
- Density, oz. per cu. in.: 0.69–0.79
- Specific Volume, cu. in. per lb.: 20.2–23.1
- Compression Ratio, vol. granular composition to vol. molded piece: 2.0–2.8
- Elongation, %: 5–48
- Tensile Strength, lb. per sq. in.: 2800–9900
- Flexural Strength, lb. per sq. in.: 3700–18,100
- Compressive Strength, lb. per sq. in.: 7500–30,400
- Impact Strength, Charpy, ft.-lb. per in. of notch: 0.8–4.4
  - Izod, ft.-lb. per in. of notch: 0.7–4.2
- Modulus of Elasticity, lb. per sq. in. $\times 10^5$: 2.0–3.5
- [18]Water Absorption (24-hr. immersion), weight gained, %: 1.2–3.8
  - Soluble matter lost, %: 0.1–3.1
- Refractive Index, N_D^{25}: 1.464–1.499
- Rockwell Hardness (M Scale): 28–107
- Shore Hardness (scleroscope adjusted to 97 steel standard): 42–78
- Brinell Hardness: 6.6–12.3
- Specific Heat, cal. per ° C. per gm.: 0.30–0.40
- Thermal Conductivity, B.t.u. per hr. per sq. ft. per ° F. per in.: 1.3–2.2
  - cal. per sec. per sq. cm. per ° C. per cm. $\times 10^{-5}$: 45–78
- Thermal Expansion, in. per in. per ° F. $\times 10^{-6}$: 61–91
  - in. per in. per ° C. $\times 10^{-6}$: 110–164
- Softening Temperature, ° F.: 140–250
- Flow Temperature, ° F.: 252–342
- Molding Temperature, Injection, (cylinder temperature), ° F.: 310–410
  - Compression (mold temperature) ° F.: 250–350
- Molding Pressure, Injection, lb. per sq. in.: 14,000–20,000
  - Compression, lb. per sq. in.: 2000–5000
- Mold Shrinkage (cold mold to finished cold article) linear in. per in., Injection Mold: 0.002–0.003
  - Positive or Confined Mold: 0.002–0.003
  - Semipositive Mold: 0.005–0.007
  - Flash or Overflow Mold: 0.008–0.009
- Shrinkage Subsequent to Molding, 40% R. H. and 75° F. for 1 yr., linear in. per in.: 0.001–0.016
- [8]Volume Resistivity, 50% R. H., megohm-cm. $\times 10^5$: 7–14
- [18]Dielectric Strength, 60 cycles, 50% R. H., volts per mil: 350–900
- [18]Dielectric Constant, 60 cycles, 50% R. H.: 3.5–6.4
  - 10^6 cycles, 50% R. H.: 3.2–6.2
- [18]Power Factor, 60 cycles, 50% R. H., %: 1.0–6.1
  - 10^6 cycles, 50% R. H., %: 0.8–5.2

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[18] Tests run on specimens ⅛ in. in thickness.

Molding of Tenite. Being thermoplastic, Tenite may be molded by either the compression or the injection process.

The outstanding molding advantage of Tenite is its adaptability to injection, which permits the manufacture of many articles that could not be molded by the compression method. For example, a thin coating of Tenite may be injected over a die casting to make an article that combines the rigidity of metal with the beautiful colors, pleasant feel, and smooth surface of Tenite.

Injection molds are usually smaller and less costly than compression molds. In some cases, the cost per piece by injection is lower than that of a similar piece molded by compression of a cheaper type of composition.

In *compression* molding, the plastic, in granular or blank form, is placed in the cavities of the mold, which is heated to the required temperature. The mold is then closed, cooled and opened to eject the molded pieces.

Th compression method permits the molding of pieces too large for injection and also those having such thick sections that excessive shrinkage might result from the injection process. Furthermore, the fact that blanks can be used in compression molding makes it possible to secure more sharply defined striations from variegated Tenite blank stock than could be obtained from the mixed granulation for injection molding.

Tenite takes a lustrous finish directly from polished mold cavities, thus eliminating, in most cases, the need for subsequent finishing operations. However, additional gloss may be secured if desired by wheel polishing, buffing or tumbling the molded article.

Uses: Automotive interior appointments, automotive handles, escutcheon plates and steering wheels.

CELLULOSE NITRATE

Monsanto

Monsanto cellulose nitrate is supplied in sheets, rods, and tubes. In the manufacturing process, cotton linters are highly purified, washed, dried, fluffed, and compressed into bales. Treatment with a mixture of nitric and sulfuric acids and water forms cellulose nitrate, or nitrocellulose. Refined cellulose nitrate is mixed with camphor and alcohol to form the colloidal plastics structure.

Chromium-plated rolls then knead the plastic, removing much of the alcohol and compacting and homogenizing the texture of the material until it is built up into slabs about 1 in. thick and about 20 in. by 50 in. in size. These slabs are laid on a steel plate and molded in baking presses under heat and pressure to produce a solid cake.

Constants

Specific Gravity: 1.35 to 1.60
Specific Volume, cu. in. per lb.: 20.5 to 17.3
Density, gm. per cc.: 1.35 to 1.60
Weight per cu. in., lb.: 0.0507
or (based on specific gravity of 1.4) gm.: 23.0
Refractive Index N_D: 1.46 to 1.50
Tensile Strength, lb. per sq. in.: 6000 to 9000
Elongation, %: 4 to 20
Modulus of Elasticity, lb. per sq. in. $\times 10^5$: 2 to 4
Impact strength, Charpy (Notched) per sq. in.: 3 to 12
Brinell Hardness, 10-kg. load: 10 to 20
Shrinkage, %: 0 to 1.4
Machining Qualities: Very Good
Burning Rate: Rapid
Thermal Conductivity, 10^{-4} cal. per sec. per sq. cm. per ° C.: 3.1 to 5.1
Specific Heat, cal. per ° C. per gm.: 0.34 to 0.38
Thermal Expansion, 10^{-5} per 1° F.: 6.5 to 8.9
10^{-5} per 1° C.: 12.0 to 16.0

Constants — *Continued*

Resistance to Heat, ° F. (continuous), approximately: 140

Softening Point, ° F. (decomposes at 272° F. in 30 min.): −60 to 195

Effect of Heat, Dry, Discolors on Continued Heating at ° F.: 212

Volume Resistivity, ohm.-cm., 50% R.H.: (2 to 30) $\times 10^{10}$

Breakdown Voltage, 60 cycles, volts per mil: 600 to 1200

Dielectric Constant, 60 cycles: 6.9 to 8.8

Dielectric Constant, 10^6 cycles: 6.15

Power Factor, 60 cycles: 0.062 to 0.144

Power Factor, 10^6 cycles: 0.074 to 0.097

Chemical and Physical Properties

Odor: None or camphorous.

Taste: Tasteless.

Effect of Age: Slight hardening.

Effect of Sunlight: Yellows on long exposure.

Effect of Ultra-violet Light: Yellows and decomposes on extended exposure.

Effect of Weak Mineral Acids: Good resistance.

Effect of Strong Acids: Poor resistance, decomposes.

Effect of Weak Alkalies: Very slowly decomposes.

Effect of Strong Alkalies: Decomposes.

Water Absorption, %, 24-hr. immersion: 1.3 to 2.6.

Effect of Hot Water: Softens, slight shrinkage.

Effect of Cold Water: None.

Moisture Transfer, gm. per sq. meter per day per 0.005 in.: 50 to 75.

Effects on Metal Inserts: None.

Soluble In: Alcohols, ketones, esters.

Insoluble In: Aromatic hydrocarbons, aliphatic hydrocarbons, mineral oils, animal oils, vegetable oils.

Color: Wide variety.

Molding Properties

Type Plastic: Thermoplastic

Molding Quality: Good

Compression Molding Temperature ° F.: 185 to 250

Compression Molding Pressure, lb. per sq. in.: 100 to 500

Performing: Very Good

Tendency to Cold Flow: Very Slight

Molding Methods Applicable: Extrusion, swaging, shearing, blowing — all very good

Extruding Quality: Good

CELLULOSE NITRATE

Pyralin[19]

Pyralin is the registered trade-mark for pyroxylin plastics manufactured by the du Pont Company. It is similar in composition to the product commonly referred to as celluloid. Pyralin is available in sheets, rods, and tubes, having a wide variety of thicknesses and an unlimited range of colors. Sheets are sold on the basis of one standard size, 20 in. by 50 in. and vary in thickness from 0.005 to 1.000 in. In addition to an unlimited choice of transparent, translucent, and opaque colors, a wide variety of special effects are available, such as mottles, pearl and imitation shell, horn and wood effects.

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[19] E. I. du Pont.

While the majority of Pyralin is manufactured in one standard composition, the formation is modified to fit the specific use to which the stock is to be placed. Some of the special compositions which have been developed and may be regularly ordered are for swaging stock, wood heel stock, sanitary sheeting, sound damping material, drawing instrument stock, printing stock, shaving brush tubing, towel bar tubing and fountain pen tubing.

Pyralin pyroxylin plastic can be cut, sawed, formed and shaped. In sawing, a generous stream of water should be kept on the saw. A high luster can be developed by ashing and polishing with rouge or Pyralin can be machined on a lathe with tools similar to those used in the wood or metal working industries with the cutting tool being kept lubricated with regular metal cutting compound. Since Pyralin is thermoplastic, forming and shaping can be accomplished by the die-pressing method, using preheated stock and dies and then quickly chilling the formed piece in cold water. Softening can also be accomplished by placing the stock for a short time in hot water maintained at its boiling point. To obtain a hotter bath, the surface of the water is sometimes covered with a film of oil, or Nujol is used for the bath in place of water. Dry heat may also be used, but care must be taken that the temperature does not exceed 240° F. This property of thermoplasticity, or softening with heat, also allows the well known press polishing operation, whereby the polished, sand blasted, or ornamented surface is given to the sheet by transfer from an appropriate metal plate with the use of heat and pressure. In this way, a variety of surface effects may be built up. Many of these are carried in the standard line, such as HH polished on both sides, NN matte finish on both sides, SS sheeter finish on both sides, CC caustic finish on both sides, and various combinations of these formulas.

Thin Pyralin can be softened for stretching — as in covering wood heel blocks or toilet seats — by immersion for several minutes in a solution of water and an active organic solvent such as acetone or methanol. Various designs can be embossed on the Pyralin while in this softened state with the use of cold pressure. The solution should be weak enough so that it requires at least 20 minutes to soften thoroughly. If a stronger solution is used, the blank will soften unequally and not stretch well. Pyralin can be composited by heat and pressure, and cemented by the use of an active solvent such as acetone. The addition of a higher boiling solvent such as ethyl acetate, will reduce the tendency to condense moisture and blush in humid water. Blushing, aside from making the sheet opaque, will cause poor adhesion. Dip polishing and staining can similarly be accomplished with less active solvents carrying the appropriate dyestuffs. The use of too active solvent in dipping extruded tubing will cause a rough or " orange-peel " surface.

Pyralin pyroxylin plastic is more resistant to moisture absorption than cellulose acetate base materials, and consequently will not distort as much on exposure to moisture. However, it is sensitive to long exposure to heat or ultra-violet rays and will discolor and become brittle under these conditions. It should be stored, therefore, in a cool, well ventilated place, and not exposed to the direct rays of the sun.

The specific gravity of Pyralin varies over a small range depending upon the pigment content. The following table will serve to compare several standard pigment classes with wood.

TABLE 21. PYRALIN: COMPARISON WITH WOOD

	Specific Gravity	Approximate Weight per Sheet, pounds	
		0.020 in.*	0.100 in.
Transparent and shell	1.37	0.99	5.43
Metallic pearl	1.38	1.00	5.47
Black	1.39	1.00	5.50
Essence pearl	1.41	1.02	5.59
Translucent, white and ivory	1.42	1.03	5.64
Cream	1.51	1.09	5.98
Opaque white	1.58	1.14	6.25
White pine	0.43	——	——
Black walnut	0.59	——	——
Live oak	0.87	——	——

* Sheet thickness.

CUMARONE–INDENE

Cumar[20]

Cumar is offered in several grades ranging in color from pale to dark and in consistency from semi-fluids to resins of high melting point.

The various forms of Cumar are classified by gradings established to meet the major industrial requirements for standardized resins. Other Cumars can be produced for users desiring resins of characteristics specifically suited to their own needs.

W Grades — Hardest, highest form of Cumar; often called " Indene Resin " in the industry.

Uses: Quick-setting varnishes, insulating compounds, rotogravure inks.

V Grades — Lower melting than the W Grade.

Uses: The standard Cumar for varnish and allied lines; rubber compounding and adhesives.

P Grades — Plastics low melting resins.

Uses: Adhesives, rubber, plastics compounds, waterproofing.

R Grades — Produced especially for the rubber industry.

Uses: Rubber softeners, tack producers, and extenders.

M Grades — (M.H., Medium Hard; M.S., Medium Soft.) — Resins of intermediate hardness.

Uses: Special varnishes, rubber compounding, adhesives.

X Grades — Of value in products not requiring pale resins. Are widely employed in improving chemical resistance of low priced coatings and compounds.

Uses: Varnishes and enamels, waterproofing compounds, caulking compounds, rubber compounding and reclaiming.

ETHYL CELLULOSE

Ethocel[21]

Ethocel is an ethyl ether of cellulose resulting from the interaction of ethyl chloride with alkali cellulose. It is colorless, odorless, tasteless, and nontoxic. It resists attack

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[20] Barrett Co.

[21] Dow Chemical Co.

by alkalies and dilute acids, is not discolored by strong sunlight, is stable to heat, and has a low order of flammability. These properties, together with its excellent insulating qualities and its flexibility, toughness, and compatibility, combine to make it the most versatile of the cellulose derivatives in the manufacture of coating compositions, films, and plastics.

Ethocel is developing wide utility in molding plastics and other plastics applications because of its unusually fortunate combination of properties. It is inherently resistant to degradation under molding temperatures, has a low softening point compared to the cellulose esters, and is compatible with a wide variety of plasticizers, resins, oils, and waxes. Its low flammability permits the formulation of relatively non-flammable plastics by the use of suitable plasticizers. The dielectric properties of Ethocel plastics, their resistance to alkalies and dilute acids, and their good dimensional stability with variations in humidity indicate them for many electrical uses.

Ethocel Plastics Granules are available in a variety of colors ready for molding. They are particularly suited to molding by injection methods. They flow readily, release easily, and yield tough moldings of good gloss, surface hardness, and shock resistance.

Molding Material
Compression Molding Temperature, ° F.: 320°-360° F.
Compression Molding Pressure, lb. per sq. in.: 1000-5000
Injection Molding Temperature, ° F: 380°-420° F.
Injection Molding Pressure, lb. per sq. in.: 3000-30,000
Compression Ratio: 2.2-2.5
Mold Shrinkage, in. per in.: 0.004-0.007

Extruded Plastics. Extruded wire coatings and small bore tubing are natural applications for Ethocel plastics. These uses require a large propertion of plasticizer and that the plasticizer be selected for its electrical properties and lack of toxicity as well as its effect upon the toughness and flexibility of the plastic.

Thermoplastic Adhesives. Ethocel forms the basis of thermoplastic adhesives for a wide variety of uses. Among them are splicing leather, bonding plywood, fusing fabric plies as in the manufacture of collars, laminating paper stock, and bonding metal foils to paper. Ethocel may be employed for these uses in the form of a coating, or a free film formulated to fit the particular use.

Hot Melt Coatings. Ethocel is highly adapted to the manufacture of solvent-free compositions which can be applied in a molten condition. Standard Ethocel dissolves in ester-type waxes, the higher fatty acids, and their corresponding alcohols to form melts which are harder, tougher, higher melting, and shrink less on cooling than the waxy materials themselves. When plasticizers or resins are added, the melt will tolerate the addition of the mineral hydrocarbon waxes such as paraffin, ceresin, and ozokerite with which Ethocel is incompatible alone. These melted compositions are readily applied to paper, transparent films, and metal foils by the use of ordinary paper-waxing machines. They form moistureproof, heat-sealing, glossy coatings which are superior in flexibility to the wax or lacquer coatings commonly used. The coatings can be used for food wrapping papers since the ingredients can be selected for their lack of toxicity and freedom from odor and taste. Hot melt coatings promise to be one of the major fields of utility of Ethocel.

Pigment Dispersion. One of the most useful applications of Ethocel is in the dispersion of pigments. Ethocel is heat softened in a Banbury type mixer or two-roll compounding mill, and the pigment added. The pigment agglomerates are torn apart by the shearing action of the hot plastics mass and the individual particles are encased in a sheath of Ethocel. The hot plastic is sheeted on the rolls and broken up into chips or ground. The chips contain the pigment particles dispersed to an unusually fine state of subdivision and may be used to color lacquers or plastics.

Ethofoil[22]

Ethofoil is Ethocel in the form of transparent film. It is a clear, glossy sheet which transmits up to 95 per cent of ordinary daylight and more than 90 per cent of ultraviolet light. It is tough, highly flexible, and does not shrink or curl. It retains these properties on aging, on exposure to light, and on exposure to wide variations in temperature and humidity. These qualities indicate Ethofoil as a wrapping sheet for year-round utility.

Ethofoil 610: Dow ethyl cellulose cast into clear transparent sheeting.

Uses: Transparent envelopes, rigid containers, point of sale displays, electrical insulation, greeting cards, flexible windows, industrial helmets and goggles, plastics ring binders.

Ethofoil is tough and flexible. It can be scored through a beaded edge without cracking.

Ethofoil is ductile. It is readily heat formed by drawing processes. The ductility of Ethofoil makes practical the fabrication of slip-on covers and one-piece bottoms for cylindrical boxes by mass production methods. Ethofoil is economical to use for deep draws since it greatly increases the yield of perfect pieces.

Ethofoil is thermoplastic. It is unusually adapted to hot scoring and continuous beading and is not embrittled by these operations. Temperatures recommended for:

Scoring and folding	180°–225° F.
Continuous beading	225°–275° F.
Deep drawing	225°–280° F.

Ethofoil 610 Stock Sizes:

Continuous rolls: approx. 25 in. wide by 12 in. O.D.

Ethofoil gauge: 0.003 in., 0.005 in., 0.0075 in., 0.010 in., 0.015 in., 0.020 in.

Sheets: 25 in. by 40 in.

Also cut-to-size sheets

Special grades: Ethofoil 611, and HD–33

PHENOL–FORMALDEHYDE

Durez[23]

Durez molding compounds are all of the phenolic type. In common with other plastics they are relatively light in weight, pleasant to the touch because of their low thermal conductivity, and high in electric insulating value. They are distinguished from other thermosetting materials by their ready moldability, high finish, permanence, and resistance to solvents, acids, mild alkalies, heat, and weather. They have, in

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[22] Dow Chemical Co.

[23] Durez Plastics & Chemicals, Inc.

common with other phenolic plastics, a lack of color permanence in light shades and a lack of resistance to very strong alkalies.

Several hundred types of Durez are available, designed to meet varying conditions of use and procedures of molding. These compounds differ in the type of phenolic resin used and in the amount and nature of the filler. It is impossible to do more than list the properties of some important types of compounds in the tables that follow. The special properties of one class of compound are often found in those of another class, e.g., heat resistance combined with high impact strength.

General-purpose Materials. These materials are intended for the ordinary run of work where ready moldability and a smooth, high finish are the prime requisites. General-purpose materials have adequate strength and resistance to solvents, water, heat, and electricity for the ordinary conditions. The table lists the properties of a general purpose compound. There is also given, for comparison, a list of the properties of a phenolic resin molded under the same conditions.

TABLE 22. GENERAL-PURPOSE EXAMPLE

Properties*	Durez 3971 Black	Cured Durez Resin
Specific Gravity	1.36	1.28
Compressive Strength	30,000	25,000
Impact Strength	0.15	0.12
Flexural Strength	10,000	10,000
Tensile Strength	6000	6000
Dielectric Breakdown	250	350
Dielectric Constant (10 E cycles)	5.5	5.6
Power Factor, % (cycles)	5.0	2.7
Water Absorption, %	0.7	0.3

* As determined by A.S.T.M. Standard methods.

High-impact Materials. The general-purpose materials are somewhat brittle. The impact strength can, however, be increased greatly by proper selection of fillers. The fillers used for this purpose may be cotton, linen, hemp, or asbestos in the form of long fibers, threads, cloth, or paper. Because of the bulky filler, high-impact materials (before molding) are less dense than general-purpose compounds and have a tendency to give a thick fin (poor cutoff) in molding. Automatic preforming is impossible with the highest impact grades, but is feasible with Durez 1905, which has an impact strength of 0.5 to 0.6, three to four times that of general-purpose material.

Minimum Odor and Bleed. General-purpose compounds have a faint odor of phenol and ammonia and should not be used for bottle caps or in direct contact with foodstuffs. The dyestuffs used in ordinary compounds are also used in pharmaceutical preparations. Materials are therefore available which are sufficiently free from odor for use in closure caps and in which the coloring materials are selected for their resistance to organic solvents. These compounds are designed to give high torque strength and are usually made extremely fast curing because of the short draw required for molding. Physical properties are otherwise the same as for general-purpose materials, electric properties slightly poorer. Durez 3948 and 3949 are especially suitable for the molding of caps on the Lauterbach machine.

Heat Resistance. For best heat resistance it is necessary to replace the cellulose filler of standard compounds with a mineral such as asbestos. The mineral filler increases the specific gravity of the compound and decreases its water absorption. A typical example is Durez 38–443 which will stand 400° F. continuously and has an impact strength of 0.23, a water absorption of 0.23 per cent, and a specific gravity of 1.80.

Electrical Properties. The dielectric strength of molding compounds can be increased markedly without much change in other properties. Thus Durez 2491, which is a wood-filled compound, has a dielectric strength of 550 V/mil. This compound has improved arc resistance over standard compounds but is surpassed in this particular by Durez 8685.

Special compounds are available for molding of electrical condenser and resistor jackets. For high-frequency work a compound with the unusually low power factor of 0.34 per cent at 1 megacycle may be obtained (Durez 1601).

Colors. Many colored molding materials are manufactured in shades ranging from black to ivory, pure white being unavailable. Light colors discolor in sunlight or under heat, the least discoloration being observed in reds and yellows. The physical properties of colors do not vary markedly from standard blacks and browns. The primary variation is in specific gravity, which ranges from 1.34 to 1.60 and is highest for light colors. Many colors are produced as standard products, and special colors can be made to order.

Water and Solvent Resistance. The surface of ordinary grades of molding compound is dulled by continuous immersion in water or certain organic solvents. Special resistant grades are produced which have a record of continuous performance in water up to 212° F. (Durez 75.) This same material resists solvents, acid and mild alkalies almost as well as water. For instance, no bleeding or etching effect on prolonged immersion is produced by alcohol, acetic acid, butyl, ethyl acetate, acetone or 10 per cent hydrochloric acid.

Makalot[24]

Makalot is thermosetting molding material comprised of a synthetic phenol-formaldehyde resin compounded with various fillers, pigments, and dyestuffs. It is supplied to molders in various forms, most commonly a granular powder, to be molded with heat and pressure. The finished castings are infusible and insoluble and possess in general the physical and electric properties listed in Table 23.

With the advance of molding technique, it became imperative to develop compounds more specifically designed to meet individual molding conditions, an indicative few of which are listed in Table 24.

[24] Makalot Corp.

TABLE 23. PROPERTIES OF MAKALOT

Constants	Wood Flour Filler	Mineral Filler	Fabric Filler
Molding Qualities	Excellent	Excellent	Good
Compression Molding, ° F.	280–360	270–350	270–330
Compression Molding Pressure, lb. per sq. in	2000–4500	2000–4000	3000–8000
Injection Molding Temperature, ° F.	275–375	275–350	—
Injection Molding Pressure, lb. per sq. in.	2000–10,000	2000–10,000	—
Compression Ratio	2.2–2.8	2.0–6.0	3.0–11.0
Mold Shrinkage, in. per in.	0.006–0.010	0.002–0.006	0.003–0.007
Specific Gravity	1.36–1.52	1.60–2.0	1.37–1.45
Specific Volume, cu. in. per lb.	22.2–18.2	16.4–13.0	20.2–19.5
Tensile Strength, lb. per sq. in.	4000–11,000	4000–10,000	6500–12,000
Modulus of Elasticity, lb. per sq. in.	10–15	10–45	7–12
Compressive Strength, lb. per sq. in.	16,000–36,000	18,000–36,000	20,000–32,000
Flexural Strength, lb. per sq. in	8000–15,000	8000–20,000	10,000–13,000
Impact Strength, ½ by ½ in. bar — Izod	0.10–0.28	0.11–0.36	0.4–2.4
Thermal Conductivity, 10^4 cal. per sec. per sq. cm. ° C. per cm.	4–12	8–20	3–5
Specific Heat, cal. per ° C. per gm.	0.35–0.36	0.25–0.35	0.30–0.35
Thermal Expansion, 10^5 per ° C.	3.7–7.5	2.5–4.0	2–6
Resistance to Heat, ° F. (continuous)	350	450	350
Softening Point	None	None	None
Tendency to Cold Flow	None	None	None
Volume Resistivity, ohm.-cm. (25° C.)	10^{10}–10^{12}	10^{9}–10^{11}	10^{9}–10^{11}
Breakdown voltage, 60 cycles, volts per mil	300–500	250–400	300–450
Dielectric Constant, 60 cycles	5–12	5–20	5–12
Power Factor, 60 cycles	0.04–0.30	0.10–0.30	0.08–0.30
Water Absorption, 24 hr.	0.05–0.6	0.0–0.2	1.0–1.5
Burning Rate	Very low	None	Very low
Effect of Age	None	None	None
Effect of Weak Acids	Slight	Slight to none	Slight
Effect of Strong Acids	Decomposed	Some numbers not affected	Decomposed
Effect of Strong Alkalies	Decomposed	Decomposed	Decomposes

TABLE 24. MAKALOT COMPOUNDS

Number	Specific Gravity	Gm. per cu. in.	Makalot-Cellulose Filler Materials Black — Description
1016	1.42	22.2	Fast-curing general-purpose black with smooth lustrous finish. Hard, Medium, Soft.
1005	1.41	22.9	Smooth surface. Fast cure of the double-dyed type for use on parts requiring sanding and buffing. Flow range: Soft, Medium, Hard.
1022	1.40	22.9	Fast-curing compound. Brilliant finish. Short flow period. Used on shallow draft closures, etc. Flow-range: Medium, Hard.
1125	1.43	22.3	Fast-curing medium-flow range. Exceptionally smooth luster. Used on boxes, cases, etc. Flow range: Soft, Medium, Hard.

TABLE 25. MAKALOT — MOLDED

Properties	Wood Flour Filler	Mineral Filler	Fabric Filler
Effect of most organic solvents	None	None	None
Effect of metal inserts	None	None	None
Color possibilities	Limited	Limited	Limited

TABLE 26. MAKALOT CELLULOSE FILLER MATERIALS

Number	Specific Gravity	Gm. per cu. in.	Black — Description
1212	1.39	22.8	For extrusion or transfer molding. Extremely long flowing compound with quick final set. For use in extrusion molding. 190 Flow.
1762	1.39	22.8	Highest grade general purpose. Exceptionally fast cure. Fairly high shrinkage for easy ejection. Flow range: Soft, Medium.
1803	1.36	22.2	Extra-strength black. Can be preformed and molded as general-purpose material but has an impact strength of 25 to 35% higher. Smooth high-luster surface. Flow range: Soft, Medium.
1955	1.	---	Nonbleeding closure compound. Possess best unscrewing and stripping properties. Flow range: Medium, Hard, Extra Hard.
1962	1.40	22.9	Lowest shrinkage compound. No cracking or looseness when molded around large inserts. Practically unaffected by reasonable temperature variations. Brown equivalent 2962. Flow range: Soft, Medium, Hard.
1963	1.40	22.9	General-purpose compound of highest grade. Combining long flow period with fast cure. Pieces possess a greater degree of flexibility. Flow range: Soft, Medium.
			Brown — Description
2005	1.40	22.9	Double-dyed brown. Shows no specks after sanding and buffing. Flow range: Soft, Medium.
2402	1.40	22.9	General-purpose, long-draw compound with smooth lustrous finish. Black equivalent No. 1403. Flow range: Soft, Medium, and Hard.
2962	1.40	22.9	Lowest shrinkage compound. No cracking or looseness when molded around large inserts. Practically unaffected by reasonable temperature variations. Black equivalent 1962. Flow range: Soft, Medium, and Hard.
2963	1.40	22.9	General-purpose compound of highest grade Combining long flow period with fast cure. Pieces possess a greater degree of flexibility. Flow range: Soft, Medium.

Reilly Indur[25]

Reilly Indur includes molding compounds and thermosetting resins of the phenol-formaldehyde type. Many types of liquid resins, with or without solvents, are available.

Indur molding powders are obtainable in a variety of colors including black, brown, and mottle effects.

Indur molding resins offer a choice of colors including green, red, yellow, orange, and dark blue.

Indur molding powders are compounded from resins formed during the condensa-

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[25] Reilly Tar & Chemical Co.

tion reaction of phenol and formaldehyde. Necessary fillers including wood flour, asbestos, and mineral matter are added. Further additions include pigments and other chemicals to give the powder the required molding properties.

Fabrication of Indur molding powders is carried out in steel molds at temperatures ranging from 250° to 450° F. The molded article is hard and strong, and in most instances, further work is not required.

Constants

	Wood Flour Filler	Mineral Filler
Molding Qualities	Excellent	Excellent
Compression Molding Temperature, ° F.	330–400	330–360
Compression Molding Pressure, lb. per sq. in.	1000–3000	1000–3000
Compression Ratio	2.5–3.0	2.5–6.0
Mold Shrinkage, in. per in.	0.005–0.009	0.002–0.006
Specific Gravity	1.3–1.4	1.6–2.0
Specific Volume, cu. in. per lb.	21.3–19.8	17.3–13.9
Tensile Strength, lb. per sq. in.	6000–11,000	5000–10,000
Compressive Strength, lb. per sq. in.	28,000–36,000	24,000–36,000
Flexural Strength	8000–15,000	8000–20,000
Impact Strength, ft.-lb. energy to break ½ by ½ in. bar (Charpy)	0.1–0.50	0.10
Volume Resistivity, ohms (50% relative humidity at 25° C.)	1010–1012	109–1011
Breakdown Voltage, 60 cycles, volts per mil (instantaneous)	400–600	200–500
Dielectric Constant, 60 cycles		
10^3 cycles	4–12	4.5–20
10^6 cycles	6–7.5	5–18
Power Factor, 60 cycles		
10^3 cycles	0.04–0.15	0.1–0.15
10^6 cycles	0.035–0.11	0.04–0.15
Water Absorption, 24 hr.	0.2–0.6	0.01–0.15
Burning Rate	Very low	Nil

Resinox[26]

The Monsanto phenol-formaldehyde molding compounds are known as Resinox. They are supplied in a variety of opaque colors and mottles and in several filler mixtures.

Many different grades are available, such as: general purpose, impact, high-heat, high water-resistant, minimum odor, non-bleeding, and compounds in wide variety of colors. For use in plants where only low pressure is available or where molds are necessarily large and intricate, compounds are furnished in soft flows. When available pressure is high and molded pieces are small, medium- to stiff-flow materials are recommended. In general, the finish is better when medium- or stiff-flowing compounds are

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[26] Monsanto.

used. Medium- and stiff-flow compounds also tend to shorten the cure and reduce production costs. Wherever possible, the use of extremely soft material should be avoided.

When ordering or requesting samples of Resinox molding compounds, it is important to give sufficient information so that the proper material may be chosen. The flow of the material should be indicated and, whenever possible, a sample of the articles to be molded should be furnished together with full information concerning the use to which it is to be put. Information should also be given regarding the importance of surface finish. On new applications of phenolic material, or when it is impossible for the molder to specify the type and character of material needed, the manufacturer's technical service department will be glad to give assistance.

In ordering colored molding materials, even greater care should be exercised in giving complete information regarding the intended use. Dyestuffs and pigments used in molding compounds are of almost unlimited variety, and when the use is known, ingredients may be chosen which will have no undesirable reaction.

Compounds are packed in welded-seam steel drums, each drum containing approximately 300 lb. net, except in the case of highly pigmented and high-heat compounds when the net weight will run up about 450 lb. The tare weight of drums is approximately 25 lb. Drums are sealed with removable tops and rubber gaskets, making them air- and watertight. The compound stores well in unopened drums, but, when exposed in a humid atmosphere, may pick up sufficient moisture to produce a mottling or flow-marking effect. It is, therefore, advisable to replace the lid of the drum whenever it is to stand for an extended period. The best storage temperature is approximately 70° F. If it is stored in a cold warehouse and used when cold, it will require a longer curing period since it is necessary for the molding material to absorb more heat to become plastic. Compounds, when used cold, may have a tendency to blister at normal molding cycles.

Care is taken to prevent contamination of molding material before leaving the manufacturing plant and it is important that contamination with other compounds be avoided in the molding shop. This is particularly important with colors in which even small particles of black or brown material will appear as specks in the finished piece.

The properties following were determined by A.S.T.M. methods on standard-size pieces molded under carefully controlled conditions and are, therefore, indicative of the properties of articles molded from these materials.

Resinox 3533 Black

A general-purpose material recommended for molding articles requiring a smooth, jet-black finish. It is particularly suitable for clock cases, radio cabinets, boxes, and similar objects.

Brown equivalent, Resinox 3533 Brown

Powder

Particle Size: Ground to pass U. S. Standard 16-mesh screen
Apparent Density, gm. per cc.: 0.52 to 0.60
Bulk Factor: 2.40 to 2.77
Pourability, seconds: 15 to 20
Preforming Characteristics: Good
Flow Range: 5 to 10

Moldings

Specific Gravity: 1.44
Weight per cu. in., gm.: 23.6
Flexural Strength, lb. per sq. in.: 9200
Tensile Strength, lb. per sq. in.: 6800
Impact Strength, ft.-lb. per sq. in.: 2.50
Water Absorption, % by wt.: 0.63
Shrinkage, in. per in.: 0.0065 to 0.0075

Resinox 1808 Black

A molding material combining good molding properties with very high water and alkali resistance and good mechanical strength. It is recommended for molding parts which are to be subjected to moisture, water, or oil and water emulsions. While this material is not nearly as odorless as Resinox 1604 and 3510, extended tests with containers in contact with a variety of cosmetic creams have shown Resinox 1808 Black to be unaffected by, and to have no effect on, such preparations.

Brown equivalent, Resinox 1808 Brown

Powder

Particle Size: Ground to pass U. S. Standard 16-mesh screen
Apparent Density, gm. per cc.: 0.54 to 0.64
Bulk Factor: 2.03 to 2.41
Pourability, seconds: 17 to 24
Preforming Charactertistics: Good
Flow: 8 to 12

Moldings

Specific Gravity: 1.30
Weight per cu. in., gm.: 21.3
Flexural Strength, lb. per sq. in.: 10,600
Maximum Deflection, in.: 0.075
Water Absorption, % by wt.: 0.18
Shrinkage, in. per in.: 0.009 to 0.0105

Resinox 1806 Black

A general-purpose molding material designed especially for molding pieces with comparatively long draw. The molded parts are characterized by a deep, jet-black color and a smooth, lustrous surface.

Powder

Particle Size: Ground to pass U. S. standard 16-mesh screen
Apparent Density, gm. per cc.: 0.53 to 0.62
Bulk Factor.: 2.16 to 2.53
Pourability, seconds: 15 to 20
Preforming Characteristics: Good
Flow: 8 to 16

Moldings

Specific Gravity: 1.34
Weight per cu. in., gm.: 22.0
Flexural Strength, lb. per. sq. in.: 10,200
Maximum Deflection, in.: 0.056
Tensile Strength, lb. per sq. in.: 6700
Impact Strength, ft.-lb. per sq. in.: 2.70
Dielectric Strength, 60 cycles, volts per mil: 450
Water Absorption, % by wt.: 0.65
Shrinkage, in. per in.: 0.0065 to 0.0075

Resinox 1602 Black

A general-purpose molding material combining rapid cure with high mechanical strength of the molded piece. Resinox 1602 Black is particularly suited for the molding of parts requiring superior flexural strength with medium gloss and finish.

Brown equivalent, Resinox 1602 Brown

Powder

Particle Size: Ground to pass U. S. standard 16-mesh screen
Apparent Density, gm. per cc.: 0.55 to 0.93
Bulk Factor: 2.21 to 2.53
Pourability, seconds: 15 to 22
Preforming Characteristics: Good
Flow: 7 to 16

Moldings

Specific Gravity: 1.39
Weight per cu. in., gm.: 22.8
Flexural Strength, lb. per sq. in.: 11,000
Maximum Deflection, in.: 0.060
Tensile Strength, lb. per sq. in.: 6500
Impact Strength, ft.-lb. per sq. in.: 2.96
Dielectric Strength, 60 cycles, volts per mil: 450
Water Absorption, % by wt.: 0.83
Shrinkage, in. per in.: 0.006 to 0.0075

Resinox 1604 Black

Parts molded from this compound have exceptionally high torque strength, good finish, and more flexibility than the standard molding materials. Resinox 1604 Black is recommended for molding closures and other shallow-draw pieces where fast cure, flexibility, and odorless and non-bleeding characteristics are required. (Brown equivalent, Resinox 1604 Brown.)

Powders

Particle Size: Ground to U. S. standard 16-mesh screen
Apparent Density, gm. per cc.: 0.50 to 0.61
Bulk Factor: 2.23 to 2.72
Pourability, seconds: 16 to 23
Preforming Characteristics: Good
Flow: 7 to 14

Moldings

Specific Gravity: 1.36
Weight per cu. in., gm.: 22.3
Flexural Strength, lb. per sq. in.: 12,000
Maximum Deflection, in.: 0.068
Tensile Strength, lb. per sq. in.: 7500
Impact Strength, ft.-lb. per sq. in.: 3.02
Dielectric Strength, 60 cycles, volts per mil: 400
Water Absorption, % by wt.: 0.87
Shrinkage, in. per in.: 0.006 to 0.0075

Resinox 4410 Black

(Tentative Specifications)

A splendid closure material especially adapted for Lauterbach machine operation. Produces molded parts possessing excellent finish and strength.

Powders

Particle Size: Ground to pass U. S. standard 16-mesh screen
Apparent Density, gm. per cc.: 0.53 to 0.61
Pourability, seconds: 15 to 22
Preforming Characteristics: Good
Flow: 6 to 16

Moldings

Specific Gravity: 1.39
Weight per cu. in., gm.: 22.8
Flexural Strength, lb. per sq. in.: 11,000
Maximum Deflection, in.: 0.063
Tensile Strength, lb. per sq. in.: 7000
Impact Strength, ft.-lb. per sq. in.: 2.45
Dielectric Strength, 60 cycles, volts per mil: 450
Water Absorption, % by wt. :0.66
Shrinkage, in. per in.: 0.007 to 0.008

Resinox 3941 Black

(Tentative Specifications)

A semi-impact material of highest quality. With Izod method, notched bar, requires 0.274 foot-pounds energy to break. Produce molded parts having excellent finish and strength.

Powders

Particle Size: Ground to pass U. S. standard 10-mesh screen
Apparent Density, gm. per cc.: 0.39 to 0.44
Bulk Factor: 3.1 to 3.5
Pourability: Pours through standard opening poorly
Preforming Characteristics: May require special feeder on preforming machine
Flow: 8 to 15

Moldings

Specific Gravity: 1.36
Weight per cu. in., gm.: 22.3
Flexural Strength, lb. per sq. in.: 11,000
Tensile Strength, lb. per sq. in.: 8500
Impact Strength, ft.-lb. per sq. in.: 5.0
Dielectric Strength, 60 cycles, volts per mil: 350
Water Absorption, % by wt.: 0.60
Shrinkage, in. per in.: 0.0048 to 0.0058

Resinox 3827 Black

(Tentative Specifications)

This material is recommended for applications requiring high heat resistance. Parts molded from Resinox 3827 Black will withstand temperatures up to 475° F. This material is an improvement over, and displaces, Resinox 1629 Black.

Powders

Particle Size: Ground to pass U. S. standard 10-mesh screen
Apparent Density, gm. per cc.: 0.75 to 0.86
Bulk Factor: 2.15 to 2.45
Pourability, seconds: 25 to 32
Preforming Characteristics: Good
Flow: 8 to 14

Moldings

Specific Gravity: 1.84
Weight per cu. in., gm.: 30.7
Flexural Strength, lb. per sq. in.: 8000
Tensile Strength, lb. per sq. in.: 4200
Impact Strength, ft.-lb. per sq. in.: 1.90
Water Absorption, % by wt.: 0.10
Shrinkage, in. per in.: 0.003 to 0.004

Resinox 5002 Brown

(Tentative Specifications)

A general-purpose brown molding compound with splendid flow characteristics. Pieces molded of this material possess good mechanical strength, excellent gloss and finish. Particularly recommended for intricate molding operations. Flow range is unusually wide.

Powders

Particle Size: Ground to pass U. S. standard 16-mesh screen
Apparent Density, gm. per cc.: 0.52 to 0.59
Bulk Factor: 2.34 to 2.66
Pourability, seconds: 15 to 20
Preforming Characteristics: Good
Flow: 10 to 16

Moldings

Specific Gravity: 1.38
Weight per cu. in., gm.: 22.6
Flexural Strength, lb. per sq. in.: 10,000
Tensile Strength, lb. per sq. in.: 7000
Impact Strength, ft.-lb. per sq. in.: 2.8
Water Absorption, % by wt.: 0.8
Shrinkage, in. per in.: 0.0065 to 0.0075

PHENOL–FORMALDEHYDE AND PHENOL–FURFURAL

Durite[27]

Durite includes phenol-furfural and phenol-formaldehyde thermosetting resins and molding compositions, liquid resins for impregnation and bonding, and oil-soluble resinoids for paints and varnishes.

Molding compounds are available in powder form in black and brown and other dark shades, oil-soluble reactive resins are made in lump form, and liquid resins for impregnation and bonding come in water and alcohol solutions.

Durite molding material is compounded from phenol-furfural and phenol-formaldehyde resin, filler, pigments, and plasticizing agents. The resulting compound after suitable preparation (as a powder or preforms) is fabricated in tool steel, casehardened dies under a temperature of 250° to 450° F., and a pressure of 500 to 4000 lb. per sq. in. on the projected area of the mold. During the molding process the material softens

[27] Durite Plastics.

TABLE 27. PROPERTIES OF DURITE MOLDING MATERIALS

Constants	Wood Flour Filler	Mineral Filler	Fabric Filler
Molding Qualities	Excellent	Excellent	Good to fair
Compression Molding Temperature, ° F	330–400	330–360	300–360
Compression Molding Pressure, lb. per sq. in.	1000–3000	1000–3000	1000–3000
Injection Molding Temperature, ° F.	250–290	250–290	250–290
Injection Molding Pressure, lb. per sq. in.	300–5000	300–5000	300–5000
Compression Ratio	2.5–3.0	2.5–6.0	4.0–15.0
Mold Shrinkage, in. per in.	0.005–0.009	0.002–0.006	0.0025–0.006
Specific Gravity	1.3–1.4	1.6–2.0	1.3–1.4
Specific Volume, cu. in. per lb.	21.3–19.8	17.3–13.9	21.3–19.8
Refractive Index, N_D	—	—	—
Tensile Strength, lb. per sq. in.	6000–11,000	5000–10,000	6500–8000
Elongation, %	—	—	—
Modulus of Elasticity, lb. per sq. in. $\times 10^5$	10–25	10–45	7–12
Compressive Strength, lb. per sq. in.	28,000–36,000	24,000–36,000	26,000–30,000
Flexural Strength, lb. per sq. in.	8000–15,000	8000–20,000	10,000–13,000
Impact Strength, ft.-lb. energy to break ¼ by ¼ in. bar (Charpy)	0.08–0.52	0.08–0.48	1.6–3.1
Hardness (2.5-mm. ball, 2.5-kg. load), Brinell No.	35–40 (50 kg.)	44–46 (50 kg.)	30–35 (50 kg.)
Thermal Conductivity, 10^4 cal. per sec. per sq. cm. per ° C. per cm.	3.5–5	10–20	5–8
Specific Heat, cal. per ° C. per gm.	0.3–0.4	0.3–0.4	0.3–0.4
Thermal Expansion, 10^6 per ° C.	3	2	4.5
Resistance to Heat, ° F. (continuous)	280–400	350–500	280–350
Softening Point, ° F.	Chars 450	Chars 550	Chars 400
Distortion under Heat, ° F.	268–288	277–297	—
Tendency to Cold Flow	None	None	None
Volume Resistivity, ohm.-cm. (50% r.h. and 25° C.	10^{10}–10^{12}	10^9–10^{11}	10^9–10^{11}
Breakdown Voltage, 60 cycles, volts per mil (instantaneous)	400–600	200–500	200–500
Dielectric Constant, 60 cycles	—	—	—
10^3 cycles	4–8	4.5–20	4.5–6
10^6 cycles	6–7.5	5–18	5–7.5
Power Factor, 60 cycles	—	—	—
10^3 cycles	0.04–0.15	0.1–0.15	0.08–0.20
10^6 cycles	0.035–0.1	0.04–0.1	0.035–0.1
Water Absorption, immersion 24 hr.	0.2–0.6	0.01–0.15	0.8–1.4
Burning Rate	Very low	Nil	Nil
Effect of Age	Hardens slightly	Hardens slightly	Hardens slightly
Effect of Sunlight	Light Shades Discolor		
Effect of Weak Acids	None to slight depending on acid		
Effect of Strong Acids	Decomposed by oxidizing acids, reducing and organic acids no effect		
Effect of Weak Alkalies	Slight to marked depending on alkalinity		
Effect of Strong Alkalies	Decomposes	Decomposes	Decomposes
Effect of Organic Solvents	None on bleedproof materials		
Effect on Metal Inserts	Inert	Inert	Inert
Machining Qualities	Fair to good	Fair to good	Fair to good
Clarity	Opaque	Opaque	Opaque
Color possibilities	Limited	Limited	Limited

into a plastic mass which flows into every unrestricted area of the die. Within a few seconds the compound undergoes a chemical reaction and converts to an infusible, hard, strong, and insoluble form. Taking its shape from the die, it becomes ready for use after a simple finishing operation.

Polystyrene Resin

Loalin[28]

Loalin, now available in water-clear transparent molding material, is a thermoplastic resin characterized by its own exceptionally low water absorption, resistance to alkalies and acids, and great dimensional stability. It also has exceptionally good electrical properties, having a low power factor and high dielectric strength and insulation resistance.

Constants

Specific Gravity: 1.05 to 1.07
Specific Weight, gm. per cu. in.: 17½
lb. per cu. in.: .0385
Tensile Strength, lb. per sq. in.: 5500 to 7000
Modulus of Elasticity, lb. per sq. in.: 375,000 to 425,000
Impact Strength, ft.-lb. energy to break: 0.2 to 0.6
Flexural Strength, lb. per sq. in.: 14,000 to 19,000
Bulk Factor: 2.2
Shrinkage, in. per in.: 0.002 to 0.008
Distortion under Heat, ° F.: 175 to 185
Water Absorption, %: from 0 to 0.05
Index of Refraction: 1.59 to 1.597
Thermal Coefficient of Expansion, per ° C. × 10^{-6}: 65 to 75
Specific Heat, cal. per ° C. per gm.: 0.32
Dielectric Strength, 60 cycles, step by step, volts per mil: 500 to 525
Volume Resistivity, megohm-cm.: from 109 to infinity
Arc Resistivity, seconds: from 120 to 140
Power Factor, 60 cycles to 50 million cycles: 0.0002 to 0.0003
Dielectric Constant, 60 cycles to 50 million cycles: 2.5 to 2.6
Loss Factor, 60 cycles to 50 million cycles: 0.0005 to 0.0008

Loalin has excellent resistance to non-oxidizing acids. It will discolor slightly with oxidizing acids. It resists almost all alkalies, is insoluble in the alcohols, but is soluble in most of the aromatic hydrocarbons such as benzene, toluene, ethyl benzene, ethyl acetate, Carbona (carbon tetrachloride), turpentine and ethylene chloride.

Loalin may be readily molded by injection. Standard injection molding machines are suitable. The temperature required to flux completely and soften Loalin is from 350° to 400° F. The pressure depends on the size and number of cavities in the mold, and is best determined by trial to find the one best suited.

Loalin sets rapidly and in some cases the cooling cycle may be considerably shortened, as compared to acetates and methacrylates. It is sometimes necessary to shut off the cooling water and let the mold warm up slightly, especially when long drafts and thin sections are being molded. This is also necessary when molding shapes in which mandrels are used, to prevent too much contraction on the mandrel.

The molds should be highly polished and free from marks and scratches, as the material reproduces all marks and details to a greater degree of accuracy than acetates.

The fast setting nature of Loalin requires short distances between nozzle and cavities.

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[28] Catalin Corporation.

Although it is generally recommended that Loalin be used for injection molding, it may also be used for compression molding. However, in the case of compression molding, the mold should be cooled to 200° F. or less before removing the article from the mold.

Lustron[29]

Lustron, Monsanto polystyrene, is a thermoplastic molding material. Lustron molded parts are characterized by sparkling transparency or a broad range of color, resistance to acids, alkalies, alcohols, and many solvents, high dimensional stability, exceptional electrical insulating properties, good thermal insulating properties, and low unit weight.

Lustron molding materials are thermoplastic. The molding methods used with Lustron take advantage of this property.

Most Lustron parts are molded by the injection method, although the material can be compression molded. Injection molding, which has tremendously expanded the use of thermoplastics during the last decade, has many advantages as applied to Lustron, permitting high speed production, careful control of dimensions, handling of delicate inserts, and in many cases almost completely automatic operation.

Lustron has been developed as a molding material particularly adapted to injection molding. All grades of Lustron are characterized by uniformly good flow under varying humidity conditions, stability under high heat and low mold shrinkage.

Since molding materials are occasionally subject to prolonged heating in injection machine cylinders, it is necessary that molding materials be stable under such conditions with no effect on color or on physical properties. The use of Lustron in all types of machines under all possible conditions, has proved the stability of Lustron in this regard.

Notable among the properties of Lustron is clear transparency. Parts molded of transparent Lustron are as clear as glass and in many cases even more sparkling and crystal-like. Millions of inexpensive magnifying glasses are being made of Lustron because of this transparency. Small molded packages, which reveal the eye-catching color of the product, sparkling salad sets, gauge crystals for industrial instruments, and pendants for electrical fixtures are among the diverse applications of transparent Lustron.

Related to the transparency of Lustron is its ability to carry light around curves or through flat sections. Instrument panels for radios and automobiles are molded of Lustron and mounted so that the edges are exposed to a concealed light. At each marking on the surface the light glows forth. In aircraft instruments a ring molded of Lustron goes around the face of the dial and is lighted from the rear. The glow of light from the ring fully illuminates the dial face without causing distracting glare to the pilot.

Uses: Interior refrigerator parts, liquor pourers, soap dishes, acid-lead type battery cases, aircraft instrument panels, magnifying glasses, toiletware, containers.

Limitations: Thermoplastic (softens under high heat).

Constants

Molding Quality: Excellent

Compression Molding Temperature, ° F: 270–350

Compression Molding Pressure, lb. per sq. in.: 1000–5000

Injection Molding Temperature, ° F.: 300–500

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[29] **Monsanto.**

Constants — *Continued*

Injection Molding Pressure, lb. per sq. in.: 10,000 and up

Compression Ratio: 2.0–2.3

Mold Shrinkage, in. per in.: Compression 0.002–0.005; Injection 0.002–0.008

Specific Gravity: 1.054–1.070

Specific Volume, cu. in. per lb.: 26.3–25.9

Refractive Index: 1.59

Tensile Strength, lb. per sq. in.: 5000–9000

Elongation, %: 2–5

Modulus of Elasticity, in tension, lb. per sq. in.: $1.7–2.6 \times 10^5$

Compressive Strength, lb. per sq. in.: 11,500–13,500

Flexural Strength, lb. per sq. in.: 14,000–19,000

Impact Strength, ft.-lb. per in. of notch ½ by ½ in. notched bar, Izod test: 0.35–0.50

Brinell Hardness, (2.5-mm. ball, 25-kg. load): 20–30

Rockwell Hardness: M87–M90

Light Transmission: 88–90%

Thermal Conductivity, 10^{-4} cal. per sec. per sq. cm. per ° C. per cm.: 1.9

Specific Heat, cal. per ° C. per gm.: 0.32

Thermal Expansion, per ° C.: $6–8 \times 10^5$

Resistance to Heat, ° F. (continuous):

Softening Point, ° F.: 190–230

Distortion under Heat, ° F. (A.S.T.M.): 170–180

Tendency to Cold Flow: Slight

Volume Resistivity, ohm-cm. (50% R.H. and 25° C.): $10^{17}–10^{19}$

Dielectric Strength, short time, volts per mil, ⅛ in. thickness: 500–700

Dielectric Constant, 60 cycles: 2.5–2.6

Dielectric Constant, 10^3 cycles: 2.5–2.6

Dielectric Constant, 10^6 cycles: 2.5–2.6

Power Factor, 60 cycles: 0.0001–0.0002

Power Factor, 10^3 cycles: 0.0001–0.0002

Power Factor, 10^6 cycles: 0.0001–0.0004

Water Absorption, immersion 24 hr.: 0.00

Burning Rate: Moderate

Effect of Age, Very slight.
Effect of Sunlight, Yellows slightly.
Effects of Weak Acids and Strong Acids, None.
Effect of Weak Alkalies and Strong Alkalies, None.
Effects of Organic Solvents, Soluble in aromatic and chlorinated hydrocarbons.
Machining Qualities, Fair to good.
Color Possibilities, Unlimited.
Effect on Metal Inserts, None.

Styron[30]

Styron is a clear, colorless, highly thermoplastic resin. It is polystyrene of exceptional purity made by polymerizing Dow Styrene under scientifically precise conditions. Styron is a molding material which is remarkable for its unusual combination of superior insulating properties with crystal clarity, moisture resistance, inertness, dimensional stability, and low temperature impact strength. It has a specific gravity of 1.05, which is lower than any other commercial molding material. This results in a greater volume of moldings per pound.

Styron is insoluble in ethanol and other alcohol-type solvents. It is insoluble in petroleum naphthas from paraffin base crudes, but is slightly swelled by them on long contact. It readily dissolves in aromatic naphthas or mixtures of aromatic hydrocarbons with petroleum naphthas. It is soluble in all proportions in aromatic hydrocarbons, chlorinated hydrocarbons, and the ester and ketone solvents commonly used for nitrocellulose, with the exception of acetone, which swells but does not completely dissolve

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[30] Dow Chemical Co

Styron without the aid of another solvent. It is insoluble in vegetable oils, fats, and waxes.

Styron is particularly suited to the quantity production of insulating shapes, ornaments, boxes, and other forms. Its utility results from its ease of molding, superior electrical properties, low moisture absorption, excellent dimensional stability, hard glossy surface, practical shock resistance, and crystal clarity. Styron is adapted to the production of transparent, translucent, and opaque moldings in a wide variety of colors.

Thermoplasticity. Styron is remarkable among thermoplastic molding materials for its fluidity under ordinary molding conditions. It readily fills the thinnest sections at temperatures and pressures well within the range of presses used for other thermoplastics. The ability of Styron to flow under application of heat and pressure is inherent in the material and is not obtained through the addition of plasticizers.

Constants

(Determined on Compression Molded Test Pieces)
Compression Temperature, ° F.: 280–350
Compression Pressure, lb. per sq. in.: 300–2000
Compression Ratio: 2.5
Injection Temperature, ° F.: 380–420
Injection Pressure, lb. per sq. in.: 3000–30,000
Mold Shrinkage, in. per in.: 0.003–0.004
Machining Qualities: Good
Buffing or Polishing: Fair
Clarity: Crystal clear
Color Possibilities: Unlimited
Specific Heat, cal. per ° C. per gm.: 0.324
Thermal Expansion Coefficient, per ° C.: 7.0×10^{-5}
Softening Point, ° F.: 220–240
Distortion Temperature,[31] ° F.: 172–176
Heat conductivity, cal. per sec. per cm. per ° C.: 3.2×10^{-4}
Tensile Strength,[28] lb. per sq. in.: 5500–7000
Elongation, %: 1
Modulus of Elasticity, lb. per sq. in.: $5.5–7.0 \times 10^{5}$
Impact Strength,[32] 25° C. to −70° C., ft.-lb.: 0.2–0.3
Hardness, Rockwell No. (½-in. ball, 60-kg. load): 90–93
Shore Scleroscope No.: 83–85
Dielectric Strength, volts per mil: 500
Dielectric Constant, 60 cycles: 2.6–2.7
10^3 cycles: 2.6–2.7
10^6 cycles: 2.6–2.8
Power factor, 60 cycles: 0.002%
10^3 cycles: 0.02%
10^6 cycles: 0.4%
Resistivity, ohm-cm., more than: 1×10^{15}
Arc Resistance, seconds: 240–250
Refractive Index at 25° C.: 1.59
Light transmission through 0.1 in. thickness, %: 90
Ultra-violet Absorption, complete below: 3000 Å
Water Absorption,[33] (96 hours' immersion), %: 0.00
Specific Gravity: 1.05
Specific Volume, cu. in. per lb.: 26.3
Burning Rate: Low
Effect of Weak Acids: None
Effect of Strong Acids: Discolors
Effect of Weak Alkalies: None
Effect of Strong Alkalies: None
Toxicity: Nontoxic

Injection Molding. Styron is molded with extreme ease by injection processes. When the section to be molded is thin, gates may be thinner with Styron than with most thermoplastics. To facilitate breaking off the sprues, the cross section of the gate may be further reduced by notching it. However, if Styron is to be injected into cast-

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[31] A.S.T.M. D 48–37.

[32] A.S.T.M. D 256–34 T, ft.-lb. to break Izod notched bar.

[33] A.S.T.M. D 48–37.

ings of relatively thick section, it is usually necessary to employ a larger gate through which pressure can be maintained on the cooling casting, in order to overcome internal voids resulting from shrinkage.

Injection moldings of Styron possess practical shock resistance at normal temperatures but have little extensibility. Since they tend to shrink tightly onto the male parts of the mold, such parts should be tapered as much as possible. In order to avoid breakage when sticking due to shrinkage proves troublesome, it is often necessary to remove the pieces from the mold by the use of stripper plates.

When molded or cast polymerized preforms are used in compression moldings, the molded articles have greater strength, shock resistance, soundness, and clarity than those made from granules under the same conditions.

Styron moldings retain their dimensions extremely well on aging. They have little tendency to cold flow, no plasticizer to lose, and their water absorption is negligible. Styron molded pieces begin to show pronounced distortion in the A.S.T.M. test at about 75° C. This indicates their utility at temperatures well above those practical for most thermoplastics.

Styron moldings possess practical shock resistance at ordinary temperatures. They do not decrease appreciably in impact strength at low temperatures as do most other thermoplastics.

Specifications

Physical Form: clear, colorless particles

Polystyrene Content: more than 98%

Viscosity of 10% solution in toluene at 25° C.: centipoises 30–50

Shipping Classification

Chemicals, N.O.I.B.N.: 51.5 lb. gross

Packing Bags: 50 lb. net

UREA–FORMALDEHYDE

Beetle[34]

Beetle is compounded basically of urea-formaldehyde resin. Manufactured as a molding material it is a combination of urea-formaldehyde resin, filler, pigments and plasticizing agents. Beetle is sold also as a resin solution for the construction of translucent laminated sheets or for the surfacing of opaque laminated stock. Used in solution for treating textiles it renders them crushproof, water repellent, and more permanent in form, finish, and drape. Beetle resins are also used for the manufacture of hot-setting cements, cold-setting cements and baking enamels.

Molding material is supplied in granules or as a finely divided powder and is molded in steel dies under heat and pressure.

Almost any shape moldable by direct compression molding is available. The finished product is hard and durable; the finish is practically permanent, and the color or colors are permanent and are throughout the piece.

Practically any color from a translucent pearl white through the brilliant colors to a jet black is available. These colors are as permanent as are the dyes or pigments used to formulate them.

Molded Beetle is resistant to organic solvents such as alcohol and acetone but is affected by acids and alkalies. It is unaffected by oils, grease, or salves and has been successfully used outdoors for gasoline pump frames.

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[34] American Cyanamid Corporation.

Molded Beetle will withstand temperatures of 170° F. continuously, but up to 300° F. it will eventually whiten, blister, and char. Beetle in its molded form is odorless, tasteless, and practically inert.

Constants

Specific Gravity: 1.46–1.50

Weight per cu. in., oz.: 0.85–0.89
gm.: 24–25

Flexural Strength, (A.S.T.M. D48–34T), 5 by ½ by ½ in. bar, supports 4 in. apart loaded in the center, lb. per sq. in.: 10,000–13,000

Compressive Strength (A.S.T.M. D48–33), lb. per sq. in.: 20,000–24,000

Tensile Strength (A.S.T.M. D48–33), lb. per sq. in.: 5500–7000

Coefficient of Heat Expansion, in. per in., ° F.: 0.00001–0.00002
These values apply for temperatures from 100° F. and lower. At higher temperatures, a slight shrinkage occurs which will reduce apparent expansion.

Hardness, Rockwell (A.S.T.M. D229–34T) ¼-in. ball 100-kg. load: 78.9

Impact, Dynstat, 1.5 × 1.0 × 0.2 cm., cm. kg. per sq. in.: 10–12

Impact, Charpy unnotched, 5 by ½ by ½ in., ft.-lb.: 1.2–1.4

Dielectric Strength (A.S.T.M. D149–36T), Thickness: 0.080 in., 25° C. room temperature, volts per mil: 300–385
100° C. under oil, volts per mil: 100–140

Volume Resistance, megohm-cm., after 48 hr. at 60% R. H.: 10^6–10^7
After 24 hr. immersion in water: 10^5–10^6

Surface Resistance, megohms, after 48 hr. at 60% R. H.: 3–10 × 10^6
After 48 hr. immersion in water: 0.08–0.11 × 10^6

Power Factor and Dielectric Constant, Low Frequency, 60 cycles, Temperature, 25° C. (77° F.): Power Factor, 4.0–4.9; Dielectric Constant, 7.6–8.2; Temperature, 60° C. (140° F.): Power Factor, 8.0–9.0; Dielectric Constant, 8.0–9.2

High Frequency, 10^6 cycles, after 48 hr. at room temperature, 60% R. H.: Power Factor, 3.0–3.5; Dielectric Constant, 7.5–7.7
After 24 hr. in water at room temperature: Power Factor, 2.7–3.1; Dielectric Constant, 7.4–7.9

Arc Resistance, A.S.T.M. D495–38T, seconds: 120–180

For Illumination Purposes. Molded Beetle is widely used for the construction of luminaires or reflectors. In fact, the Beetle Products Division pioneered in this field, and its material was the first to be approved by the I.E.S.

Molded Beetle has excellent powers of light diffusion. Since the material is composed of a colorless resin and a finely divided cellulose filler, it transmits a diffuse light in its natural unpigmented state. By altering the thickness of the piece and the pigmentation of the compound, the ratio of reflection or transmission can be raised considerably. Below are a few typical examples (thickness of sample tested 0.090 in.):

TABLE 28. MOLDED BEETLE — LIGHT PROPERTIES

	% Reflection	% Transmission	% Efficiency
E-15-C	67.	16.5	83.5
E-15-B	70.	10.5	80.5
515-10	61.4	21.0	82.4
2157 Ivory	65.7	9.6	75.3

Beetle is not recommended for use on fixtures where the temperature of the reflector exceeds 170° F.

Beetle may be used with 10- or 1000-watt bulbs depending on the design of the piece. Light output, brightness, and color of the light can be accurately controlled and reproduced from one piece to the next.

Reasons for use of Beetle for Lighting:

1. Light weight, one-third of that for glass of similar size.
2. Less expensive in larger sizes.
3. Less dangerous, shatterproof.
4. More easily handled and cleaned.
5. More easily controlled with regard to color and character of light.

Beetle parts should be designed according to certain standards such as rounded corners, uniform wall thickness, lack of re-entrant curves, etc., which are used for all urea compounds in the molding operations.

If the molder cannot provide the necessary details, the American Cyanamid Laboratory will recommend suitable design and material modifications or suggestions. Beetle is a custom-built urea plastic designed to meet the situation on a given molding in a given plant. Materials are supplied in a wide range of plasticities from soft to hard. Such variations do not in any way affect the curing or molding time.

TABLE 29. BEETLE MOLDING DATA

Part	Projected Area, sq. in.	Draw in.	Section Thickness, in.	Mold Temperature, °F.	Molding Pressure, tons per cavity	Cure Time	Type Mold
Buttons	1/4–2	—	3/32–5/32	310–340	1/2–3	20 Sec. to 1 Min.	Flash
Closures	1/2–5	1/2–1	3/32–	305–325	1–9	40 Sec. to 2 Min.	Flash or semipositive
Wall plates	15–25	-	3/32–1/8	300–325	20–35	50 Sec. to 2 Min.	Flash or semipositive
Razor housings	8–12	3/4–1	1/16–1/8	300–315	15–25	2–3 Min.	Semipositive
Housings, small	25–40	2–4	3/32–1/8	295–315	50–100	2–4 Min.	Semipositive
Housings, large	70–200	5–9	1/8–3/16	285–305	150–1000	2¼–5 Min.	Semipositive
Lighting reflector	200–400	3–10	5/64–7/64	280–300	600–1500	3–5 Min.	Semipositive

Shrinkage of Molded Beetle. Molded Beetle has an immediate after-molding shrinkage or " cold mold to cold piece shrinkage " of 0.006 to 0.008 in. per in. and a shrinkage on aging of from 0.003 to 0.005 in. per in. Factors that decrease shrinkage are minimum cure, very heavy sections, and damp service conditions. Factors that increase shrinkage are prolonged cure, unsupported open ends on deep draw pieces, and hot, dry service conditions.

The supplier of ureas or a competent molder should be consulted on design and function of any urea molded piece before dies are constructed.

Beetle Resins. Beetle resins are supplied in solution for the construction of translucent laminated sheets or panels. Sheets of absorbent paper are impregnated, dried, piled up to desired thickness and laminated under heat of about 280° F. and pressure of about 1500 lb. per sq. in. Thickness may vary from 0.020 to ⅛ in. and area varies up to 9 by 4 ft. Cure time is dependent upon thickness of sheet and may run about 20 min.

Many translucent colors are available. This sheet stock cannot be softened again for forming. It is customarily used for indirect lighting, signs, theatre marquees and other architectural lighting effects.

Applications of Beetle resins in solution include table tops, wall panels, refrigerator door panels, and breaker strips. The resins are also used for impregnating wood veneers and textiles and for cold-setting cements, baking enamels, and the treatment of paper.

Plaskon[35]

Plaskon molding material is compounded from urea-formaldehyde resin, filler, pigments, and plasticizing agents. The resulting compound (as gransules or pills) is fabricated under heat and pressure in steel dies. During the molding process, the material softens into a plastic mass, which gradually undergoes a chemical reaction and converts to an infusible, insoluble form taking the shape of the die.

Plaskon has almost unlimited flexibility of form, clean, clear colors of permanent hue, permanence of finish and great strength.

Colors available include a complete range of standard shades, from translucent, colorless, and pure white through the pastels and brilliant hues to jet black. These for the most part are completely lightfast.

Molded Plaskon is completely resistant to common organic solvents, such as alcohol and acetone, only fairly resistant to weak acids, and is affected markedly by strong acids and alkalies. Since it is impervious to all oils and greases, it is an ideal material for containers for salves and creams having such materials as bases. It is comparatively resistant to the elements, successfully used for outdoor gasoline pump frames, withstands about 170° F. continuously, and temperatures as high as 245° F. for short periods. Higher temperatures are likely to cause discoloration and opacification.

Machinability is good but not often necessary.

Constants

Specific Gravity: 1.48 to 1.50
Hardness, Mineral Scale: 3.5
Hardness, Scleroscope: 85
Hardness, Brinell, 500-kg. load, 10-mm. ball: 48 to 54
Flexural Strength[36] (Modulus of Rupture), lb. per sq. in.: 10,000 to 16,000
Impact Strength[36] (Charpy, Unnotched Specimen, ½ by ½ in. bar), ft.-lb.: 1.70
Tensile Strength, lb. per sq. in.: 8000 to 13,000
Distortion under heat[36] at 127° C., 5½-lb. load, mils max.: 7
Modulus of Elasticity[36] (tensile), lb. per sq. in.: 1,555,000 to 1,650,000
Compressive Strength, lb. per sq. in.: 25,000 to 35,000
Weight per cu. in. (molded), gm.: 24.5

For Illumination Purposes. Unpigmented Plaskon transmits 65 per cent of the incident light through a thickness of 0.040 in. This maximum may be cut down to complete opacity by the addition of suitable pigments.

[35] Plaskon Co. Inc.

[36] A.S.T.M. Standards of Tentative Test.

TABLE 30. LIGHTING EFFICIENCY*

	Light Reflection %	Light Transmission %	Total Light or Efficiency %
Plaskon White 8815-A	50	39	89
Plaskon White 8070	59.3	32.6	91.9
Plaskon White 7142	68.7	22.4	91.9

* Test Plates 0.047 in. thick.

In designing a Plaskon reflector, consider the maximum temperature to which the reflector will be subjected. The following table shows the recommended distances of reflectors from various lamps.

Lamp wattage	*Recommended distance, filament to reflector, inches*
250	3
400	4
600	5
800	6
1000	7

Metal inserts, holes (to be threaded later or used with self-tapping screws), metal heels, threads, or projecting lugs may easily be molded or inserted in Plaskon reflectors during molding.

Plaskon diffusers are approved by the Illuminating Engineering Society for use with the portable study lamp it sponsors. Specifications set for this diffuser cover such features as surface brightness, total light output and balance of distribution of output between reflection and transmission.

Molded Plaskon bowls vary from 6 to 26½ in. in diameter and from 3 to 12 in. in depth. Automobile dome-light lenses, bus lights, Pullman and airplane fixtures are examples of Plaskon application.

Weight: about one-third that of glass for the same thickness.

Thickness: minimum about 0.025 in. For general use 0.040 to 0.100 in.

Optical Efficiency: equal to the best grades of illuminating glass and approximately 10 per cent better in the larger semi-direct units.

Color: unlimited range.

Surface: smooth, easily cleaned.

Dimensional Tolerance: accurate, varying less than 0.002 in. from piece to piece, or within each piece.

Electrical Properties

Dielectric Constants, 60 cycles: 7.0
10^3 cycles: 6.4
10^6 cycles: 6.3
Dielectric Strength[37] (puncture voltage), 60 cycles, volts per mil: 500 to 700 (0.05 thickness)

Resistivity, Volume, ohm-cm. units: 2.8×10^{13}
Surface, ohm-cm. units: 2×10^{13}
Power Factor, 60 cycles, %: 3.9
10^6 cycles, %: 3.2

Plaskon is suitable for both general and high-frequency type insulators. These maintain their dielectric properties when subjected to electrical arcs, owing to the

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[37] Determined by Electrical Testing Laboratories (Report No. 142,116).

formation on the surface of condensed chemical residues, high in insulation value. Even long exposure to high humidities and immersion in salt solution for 24 hr. fail to destroy the resistance of Plaskon to arcing.

Design Features. Abrupt changes in wall section should be avoided, and when difference in section is necessary it should be held to a minimum.

Sections heavier than 1 in. are not recommended because slow cure cycles involve the danger of undercure at the center. This limitation is often overcome, as in gear shift knobs, by assembling two hollow sections with resultant economy both in material and molding speed.

For flat shapes, the surface should curve to some extent both ways, and there should be at least a partial flow of material in molding, resulting in a stronger piece. A fully rounded edge and inside fillets should be used whenever possible. Parting lines should be used on an edge rather than on a rounded surface.

Allowance is needed for a thinner section at the top of the " draw " than at the base in a casting such as radio housing. Inserts are readily molded securely into place, but the materials around them should be sufficiently thick to prevent cracking due to the difference in coefficients of expansion between metal and plastics. Plaskon is not recommended for complicated machining operations.

Molding Compound. Plaskon molding compound is supplied either in the form of finely ground powder comparable in consistency to talcum powder, or in granular form. The physical excellence of the molded piece depends on the design and polish of the die, on the pressure employed and, to a greater extent, on the cure. Because of its high bulk factor, fine powder can be used only when the loading cavity of the mold has a volume more than five times that of the piece to be fabricated. Fine powder, too, is difficult to preform except in heavy-duty rotary tableting machines not in general use. Its bulk factor is 4.9, and its specific volume 3.3 to 3.4 cc. per gm.

Granular compound (compressed fine powder) is slightly more expensive but has the advantages of easy preforming, minimum of dust, and low bulk factor. The bulk factor of granular material varies between 2.4 and 2.8, and the specific volume between 1.6 and 1.9 cc. per gm.

In both fine powder and granular form, Plaskon is available in several standard plasticities ranging from a hard type to an extra soft plasticity. The material generally used is called standard medium.

In general, the rate of cure of various standard plasticities is similar. However, the grades that are of the soft or extra soft variety are somewhat slower curing.

Preheating Plaskon to temperatures as low as 100° F. brings beneficial results. The best results, however, with equipment in ordinary use, are obtained by preheating the compound to between 160° and 175° F. Plaskon compound should be used as soon as preheated, since the plasticity is irreparably reduced by cooling.

Because the plasticity of Plaskon compound is reduced on exposure for protracted periods to temperatures above 80° F., it is recommended that the material be kept below 70° F. Low temperatures even below freezing have no effect on the material, but it should be brought up to room temperature prior to use. It readily absorbs moisture from the air when exposed in relative humidities exceeding 50 per cent.

Tests for Undercure and Improper Fusion. Plaskon moldings, if placed in boiling water for 15 min., are sufficiently well cured if no chalking or whitening of the surface

TABLE 31. APPROXIMATE MOLDING CONDITIONS

Piece	Projected Area, sq. in.	Depth in inches	Thickness in inches	Pressure in tons per cavity	Mold Temperatures, °F.	Cure, Time, minutes
Slides	3	0.06	0.06	6–7	305–315	1–1½
Trays	6–3	5	0.10	175	295–300	3–5
Small light reflectors	50	8	0.06	150	300–310	1–2
Large light reflectors	250	8	0.08	675	290–295	5
Small cabinets	60	5	0.125	225	295–300	3
Large cabinets	250–300	11	0.125	1100–1500	285–295	7–10
Tumblers	6	4	0.05	20	300–310	1½
Escutcheons and plates	6	0.25	0.08	15	305–310	1½–2
Dome lights	7	0.5	0.04	17	320–330	3–4
Handles	3–4	0.5	0.50	12	295–300	3–4

results. This test is simple but indicative and especially valuable as a comparative test in determining the minimum acceptable curing time at a given temperature for Plaskon molding.

The molding is weighed, immersed in boiling water for 15 min., removed and immediately immersed in cold water for 5 min., and then wiped dry and weighed again. The permissible gain in weight is not more than 0.030 gm. per sq. in. of surface and may be as low as 0.020 gm. per sq. in.

The moldings to be tested for heat resistance are baked after the finishing operation in a circulating oven at a temperature of 140° F. for from 16 to 24 hr. Pieces that resist this test may be regarded as entirely satisfactory. In fact, they are if anything improved in cure and may be safely used.

It is sometimes possible to conduct tests under conditions actually met in service. For instance, shirt buttons may be sewed on cloth, laundered, dried, and relaundered until failure occurs. In this way it may be determined whether the buttons may be expected to last 2 months or 3 years.

It is fortunately possible to detect an overcured molding merely by looking at it. Overcure of Plaskon molding compound, because of either too high temperatures or too long a curing time, results in a burned condition.

Shrinkage in Molding. The initial shrinkage from mold dimensions of dry Plaskon is approximately 0.006 to 0.008 in. per in. Since the extent of this initial shrinkage is influenced to a greater or less degree by such varying factors as the design of the mold, the thickness of section, and the degree of cure, an exact figure cannot be given. These variables and the relative humidity of the atmosphere also influence the extent of the secondary or aftershrinkage which amounts to approximately 0.002 to 0.004 in. per in.

Most satisfactory in molding Plaskon is the semi-positive, semi-automatic type of die in which all available pressure is kept on the material during the entire molding cycle.

POLYVINAL ACETATE

Vinylite[38]

The various commercial copolymers of vinyl chloride and vinyl acetate are all manufactured under the trade name, " Vinylite Resins — Series V." These resins range in vinyl chloride content from 85 to 95 per cent and vary in molecular weight depending on the use for which they are intended. The brand name Vinylite is applied also to films and heavier sheetings produced from the resin, but fabricators who convert these materials into belts, suspenders, raincoats, etc., often identify their products with their own copyrighted name.

Vinylite Series A Resins[39]

Formula: $(CH_3COOCHCH_2)_x$

Properties: Vinylite resins of series A are thermoplastic, white granular powders which are slow burning when ignited, nontoxic, tasteless, odorless, and are relatively resistant to moisture absorption. They are stable to both heat and light, maintain their clarity of color over long periods of exposure, and resist weak acid, alkaline, and salt solutions. Without filler, they become very tacky at 200° F. and adhere to almost any surface to form a strong, tough bond when cold. They are supplied in a range of viscosities, their plasticity and solubility decreasing as viscosity increases.

Uses: Vinylite series A resins are used extensively as thermoplastic adhesives for cloth, paper, cardboard, porcelain, metal, mica, stone, leather, wood, glass, and plastics sheets and film. Their excellent aging qualities, coupled with the lack of color, odor, or taste, make them suitable for the sealing of paper drinking cups, milk containers, food containers, and for laminating cellulose acetate sheets and metal foil to paper wrappers. Their high gloss and zero acid number make them excellent vehicles for metallic lacquers and inks. Mixed with fillers, their low shrinkage properties make them well suited for sealing glass bricks, for the molding of intricate designs, and for the binding of plastic wood.

Vinylseal

Properties: Vinylseal adhesive is a colorless liquid consisting of a 35 per cent by weight solution of Vinylite resin AYAF in acetone; while adhesive XL–5041 is a 24.5 per cent solution of modified series A resin in toluol; and adhesive XL–5075 is a 28 per cent solution of modified series A resin in methyl acetate. After application, the solvents are evaporated by heating in an oven. Adhesives XL–5041 and XL–5075 have extraordinary bonding powers, particularly for metal surfaces where the resin bond is often stronger than the metal itself.

Uses: These adhesives are especially valuable for bonding metals, paper, cloth, leather, and rubber. They are used as cold adhesives for sealing clear cellulosic films, " tamperproof " bottles, nitrocellulose sheet around the wooden heels on shoes, and as coatings on paper for nonaqueous gumming tape. Adhesive XL–5041 has been found especially useful for making the laminated steel cores used in small motors.

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[38] Union Carbide & Carbon Co.

[39] See also under Films, Part III.

POLYVINYL CHLORIDE[40]

Vinylite Series Q Resin

Formula: $(CH_2CHCl)_x$

Properties: Vinylite resin of series Q is a fine, white powder. It has a high degree of resistance to concentrated acids, alkalies, and alcohols; almost no water absorption, and the resin will not support combustion. It is incompatible with most other resinous materials, and owing to its toughness and low plasticity, it is usually plasticized. The plasticized material may be milled, calendered, extruded, and molded with standard equipment.

Uses: Vinylite series Q resin has found wide industrial use as a resilient, rubberlike material in cases where rubber fails to meet the conditions of service. The plasticized resin is far superior to rubber in flexing life, resistance to sunlight, water, oxidation, acids, and other chemicals. It is used as sheet packing, flexible tubings, extruded coatings on low-voltage cables, and as coverings on small friction rollers in textile mills. It is especially recommended for gaskets and washers and for wrapping underground pipelines to prevent corrosion. Solutions of this resin are used to impregnate fabrics, such as silk, which are used for raincoats, shower curtains, tobacco pouches, and other waterproof articles.

VINYL CHLORIDE–VINYL ACETATE COPOLYMER

Vinyl Series V Resins

Formula: $(CH_2CHCl)_x(CH_3COOCHCH_2)_y$

Properties: Vinylite resins of series V are fine, white, thermoplastic powders which are copolymers of vinyl chloride and vinyl acetate. They are supplied in a variety of molecular weights or grades to meet the requirements of various industrial applications. Various grades are suitable for calendering, extruding, and compression or injection molding. Certain of the series V resins are also available in the form of plasticized and unplasticized sheets; coated on paper; in calendered film 3 to 10 mils in thickness; as rods, tubes, and special extruded shapes; as well as surface-coating solutions which are supplied by leading lacquer manufacturers.

Uses: Articles molded from Vinylite series V resins do not warp, shrink, crack, absorb water, or transmit moisture vapor. In addition, such articles are highly impact-resistant, only slightly affected by certain corrosive agents, and have but slight tendency to cold flow. For example, toothbrush handles molded from Vinylite resins are strong and tough, and permit bristling without warping or checking. Most transcription records for radio broadcasts are molded from Vinylite resins because they have low noise level, excellent frequency response, long life, no tendency to warp and thus distort sound tracks. Furthermore, they may be molded in thin cross sections with consequent saving of material. The nonflammability, complete lack of odor, taste, and toxicity combine to make Vinylite resins an ideal material for molded cosmetic and food containers, and bottle caps.

Calendered film stock is well suited for moisture- and grease-resistant linings of food cartons, pipelines, and conveying equipment; and for transparent, nonflammable, washable coatings for lamp shades, table tops, file folders, shelf and book covers.

Vinylite resin sheet stock — in all colors, transparent, translucent, or opaque, in either polish or matte finish, and in thicknesses from 0.01 to 0.5 in. — can be printed, stamped, engraved, drawn, or molded. Because they have no surface warpage,

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[40] Union Carbide & Carbon Co.

or even slight shrinkage to distort vision or change dimensions, these sheets are finding use as watch crystals, drawing instruments, slide rules, plastics book and catalogue bindings, radio and refrigerator dials, as well as many specialty and novelty items.

By calendering a 0.0020-in. layer of Vinylite resins to a continuous sheet of suitable stock, a coated paper is obtained which has a glossy surface with all the excellent resistant properties of Vinylite resin itself. The resin is intimately bonded to the paper, which is considerably strengthened by the coating. White, black, red, or green paper is produced for some applications, and if volume warrants, papers coated with a resin surface of any color can be obtained. Over 30,000 perishable products — from mayonnaise to toothpaste — are packaged with Vinylite-resin coated cap liners.

The exceptional toughness and flexibility of Vinylite series V resins make them especially well suited for finishes on sheet metal which is to be fabricated after being coated. For example, this finish is being used to advantage for sheet metal to be stamped into caps and as a lining for metal containers for beer, fountain sirups, fruit juices, soap, and bleaching solutions. Vinylite resin coatings are also used for concrete, and for composition wall board.

POLYVINYL BUTYRAL[41]

Vinylite Series X Resins

Formula: $CHOHCH_2CHOCH_2CHOCH_2CH(C_3H_7)_x$

Properties: Vinylite resin of series X is a white, granular powder which is very heat-stable at 100° C. It is also resistant to sunlight and will not discolor when exposed for long periods to intense ultra-violet radiation. It is tough, retaining most of its high tensile strength up to its elastic limit.

Uses: Vinylite series X resin is used primarily in the form of highly plasticized sheeting as the interlayer for high-test safety glass. It absorbs shocks to a large degree, does not shatter at low temperatures, and has excellent adhesion to glass. No edge sealing or special adhesive is required when this resin is used. It is also a remarkable adhesive and leather-finishing base. Unplasticized sheets are used by fabricators where its extraordinary strength is desirable.

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[41] Union Carbide & Carbon Co.

TABLE 32. VINYL RESINS — PROPERTIES

Solubility (a)

Chemical	Vinylite Resin AYAF 10% in solvent		Vinylite Resin QYNA 2% in solvent		Vinylite Resin VYHH 10% in solvent		Vinylite Resin VYLF 10% in solvent		Vinylite Resin XYSG 4% in solvent	
	25° C	95° C (b)	25°C.	95° C. (b)	25° C.	95° C. (b)	25° C.	95° C. (b)	25° C.	95° C. (b)
Acetone	S	S	I	SW	S	S	S	S	SW	PS
Acetonylacetone	S	S	S	S	S	S	S	S	G	S
Benzyl "Cellosolve"	S	S	I	I	G	S	G	S	S	S
Butanol	G	S	I	I	I	I	I	I	S	S
Butyl Acetate (98%)	S	S	S-CL	S-CL	S	S	S	S	G	S
Butyl "Carbitol"	S	S	I	I	PS	S	S	S	S	S
Butyl "Carbitol" Acetate	S	S	I	I	S	S	S	S	G	S
Butyl "Cellosolve"	G	S	I	I	I	I	SW	PS	S	S
Butyl Ether	I	I	I	I	I	I	I	I	I	SW
"Carbitol" solvent	S	S	I	I	I	I	I	I	S	S
"Carbitol" Acetate	S	S	I	I	S	S	S	S	G	S
"Cellosolve" solvent	S	S	I	I	I	I	S-CL	S	S	S
"Cellosolve" Acetate	S	S	I	SW	S	S	S	S	G	S
Diacetone Alcohol	S	S	I	SW	G	S	S	S	S	S
Dibutyl Phthalate	S	S	PS	S	S	S	S	S	PS	S
Dichlorethyl Ether	S	S	PS	S	S	S	S	S	G	S
Dichlorisopropyl Ether	S	S	I	SW	S	S	S	S	G	PS
Diethyl "Carbitol"	S	S	I	I	S	S	S	S	S	S
Diethylene Glycol	I	SO	I	I	I	I	I	I	SO	SO
Diisobutyl Ketone	I	SO	PS	S-CL	S	S	S	S	SO	SO
Dimethoxytetraglycol	S	S	I	SW	S	S	S	S	G	S
Dimethyl Phthalate	S	S	PS	S-CL	S	S	S	S	G	S
Dioxane	S	S	S	S	S	S	S	S	S	S
Dipropylene Glycol	G	PS	I	I	I	I	I	I	S	S
Ethanol (95%)	S	S	I	I	I	I	I	I	S	S
Ethyl Acetate	S	S	I	SW	S	S	S	S	S	S
Ethylbutanol	SO	S	I	I	I	I	I	I	S	S
Ethylbutyl Acetate	PS	S	S-CL	S-CL	S	S	S	S	S-CL	S-CL
Ethylene Dichloride	S	S	S	S	S	S	S	S	G	S
Ethylene Glycol	I	I	I	I	I	I	I	I	SW	SW
Ethyl Ether	S	S	I	I	I	I	I	I	I	SW
Ethylhexanol	SO	S	I	I	I	I	I	I	S	S
Ethylhexyl Acetate	I	SO	I	SW	S	S	S	S	SW	SW
Ethyl Silicate	I	I	I	I	I	I	I	I	I	I
"Flexol" plasticizer 3GH	S	S	I	I	S	S	S	S	I	SW
Glycol Diacetate	S	S	I	SW	G	PS	G	S	SW	SW
Heptadecanol	I	I	I	I	I	I	I	I	SW	SW
Hexanol	I	PS	I	I	I	I	I	I	S	S
Isopropanol (anhydrous)	I	PS	I	I	I	I	I	I	S	S
Isopropanol (technical)	S	S	I	I	I	I	I	I	S	S
Isopropyl Acetate (98%)	S	S	SW	SW	S	S	S	S	SW	PS
Isopropyl Ether	I	I	I	I	I	I	I	I	I	I

TABLE 32. VINYL RESINS — PROPERTIES (*Continued*)

Solubility (a)

Chemical	Vinylite Resin AYAF 10% in solvent		Vinylite Resin QYNA 2% in solvent		Vinylite Resin VYHH 10% in solvent		Vinylite Resin VYLF 10% in solvent		Vinylite Resin XYSG 4% in solvent	
	25° C.	95° C. (b)	25° C.	95° C. (b)	25° C.	95° C. (b)	25° C.	95° C. (b)	25° C.	95° C. (b)
Mesityl Oxide	S	S	S	S	S	S	S	S	G	S
Methanol	S	S	I	I	I	I	I	I	S	S
Methyl Acetate (82%)	S	S	I	I	S-CL	S-CL	S-CL	S	S	S
Methyl Amyl Acetate	SO	S	I	I	S	S	S	S	SW	SW
Methyl Amyl Alcohol	SO	S	I	I	I	I	I	I	S	S
Methyl n-Amyl Ketone	S	S	S	S	S	S	S	S	G	S
Methyl "Carbitol"	S	S	I	I	I	I	I	I	S	S
Methyl "Cellosolve"	S	S	I	I	S	S	S	S	S	S
Methyl "Cellosolve" Acetate	S	S	SW	SW	S	S	S	S	G CL	S
Methyl Isobutyl Ketone	S	S	S	S	S	S	S	S	PS	S
Phenyl "Cellosolve"	S	S	I	I	G	S	G	S	S	S
Propylene Dichloride	S	S	PS	S	S	S	S	S	G	S
Propylene Glycol	SO	PS	I	I	I	I	I	I	I	SO
Propylene Oxide	S	S	PS	PS	S	S	S	S	S	S
Tetradecanol	I	I	I	I	I	I	I	I	SW	PS
Tetraethylene Glycol	I	I	I	I	I	I	I	I	I	SO
Trichlorethylene	S	S	I	SW	G	S	G	S	G	PS
Triethylene Glycol	I	SO	I	I	I	I	I	I	I	SO
Triglycol Dichloride	S	S	I	I	S	S	S	S	I	SO
Undecanol	I	SO	I	I	I	I	I	I	S	S

S — Soluble SO — Softens G — Gels CL — Cloudy Solution I — Insoluble SW — Swells P — Partially.

(a) Liquids in which the resins are soluble are not necessarily sufficiently active solvents to permit their use in Vinylite resin coating formulations. For solvents suitable for use in coating formulations, ask for other Vinylite resin pamphlets.

(b) Tests were made at temperatures slightly below the boiling points on those chemicals which boil below 95° C.

TABLE 32. VINYL RESINS — PROPERTIES (*Continued*)

Physical Properties

Series of Resin	Vinylite Series A Resins	Vinylite Series Q Resin (Plasticized)	Vinylite Series V Resins (No Filler) (b)	Vinylite Series X Resin
Specific Gravity, 20/20° C.	1.191	1.2 to 1.6	1.34 to 1.36	1.1
Specific Volume, cu. in. per lb.	—	23.0 to 17.3	20.7 to 20.4	—
Refractive Index, N_D 20° C.	1.4665	1.544	1.53	—
Tensile Strength, lb. per sq. in.	—	1000 to 9000	8000 to 10,000	8100 to 8500
Distortion under Heat, ° F.	103	—	140 to 150	130 to 140
Water Absorption, Immersion	2% in 144 hr.	—	0.1% in 168 hr.	3 to 5% in 16 hr.
Burning Rate	Slow burning	Slow burning	Nonflammable	Slow burning
Effect of Age	None	None	None	None
Effect of Sunlight	None	None	Darkens (c)	Very Resistant
Effect of Weak Acids	Resistant	None	Highly resistant	Affected
Effect of Strong Acids	Affected	None	Highly resistant	Affected
Effect of Weak Alkalies	Resistant	None	Highly resistant	Resistant
Effect of Strong Alkalies	Affected	None	Highly resistant	Resistant
Effect of Organic Solvents	(a)	Limited solubility in esters, ketones, chlorhydrocarbons	(a)	Limited solubility in alcohols and some esters
Effect on Metal Inserts	Inert	Inert	Inert	Inert
Clarity	Transparent to opaque	Transparent to opaque	Transparent to opaque	Transparent
Color Possibilities	Unlimited	Unlimited	Unlimited	Unlimited

(a) For solubilities of Vinylite resins, see page 203 and also tables of solubilities in other chapters throughout this book.
(b) The properties of the base resins can be varied markedly by the addition of proper fillers and plasticizers.
(c) Certain stabilizers will greatly increase the time of exposure to sunlight before darkness occurs.

Molding Properties

Series of Resin	Vinylite Series A Resins	Vinylite Series Q Resin (Plasticized)	Vinylite Series V Resins (No Filler) (b)	Vinylite Series X Resin
Molding Qualities	Poor	Fair	Good	Fair
Compression Molding Temp., ° F.	—	220 to 350	270 to 290	225 to 275
Compression Molding Press., lb. per sq. in.	—	500 to 1000	1500 to 2000	1000 to 2000
Injection Molding Temp., ° F.	—	—	280 to 300	—
Injection Molding Press., lb. per sq. in.	—	—	300 to 30,000	—
Mold Shrinkage, in. per in.	—	0.016	0.001	—
Machining Qualities	—	Good	Good	—

POLYVINYL ACETAL RESIN

Butacite[42]

Butacite is the du Pont Company's registered trade-mark for polyvinyl acetal resin. Sheeting used as an interlayer in safety glass is compounded from this resin and a plasticizer and is furnished in the form of continuous sheeting. The standard widths, 12 to 48 in., and the standard thickness, 0.015 in., are those required by the safety-glass trade.

This sheeting is substantially colorless and free from haze, capable of being bonded securely to glass, with or without auxiliary adhesive, and not subject to deterioration by ultra-violet light within the normal life of an automobile. Its principal advantage over other interlayer materials lies, however, in its mechanical characteristics. Its toughness is not seriously impaired by low temperature, nor are its strength and form stability seriously impaired by high temperature, and accordingly, the safety glass in which it is used as interlayer retains its protective characteristics at extremes of winter and summer temperatures. Furthermore, the pliable and yielding nature of this interlayer is much to be preferred over the rigid and unyielding character of earlier interlayer materials, in that the safety glass yields more readily under impact and is thus less likely to cause injury by concussion.

Polyvinyl Acetate[43]

Formula: $(CH_2CHOCH_3)_x$.

Properties: Colorless, odorless, tasteless, transparent, synthetic resin. Thermoplastic. Density 1.189 (15° C.).

Insoluble in: Water, gasoline, oils; fats.

Soluble in: Lower alcohols and esters, benzene, chlorinated hydrocarbons, ketones; water-emulsion, stable.

Grades: Solid resin in low, medium, and high viscosities; 50 per cent solution in methanol, low viscosity; water-emulsions containing 60 per cent solids, low and high viscosity.

Uses: In protective, wear-resistant films and coatings; as a size or stiffener for textiles and paper; in heat-sealing and solvent-activated adhesives; in lacquers, paints, gravure and emulsion-type printing inks.

Polyvinyl Alcohol[44]

Formula: $(CH_2CHOH)_x$.

Properties: Colorless, odorless, tasteless, thermoplastic, synthetic resin. Transparent when molded or cast in film form. Density 1.27–1.30 (20° C.).

Soluble in: Water.

Insoluble in: Ordinary organic solvents.

Grades: Type " A ," containing unsaponified acetyl groups; Type " B," fully saponified; both types available in low, medium, and high viscosities.

Uses: For sizing and greaseproofing paper; in adhesives; as an emulsifier; in gas- and oil-impervious films and coatings; in oil-resistant extruded and molded articles.

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[42] E. I. du Pont.

[43] E. I. du Pont de Nemours & Co., Inc. The R. & H. Chemicals Dept.

[44] E. I. du Pont de Nemours & Co., Inc. The R. & H. Chemicals Dept.

BAKELITE[45] PLASTICS

Available Forms. Bakelite Corporation produces basic, or primary, materials which in most instances are converted into finished products by other manufacturers or fabricators. These materials are supplied in several forms suitable for processing by various methods, such as molding, laminating, bonding, and machining.

There are Bakelite molding materials in powder, sheet, and granule form; laminating varnishes for the production of laminated plastics; cast resins; oil-soluble resins for paints and varnishes; heat-reactive varnishes for chemical- and corrosion-resistant coatings and linings; plywood bonding materials in powder and liquid form; bonds for abrasive wheels, brake linings; flexible resins for waterproofing cloth, and many other types of materials for specific industrial needs.

Molding Materials. There are two broad classes of Bakelite molding materials — thermosetting and thermoplastic. Each type requires a distinctive molding technic for processing into finished molded products.

1. Thermosetting materials, such as phenolics and ureas, are usually fabricated by compression molding in heated molds under high pressure. These materials, upon application of *initial* heat, first soften and flux and, under pressure, fill every crevice of the mold cavity. Upon continued application of heat, these materials *polymerize*, or harden, into a permanently infusible, insoluble state, after which they cannot again be melted or softened with further heating.
2. Thermoplastic materials, such as cellulose acetates and polystyrenes, are usually fabricated by injection molding. These materials are first softened in heating chamber, then injected into closed molds under pressure and quickly hardened by cooling. They can be reheated to soften, and recooled to set, almost indefinitely.

In either case, the final molded product takes the exact shape and form of the mold. Color is uniform throughout the molded piece, and a lasting surface luster is acquired in the mold without additional finishing operations. Bakelite molding materials are supplied to the trade ready for use in powder, granular, or sheet form.

Bakelite Phenolic Molding Materials. Because of their dimensional stability, superior electrical insulating qualities, moldability, low cost, and resistance to heat, water, and chemicals, phenolic molding materials are outstanding among plastics. They are prepared from primary phenol resinoid and suitable fillers, such as wood flour, asbestos, fabric, and paper. The all-important ingredient is the resinoid, which is produced through the chemical union of phenol (carbolic acid) and formaldehyde. The fillers are employed for the special properties which they give to molding materials — better molding qualities, greater toughness and strength, and other important characteristics.

The unique combination of properties found in phenolics is responsible for their widespread adoption throughout all branches of industry and the reason why they have become the largest of all plastics groups in both volume and value. Bakelite phenolic molding materials are produced in stock colors, and black, brown, and mottled effects.

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[45] The word " Bakelite " is a registered trade-mark of Bakelite Corporation, Unit of Union Carbide and Carbon Corporation, New York, N. Y.

CLASS 1 — GENERAL PURPOSE PHENOLICS

PHYSICAL (Molded)

Specific gravity	1.35–1.44
Weight per cubic inch — grams	22.1–23.6
Tensile strength — (pounds per square inch)	6500–8500
Impact strength (Izod)	
Foot pounds energy to break	0.13–0.20
Foot pounds per inch of notch	0.26–0.40
Foot pounds per inch square	1.63–2.50
Heat resistance (maximum temperature recommended)	302° F. (150° C.)
Molding shrinkage (inches per inch)	0.006–0.008
Flexural strength (pounds per square inch)	8800–13,000
Modulus of elasticity (pounds per square inch)	8.8×10^5–9.7×10^5
Maximum deflection at center (inches)	0.050–0.065
Distortion under heat	284° F.–302° F. (140° C.–150° C.)
Water absorption (gain after 48 hr. immersion)	0.5%–0.6%

ELECTRICAL (Molded)

Dielectric strength (volts per mil at 60 cycles)	270–350
Power factor — at 60 cycles	0.30–0.43
at 1000 cycles	0.12–0.16
at 1,000,000 cycles	0.05–0.06
Volume resistivity (megohm centimeters)	0.9×10^5–1.7×10^5
Dielectric constant — at 60 cycles	10.–12.
at 1000 cycles	7. – 9.
at 1,000,000 cycles	5.8– 6.

Similar tables of properties for other Bakelite products are omitted here to reduce duplication as the same properties are found elsewhere.

Bakelite Urea Molding Materials have excellent resistance to color change, and even their most delicate pastel shades remain unaffected by exposure to light over long periods of time. Their depth of luster gives a distinctive, rich appearance.

Through the chemical union of urea and formaldehyde, a light-colored resin is obtained. This resin is the basis for the wide variety of urea molding materials. Like the phenolics, fillers are added to gain certain desirable molding characteristics.

Not only are Bakelite urea materials particularly valuable in product styling, but they possess properties that meet diversified industrial needs, such as unusual flexural and tensile strength, resistance to alcohol, and good dielectric qualities.

Bakelite urea laminating varnishes are used for the impregnation of sheets of cloth or paper which are conditioned, stacked to the required thickness, and, under heat and pressure, compressed into a solid, homogeneous mass. The finished laminated stock may be machined by operations similar to those employed in the shaping of metals. The flat plates are used extensively for decorative construction, such as table tops, bar tops, wall paneling, signs, and displays. Translucent and opaque colors are supplied in a wide range of brilliant shades which are an integral part of the material.

Bakelite Cellulose Acetate Molding Materials are furnished in virtually any color desired, in opaque, translucent, and crystal-clear forms. These materials possess extreme toughness and resiliency, offering unusually high resistance to impact. Products and parts molded from these materials are noted for their exceptional luster. These characteristics, combined with relative lightness in weight, give these materials unquestioned superiority over other types of plastics for many uses. However, they are not as resistant to high relative humidities or immersion in water as the phenolic, urea, and polystyrene molding materials.

Bakelite Cellulose Acetates are custom-made thermoplastics, and, therefore, their molding properties and finished characteristics may be varied to suit a diversity of specific requirements.

Bakelite Polystyrene Molding Materials. An unusual combination of properties is available in Bakelite polystyrene plastics. As an electrical insulator, this material provides extraordinary insulation value for high-frequency circuits. It ranks first in water resistance, and withstands numerous caustics and acids, including concentrated sulfuric acid. It is light in weight, but strong, having a tensile strength of 5000 to 5500 lb.

Natural Bakelite polystyrene is a crystal-clear, water-white material. It is also supplied in a wide range of beautiful translucent and transparent colors for unusual effects in product and package design.

Bakelite Laminating Plastics are made by impregnating sheets of paper or fabric with Bakelite thermosetting resin solutions which are provided in several distinct formulations to meet specific requirements. The sheets are then stacked to required thickness, and finally, under heat and pressure, compressed into a solid, homogeneous mass. Laminated plastics are furnished in sheets, tubes, rods, and special shapes.

In general, the same operations which are used in machining metal are adaptable to laminated plastics. They can be planed, milled, drilled, sawed, punched, and threaded, and are supplied, ready for use, in selected sizes, shapes, and thicknesses.

Industrial service, such as silent gears, fire-extinguisher nozzles, and a wide range of mechanical and electrical equipment parts. Rugged, wear-resistant laminated plastics are generally supplied for these uses in black or natural tan color.

Electrical insulation for radios, power-plant equipment, domestic appliances and many other electrical products is made from Bakelite laminating plastics. They provide tough, shatterproof insulation for high and low voltages.

Decorative construction, such as table and bar tops, wall paneling, signs, and displays. Furnished in translucent and opaque sheets in varied widths, lengths, and thicknesses. Laminated products based on Bakelite laminating plastics possess a rich luster and are available in a wide range of brilliant colors that are integral with the material. They may be readily bonded to plywood or other materials for beautiful surface effects. They are nonflammable and resistant to water, alcohol, washing compounds, burning cigars and abrasion, and may be cleaned as easily as glass.

Bakelite Synthetic Resins for Paints and Varnishes. Two outstanding benefits that may be obtained by using paints, varnishes, or enamels, made with Bakelite synthetic resins, are:

1. *Longer decorative and protective life* in the finish on products or equipment;
2. *Greater economy* in finishing operations, resulting from speedier drying when the coating is applied.

Because they have inherent chemical stability, Bakelite resins are rapidly replacing the natural vegetable or animal resins that have been employed in paint-and-varnish-making for countless generations. They are more resistant to all the factors that attack protective coatings — sunlight, moisture, perspiration, salt air and water, fumes, soapsuds, and mechanical abrasion.

Modern protective coatings based on Bakelite resins dry faster, saving valuable time where several coats must be applied. For example, ordinary linseed oil paints which may require days to dry can be speeded up to dry within a few hours by correct use of Bakelite resins. A special type of Bakelite resin has been developed for product finishing, providing anti-corrosive primers that dry in one minute, and finishing coats that dry hard in ten minutes.

These benefits of Bakelite resins can be obtained in virtually any type of protective coating: paints, varnishes, enamels, or nitrocellulose lacquers; product finishes or structural coatings; durable surface finishes for any indoor or outdoor service.

Bakelite resin finishes are now produced by leading paint and varnish manufacturers for all types of service, including product finishing or plant maintenance operations.

Bakelite Varnishes, Lacquers, and Cements. Bakelite heat-hardenable varnishes and lacquers are made by dissolving primary resinoids in common solvents, such as alcohol and acetone. Unlike air-drying finishes which are based on Bakelite oil-soluble synthetic resins, these coatings require baking at elevated temperatures after they have been applied. The baking process expels the solvent and converts the resinoid coating to its final resistant and durable state.

Bakelite heat-hardenable varnishes and lacquers are applied by spraying, brushing, or dipping and provide a hard uniform coating for metal, wood, or porous ceramic material. They are non-hygroscopic and withstand extremes of climate, temperature or humidity; are unaffected by water, alcohol, acetone, benzene, or other common solvents, oil, greases, organic acids, dilute mineral acids, and most of the soap lubricants.

Bakelite heat-hardenable varnishes and lacquers furnish unusually strong and durable impregnation for insulating electrical coils and armatures. They provide hard, transparent, and corrosion-resisting coatings for builders' hardware or other highly finished metal. These coatings are also finding use as chemical- and corrosion-resistant linings for tanks, drums, pails, and containers.

Bakelite heat-hardenable cements furnish a strong and durable bond for joining metal, porcelain, wood, fiber, and glass. They are employed to seal incandescent lamps and radio tubes in their bases. They also provide a tenacious bond for setting bristles in brushes.

Bakelite Bonding Materials. A broad range of special Bakelite resins have been developed for applications requiring strong bonding properties. These special bonding resins have revolutionized the abrasive industry by making possible the modern high-speed grinding wheels so indispensable in the grinding and finishing of present-day alloy steels. Grinding wheels bonded with Bakelite resins can be safely operated at higher speeds than other types of wheels because the wheel structure is stronger. This permits production efficiency, because the rate of metal removal increases in proportion to the increase in operating speed.

Bakelite resins also contribute to the long-wearing qualities of brake-lining for motor vehicles, and serve as permanently strong, heat-resistant bonding agents in numerous other applications.

Bakelite Printing Materials comprise a group of plastics and accessory products which may be classified roughly into two divisions:

Phenolic Matrix Materials. When placed in contact with a pattern, such as a type form, or metal printing plate, and subjected to heat and pressure, these materials become soft. In this plastic condition, they readily produce a sharp, reverse impression of the original pattern. Further heating renders them permanently hard and infusible, producing ideal matrices for the forming of duplicate printing plates. In addition, these matrix materials are finding use for the manufacture of dies employed in the forming of rubber stamps and mechanical rubber goods, such as floor mats, shoe heels and soles.

Printing Plate Materials. These materials are employed in the manufacture of duplicate plates which are formed in Bakelite phenolic matrices. There are two distinct classes of such materials: (1) thermoplastic materials, which provide hard, tough plates designed to replace present electrotypes and stereotypes. These plates are adaptable to multi-color work, such as book and publication printing; and (2) rubber compounds which provide duplicate plates suitable for oil- and aniline-ink printing on flat-bed or high-speed rotary presses. Rubber plates are employed extensively for specialty printing in the paper converting branch of the graphic arts.

Bakelite Plybonds are synthetic resin wood-adhesives. The development of these superior, durable resin bonds has contributed largely to the rapidly growing use of plywoods for construction and decorative purposes.

Bakelite plybonds include urea resin adhesives supplied in liquid and powder form, providing the strongest wood bonds that have been developed for practical use. The heat-reactive types require curing under heat and pressure, after which the bonds become permanently tough, tenacious, and exceptionally resistant to heat, moisture, fungi, and insects.

The cold-setting Bakelite plybonds, requiring pressure but no heat, are employed for specialized applications, such as molded forms and joint work.

GENERAL ELECTRIC PLASTICS

Textolite

The General Electric Company's plastics materials are known by the trade name of Textolite. With a few exceptions, which are noted later, these materials are molded or laminated to customer specification. They include the following types:

Phenol-formaldehyde
Phenol-aniline formaldehyde
Phenol furfural
Urea-formaldehyde
Cellulose acetate
Cellulose acetate-butyrate
Methyl methacrylate
Polystyrene
Cold molded (organic and inorganic)
Laminated

Of approximately 80 different formulations that are available for a wide variety of property requirements in the finished parts, there are a number of types of Textolite which are representative materials for compression, injection, and cold molding, as well as laminating. These typical materials are as follows:

Grade 118: General purpose phenolic for all applications which do not involve special properties. All colors except pastels.

Grade 1376: Phenolic compound with long flow period for intricate parts, or where delicate inserts are used.

Grade 1379: General purpose phenolic for all applications requiring high impact strength. Rag filler provides strength but makes molding of intricate parts difficult.

Grade 70: Asbestos filler provides heat resistance to 220° C. Colors are limited to black or brown, water absorption exceptionally low. Addition of wood flour to this compound will increase strength.

Grade 105: Urea compound used where light colors or translucency are desired, e.g., lighting fixtures, reflectors, panels. Shrinkages must be considered when designing part and mold.

Grade 74: Nonrefractory cold molding material for parts requiring low water absorption, and higher heat resistance and arc resistance than phenolic materials.

Grade 94: Refractory cold molding material for heat and arc resistance where high dielectric strength and low water absorption are not required.

Grade 2008: General-purpose paper base laminated material. Machines well, punches hot. Average flexural strength, 16,000 lb. per sq. in. Excellent electrical properties. Black, natural, chocolate colors.

Grade 113: General-purpose fabric base laminated material. Good impact strength, easily machined or punched.

Special Types

Grade 1403: Polystyrene material for extreme resistance to chemicals. High dielectric strength. Can be injection or compression molded.

Grade 1835: Fabric base laminated material for use where extremely high impact strength is required. Used mainly for high-speed silent gears.

Grade 2039: Laminated material with heavy canvas base, used for water-lubricated bearings for steel mill roll necks. Compressive strength, 40,000 lb. per sq. in.

Grade 2028: Paper base laminated material for use where odorless, tasteless material is required.

Grade 2040C-D-E: Urea base paper base laminated material for nameplates, signs, panels.

Grades 2800–2801 (Mycalex): Ground mica and special glass compound for extremely high heat resistance (325° C.), high dielectric strength, chemical and dimensional stability.

General Electric offers the following services to customers:

Development
Designing
Moldmaking
Application and production engineering
Injection, compression, transfer, and cold molding
Laminating and molding laminating
Finishing
Fabricating

Special Products

Silent Textolite Gears: Laminated impregnated woven fabric available as blanks and finished gears.

Sheets, Rods, and Tubes: Paper or fabric laminated material. Special types developed. Fabricated parts.

Lighting Line: Reflectors, bowls, shades, and diffusing panels, molded and laminated in a variety of sizes and styles in stock or made to customer order.

RESIN ADHESIVES

Tego,[46] A phenol-formaldehyde resin film, weighting about 12½ lb. per 1000 sq. ft., available in 50 and 74 in. widths, in standard sized drums of 16,000 and 19,000 sq. ft., respectively. Produces a boilproof bond. Grade No. 2 is standard and used extensively for airplanes and boats. Grade No. 1 is of equal durability, slightly slower in cure at the same temperature (280° to 300° F.), and preferred for thick assemblies and dense woods requiring maximum penetration. Storage life, under favorable conditions, 6 to 12 months and up.

Uformite No. 430,[46] a urea-formaldehyde resin, dispersed in water, at 70 per cent solids concentration. Used with catalyst Y for hot pressing at 240° to 260° F. Catalysts Z, Q–87, and Q–92 are provided for use where hot presses are not available. These last three catalysts rate, in useful life of mixture, from approximately four hours down to one hour or less, respectively. Extenders are commonly used in varying ratios. Standard package, 550-lb. drum. Storage life, under favorable conditions, 3 months and upward.

Uformite No. 500,[46] a urea-formaldehyde resin, similar to No. 430, but supplied in powder form, requiring mixing with water and catalyst. Standard package, 70 lb. Storage life excellent under favorable conditions.

Uformite CB-550,[46] a urea-formaldehyde resin, similar to No. 500, supplied in powder form with catalyst incorporated, requiring mixing only with water. Normal life of mixture four hours at 70° F. Is normally cured without heat, but bonds improved and accelerated by placing clamped bundles in temperatures of 100° to 450° F. Standard package, 70 lb. Storage life under favorable conditions 6 months and up.

Amberlite PR-14,[46] a phenol-formaldehyde resin, supplied in dry powder form, to be mixed in water and requiring no catalyst. It is comparable to Tego in durability and requires the same conditions for cure. Stability of mixture, approximately one day. Standard package, 100 lb. Storage life excellent under favorable conditions.

Amberlite PR-23,[46] a phenol-formaldehyde resin, supplied in dry powder form, especially intended to be extended with soluble dry blood. To be mixed in water and, in connection with blood, requires no catalyst. Cures at 240° to 260° F. Durability approaches that of PR-14, depending on rate of extender. Standard package, 100 lb. Storage life excellent under favorable conditions.

Amberlite PR-28,[46] a phenol-formaldehyde resin, supplied in dry powder form, especially intended for use in flexible-bag pressure equipment. Curing temperature, depending on time, approximately 230° to 250° F. Requires mixing with water and a catalyst. Stability of mixture approximately eight hours. Standard package, 100 lb. Storage life excellent under favorable conditions.

Urea-formaldehyde.[47] *Thermosetting Types.*

107–2	Thermosetting two-part water soluble glue.
107–2	PHP No. 11 Thermosetting glue for certified commercial aircraft.
700–2	Thermosetting copolymer glue, developed especially for autoclave formed plywood processes.

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[46] Resinous Products & Chemical Co., Inc.

[47] Plaskon Co. Inc.

Thermoplastic Types.

201–2 Thermoplastic two-part water-soluble glue for plywood and joint gluing.
PCP No. 7 Thermoplastic glue for certified commercial aircraft.
250–2 Ready-mixed thermoplastic glue.

LAMINATES

Formica[48]

A plastics finishing material known as Formica is made with phenolic or urea resins and cured at 350° F. and 1100 lb. per sq. in. pressure or more. It is hard, dense, and durable and offers a smooth nonporous chemically inert and lasting covering for many types of flat surfaces. Some grades are cigarette-proof.

It is available in a wide range of colors, patterns, and wood grains. The most commonly used form is a sheet 1/16 in. thick. It is also made as wall board, and the translucent type can be bent to a radius so that it will serve some of the purposes of tubing.

Uses: Table and counter tops, counter panels, doors, interiors, signs, soda fountains, and numerous other decorative applications.

Insurok[49]

Grades Available

Grade XP. A cold punching, paper base material from which parts can be punched to size. This material possesses good electrical properties.

Grade X. This material should be punched hot and is mechanically stronger than Grade XP.

Grade XX. This material is used for most ordinary electrical applications. It is easily machined.

Grade XXX. A paper base material having excellent finish with good machining characteristics for panels, separators, supporting members, etc. This grade has a very low cold flow, high dielectric strength, and excellent insulating qualities.

Grade T-640. A paper base product having low moisture absorption, minimum cold flow, high dielectric strength, etc. This product is recommended for use in tropical or high humidity conditions, chemical processes, or similar applications.

Grade C. This grade is an excellent general all-purpose material. It was originally developed for gears and consists of a strong fabric base with proper type resin. Grade C can be subjected to all types of machining processes and produces excellent results. It resists shock, abrasion, chemical action, and has good dielectric properties.

Grade CG. This material, having a high natural graphite content, is recommended for bearings and parts subject to friction. It is generally used with water or other liquid as the lubricating medium; however, the graphitic content permits its usage in a wide field of applications for oil-less type bearings.

Grade T-638. This grade is a fabric base material having the highest impact resistance of any of the various grades. It is not supplied in sheets or parts thicker than

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[48] Formica Insulation Co.

[49] Richardson Company.

½ in. For those applications requiring more than ½-in. thickness, the material is mechanically laminated by riveting or bolting, with or without shrouds.

Grade CV. For use as valve disk material, especially good in the following applications: replaceable valve seats for handling hot or cold water, gasoline, oil, naphtha, and chemical solutions having acid content. Grade CV also used for valves in reciprocating pumps, plating barrel applications, agitator paddles, etc.

Grade CVAR. For use as valve disk material, especially good in the following applications: Hot and cold water, boiler feed pumps, reciprocating pumps, and chemical solutions having caustic content.

Grade L. This material is for mechanical purposes where fine machining characteristics are required, such as in fine-pitched gears and intricate mechanisms where a very close weave fabric is necessary.

Grade T-688. An extra fine weave fabric base material of a special nature for extremely fine-pitched gears under ⅛-in. face.

Grade T-689. A modification of Grade T-688 for fine-pitched gears over ⅛-in. face.

Grade T-690. A fine weave (linen type) fabric having minimum dimensional change characteristics for rotor blades and similar applications.

Grade A. An asbestos base material for applications subject to higher temperatures than regular grades of paper or fabric materials. Has lowest dimensional change when subjected to high humidity or immersion conditions.

Grade AA. An asbestos fabric base material (with or without wire reinforcement). For use as valve disks and other applications subject to steam or high temperatures. Mechanically the strongest material for high temperature operating conditions.

Grades XPL and XPC. These grades are combinations of paper and fabric material with the fabric surfaces on one or both sides as specified. Specifications should be submitted to our engineering department for recommendation regarding usage of these grades.

The following identifications are common to the industry:

X represents paper
C represents canvas
L represents linen
A represents asbestos
P represents punching

The various grades of Insurok are furnished in standard sheets 36 in. by 42 in. and 36 in. by 59 in., with most grades available in sheets 36 in. by 59 in. Furnished in cut-to-size sheets as well. Material is also produced in rod and tube form.

Micarta[50]

The special field of usefulness of Micarta as an engineering material depends upon:

1. Its advantages as an electric insulating material combined with good electric properties.
2. Its permanence in or resistance to all liquids and gases except strong acids or alkalies.
3. Its toughness, strength, durability, machinability, and noiseless wearing qualities, along with light weight.
4. Its beauty, permanence, and adaptibility for building purposes.

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[50] Westinghouse Electric & Mfg. Co.

As an electric insulating material, it is used for spacers, switchboard panels, covers for busbars, supporting and insulating members, terminal blocks, and many other proved applications.

Because it is unaffected by most liquids and gases, it is widely used for doctor blades, suction box covers, tank linings, pump valves, valve disks, and roll covers.

Because of its light weight and great strength, toughness, durability and noiseless qualities, and because it minimizes wear on the metal it contacts, it is valuable for gears, airplane pulleys, fan blades, bearings, and bobbins.

Its beauty, resistance to scratching, denting, or liquids, and ease of fabrication make it desirable as a decorative veneer for table tops, bar tops, wall panels, and refrigerator door liners and panels.

Manufacture of Micarta Plate. Micarta plate is a laminated plastics material using sheets of paper (plain or printed) cambric, canvas, asbestos paper and cloth, or wood veneer impregnated with a liquid resin and dried in a continuous operation so the original interlacing and length of the fiber is not destroyed. This treated material is then cut into sheets, and the number required to give a thickness of finished product are placed between polished metal plates and cured under pressure of 1000 to 2500 lb. per sq. in. at a temperature ranging from 135° to 185° C. (275° to 365° F.). A complete chemical and physical transformation takes place in this curing process which sets the mass into a solid plate — insoluble and infusible.

Physical Properties. The outstanding characteristics of Micarta are its great mechanical strength, light weight, relative toughness, thermal and electric insulating values, and resistance to corrosion. It is lighter and resists corrosion better than any of the common metals and is as strong or stronger than the majority of them per unit weight as shown in the accompanying table. These values are the average for the various materials and may be of value for structural applications where weight is of importance.

TABLE 33. COMPARISON OF PHYSICAL PROPERTIES

	Specific Gravity	Average Tensile Strength lb. per sq. in.	Average Compression Strength lb. per sq. in	Load per cross-sectiona area that has weight equivalent to same length of Micarta 1 in. sq.	
				Tensile	Compression
Aluminum, cast	2.70	15,000	12,000	7700	6130
Copper, cast	8.89	24,000	40,000	3730	6200
Cast iron, gray	7.07	15,000	90,000	2920	17,500
Steel structural, 10% carbon	7.70	60,000	65,000	10,750	11,650
Tin, cast	7.30	3500	6000	660	1135
Fiber, hard	1.50	15,000	32,000	13,800	29,500
Micarta, fabric base	1.38	10,000	35,000	10,000	35,000

With the wide choice of fillers, binders, and processes, the properties may be varied through a wide range. Certain properties, however, are opposed to others and cannot always be combined in the same grades. Consequently, various grades (shown elsewhere in tables) have been developed, possessing different properties to meet the demands of the application.

Factors Influencing Properties. There are at least four important factors that influence the properties of Micarta plate. They are: (1) type of resin used, (2) resin content, (3) filler, and (4) state of cure.

1. The two general types of resin used are phenol-formaldehyde and urea-formaldehyde, produced as a varnish in the conventional manner. Their characteristics may be varied by the addition of various ingredients, such as chinawood oil in phenol-formaldehyde resin, which acts as a plasticizer and gives flexibility to the cured resin or lime which acts as a catalyst and speeds up the reaction. Variations can also be obtained by combining various amounts of the two principal ingredients. A high percentage of formaldehyde in the phenol-formaldehyde type will result in a larger molecule of the resin, producing a more resilient and stronger finished product. Conversely, a higher percentage of phenol will result in a smaller molecule of resin, resulting in a more brittle and mechanically weaker finished product.

2. The amount of resin with which a filler is impregnated depends upon the final properties required in the finished product. For products requiring high strength and resiliency, a lower percentage of resin is used than for products requiring good resistance to moisture, oils, acids, or alkalies. The resin content varies from 30 to as much as 65 per cent depending on the requirements of the finished product.

3. The principal fillers are: (a) papers of various grades and colors, (b) cloths of various weaves, patterns, and strength, (c) asbestos — paper or cloth, and (d) wood veneer.

(a) The fillers are selected to give specific properties to the finished product. For example, if a relatively low cost plastic is required with good physical and electric properties under low humidity conditions, kraft paper would be used as a filler. Owing to the long fibers this paper imparts high strength and good insulating properties to the finished material, but thorough impregnation is not easily obtained and relatively poor resistance to liquids results.

Conversely, if good resistance to liquids and good electrical properties are required, but the physical properties are not of primary importance, an alpha cellulose paper would be used. Because of the nature of the fiber, thorough impregnation is easily obtained.

(b) Loosely woven fine-weave cloth can be impregnated more readily than tightly woven or coarser fabrics. As with paper, a thoroughly impregnated material gives a harder product with better resistance to liquids than a material not thoroughly impregnated. In fabrics not thoroughly impregnated, the identifying characteristics carry through to give similar modified identifying properties to the finished product.

(c) The asbestos paper and cloth, which contain small percentages of cotton fiber to give sufficient strength for processing, result in a finished product with better resistance to heat than the organic materials.

(d) Wood veneers with open structure are easily impregnated. Because the identifying characteristics of the wood are not lost in the processing, a finished product is obtained more uniform in strength and more resistant to liquids than in its original state.

4. The state of cure, which may be determined by standard tests is directly related to electric insulation properties.

Fabricating. In fabricating Micarta, the general rule is to follow the same setup for any operation such as a sawing, drilling, tapping, punching, milling, or turning that is used for brass or any soft metals. It is possible, however, to lay down precise rules covering this, since many grades have been developed for particular uses where certain features in the material itself require slightly different methods.

The tool that gives the best results in machining operations is the diamond cutter, and the chrome-tungsten steel alloys are next in order of effectiveness.

In all machining, drilling, or tapping operations, care must be exercised not to generate an excessive amount of heat, or delamination of the plastic and rapid dulling of the tools will occur. Adequate clearance should be allowed on all tools.

Micarta Angles, Channels, and Rods. Numerous laminated molded products, in other than plate form requiring simple molds, are made using basically the same treated materials as the Micarta plate. These treated sheets are simply cut into the desired shapes and sizes to fit the molds. The physical and electric properties conform closely to those for Micarta plate for the various grades.

Micarta Tubing. There are two kinds of Micarta tubing: rolled and molded. The rolled tubing is made by rolling impregnated material on a steel mandrel, applying heat and pressure by means of heated rolls. The rolled tubing and mandrel are then placed in an oven maintained at 284° F. and baked until the resin is thoroughly cured. The baking time is determined by the wall thickness. After curing in the oven, the tube is stripped from the mandrel, ground on a centerless grinder to the specified diameter, and buffed or coated with varnish as specified. It is stronger, tougher, and more flexible than molded tubing.

Molded tubing is made in the same way except that the curing is done in special molds under heat and pressure before removing the mandrel. It is particularly adapted to uses where intensive machining, threading, and drilling are to be carried out and where low moisture absorption is essential.

Molded Micarta. Where intricate molds are used and strength is not of prime importance, the treated materials used for Micarta plate are chopped into fine pieces and molded. The average properties of this type of Micarta are shown in the following table.

TABLE 34. PROPERTIES OF MOLDED MICARTA (CHOPPED TREATED MATERIAL)

(Average values)

Description	Size of Chopped Pieces	Approximate Resin Content %	Shrinkage, in. per in. from Mold Dimensions	H_2O Absorp. % Gain 24-hr. Immersion	Dielectric Strength volts per in. ⅛-in. tk.	Physical Properties				
						Tensile, lb. per sq. in.	Compression, lb. per sq. in.	Impact in. per lb. per in. width	Flexural	
									lb. per sq. in.	Def., in.
Kraft paper, black	¼	35	0.0015	1.9	220	5400	23,000	20	10,500	0.060
Coarse weave cloth, tan	¼	41	0.0022	2.9	180	6100	28,000	36	9000	0.066
Coarse weave cloth, tan	¼	52	0.0029	1.9	260	6500	30,000	36	10,000	0.077
Coarse weave cloth, tan	⅛	52	0.0022	2.1	250	6400	29,000	30	8000	0.069
Coarse weave cloth, tan	1/16	55	0.0022	2.0	230	5600	28,000	25	9000	0.059
Coarse weave cloth, black	⅛	55	0.0015	3.7	140	5900	27,500	41	9000	0.073
Medium coarse weave cloth, tan	⅛	66	0.0020	0.80	390	5800	31,000	14	10,000	0.059
Coarse weave cloth, black	⅛	58	0.0018	2.2	140	5900	27,500	26	10,000	0.075
Cord fabric	¼	66	0.0030	1.2	250	6000	32,000	41	17,000	0.089
Medium coarse weave, tan	3/16	51	0.0020	2.3	180	7200	31,000	35	10,000	0.061

TABLE 35. AVERAGE VALUES OF PHENOLITE SHEET

Grade	Tensile Strength (1)	Flexural Strength (1)	Compressive Strength (1)	Impact Strength (2)	Moisture Absorption (3)	Dielectric Strength (4)	Power Factor (5)	Dielectric Constant (5)	Loss Factor (5)	Heat Resistance		Grade
										Continuous, ° F.	Short time, ° F.	
X	12,500	21,000	35,000	0.7	4.0	700	—	—	—	225	275	X
XP	8000	15,000	22,000	0.6	3.0	600	—	—	—	250	275	XP
XXE	8000	16,000	34,000	0.5	1.3	700	0.040	5.0	0.20	250	300	XXE
XXP	8000	16,000	25,000	0.5	1.3	700	0.035	4.8	0.17	250	275	XXP
XXXH	7000	15,000	32,000	0.4	1.0	650	0.032	4.8	0.15	250	300	XXXH
XXXP	7000	15,000	25,000	0.4	1.0	650	0.027	4.5	0.12	250	275	XXXP
CO	10,000	20,000	38,000	3.5	3.0	150	0.10	7.0	0.70	225	275	CO
CEO	9000	18,000	36,000	2.5	1.5	500	0.055	5.5	0.30	250	300	CEO
L	9500	20,000	35,000	2.0	2.0	200	0.10	7.0	0.70	225	275	L
LE	9000	19,000	37,000	1.5	1.2	500	0.045	5.0	0.22	250	300	LE
A	8000	16,000	40,000	1.0	1.2	225	—	—	—	300	400	A
FAA	10,000	20,000	38,000	5.0	1.5	50 (6)	—	—	—	300	400	FAA

(1) lb. per sq. in.
(2) lb. load-seam or lap in vertical position.
(3) %-24 hr. @ 25° ± 2° C., specimen 1 in. long.
(4) Volts per mil — short time test.
(5) At 1000 Kc.
(6) The high dielectric strength of Grade X rolled tubing is only effective under dry conditions. Under high humidity its dielectric strength is low.

Phenolite[51]

Phenolite laminated phenolic sheets and tubing are available in a variety of grades, having the properties set forth in the preceding table.

TABLE 36. AVERAGE VALUES OF PHENOLITE TUBING

R — Rolled Tube (Density — 1.10 to 130) rolled under heat and pressure, then oven cured.
M — Molded Tube (Density — 1.35 approx.) rolled under heat and pressure, then given final cure under high pressure and heat in molds.

Grade	Tensile Strength (1)	Compression Strength Axial (1)	Compression Strength Radial (2)	Moisture Absorption (3)	Dielectric Strength (4)	Power Factor (5)	Dielectric Constant (5)	Loss Factor (5)
X_R	8500	12,000	80	0.5	700 (6)	0.030	4.0	0.12
X_M	11,000	20,000	90	3.0	600	0.040	5.0	0.20
XX_R	9000	16,000	90	1.8	550	0.030	4.0	0.12
XX_M	10,000	19,000	85	1.6	450	0.040	4.8	0.19
C_R	6000	12,000	—	2.8	—	—	—	—
CE_M	9000	25,000	150	1.1	250	0.055	5.5	0.30
L_M	8000	20,000	200	1.6	—	—	—	—
LE_R	7000	18,000	—	2.0	350	0.040	4.5	0.18
LE_M	7500	22,000	240	0.95	250	0.045	5.0	0.22

(1) lb. per sq. in.
(2) lb. load seam or lap in vertical position.
(3) %-24 hr. @ 25° ± 2° C., specimen 1 in. long.
(4) Volts per mil - short time test.
(5) At 1000 Kc.
(6) The high dielectric strength of Grade X rolled tubing is only effective under dry conditions. Under high humidity its dielectric strength is low.

Spauldite[52]

Spauldite is available in laminated phenolic sheets in the following grades:

Requirements	*Grade and Color*	
For hot punching and for general electrical and mechanical service.	X	Natural Black Walnut Brown
For cold punching and shearing up to 3/32 in.	XP14 Dull XP16 Mirror	Natural Black Walnut Brown
Special flexible and tough paper base grade. Exceeds all other paper base grades in flexibility and toughness.	XPK20	Walnut Brown
For panels and general use where low moisture absorption, good electrical properties and fine surface finish are required.	XX	Natural Black
Paper base grade similar to grade XX in electrical and moisture resisting properties, but more suitable for hot punching.	XXP	Natural Black Walnut Brown

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[51] National Vulcanized Fibre Co.
[52] Spaulding Fibre Co., Inc.

For use where highest electrical properties and lowest moisture absorption are required.	XXX	Natural Black
Paper base grade similar to grade XXX, but with lower dielectric losses and more suitable for hot punching.	XXXP	Natural
Coarse fabric base for electrical and general use, combining toughness and good punching.	CE	Natural Black
Fine fabric base for fine work, combining toughness and good punching qualities.	LE	Natural Black
For heavy-duty gears, made of the toughest, strongest coarse weave fabric available.	CG	Natural
For fine-tooth gears, made of special closely woven strong fabric.	LG	Natural
For shut-off valves and pump valves for steam and high temperatures.	AA	Asbestos fabric
For pump or shut-off valve disks.	CV LV	Coarse fabric Fine fabric
For panels requiring special wood grain or colored finishes.	D	Mahogany Walnut

Spauldite Rolled Tubing is made by substantially the same process used in the manufacture of Spauldite Laminated Phenolic Sheets.

The impregnated paper or fabric base is wound on mandrels and thoroughly bonded together with the application of heat and pressure. The rigidly controlled process continues through further heat treating and grinding operations, producing a finished seamless concentric tube of hard, dense, homogeneous structure.

Synthane[53]

Synthane laminated sheets are available in the following grades.

Grade X. A strong laminated material, primarily intended for mechanical applications where electrical requirements are of secondary importance. Punches and machines easily.

Grade XX. For usual electrical applications. Good machinability and low water absorption.

Grade XXX. For radio frequency work, for high humidity applications. Has minimum cold flow characteristics, extremely low moisture absorption and stable electrical characteristics.

Grade XP. Primarily intended for punching. More flexible and not quite as strong as Grade X. Has good moisture resistance and electrical properties. Punches cold up to ⅛ in.

Grade XXP. Similar to Grade XX in electrical and moisture-resistant properties, but more suitable for hot punching. Punches cold to 3/64 in.; warm, over 3/64 in. to ⅛ in. High dielectric strength.

Grade XXXP. Similar to Grade XXX, but with lower dielectric losses and more suitable for hot punching. Has excellent moisture resistance and best electrical properties. Punches warm to 3/64 in.; hot, over 3/64 in. to ⅛ in.

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[53] Synthane Corporation.

Grade C. Made from cotton fabric weighing over 4 oz. per sq. yd. A strong, tough material suitable for gears and other applications requiring high impact strength. Punches cold to 1/8 in.

Grade CE. Same fabric weight and thread count as Grade C. For electrical applications requiring greater toughness than Grade XX, or mechanical applications requiring greater resistance to moisture than Grade C. Punches cold to 3/32 in.

Grade L. Fine weave fabric base. Made from cotton fabric weighing 4 oz. or less per sq. yd. Suitable for small gears and other fine machining applications. Not quite as tough as Grade C. Punches cold to 1/8 in.

Grade LE. Fine weave fabric base. Same fabric weight and thread count as Grade L. Punches cold to 3/32 in. For electrical applications requiring greater toughness than Grade XX. Good moisture resistance and excellent machining properties.

Grade AA. Similar to Grade A but stronger and tougher. Suitable for low voltage applications. Minimum dimensional changes when exposed to moisture. Punches hot to 1/8 in.

Grade A. More resistant to flame and slightly more resistant to heat than other laminated grades. Suitable for low voltage applications. Excellent moisture resistance. Punches cold to 1/16 in.; hot, to 1/8 in.

Synthane laminated tubing is available in the following grades.

Grade X. For general use where high mechanical strength with good punching and machining qualities are required. Good electrical properties under normal atmospheric conditions. Paper base.

Grade XX. For low moisture absorption, low power factor and low surface leakage. Machines readily and has minimum cold flow. Rolled tubes are preferred for punching. Paper base.

Grade C. Good mechanical properties. High compressive and impact strength. Punches and machines easily. Exceptional structural qualities make it useful, especially where mechanical strength is desired. Fabric base.

Grade CE. Good mechanical and machining properties. Recommended in place of Grade C where good electrical properties are required. Fabric base.

Grade L. Good mechanical properties. Fine weave fabric base gives it unusually easy machining qualities, particularly for fine threading and punching operations. Fine weave fabric base.

Grade LE. Good mechanical and moisture resisting properties. Excellent machining qualities. Good electrical properties. Molded tubing recommended in electrical applications under humid conditions. Fine weave fabric base.

Grade A. Denser than other paper or fabric base grades, low moisture absorption, heat and flame resistant. Asbestos paper base.

Grade AA. Properties similar to paper base except it machines more readily. Very low moisture absorption. Asbestos fabric base.

TABLE 37. STANDARD TUBE DIAMETERS AVAILABLE

(In. inside)

From	Up to and Including	In Steps of
⅛	½	$\frac{1}{64}$
½	1	$\frac{1}{32}$
1	2	$\frac{1}{16}$
2	4	⅛
4	22	various to order

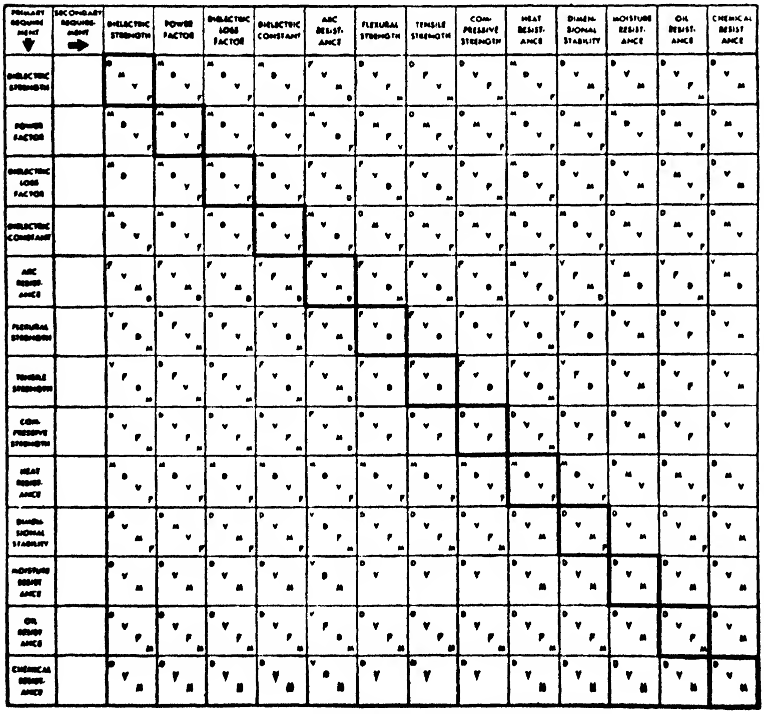
Note: (a) Intermediate inside diameters available to order.
(b) Molded tubing in any outside diameter up to 4 in.
(c) Minimum inside diameter for Grade C, $\frac{3}{16}$ in.
(d) All outside diameters made to specification.

TABLE 38. TOLERANCE ON INSIDE AND OUTSIDE DIAMETER

(Rolled and Molded)

Tube Diameter, Inches		Tolerance (Plus or Minus), Inches	
From	Up to and Including	Inside Diam.	Outside Diam.
⅛	$\frac{23}{32}$	0.003	0.005
¾	$1\frac{15}{16}$	0.004	0.005
2	4	0.008	0.008
$4\frac{1}{8}$*	$12\frac{1}{8}$*	0.010	0.025

* Rolled only.



Companies producing materials with varying physical properties often find that customers have difficulty in proper applications. The Continental-Diamond Fibre Company has prepared this ingenious chart to help solve application problems for the following materials:

Dilecto (D), a special grade of material having good arc and moisture resistance.

Vulcanized fiber (F), a cotton cellulose product made by hydrolyzing fiber paper, has high dielectric strength and good physical properties.

Micabond (M), designed especially to withstand high temperature.

Vulcoid (V), a new material having chemical resistance combined with dimensional stability.

Letters in the diagram are arranged in order of suitability, top position being best.

Fig. 4.1 — Application chart.

PART III

Materials

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CHAPTER V

INGREDIENTS OF THE PLASTICS MIX

From five to ten or more different items enter into the mix from which commercial molding powders emerge. Most important of these is the binder or synthetic resin. Other items are fillers, catalysts, plasticizers, solvents, lubricants, extenders, hardeners and coloring agents. Frequently two or more binders are used in producing a single molding compound and many of the other ingredients may be used in variety as well. The plan in this section is to describe separately each of the various ingredient classifications. Thus lists of solvents, plasticizers, catalysts, etc., are included as well as longer descriptions of some of the more important items. Wood flour, because of its prominence as an ingredient, occupies a subsection which is in effect a condensed treatise covering production and application.

Binders are considered at length even at the risk of some duplication. For further amplification of subjects covered in this section readers are again referred to the general index.

FILLERS

Filling materials are used in plastics for two principal reasons: (1) to modify, improve, or introduce one or more desirable properties into a plastic, to make it suitable for special uses; (2) to reduce the cost of a molded article by replacing part of the more expensive chemical materials with cheaper filling materials.

The properties of any plastic may be altered considerably by the use of different fillers. Thus phenolic plastics may be made heat resistant, shock resistant, moisture resistant, abrasive, etc., according to the various fillers employed.

One of the most important fillers widely used in phenolic plastics is wood flour. Its properties, low cost, and availability make it satisfactory for general purpose plastics.

Cotton fillers, flock or fabric, lend properties of increased strength to thermosetting plastics.

Alpha cellulose, bleached wood pulp, is used for urea-formaldehyde plastics.

Mineral-filled materials are more difficult to process in molding and tableting than wood flour-filled materials and the products are less easily machined. They have better water resistance and higher heat resistance than the standard wood flour-filled materials, as well as a lower coefficient of heat expansion and a lower shrinkage in molding.

Arc-resistant grades of plastics have mineral fillers, especially asbestos and mica. Heat-resistant grades have asbestos fiber fillers; high dielectric grades, ground mica. Low-friction grades often contain powdered graphite fillers.

Inorganic fillers such as powdered slate, gypsum, barium sulfate, calcium sulfate, China clay, zinc oxide, and infusorial earths are used especially where hardness is more important than strength.

Rubber, horn, bone, starch, pumice, or cork may be used for fillers also, each lending special properties to the plastic.

TABLE 39. PROPERTIES OF SOME COMMON FILLERS

Filler	Physical Characteristics	Resistance to Heat	Resistance to Moisture	Resistance to Oil	Electrical Insulation Properties
Organic					
Wood flour	Fibrous and tough	115°-135° C. 221°-275° F.	Poor	Absorbs	Good when dr
Pulp	Fibrous and tough	115° C. 221° F.	Poor	Absorbs	Good when dry
Woven fabrics	Woven, strong	115° C.	Poor	Absorbs	Good when dry
Macerated	—	221° F.			
Inorganic					
Asbestos	Fibrous, tough	700° C. 1292° F.	Medium	Good	Medium when pure
Mica	Flakes	800° C. 1472° F.	Good	Good	Excellent
China clay	Granular	1200° C. 2192° F.	Poor	Good	Fairly good
Slate dust	Amorphous	1200° C. 2192° F.	Medium	Good	Fairly good

Wood Flour Fillers.[1] The material called wood flour is undoubtedly the least known of the commercial forms of wood, although it makes up more than half the bulk of many of our most commonplace articles, particularly articles in the plastics industry.

The wood flour industry in this country is approximately 40 years old and wood flour has been used in plastics for the past 25 to 30 years. Very little was used at first but during the past 10 or 12 years its use has increased from several hundred tons per year to 12,000 to 15,000 tons per year.

Specifications as to quality have become extremely important during the last 10 years and at present not only screen analysis is essential but the method of pulverizing, kind of wood, absorption value, color, natural resin content, and moisture content must all be carefully considered.

The percentage of wood flour used in the plastics industry varies accordingly from 30 to 60 per cent with the specifications required in the finished article. Delicate color shades and high luster necessitate a lower percentage of wood flour, while in molded articles where strength is more desired than appearance a greater percentage of this filler may be used.

While it has been known for some years that white pine was the best of the common varieties of soft wood from which to make wood flour it was learned recently that there are many different grades and varieties of white pine. It was learned that the geographical conditions under which certain white pine was grown had much to do with its ultimate use in the plastics industry. Considerable difference was discovered in the fibrous structure of the wood and the natural resinous content in the white pine from the different localities.

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[1] Prepared in co-operation with Percy Bowen of Becker, Moore & Co.

Wood flour for years has been sold on screen analysis and the different grades have been so designated, i.e., 40-mesh, 60-mesh, 80-mesh, and so on. This has also been the basis for prices; the finer the mesh, the more expensive the material.

For the plastics industry the method of pulverizing and the nature of the wood itself are also of prime importance. It has been found that some 80- and 100-mesh wood flour, made from one grade of pine, which would usually be considered satisfactory for molding powder purposes, is not nearly so desirable as a 40- to 60-mesh flour made from another grade. Numerous tests have been made on very fine flour from 150- to 200-mesh, which is very fine for wood flour due to its fibrous nature, and it was found that the strength tests, both impact and flexural, dropped off considerably. The finer the flour, the lower the strength.

One of the most interesting discoveries in experimental work was the entire elimination of all the grainy particles which proved to be the main source of trouble in wood flour. By a new process which was developed several years ago these hard resinous particles which come from the streaks of grain through the wood can be removed. With these removed it reduced the natural resin content of the flour to a very low percentage and thus materially increased its absorption value and affinity for the synthetic resins.

Tests are made to determine the most desirable percentage of wood flour by making up mixtures in the laboratory of different percentages and molding several different articles from each mix. Sample blocks are molded for strength tests and other pieces are molded to test the flowing characteristics and surface appearance. Because wood flour is the lowest priced ingredient, the higher the percentage of this filler used, the lower the cost of the product.

The use of wood flour in molded plastics articles is subject to variations of the type and quantity of resin, of coloring, of plasticizer and other ingredients employed in the formula. The following table may be taken as roughly representative of the results to be expected when wood flour is used with synthetic resins.

TABLE 40. FLEXURAL AND IMPACT STRENGTH OF WOOD FLOUR FILLED RESINS

Wood Flour	Resin	Flexural Strength	Impact Strength
80 per cent	10 per cent	16,000 lb. per sq. in.	0.75
75 per cent	15 per cent	14,000 lb. per sq. in.	0.70
70 per cent	20 per cent	12,000 lb. per sq. in.	0.65
60 per cent	30 per cent	10,000 lb. per sq. in.	0.60
50 per cent	40 per cent	9,000 lb. per sq. in.	0.40
45 per cent	45 per cent	8,500 lb. per sq. in.	0.35

In physical appearance, however, the larger the percentage of wood flour incorporated, the less smooth and brilliant the finish.

Mica Fillers. One grade of mica used in plastics is a finely wet-ground, white muscovite. Where the electrical characteristics and heat-resistant qualities are important, it is widely used with phenol resin, shellac, or alkyd resins. One plastics company uses two-thirds of mica to one-third of phenol resin. However, too large a proportion of mica has a tendency to cause peeling or sticking to the mold as phenol does not coat the mica sufficiently. It has not yet been adapted to use with the vinyl and urea resins, but experimental work may lead to new developments in this field.

The price of mica is about 1½ cents per pound. Used as a filler it reduces the cost of the plastic materially. One manufacturer using mica as a filler lists the following advantages:

It has prominent electrical characteristics.
It has high heat-resisting qualities.
It is easily wetted by resins and dyes.
It does not absorb moisture.
It has low specific gravity (2.26).
It has no abrasive effects on steel dies.
The light color is retained at elevated temperature in the presence of resins and chemicals.
It is inert to acids, alkalies, and solvents.

Vermiculite Fillers. Vermiculite is an interesting type of expanded mica pellets used in the plastics industry. It has been estimated that in its natural form there are a million laminations per inch. In between these laminations there is a small amount of water. When the material is subjected to high temperatures, it turns to steam and in escaping separates the laminations. This causes the material to expand. The amount of expansion depends upon how the material is handled and how rapidly the heat is applied while the material is being exfoliated or expanded. The crude ore will weigh from 75 to 90 pounds per cubic foot and the heated or expanded material will weigh from 5 to 8 pounds per cubic foot, depending more or less on the particle size and the expanding method used.

Vermiculite is of more or less indefinite chemical composition. The following is an approximate chemical analysis:

	Per Cent
Silica	42.6
Iron oxide	7.2
Aluminum oxide	19.0
Lime	1.9
Magnesia	24.6
Sodium and potassium oxide	3.8

The fusion point of the expanded material will vary. It is between 2300° and 2400° F. Vermiculite is an inert material and is highly resistant to most acids and alkalies.

Commercially, vermiculite is all of the same quality; the only difference between the different types is the particle size. The largest size available at the present time is approximately ½ to ¼ in. The next size is from ¼ in. to 10-mesh and the third size runs from approximately ⅛ in. to 16-mesh. Other sizes could be made available either by screening or grinding. The material ground to approximately 100-mesh will weigh 13 to 15 pounds per cubic foot.

Although there are only approximately twelve to fifteen common filler materials being used in commercial plastics production at the present time there are many materials which have been found to be compatible with plastics in laboratory development work. The following chart gives an indication of what many of the materials are and the plastics with which they may be used.

The chart also includes the base materials for laminates which, while not fillers in the strictest sense, are related in the properties which they give the plastics material and are similar in effect on the binder.

TABLE 41. BASE MATERIALS WHICH MAY BE USED IN PLASTICS

FOR MOLDING COMPOUNDS	Phenolics	Ureas	Alkyds	Acrylics	Vinyls	Cellulose Nitrate	Cellulose Acetate	Cellulose Ethers	Melamine	Shellac	Cold Molded, Bituminous	Remarks
I. ORGANIC COMPOUNDS												
A. Cellulosic												
Alpha cellulose	—	X	—	—	X	X	X	X	X	X	—	A very fine, purified product especially valuable for producing translucent ureas
Wood flour	X	X	X	—	X	X	X	—	X	X	X	Most widely used as an inexpensive general purpose filler
Wood fiber	X	—	—	—	—	X	X	—	—	X	—	—
Wood shavings	X	—	—	—	—	—	—	—	—	—	—	—
Cotton flock	X	X	—	—	—	X	—	—	X	X	—	A filler giving good strength but poor finishing properties
Sawdust	X	—	—	—	—	—	—	—	—	X	—	A cheap, low-grade filler
Paper or paper pulp	X	X	—	—	—	X	—	—	X	X	—	—
Vegetable fibers	—	—	—	—	—	—	—	—	—	—	—	Fibers give good tensile strength but create molding difficulties
Flax	X	—	X	—	—	—	—	—	—	X	—	—
Hemp	X	—	—	—	—	—	—	—	—	—	—	—
Jute	X	—	—	—	—	—	—	—	—	—	—	—
Palm fiber	X	—	—	—	—	—	—	—	—	—	—	—
Cornstalk	X	—	—	—	—	—	—	—	—	—	—	—
Seed hulls or husks	—	—	—	—	—	—	—	—	—	—	—	These are being developed to make some valuable use of waste form materials
Grain husks	X	—	—	—	—	—	—	—	—	—	—	—
Cottonseed hulls	X	—	—	—	—	—	—	—	—	—	—	—
Ground nutshells	X	—	—	—	—	—	—	—	X	—	—	—
Ground cork or cork flour	X	X	X	—	X	—	—	—	—	—	X	—
Hydrocellulose	X	—	—	—	—	—	—	—	—	—	—	—
Oxycellulose	X	—	—	—	—	—	—	—	—	—	—	—
B. Textiles												
Textile fiber	X	X	X	—	—	—	—	—	X	—	—	—
Macerated cloth	—	X	—	—	—	—	—	—	X	—	—	—
C. Natural resins	X	—	—	—	—	X	—	—	—	—	—	—
Rosin	—	—	—	—	—	—	—	—	—	—	X	—
Shellac	—	—	—	—	—	X	—	—	—	—	—	—

TABLE 41. BASE MATERIALS WHICH MAY BE USED IN PLASTICS — (*Continued*)

FOR MOLDING COMPOUNDS	Phenolics	Ureas	Alkyds	Acrylics	Vinyls	Cellulose Nitrate	Cellulose Acetate	Cellulose Ethers	Melamine	Shellac	Cold Molded, Bituminous	Remarks
D. Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	Most of these are used to modify the properties of the plastics. They are usually added in small amounts
Rubber	X	—	—	X	—	—	—	—	—	—	—	—
Gutta percha	X	—	—	X	—	—	—	—	—	—	—	—
Paraffin	—	—	—	—	—	—	—	—	—	—	—	—
Ceresin	—	—	—	—	—	—	—	—	—	—	—	—
Gelatin	—	X	—	—	—	—	—	—	—	—	—	—
Glue	—	X	—	—	—	—	—	—	—	—	—	—
Casein	—	X	—	—	—	—	—	—	—	—	—	—
Metal caseinates	—	—	—	—	—	—	—	—	—	—	—	—
Gluten	X	—	—	—	—	—	—	—	—	—	—	—
Soybean meal	X	—	—	—	—	—	—	—	—	—	—	—
Coffee (ground), also caffelite	X	—	—	—	—	—	—	—	—	—	—	—
Asphalt	—	—	—	—	—	—	—	—	—	—	X	—
II. INORGANIC COMPOUNDS												
A. Minerals												
Asbestos powder	X	—	X	—	—	—	X	—	—	X	X	Asbestos is used for improving the insulating properties of a plastic and for heat and fire resistance
Asbestos fiber	X	X	X	—	X	—	X	—	X	X	X	
Mica	X	X	X	—	X	—	—	—	X	X	X	Mica is usually finely ground
Talc, ground	X	—	X	—	X	—	X	—	—	—	X	—
Fibrous talc	X	—	X	—	—	—	—	—	—	—	X	—
Barytes or barium sulfate (heavy spar)	X	X	—	—	—	—	X	—	—	—	—	—
Fluorspar	X	—	—	—	—	—	—	—	—	—	—	—
Graphite	X	X	—	—	X	—	—	—	X	—	—	Graphite acts as a lubricant
Quartz	X	—	—	—	X	—	—	—	—	—	X	Quartz is ground to a flour before using
Chalk	X	—	—	—	—	—	—	—	—	—	—	—
Calcite	X	—	—	—	—	—	—	—	—	X	—	Calcite reacts with any free acid present, giving off CO_2
Sulfur	—	—	—	—	—	—	—	—	—	—	X	—
Apatite	—	—	—	—	—	—	—	—	—	X	—	—
Gypsum	X	—	—	—	—	—	X	—	—	X	—	—
Magnesite or magnesium silicate	—	—	—	—	—	—	—	—	—	X	—	—

TABLE 41. BASE MATERIALS WHICH MAY BE USED IN PLASTICS — (*Continued*)

FOR MOLDING COMPOUNDS	Phenolics	Ureas	Alkyds	Acrylics	Vinyls	Cellulose Nitrate	Cellulose Acetate	Cellulose Ethers	Melamine	Shellac	Cold Molded, Bituminous	Remarks
Marble or limestone, ground	X	—	—	—	—	—	—	—	—	—	—	—
Slate dust	X	—	—	—	X	—	—	—	—	—	X	—
Ground soapstone	—	—	—	—	—	—	—	—	—	—	X	Soapstone is used to give a pearly appearance
Basalt flour	X	—	—	—	—	—	—	—	—	—	X	Most rock flour is added to give bulk and weight cheaply
Granite flour	X	—	—	—	—	—	—	—	—	—	X	—
Feldspar flour	X	—	—	—	—	—	—	—	—	—	—	—
Ground shale	X	—	—	—	—	—	—	—	—	—	X	—
Flint	X	—	—	—	—	—	—	—	—	—	—	—
Silicate powder	—	—	—	—	—	—	—	—	—	—	X	—
Diatomaceous earth or kieselguhr	X	X	—	—	—	X	X	—	—	—	X	—
Bauxite	X	—	—	—	—	—	—	—	—	—	X	—
Kaolin and other clays	X	—	X	—	—	—	—	—	—	—	X	—
Red iron oxide	X	—	X	—	—	—	—	—	—	—	X	—
Lime	X	—	—	—	—	X	—	—	—	—	—	—
Litharge	—	—	—	—	—	—	—	—	—	—	X	—
Magnesium oxide	X	—	—	—	—	—	—	—	—	—	—	—
Lithopone	X	X	—	—	—	—	X	—	—	—	—	A white pigment
Alkaline earth salts	—	—	—	—	—	—	—	—	—	—	X	—
Titanium dioxide	X	—	—	—	—	X	X	—	—	—	—	A white pigment
Zinc sulfate	—	—	—	—	—	—	—	—	—	—	—	—
Ground slag	X	—	—	—	—	—	—	—	—	—	X	—
Porcelain meal	—	—	—	—	—	—	—	—	—	—	X	—
Metal dust	—	X	—	X	—	—	—	—	—	—	—	Used to give a metallic appearance
Aluminum powder	X	—	—	—	—	—	—	—	—	—	—	—
Powdered iron	X	—	—	—	—	—	—	—	—	—	—	—
Powdered steel	X	—	—	—	—	—	—	—	—	—	—	—
Ground seashell	—	—	—	—	—	X	—	—	—	—	—	—
Silicon alloys	X	—	—	—	—	—	—	—	—	—	—	—
Soot	—	—	—	X	—	—	—	—	—	—	—	—
Glass fiber	X	X	—	X	X	—	—	—	X	—	—	" Invisible " strengthening fiber
White lead	X	—	—	—	—	—	—	—	—	—	—	—
Plaster of Paris	—	X	—	—	—	—	—	—	—	—	—	—
Oxides of heavy metals	X	X	—	—	—	—	X	—	—	—	—	—
Hydroxides of heavy metals	X	—	—	—	—	—	—	—	—	—	—	—
Silicate mixture	X	X	—	—	—	—	—	—	—	—	X	—

TABLE 41. BASE MATERIALS WHICH MAY BE USED IN PLASTICS — (*Continued*)

FOR MOLDING COMPOUNDS	Phenolics	Ureas	Alkyds	Acrylics	Vinyls	Cellulose Nitrate	Cellulose Acetate	Cellulose Ethers	Melamine	Shellac	Cold Molded, Bituminous	Remarks
FOR LAMINATES												
A. Paper												
Rag paper	X	X	X	—	X	—	—	—	X	—	—	—
Kraft paper	X	X	—	—	—	—	—	—	X	—	—	—
Asbestos paper	X	—	X	—	—	—	—	—	X	—	—	—
Cardboard	X	X	—	—	—	—	—	—	—	—	—	—
B. Textiles												
Fine weave, lightweight textile fabrics	—	—	—	—	—	—	—	—	—	—	—	—
Cotton	X	X	—	—	X	—	—	—	X	X	—	—
Linen	X	X	—	—	—	—	—	—	X	X	—	—
Silk	—	—	—	—	—	—	—	—	—	—	—	—
Wool	—	X	—	—	—	—	—	—	—	—	—	—
Woven rayon textiles	—	X	—	—	—	—	—	—	—	—	—	—
Heavy weave fabrics	—	—	—	—	—	—	—	—	—	—	—	—
Canvas	X	—	—	—	—	—	—	—	X	—	—	Used to make strong, silent gears
Woven asbestos fabric	X	—	—	—	—	—	—	—	X	—	—	—
Woven sheets of glass wool	X	X	—	X	—	—	—	—	—	—	—	—
C. Woven wire or other metal												
Wire gauge or woven wire	—	—	—	X	—	—	X	—	—	—	—	Wire-enforced transparent plastics sheets used instead of glass in bombed areas in England
Asbestos reinforced with wire	—	—	X	—	—	—	—	—	—	—	—	—
Metal sheets — perforated metal foils and screens (in combination with fibrous bases)												Not very successful because of different coefficient of thermal expansion of metal and plastic
D. Wood												
Thin wood veneers	X	X	X	—	—	—	—	—	—	X	—	—
Woven veneers	X	—	—	—	—	—	—	—	—	—	—	—
E. Cellulose												
Alpha cellulose	—	X	—	—	—	—	—	—	X	—	—	(For laminated ureas)
FOR ABRASIVE WHEELS												
Silicon carbide or Carborundum	X	X	X	—	—	—	—	—	X	—	—	—
Aluminum oxide or corundum	X	—	X	—	—	—	—	—	—	X	—	—
Sand	X	—	X	—	—	—	—	—	—	—	X	—
Emery	X	—	—	—	—	—	—	—	—	—	—	—
FOR ARTIFICIAL LEATHER												
Leather waste	—	—	—	—	X	—	—	—	—	—	—	—
Ground cork	—	—	—	—	X	—	—	—	—	—	—	—

CATALYSTS

A catalyst is a substance which by its presence in a reaction mixture alters the speed of a reaction between two or more substances. Many organic syntheses, both in the laboratory and in industry, depend on the presence of a small amount of some catalyst to cause the raw materials to react, or to accelerate the reaction enough to give a profitable yield in a reasonable length of time.

Often, especially when complex organic compounds are involved, the nature of the catalyst used determines the nature of the end-product. For example, an acid catalyst may cause the reactants to combine to form an entirely different product from that formed in the presence of a basic catalyst. This is seen in the acid condensation and basic condensation of phenol and formaldehyde. Materials which ordinarily have no affinity for each other will often combine in the presence of a suitable catalyst, and research along these lines has made possible the development of simple and direct syntheses of complex substances.

Catalysts may take part in the chemical reaction, although they are not chemically altered as a final result. They are believed to act by the formation of intermediate compounds. Acids are thought to catalyze reactions by transferring protons to molecules of the reactants to form unstable intermediate products.

Homogeneous catalysts, or those which act while in uniform gaseous liquid solution, probably act by the formation of intermediate products in somewhat the following manner, reducing the activation energy necessary to accomplish the reaction:

$$\text{REACTANT I} + \text{CATALYST} \longrightarrow \text{INTERMEDIATE PRODUCT}$$

$$\text{REACTANT II} + \text{INTERMEDIATE PRODUCT} \longrightarrow \text{CATALYST} + \text{END-PRODUCT}$$

Adsorption plays a large part in surface catalysts, such as that of finely divided platinum, but the action of surface catalysts depends so intimately on the chemical nature of the catalysts, that the formation of an actual intermediate compound between catalyst and reactant is again indicated.

Most of the more familiar catalysts of industry are " positive " catalysts; that is, they initiate or accelerate a reaction, but catalysis also goes on in a negative sense, in some cases inhibiting or decreasing the rate of a reaction. For example, stabilizers or negative catalysts are added to vinyl ester copolymer plastics to hinder darkening due to decomposition or other chemical change.

Catalysts for the manufacture of synthetic resins or plastics are sometimes referred to as *accelerators,* when they accelerate resinification reactions. Catalysts which cause or speed up the polymerization or hardening of plastics or resins are also referred to as *hardeners.* Not all hardeners are catalysts, however, for some combine chemically to form harder compounds (such as aluminum chloride with casein) and some act as vulcanizing agents. The term catalyst is rather loosely used in discussing molding powders to refer to hardeners.

NOTE. Light often has an accelerating effect on chemical reactions, but since light is not classed as a chemical substance, it is not properly called a catalyst.

TABLE 42. SOME CATALYTIC REACTIONS IMPORTANT TO THE PLASTICS INDUSTRY, WITH THE CATALYSTS USUALLY EMPLOYED

Plastic	Reaction Involved	Catalyst
Acrylic	Ethyl benzene from benzene and ethylene	Aluminum chloride
Acrylic	Vinyl benzene from ethyl benzene	Oxide of calcium, strontium, manganese, or zirconium
Cellulose acetate	Acetylation of cellulose	Sulfuric acid
Cumarone-indene	Polymerization	Sulfuric acid, aluminum chloride, ferric chloride, stannic chloride, phosphoric acid
Melamine-formaldehyde	Polymerization	Phosphoric acid
Phenolic, urea, etc.	Methanol from carbon monoxide and hydrogen	Zinc oxide, and certain other metallic oxides
Phenolic, urea, etc	Formaldehyde from methanol and oxygen	Metallic silver or copper
Phenolic	Phenol-aldehyde condensation	Acid catalysts (usually sulfuric acid). Alkaline catalysts (usually ammonia or hexamethylenetetramine, or caustic soda or potash)
Polystyrene	Polymerization	Hydrogen fluoride, oxygen, benzoyl peroxide, stannic chloride. Catalyzed by foreign matter of all kinds
Urea (and others)	Ammonia from nitrogen and hydrogen	Intimate mixtures of iron and molybdenum, or of iron in association with potassium oxide and aluminum oxide
Urea-formaldehyde	Condensation	Alkaline catalysts such as ammonia. Acid catalysts for the final condensation
Urea-formaldehyde	Polymerization	Neutral salts, ammonium salts, acid salts
Polyvinyl acetate	Vinyl acetate from acetylene and acetic acid	Acetyl sulfuric acid
Polyvinyl acetate	Polymerization	Benzoyl peroxide, perborate and percarbonate, bismuth, ferric and stannic chlorides, and strong bases. Also sulfuric acid
Polyvinyl alcohol	Solution and hydrolysis of polyvinyl acetate	Usually an alkaline catalyst, sometimes an acid
Polyvinyl chloride	Vinyl chloride from acetylene and hydrochloric acid	Ammonium chloride or cuprous chloride. A carrier for the catalyst consisting of silica gel or highly active carbon is sometimes used
Polyvinyl chloride	Polymerization	Benzoyl peroxide, soluble lead salts, 1 per cent allyl crotonate, strong bases or sulfuric acid
Vinyl chloride-acetate copolymer	Polymerization	Benzoyl peroxide

TABLE 42. SOME CATALYTIC REACTIONS IMPORTANT TO THE PLASTICS INDUSTRY, WITH THE CATALYSTS USUALLY EMPLOYED — (*Continued*)

Plastic	Reaction Involved	Catalyst
Vinyl chloride-acetate copolymer	Stabilization against discoloration from decomposition	Lead compounds, lead and other metal stearates such as those of cadmium and calcium
Vinylidene chloride	Vinylidene chloride from liquid acetylene tetrachloride and acetylene and chlorine	Ferric chloride
Vinylidene chloride	Polymerization	Phosphorus pentachloride or ozone, benzoyl or acetyl peroxides, hydrogen or barium peroxides

HARDENERS

The following is a list of substances which either accelerate the hardening of various plastics or increase the hardness of the plastics, or both. Some act catalytically, some by combining chemically with the plastics.

For Phenolic Resins.

Acids: mineral — sulfuric, nitric, hydrochloric, phosphoric; organic — oxalic, succinic.

Salts of Acid Reaction: aniline hydrochloride, ammonium chloride, ammonium sulfocyanate, inorganic and organic acid chlorides, phenyl hydrazine hydrochloride, sulfuric acid esters, urea nitrate, acid salts in general.

Bases: ammonia, ammonium salts, aniline, methyl aniline, hexamethylenetetramine.

Salts: neutral salts, titanium salts, titanium citrate, tartrate, and lactate.

Oxides: alkaline earth metal oxide, red lead, cadmium oxide.

Chlorides: bismuth, iron and tin chlorides (hardeners for thermoplastic, low-melting phenolics).

Furfural Reaction Products: reaction products of furfural with aniline, toluidine, other aromatic amines (hardening agents for fusible resin).

Other Organic Compounds: resorcinol, paraformaldehyde; quinone compounds — hydroquinone para- or benzoquinone, naphthoquinone, anthraquinone, phenanthraquinone, camphorquinone (hardeners for Novolaks).

For Urea Resins.

Acids: inorganic — phosphoric, hydrobromic, hydrochloric, hydrofluoric, sulfuric, dissolved sulfur dioxide gas; organic — aliphatic (formic, acetic, oxalic, lactic, citric, maleic, succinic, tartaric); aromatic — benzoic, salicylic, acetyl-salicylic, phthalic acid and phthalic anhydride.

Acid Salts: sodium acid sulfate, potassium acid oxalate, potassium tetraoxalate, aniline hydrochloride, toluidene hydrochloride, other hydrochlorides of organic bases.

Bases: ammonia, hexamethylenetetramine.

For Alkyd Resins.

Oxidizing Catalysts: benzoyl peroxide, acetobenzoyl peroxide, hydrogen peroxide, cobalt lineolate, magnesium lineolate.

Acids: sulfur dioxide, hydrochloric, hydrofluoric, formic, acetic, sulfonic acid catalysts (aliphatic, aromatic, and inorganic sulfonic acids, aromatic-amino and aliphatic-amino sulfonics).

Salts: tri-ethyl lead acetate, boron trifluoride; bismuth, iron, and stannic chlorides; zinc, aluminum, and lead salts.

Oxides: calcium, zinc, magnesium.

Others: phenolic resin, finely divided metal, such as is obtained by reducing finely divided iron oxide or zinc oxide.

For Vinyl Resins.

Oxidizing Catalysts: benzoyl peroxide, perborates, percarbonates, acetyl peroxide, barium peroxide, hydrogen peroxide, ozone, oxygen.

Acids: sulfuric, phosphoric.

Bases: sodium hydroxide, potassium hydroxide, barium hydroxide, cuprous hydroxide, methylamine, ethylene diamine, tetramethyl ammonium hydroxide, piperidine, ethanolamines, benzylamine, cyclohexylamine.

Others: bauxite, silica, phosphorus pentachloride.

For Casein.

Bases: hexamethylenetetramine, sodium hydroxide, potassium hydroxide, ammonium salts.

Acids: picric, tannic.

Salts: chromium salts, aluminum chloride, alkaline earth thiocyanates.

For Cumarone.

Acids: sulfuric, phosphoric.

Salts: aluminum chloride, ferric chloride, stannic chloride, bismuth trichloride, zinc chloride.

For Polystyrene.

Oxidizing Catalyst: benzoyl peroxide.

Salts: hydrogen fluoride, stannic chloride.

Other: sulfur.

For Acrylics.

Oxidizing Catalysts: oxygen, hydrogen peroxide, sodium peroxide, benzoyl peroxide.

For Zein.

Acids: hydrochloric, weaker organic acids.

Bases: ammonia, primary amines, formamide.

Heat-hardenable synthetic resins (phenolics and ureas) can be given a preliminary hardening to a sirupy, semi-liquid stage with acid-hardening accelerators alone or mixed with known catalytic hardening agents and later dispersed in organic liquid solvents of unripened resin to prevent further hardening before use.

Preliminary Hardeners: orthoboric acid, boric anhydride, phosphoric acid, phthalic acid, lactic acid, oxalic acid, hypophosphoric acid.

Hardening Catalysts: organic oxychlorides, alkyl sulfate, halogenated ethers, halogenated esters, acetyl chloride, tri-chlor hydrocarbons, benzotrichloride.

LUBRICANTS

Lubricants are often used with plastics to prevent molded pieces from sticking to the molds. Oils and waxes and salts of higher fatty acids are usually employed. The lubricants may either be applied to the molds or incorporated in the plastics composition.

The proper lubricant for use with any one plastic is best determined by trial. Consistent results are not always obtained with the same composition in different molds. Machine oil, petroleum jelly, casein, stearic acid, paraffin wax, or soap may be applied to the interior of the mold sparingly with a brush or spray. Oil on the mold surface may produce a spotted surface on the finished article, and a solid solvent for the binder of the molding composition may then be used instead. Most molding compositions on the market contain some kind of lubricant, and " molding oils " are on the market.

Adherence of a plastic to the mold, making lubricants necessary, may be caused by a dirty mold, removal of the molded article while too hot, molding at an excessively high temperature, or a peculiarity of the molding composition.

Lubricants Applied to Molds.

Oils, Waxes, and Greases: light machine oil, olive oil, paraffin, petrolatum (vaseline), ceresin, carnauba wax, grease, mineral oil, stearine pitch, lanolin, castor oil.

Soaps: water solution of common soap; metallic soaps, singly or in mixtures — oleates, stearates, palmitates; soaps of aluminum, calcium, chromium, barium, magnesium, zinc.

Stearic Acid and Esters: stearic acid, butyl stearate.

Solution of Film-forming Substance which softens above 130° C., and is not similar to the substance being molded: cellulose acetate, phthalic resin.

Materials Subject to Decomposition at Molding Temperature: collodion, cellulose nitrate, varnishes, gelatin, paper or textiles impregnated with chemicals which at molding temperature lead to destruction of fiber, as sodium bisulfate.

Spray of: copper, tin, glycerol, paraffin oil (for molds made of thermoplastic or thermosetting material, such as Celluloid).

Lubricants to Be Added to the Molding Composition.

Oils, Fats, and Waxes: lanolin, linseed oil, mineral oil, neat's foot oil, paraffin, waxes (beeswax), castor oil.

Metallic Soaps: oleates, stearates, palmitates; mixture of soaps of aluminum, chromium, zinc, calcium, magnesium, barium, zirconium.

Graphite.

Lubricants Used with Various Specific Plastics.

Bituminous, Cold Molded (added to molding composition): metallic stearates, neutral soaps.

Cellulose Derivatives (A. Added to molding composition[2]): oils and waxes, especially 1–2 per cent castor oil; (B. Applied to molds[2]): thin layer of gelatin, solution of rubber or gutta percha in benzine; soaps.

Methacrylates (added to molding composition): 2 per cent stearic acid.

Phenolics (added to molding composition): oils, fats, and waxes, especially vaseline, linseed oil (plaster of Paris mold); metallic soaps, especially barium hydroxide and barium stearate or barium hydroxide and a soap-forming substance such as stearic acid, or aluminum or magnesium soaps; less than 10 per cent water-soluble common soap; 1 per cent butyl stearate, especially with asbestos and phenol-aldehyde resin.

Applied to Molds: oils, especially linseed oil (plaster of Paris mold).

Shellac (applied to molds): gasoline.

Urea (added to molding composition): metallic soaps, less than 1 per cent; zinc stearate, magnesium stearate, calcium stearate.

Lignin (added to molding composition): oils and waxes, petrolatum, paraffin.

Melamine (added to molding composition): metallic soaps (see Ureas).

SOLVENTS

The properties of the more important commercial solvents are listed for convenience in the following tables. More about individual solvents will be found under the section on the manufacture of plastics. See page 272 for names of manufacturers of products listed.

For explanation of symbols in tables, see page 975.

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[2] A and B may be employed together.

TABLE 43. PROPERTIES

Solvents	Chemical Formula	Molecular Wt.	Sp. Gr. at 20° C./20° C.	Lb. per U.S. Gal. at 20° C. Lb.	Coefficient of Cubical Expansion per ° C.	Boiling Point of Pure Material ° C.	Distillation Range of Commercial Material ° C
Acetic acid	CH_3COOH	60.03	1.049^{20}_{4}	8.74	—	118.1	—
Acetone	CH_3COCH_3	58.08	0.7911-0.793	6.59	0.00142-0.00134	56.1	55-58
Acetonylacetone	$CH_3COCH_2CH_2COCH_3$	114.14	0.9710-0.9760	8.10	0.00093	191.4	185-195
2-Amino-1-butanol	$CH_3CH_2CHNH_2CH_2OH$	89.14	0.944	—	—	178	—
2-Amino-2-methyl-1-propanol	$CH_3C(CH_3)NH_2CH_2OH$	89.14	0.934	—	—	165	—
2-Amino-2-methyl-1,3-propanediol	$CH_2OHC(CH_3)NH_2CH_2OH$	105.14	—	—	—	$151^{10\text{ mm.}}$	—
2-Amino-2-ethyl-1,3-propanediol	$CH_2OHC(C_2H_5)NH_2CH_2OH$	119.16	1.099	—	—	$151^{10\text{ mm.}}$	—
Amyl acetate, n	$CH_3COOC_5H_{11}$	130.18	0.879	7.17	—	147.6	—
Amyl acetate, sec.	$CH_3COOC_5H_{11}$	130.18	0.862-0.866 0.868	7.19	0.00108	131	123-145
Amyl acetate, mixed	Mixed amyl isomers	130.18	0.860-0.870	7.12	$0.00110^{10°\text{-}35°C.}$	126	126-155
Amyl alcohol, n (Butyl carbinol, n)	$CH_3(CH_2)_3CH_2OH$	88.14	0.817	6.83	—	138	95% 134.5-138.5
Amyl alcohol, iso (Butyl carbinol, iso)	$(CH_3)_2CHCH_2CH_2OH$	88.14	0.812	6.76-6.79	0.00092	130.5	126-132
Amyl alcohol, active (Butyl carbinol, sec.)	$CH_3CH_2CH(CH_3)CH_2OH$	88.14	0.8169	6.80	—	128	95% 125-131
Amyl alcohol, sec. (Diethyl carbinol)	$CH_3(CH_2)_2CHOHCH_3$	88.14	0.810-0.816	6.83	$0.00088^{30°}$	115.6	95% 113.6-117.6
Amyl alcohol, tert. (Dimethyl ethyl carbinol)	$(CH_3)_2COHC_2H_5$	88.14	0.809^{20}_{4}	6.75	—	101.8	99.5-103.0
Amyl alcohols, mixed	$C_5H_{11}OH$	88.14	0.814	6.77	0.00093	121	121-139
Amylamine	$CH_3(CH_2)_3CH_2NH_2$	87.16	0.756	6.41-5	0.00116	104	102-104
Amyl chlorides, mixed	$C_5H_{11}Cl$	106.60	0.88	7.33	—	85	85-109
Amyl cyclohexanol, 4-tert.	$C_5H_{11}C_6H_{10}OH$	170.19	0.919	—	—	243	95% 243-249
Amylene, mixed	C_5H_{10}	70.13	0.66	5.50	—	32	32-60
Amyl ether	$C_5H_{11}OC_5H_{11}$	158.28	0.78-0.80	6.61	—	170	170-210
Amyl phenyl acetate, p-tert.	$C_5H_{11}C_6H_4OCOCH_3$	206.27	0.996	—	—	253	253-272
Amyl phenyl ether	$C_5H_{11}OC_6H_5$	164.24	0.924	—	—	214	214-229
Amyl propionate	$CH_3CH_2COOC_5H_{11}$	144.21	0.869-0.873	7.25	0.00108	135	135-175
Amyl tolyl ether	$C_5H_{11}OC_6H_4CH_3$	178.26	0.916	—	—	240	240-264
Amyl xylyl ether	$C_5H_{11}OC_6H_3(CH_3)_2$	192.29	0.907	—	—	264	250-263
Aniline	$C_6H_5NH_2$	93.12	1.022^{20}_{4}	—	—	184.4	—
Benzene	C_6H_6	78.10	0.878	7.31	0.00124	78	78-81
Benzyl alcohol	$C_6H_5CH_2OH$	108.13	1.047	8.71	0.00073	199	199-204
Benzyl Cellosolve *	$C_6H_5CH_2OCH_2CH_2OH$	152.19	1.0670-1.0720	8.90	0.00076	255.9	248-260
Benzyl ether	$(C_6H_5CH_2)_2O$	198.25	1.0428^{20}_{4}	8.6	—	295-298	295-298
Butyl acetate, n	$CH_3COOC_4H_9$	116.16	0.872-0.880	7.29	0.00121-0.00117	126.5	115-135
Butyl acetate, iso	$CH_3COOCH_2CH(CH_3)_2$	116.16	0.870	7.24	0.00121-0.00119	116.5-118.3	114-118
Butyl acetate, sec	$CH_3COOCH(CH_3)CH_2CH_3$	116.16	0.858-0.866	7.14-7.18	0.00112-0.00118	112-113	105-127
Butyl amine, n	$CH_3CH_2CH_2CH_2NH_2$	73.14	0.7385	6.2	—	77.1	—
Butyl alcohol, n (butanol, n)	$CH_3CH_2CH_2CH_2OH$	74.12	0.810-0.813	6.75	0.00094	117.9	115-119
Butyl alcohol, iso (propyl carbinol, iso) (Butanol, iso)	$(CH_3)_2CHCH_2OH$	74.12	0.803	6.68	0.00095	107.3	107-111
Butyl alcohol, sec (methyl ethyl carbinol) Butanol-2	$CH_3CH_2CHOHCH_3$	74.12	0.808-0.812	6.72	0.00091	99.5	94-104
Butyl alcohol, tert.	$(CH_3)_3COH$	74.12	0.789	6.52^{25}	0.00074/°F.	82.4	81.5-83
Butyl butyrate	$C_3H_7COOC_4H_9$	144.21	0.874	7.27	0.00107	—	152-170
Butyl Carbitol *	$C_4H_9OCH_2CH_2OCH_2CH_2OH$	162.23	0.9540-0.9600	8.0	0.00087	230.7	220-231
Butyl Carbitol * acetate	$C_4H_9O(CH_2)_2O(CH_2)_2OOCCH_3$	204.26	0.9750-0.9850	8.21	0.00094	246.4	236-249
Butyl chloride, n	$CH_3CH_2CH_2CH_2Cl$	92.57	—	—	—	—	—
Butyl Cellosolve *	$C_4H_9OCH_2CH_2OH$	118.17	0.900-0.905	7.51	0.00087	171.2	163-172
Butyl Cellosolve * acetate	$C_4H_9OCH_2CH_2OOCCH_3$	160.21	0.943	7.85	0.00104	191.5	188-192
Butyl crotonate	$CH_3CH{=}CHCOOC_4H_9$	142.19	0.9037	7.52	—	180.5	—
Butyl diethanolamine	$CH_3CH_2CH_2CH_2N(CH_2CH_2OH)_2$	161.24	0.968	—	—	—	$273\text{-}5^{741}_{\text{mm.}}$
Butyl ether	$C_4H_9OC_4H_9$	130.23	0.7680-0.7710	6.40	—	140.9-142.4	—
1,3-Butylene glycol	$CH_3CHOHCH_2CH_2OH$	90.12	1.0059	8.4	—	206.5	—
Butyl lactate	$CH_3CHOHCOOC_4H_9$	146.18	0.974-0.984	8.15	0.00099	188.0	140-230
Butyl monoethanolamine, n	$CH_3CH_2CH_2CH_2NHCH_2CH_2OH$	117.19	0.890	—	—	—	199-200
Butyl phenyl ether, n	$C_4H_9OC_6H_5$	150.21	0.929	—	—	—	202-212
Butyl propionate, n	$CH_3CH_2COOC_4H_9$	130.11	0.870	—	—	—	—
Butyl propionate, iso	$CH_3CH_2COOCH_2CH(CH_3)_2$	130.11	0.869	—	—	—	124-171
Butyl carbinol, n	$CH_3(CH_2)_3CH_2OH$	88.16	0.817	6.83	—	—	—
Butyl carbinol, iso	$(CH_3)_2CHCH_2CH_2OH$	88.16	0.812	6.76	0.00092	130.5	126-132
Butyl carbinol, sec.	$CH_3CH_2CH(CH_3)CH_2OH$	88.16	0.8169	6.80	—	—	—
Capryl alcohol	$CH_3CHOH(CH_2)_5CH_3$	130.23	0.818	6.81	0.00082	178.5	176.8-179.9
Carbitol *	$C_2H_5OCH_2CH_2OCH_2CH_2OH$	134.17	1.0240-1.0300	8.55	0.00082	201.9	185.205
Carbitol * acetate	$C_2H_5O(CH_2)_2O(CH_2)_2OOCCH_3$	176.12	1.0114	8.41	0.00101	217.7	208-223
Carbon disulfide	CS_2	76.12	1.260^{15}_{15}	$10.48^{25°}$	—	46.3	45-47
Carbon tetrachloride	CCl_4	153.84	1.595^{20}_{4}	13.30	0.00122	76.8	76-77.8
Cellosolve *	$C_2H_5OCH_2CH_2OH$	90.12	0.9280-0.9330	7.75	0.00097	135.1	132-137

*** Denotes trade name.**

Flash Point °F. (Open cup)	Vapor Pressure at 20° C. mm. of Hg	Surf. Ten. dynes per cm. at 20° C.	Refractive Index at 20° C.	Rate of Evaporation (by wt.) *n*-Butyl Acetate = 1.00	Solubility cc./100 cc. at 20° C.		Company Manufacturing Solvent	Solvent Action						Toler. of Cell. Nitr. Sol. for		
					Solvent in Water	Water in Solvent		Cellulose Nitrate	Cell. Acet. (Acetyl Con. 37–42%)	Cell. Ac. But. (Acetyl, 31%, Butyryl, 16%)	Eth. Cell. Ethoxy Con. 47–48%	Vinyl Resin	Chlor. Rubber	Toluol	Naphtha	50% Tol. 50% Naph.
111.0	10.0	27.63/20	1.37182	—	∞	∞	Niacet, Plastic Prods.	—	—	—	—	—	—	—	—	—
15	178.0	24.0	1 3591	7.20	∞	∞	Monsanto, U. S. I., Shell, Carbide, Commercial, Kessler	S	S	S	S	S	PS	4.5 4.3	0.65 0.7	— 1.5
185 Tag.	0.68	—	1.449	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Complete	—	Commercial	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Complete	—	Commercial	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Ca 70	—	Commercial	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Complete	—	Commercial	—	—	—	—	—	—	—	—	—
84	—	—	1.4012	0.51¾ (in min.)	0.18 (by wt.)	0.18	Sharples, U. S. I., Commercial, Kessler, Monsanto	S	I	I	I	S	S	2.7	1.4	—
89	—	—	1 3960	0 33¾ (in min.)	—	0.8	U. S. I.	S	I	I	S	S	S	2.1	1.1	—
107	—	—	1 4013	0.20 (min.)	1.00	1 5	Sharples, U. S. I.	S	I	I	S	S	S	—	—	—
136	2 8	—	1 4113	—	2 6$^{22°}$	—	Kessler, Sharples	—	—	I	S	I	I	—	—	—
132	2 3	23 8	1.4099	—	2 6$^{22°}$	—	Sharples, U. S. I.	—	—	I	S	I	I	—	—	—
122	—	—	1 4097	—	—	—	Sharples, U. S. I.	—	—	I	S	I	I	—	—	—
102	12$^{30°}$	—	1 4072	—	0 13	9.87	Sharples	—	—	I	S	I	I	—	—	—
75	—	15 2/120	1 4052	—	—	—	Sharples	—	—	I	S	I	I	—	—	—
113	14	37.7	1 4092	22 75 (min.)	3 0	8 4-8 98	Sharples, U. S. I.	—	—	I	S	I	I	—	—	—
65	35$^{26°}$	20 4/41 2	1 4166	—	Soluble	Soluble	Sharples	S	—	—	—	—	—	—	—	—
34$^{1°C.}$	42 8	—	1.4108	6.58 min.	Insoluble	—	Sharples	—	—	—	—	—	—	—	—	—
212	0 2	—	1 4758	—	Insoluble	—	Sharples	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Insoluble	—	Sharples	—	—	—	—	—	—	—	—	—
146$^{66°C.}$	0 67	21 8	1 4198	—	—	—	Sharples	I	—	—	—	—	—	—	—	—
240	—	—	—	—	—	—	Sharples	—	—	—	—	—	—	—	—	—
185	—	—	—	—	—	—	Sharples	—	—	—	—	—	—	—	—	—
106	116 9/20	—	—	126 min. (95%)	—	0 3	U. S. I.	S	I	—	—	—	—	1 4	0.7	—
194	—	—	—	—	—	—	Sharples	—	—	—	—	—	—	—	—	—
205	—	—	—	—	—	—	Sharples	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—										
<5 5	118$^{30°C.}$	28 88	1 5014	5 00	0.19	Insoluble	Shell, Barrett, Koppers	I	I	I	S	I	S	—	—	—
212	<1$^{30°C.}$	39 0	1 5399	—	0 08	8 37	Eastman	—	—	—	S	—	—	—	—	—
265	0 02	—	—	—	0 4	18 1	Carbide	—	—	—	—	—	—	—	—	—
	<1							—	—	—	—	—	—	—	—	—
275	—	—	—	—	Insoluble	Insoluble	Dow	—	—	—	PS	—	—	—	—	—
82.4-88 A.S.T.M.	10.1	25 3	1 3947-1 3951	1 0	0 43	1 86	Carbide, Commercial, Kessler, Monsanto, U. S. I.	S	I	I	S	S	S	2 7	1.45	2.1
88 A.S.T.M.	16·4	24 3	1 3997	1 52	0 67	1 64	Du Pont, Carbide	S	I	S	S	S	S	2 55	1 15	—
88 A S.T.M.	16 2	24.0	1 3887	1 8	0 62-0 8	1.43 to 1 65	Kessler, U. S. I., Shell, Carbide	S	I	I	S	S	S	2.45	1.1	1 8
45	78.4	—	1 401	—	Very soluble	Very soluble	Carbide, Sharples	—	—	—	—	—	—	—	—	—
115	4 4	24 6	1 397	0 4	12 5	44.1	Carbide, Commercial, Kessler, Monsanto, U. S. I., Shell	I	I	I	S	—	I	—	—	—
111	8 0	23 5	1 396	8 3	10 0$^{25°C.}$	16 9$^{25°C.}$	Du Pont	I	I	I	S	I	I	—	—	—
88	12 1	24.0	1.397	1 0	24.4	56.0	Kessler, U. S. I., Shell	I	I	I	S	I	I	—	—	—
60	57 3$^{30°C.}$	—	1 3841n$^{26}_{d}$	—	D	D	Eastman, Shell	—	—	—	—	—	—	—	—	—
128	4	—	1.4049	—	0 05	0 43	Carbide	S	I	—	—	—	—	—	—	—
230-240	0 06 to <1	—	1.4290$^{27°C.}$	—	D	D	Carbide	S	I	—	S	I	S	—	—	—
240	0.04 to <1	—	—	—	1.6	3 4	Carbide	—	—	—	S	—	—	—	—	—
—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—
165	0 97	28 4	1.419	0 1	D	D	Carbide	S	I	I	I	I	S	2.6	2.0	2 5
180	<1	—	1 4160	—	0.9	1.9	Carbide	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Insoluble	—	Niacet	—	—	—	—	—	—	—	—	—
244	0 07	—	1.4620	—	D	D	Sharples	—	—	—	—	—	—	—	—	—
100	6.35	22.9	1.3992	—	0.05	0.07-0.1	Carbide, Commercial	I	I	—	—	I	—	—	—	—
250	0 05	—	—	—	D	D	Carbide	I	I	I	I	I	I	—	—	—
176 A.S.T.M.	0 4	30 6	1 4216	0 06	3.5$^{25°}$	15.0$^{25°}$	Commercial	S	I	I	S	S	—	5 1	2 0	4 0
171	2.0	—	1.4437	—	D	D	Sharples	—	—	—	—	—	—	—	—	—
180	—	—	—	—	—	—	Sharples	—	—	—	—	—	—	—	—	—
—	—	—	1 3982$^{25°}$	—	—	—	Kessler, U. S. I.	S	I	—	—	—	—	—	—	—
105	—	—	1.3975	—	0 17	—	Du Pont	—	—	—	—	—	—	—	—	—
136	2.8	—	1.414$^{16°}$	—	2 6$^{22°}$	—	Kessler, Sharples	—	—	I	S	I	I	—	—	—
111	2.3	23.8	1.4099	—	2 6$^{22°}$	—	Sharples, U. S. I.	—	—	I	S	I	I	—	—	—
122	—	—	1.4097	—	—	—	Sharples, U. S. I.	—	—	I	S	I	I	—	—	—
172	0.2	27.1	1.4266	0.045	0 1	3 6	Commercial	I	I	I	PS	I	—	—	—	—
205	0.15-0.22	36.0	1.429	Hygroscopic	Complete	Complete	Commercial, Dow	S	I	I	I	I	—	—	—	—
230	0 15	—	1.4230	—	D	D	Dow, Carbide	—	—	—	PS to S	—	—	—	—	—
<39 2	127$^{0°}$	33.5	1.6295$^{18°}$	—	0.22$^{22°}$	1.0	Dow	I	I	I	PS	I	S	—	—	—
None	89.5-91.0	26.8	1.459-1.4607	9.70	0.08	Insoluble	Commercial, Dow, Shell	I	I	I	PS to S	I	S	—	—	—
130	4.9	29.1	1.4080	0.40	D	D	Carbide, Dow	S	I	I	S	I	S	4.8	1.0	1.8

TABLE 43. PROPERTIES

Solvents	Chemical Formula	Molecular Wt.	Sp. Gr. at 20° C./20° C.	Lb. per U.S. Gal. at 20° C. Lb.	Coefficient of Cubical Expansion per ° C.	Boiling Point of Pure Material ° C.	Distillation Range of Commercial Material ° C
Cellosolve* acetate	$C_2H_5OCH_2CH_2OOCCH_3$	132.16	0.9710-0.9760	8.10	0.00111	156.2	145-166
Chloracetyl chloride	$ClCH_2COCl$	112.93	$1.420^{25°}$	12.5	—	105	105-106
Chlorobenzene, mono	C_6H_5Cl	112.50	1.1066^{20}_{4}	9.25	—	132	130-134
Chloroform	$CHCl_3$	119.39	$1.477^{25°}$	12.42-12.35	0.00126	61.2	—
Crotonyl alcohol	$CH_3CH{=}CHCH_2OH$	72.06	0.873^{0}_{4}	—	—	117	117-120
Cyclohexane	$CH_2CH_2CH_2CH_2CH_2CH_2$	84.09	0.7791^{20}_{4}	6.5	—	81.4	79-82
Cyclohexanol	$CH_2CH_2CH_2CH_2CH_2CHOH$	100.10	0.951-0.962	7.92	0.00077	161.5	150-182
Cyclohexanone	$CH_2CH_2CH_2CH_2CH_2CO$	98.08	0.948	7.87	0.00091	156.7	130-173'
Cyclohexene	$CH_2CH_2CH_2CH_2CH_2\ CH$	82.08	0.8102^{20}_{4}	6.75	—	83	—
Cyclohexyl acetate	$CH_2CH_2CH_2CH_2CH_2CHOOCCH_3$	142.11	0.963-0.970	8.01	0.00095	177	165-193
Decahydronaphthalene or Decalin	$CH_2CH_2CH_2CH_2CHCHCH_2CH_2CH_2CH_2$	138.14	0.8953^{20}_{4}	7.37	0.00088	193	186-194
Decylene glycol	$CH_3CHOHC(C_2H_5)\ (C_4H_9)\ CH_2OH$	174.18	0.945	—	—	$130^{3\ mm.}$	—
*Dehydranone	$CH_3COCHCOCH{\cdot}C(CH_3)OCO$	168.06	—	—	—	—	—
Diacetoacetyl ethylene diamine	$(CH_2NHCOCH_2COCH_3)_2$	228.25	—	—	—	—	—
Diacetone alcohol	$(CH_3)_2COHCH_2COCH_3$	116.16	0.936-0.943	7.81	0.00094	167.9	130-180
Diamylamine	$C_{10}H_{23}N$ Mixed amyl isomers	157.18	0.775	6.45	$0.00102^{20-60°C}$	—	175-218
Diamylbenzene	$C_6H_4(C_5H_{11})_2$	218.21	0.868	—	—	202	—
Diamylene	$C_{10}H_{20}$ Mixed isomers	140.16	0.775	—	—	—	150-170
Diamyl naphthalene	$C_{10}H_6(C_5H_{11})_2$	268.21	0.930-0.940	7.76	—	—	329-366
Diamyl oxalate	$C_{12}H_{22}O_4$ Mixed isomers	230.18	0.963	—	—	—	240-273
Diamyl phthalate	$C_6H_4(CO_2C_5H_{11})_2$	306.21	1.022-1.026	8.52	0.00076	—	$247-255^{50mm}$
Dibenzyl	$C_6H_5CH_2CH_2C_6H_5$	182.11	$0.942^{41°}$	—	—	284	—
Dibutanol	$CH(CH_3)CH_2CH_2CH(CH_2OH)CH(CH_3)O$	144.13	0.9927	8.3	—	210.9	—
Di-*n*-butylamine	$(CH_3CH_2CH_2CH_2)_2NH$	129.24	0.768	6.33-6.39	—	161°	153-172
Di-*n*-butylaminoethanol	$(C_4H_9)_2NCH_2CH_2OH$	173.19	0.857	—	—	—	226-232
N,N-di-*n*-butylaniline	$C_6H_5N(C_4H_9)_2$	205.19	0.904	—	—	—	267-275
Di-iso-butyl ketone	$(CH_3)_2CHCH_2COCH_2CH(CH_3)_2$	142.24	0.8089	6.73	—	168.1	165-175
Dibutyl oxalate	$(COOC_4H_9)_2$	202.14	1.988-0.992	—	—	—	240-255
Dibutyl phthalate	$C_6H_4(CO_2C_4H_9)_2$	278.34	1.047-1.049	8.72	0.00074	339.2	—
Di Carbitol* maleate	$(\cdot CHCOOC_2H_4OC_2H_4OC_2H_5)_2$	348.39	—	9.5	—		—
O-Dichlorbenzene	$C_6H_4Cl_2$	146.95	$1.304^{25°}$	10.90	—	180.2	178-181
Dichlorethylether	$ClCH_2CH_2OCH_2CH_2Cl$	142.98	1.2190-1.2240	10.17	0.00097	178.5	170-180
Dichloropentanes (mixed isomers)	$C_5H_{10}Cl_2$ Mixed isomers	140.98	1.06-1.10	8.94	—	—	130-200
Dichlor-iso-propyl ether	$CH_3CH(CH_2Cl)OCH(CH_2Cl)CH_3$	171.07	1.1122	9.3	—	187.3	—
Diethyl benzene	$C_6H_4(C_2H_5)_2$	134.11	$0.868^{25°}$	—	—	181.2	—
Diethanolamine	$(HOCH_2CH_2)_2NH$	105.10	1.0880- $1.0950^{30°}$	$9.09^{30°}$	—	268	—
Diethylamine	$(C_2H_5)_2NH$	73.10	0.71	—	—	—	53-59.5
Diethyl Carbitol*	$C_2H_5OC_2H_4OC_2H_4OC_2H_5$	162.23	0.9060-0.9110	7.6	—	187.9	—
Diethyl carbonate	$(C_2H_5)_2CO_3$	118.08	0.975	7.96	0.00113	—	87-127
Diethyl carbinol	$(C_2H_5)_2CHOH$	88.09	0.815	6.74-6.83	$0.00088^{30°}$	115-119	113.6-117.6
Diethyl Cellosolve*	$C_2H_5OC_2H_4OC_2H_5$	118.17	0.8405-0.8455	7.01	—	121.4	115-140
Di-2-ethylhexyl amine	$(C_4H_9CH(C_2H_5)CH_2)_2NH$	241.45	0.8062	6.71	—	281.1	—
Diethyl ketone	$C_2H_5COC_2H_5$	86.08	0.815	6.78	0.00113	—	100-104
Diethyl oxalate	$(COOC_2H_5)_2$	146.08	1.076-1.080	—	—	—	180-190
Diethyl phthalate	$C_6H_4(COOC_2H_5)_2$	222.11	1.118-1.120	9.31	—	296.1	—
Diethylene glycol	$HOCH_2CH_2OCH_2CH_2OH$	106.12	1.1170-1.1200	9.31	—	244.8	230-270
Diglycol chlorohydrin	$ClCH_2CH_2OCH_2CH_2OH$	124.57	1.1698	9.7	—	196.8	—
Diethylene glycol diacetate	$CH_3COOCH_2CH_2OCH_2CH_2OOCCH_3$	190.19	1.1159	9.3	—	250	—
Diethylene glycol diethyl ether (Diethyl Carbitol*)	$C_2H_5OC_2H_4OC_2H_4OC_2H_5$	162.23	0.9060-0.9110	7.6	—	187.9	180-190
Diethylene glycol monobutyl ether (Butyl Carbitol*)	$C_4H_9OC_2H_4OC_2H_4OH$	162.14	0.9540-0.9600	8.0	0.00087	230.7	—
Diethylene glycol monoethyl ether (Carbitol*)	$C_2H_5OCH_2CH_2OCH_2CH_2OH$	134.17	1.0240-1.0300	8.55	0.00082	201.9	185-205
Diethylene glycol monomethyl ether (Methyl Carbitol*)	$CH_3OC_2H_4OC_2H_4OH$	120.15	1.0300-1.0400	8.61	—	194.1	—
Diethylene glycol monobutyl ether acetate (Butyl Carbitol* acetate)	$CH_3COOC_2H_4OC_2H_4OC_4H_9$	204.16	0.9810	8.21	0.00094	246.4	239-249
Diethylene glycol monoethyl ether acetate (Carbitol* acetate)	$CH_3COOC_2H_4OC_2H_4OC_2H_5$	176.11	1.0114	8.41	0.00101	217.7	208-223
Diethylene glycol monomethyl ether acetate (Methyl Carbitol* acetate)	$CH_3OOC_2H_4OC_2H_4OCH_3$	162.18	1.0396	8.7	—	209.1	—
1,4-Diethylene oxide (Dioxane)	$OCH_2CH_2OCH_2CH_2$	88.10	1.0300-1.0380	8.61	—	101.1	95-103
Diethylene triamine	$NH_2C_2H_4NHC_2H_4NH_2$	103.17	0.9542	8.0	—	206.7	—
Diglycol diacetate	$CH_3COOCH_2CH_2OCH_2CH_2OOCCH_3$	190.11	1.116	9.29	0.00095	238	238-251

* Denotes trade name.

OF SOLVENTS — (*Continued*)

Flash Point °F. (Open cup)	Vapor Pressure at 20° C. mm. of Hg	Surf. Ten. dynes per cm. at 20° C.	Refractive Index at 20° C.	Rate of Evaporation (by wt.) *n*-Butyl Acetate = 1.00	Solubility cc./100 cc. at 20° C.		Company Manufacturing Solvent	Solvent Action						Toler. of Cell. Nitr. Sol. for		
					Solvent in Water	Water in Solvent		Cellulose Nitrate	Cell. Acet. (Acetyl Con. 37–42%)	Cell. Ac. But. (Acetyl, 31%, Butyryl, 16%)	Eth. Cell. (Ethoxy Con. 47–48%)	Vinyl Resin	Chlor. Rubber	Toluol	Naphtha	50% Tol. 50% Naph.
142	1.1	29.4	1.423-1.404	0.24	23.0	6.0	Carbide, Dow, Commercial	S	I to PS	PS	S	S	S	2.5	0.9	1.4
None	15.0	—	—	—	Decomposes	Decomposes	Carbide, Dow	—	—	—	—	—	—	—	—	—
81 Cleveland	—	—	1.5248	—	0.05	Insoluble	Dow	—	—	—	S	S	S	—	—	—
None	159.6	27.1	1.444	—	0.55	0.1	Dow, Commercial	I	I	S	S	S	S	—	—	—
105 A.S.T.M.	—	—	1.430-1.4240	—	14.2	—	Shell, Carbide	—	—	—	—	—	—	—	—	—
<10	—	—	$1.4290^{15°}$	—	Insoluble	Insoluble	Dow	—	—	—	I	—	—	—	—	—
154.4 Cleveland	1.05	35.1	1.465	0.09	40-50	11.7	Barrett, Dow, Du Pont, Commercial	I	I	I	PS	I	I	—	—	—
145 A.S.T.M.	4.4	35.1	1.455-1.4507	0.25	0.13	8.68	Barrett, Du Pont, Commercial	S	PS to S	S	S	S	S	—	—	—
<10	—	—	$1.4451^{22°}$	—	V.S.S.	Insoluble	Dow	—	—	—	S	—	—	—	—	—
147.2	—	—	1.440	—	0.16	1.42	Dow, Du Pont	S	—	—	S	—	S	—	—	—
134 Cleveland	2	—	1.4828	—	Insoluble	Insoluble	Du Pont	—	—	—	PS	—	—	—	—	—
<121° C.	<0.1	—	—	—	Sl S	—	Carbide	—	—	—	—	—	—	—	—	—
—	<0.1	—	—	—	0.1	—	Carbide	—	—	—	—	—	—	—	—	—
—	—	—	—	—	S.I.	—	Carbide	—	—	—	—	—	—	—	—	—
170 Cleveland	1.47	31.0	1.4204-1.4210	0.15	D	D	Shell, Carbide, Commercial, Monsanto, Shell	S	S	PS	S	I	PS	3.0	0.5	1.1
158	9^{26}	24.4	1.4259	—	Insoluble	Insoluble	Sharples	—	—	—	—	—	—	—	—	—
—	—	—	$1.4751^{15°}$	—	Insoluble	Insoluble	Sharples	—	—	—	—	—	—	—	—	—
—	—	—	—	-	Insoluble	Insoluble	Sharples	—	—	—	—	—	—	—	—	—
315	0.0012	—	—	—	—	—	—	S	S	S	S	S	S	—	—	—
118° C.	—	—	—	—	—	—	Sharples	—	—	—	—	—	—	—	—	—
357	—	—	1.4879	—	Insoluble	Insoluble	U. S. I., Commercial	S	I	I	I	S	—	—	—	—
—	<0.01	—	$1.539^{81°}$	—	Insoluble	Insoluble	Carbide	—	—	—	—	—	—	—	—	—
215	<0.01	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
125 Cleveland	—	—	1.4186	—	D	D	Carbide, Dow, Sharples	—	—	—	—	—	—	—	—	—
93° C.	0.4	—	1.4444	—	Insoluble	Insoluble	Sharples	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Insoluble	Insoluble	Sharples	—	—	—	—	—	—	—	—	—
140	1.7	—	$1.412^{21°}$	—	<0.06	0.45	Carbide	I	I	—	—	I	—	—	—	—
330 Cleveland	—	—	—	—	—	—	U. S. I.	—	—	—	—	—	—	—	—	—
246 Commercial	—	—	—	—	—	—										
340	<0.01	—	1.4889	—	<0.02	0.46	Carbide, Commercial	S	I	I	I	S	PS	—	—	—
235	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
154	—	—	$1.5487^{25°}$	—	0.01	Insoluble	Dow	—	—	—	S	—	—	—	—	—
185	1.0	—	1.457	—	1.02	0.1	Carbide	I	I	I	I	S	—	—	—	—
106 Cleveland	—	$31.8^{25°}$	—	—	Insoluble	—	Sharples	—	—	—	—	—	S	—	—	—
185	0.85	—	—	—	0.17	0.11	Carbide	—	—	—	—	—	—	—	—	—
138	—	—	$1.493^{25°}$	—	Insoluble	Insoluble	Dow	—	—	—	—	—	—	—	—	—
280 Cleveland	<0.01	—	1.4776	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
<−0.6	220	—	$1.3873^{17.6°}$	—	V.S.	V.S.	Sharples	—	—	—	—	—	—	—	—	—
180	0.50	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
170	$3^{30°}$	—	1.3852	—	1.88	2.60	Carbide, U. S. I.	SA	SA	—	—	—	—	—	—	—
102	$12^{30°}$	—	1.4072-1.4098	—	0.13	9.87	Sharples	—	—	I	S	I	I	—	—	—
95 Tagliabue	12	—	—	—	21	3.43	Carbide	—	—	—	—	—	—	—	—	—
270	0.01	—	—	—	<0.02	0.17	Carbide	—	—	—	—	—	—	—	—	—
59	$46^{30°}$	—	—	—	4.3	2.1	Carbide	—	—	—	—	—	—	—	—	—
232 Cleveland	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
305	$14^{183°}$	37.5	1.5019	—	—	—	—	S	S	—	—	—	—	—	—	—
290	0.01	—	—	—	D	D	Carbide	S	I	—	S	S	—	—	—	—
225	0.17	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
275	0.02	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
180	0.50	—	—	—	D	D	Carbide	—	I	—	—	—	—	—	—	—
220-231	0.06 to <1	—	$1.4290^{27°}$	—	D	D	Carbide	S	I	—	S	I	—	—	—	—
210 Tagliabue	0.15-0.22	36.0	1.429	Hygroscopic	D	D	Carbide, Dow Commercial	S	I	I	I	I	—	—	—	—
200	0.34	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
240	0.04 to <1	—	—	—	1.6	3.4	Carbide	—	—	—	S	—	—	—	—	—
230	0.15	—	—	—	D	D	Commercial, Carbide	—	—	—	—	—	—	—	—	—
180	0.12	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
64	29.5	$36.9^{25°}$	1.4232	2.15	D	D	Carbide, Commercial	I	S	S	S	S	S	—	—	—
215	0.22	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
290	$<1^{30°}$	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—

TABLE 43. PROPERTIES

Solvents	Chemical Formula	Molecular Wt.	Sp. Gr. at 20° C./20° C.	Lb. per U.S. Gal. at 20° C. Lb.	Coefficient of Cubical Expansion per ° C.	Boiling Point of Pure Material ° C.	Distillation Range of Commercial Material ° C
Di-2-hydroxy ethyl amine	$(HOCH_2CH_2)_2NH$	105.10	1.0880- $1.0950^{30/20°}$	$9.09^{30°}$	—	268	—
Dihydroxy ethyl aniline	$C_6H_5N(C_2H_4OH)_2$	181.13	—	—	—	58	—
Di-2-hydroxy ethyl ether	$HOCH_2CH_2OCH_2CH_2OH$	106.12	1.1184	9.3	—	244.8	230-270
Dimethoxy tetraglycol	$(CH_3OC_2H_4OC_2H_4)_2O$	222.28	1.0110-1.0160	8.43	—	275.8	255-285
Dimethyl amine	$(CH_3)_2NH$	45.06	$0.6865^{-6° C.}$	7.8	—	$7.2^{764\ mm.\ Hg}$	—
Dimethyl dioxane	$OCH(CH_3)CH_2OCH_2CHCH_3$	116.16	0.927	—	—	117.5	—
Dimethyl ethyl carbinol	$(CH_3)_2COHC_2H_5$	88.09	0.809^{20}_{4}	6.75	—	101.8	95.5-103.0
Dimethyl phthalate	$C_6H_4(CO_2CH_3)_2$	194.08	1.192-1.1940	9.93	0.00076	281.8	280-290
Dimethyl sebacate	$[(CH_2)_4COOCH_3]_2$	230.30	0.9896^{20}_{20}	8.21	0.00077	—	—
Di-sec-octyl amine	$(CH_3(CH_2)_3CH(C_2H_5)CH_2)_2NH$	241.45	0.8062	6.7	—	281.1	—
Di-sec-octyl aminoethanol	$(CH_3(CH_2)_3CH(C_2H_5)CH_2)_2NC_2H_4OH$	286.33	—	7.2	—	—	—
Dioctyl phthalate	$C_6H_4(CO_2CH_2CH(C_2H_5)C_4H_9)_2$	390.55	0.981	8.2	—	$216^{5\ mm.}$	—
Dioxane (1,4-Diethylene oxide)	$OCH_2CH_2OCH_2CH_2$	88.10	1.0343	8.61	0.00103	101.1	95-103
Dioxolane	$OCH_2CH_2OCH_2$	74.05	1.065	8.9	—	74	74-75
Dipentene	$C_{10}H_{16}$	136.13	0.847-0.854	—	—	—	175-188
Dipentyl ketone	$CH_3(CH_2)_4CO(CH_2)_4CH_3$	170.17	0.8262^{20}_{4}	—	—	226	—
1,2-Diphenyl ethane	$C_6H_5CH_2CH_2C_6H_5$	182.11	0.995^{20}_{4}	8.2	—	284	—
1,1-Diphenyl ethane	$(C_6H_5)_2CHCH_3$	182.11	1.006^{21}_{4}	8.2	—	272	268-286
Di-iso-propanol amine	$(CH_3CHOHCH_2)_2NH$	133.13	1.0089	8.3	—	$116^{5\ mm}$	—
Dipropylene glycol	$(CH_3CHOHCH_2)O$	134.17	1.0252	8.5	—	231.8	—
Dipropyl ketone	$CH_3CH_2CH_2COCH_2CH_2CH_3$	114.11	0.8162	6.8	0.00107	143.7	138-144
Ethanol (Ethyl alcohol)	CH_3CH_2OH	46.05	0.7893^{20}_{4} 0.791	6.58	0.00108	78.5	77-79
Ethyl acetate	$CH_3COOC_2H_5$	88.10	0.883-0.889	7.37	0.00134	77.1	70-80
Ethyl amine	$CH_3CH_2NH_2$	45.06	0.689^{15}_{15}	—	—	16.6	—
n-Ethyl aniline	$C_6H_5NHC_2H_5$	121.10	0.963	—	—	—	201-205
Ethyl benzene	$C_6H_5CH_2CH_3$	106.08	$0.870^{20°}$ $0.866^{25°}$	7.25	—	135.7	135-137
2-Ethyl butanol, or 2-Ethyl butyl alcohol	$(C_2H_5)_2CHCH_2OH$	102.17	0.8300-0.8350	6.93	—	148.9	140-160
2-Ethyl butyl acetate	$CH_3COOCH_2CH(C_2H_5)_2$	144.21	0.8750-0.8810	7.33	—	162.4	155-167
Ethyl butyrate	$CH_3CH_2CH_2COOC_2H_5$	116.09	0.880	7.32	0.00116	120	107-131
Ethyl carbamate	$NH_2COOC_2H_5$	89.06	$1.06^{48°}$	—	—	180 (decomp.)	—
Ethyl chlorocarbonate, or ethyl chloroformate	$ClCOOC_2H_5$	108.50	1.137	—	—	94	—
Ethyl crotonate	$CH_3CH{=}CHCOOCH_2H_5$	114.08	0.921	—	—	139	—
Ethyl monoethanolamine	$CH_3CH_2NHCH_2CH_2OH$	89.10	0.914	—	—	$167.9^{751\ mm.}$	160-167
Ethyl diethanolamine	$CH_3CH_2N(CH_2CH_2OH)_2$	133.10	1.015	—	—	$251.2^{750\ mm.}$	246-252
Ethyl ether (Ethyl oxide)	$C_2H_5OC_2H_5$	74.12	0.7135^{20}_{4}	6.0	—	34.5	34-37
Ethyl formate	$HCOOC_2H_5$	74.08	$0.924^{28°}$	—	—	54.3	53-57
2-Ethyl hexanol, or 2-Ethyl hexyl alcohol	$C_4H_9CH(C_2H_5)CH_2OH$	130.23	0.8320-0.8370	6.94	—	183.5	180-190
2-Ethyl hexyl acetate	$CH_3COOCH_2CH(C_2H_5)C_4H_9$	172.26	0.8700-0.8750	7.27	—	198.6	192-205
Ethyl lactate	$CH_3CHOHCOOC_2H_5$	118.08	1.020-1.036	8.60	0.00098-0.00110	154.0	102-176
n-Ethyl morpholine	$CH_3CH_2NCH_2CH_2OCH_2CH_2$	115.17	0.916	7.6	—	138	—
Ethyl oleate	$C_{17}H_{33}COOC_2H_5$	310.30	0.8735	7.27	0.00080	205-208	$190\text{-}215^{10mm}$
Ethyl oxide	$C_2H_5OC_2H_5$	74.12	0.7135^{20}_{4}	6.0	—	34.5	34-37
Ethyl phenyl ethanolamine	$C_6H_5N(C_2H_5)C_2H_4OH$	165.13	1.04	8.7	—	$268^{740\ mm.}$	—
Ethyl propionate	$CH_3CH_2COOC_2H_5$	102.08	0.981	7.41	0.00125	—	90-118
Ethylene chlorohydrin	$HOCH_2CH_2Cl$	80.52	1.2020-1.2080	10.02	0.00029	128.7	122-135
Ethylene diamine	$H_2NCH_2CH_2NH_2$	60.10	0.8895	7.5	—	117.2	—
Ethylene dibromide	$BrCH_2CH_2Br$	187.88	$2.172^{25°}$	18.07	—	131.4	—
Ethylene dichloride	$CHCl_2CH_2Cl$	98.96	1.2250-1.2570	10.45	—	83.6	82-85
Ethylene glycol	$HOCH_2CH_2OH$	62.07	1.1151-1.1156	9.28	—	197.2	190-210
Ethylene glycol diacetate (Glycol diacetate)	$CH_3COOCH_2CH_2OCOCH_3$	146.14	1.1040-1.1090	9.21	—	190.5	183-195
Ethylene glycol diformate (Glycol diformate)	$HCOOCH_2CH_2OOCH$	118.09	1.2240	—	—	177	—
Ethylene glycol monobenzyl ether (Benzyl Cellosolve*)	$C_6H_5CH_2OCH_2CH_2OH$	152.19	1.0670-1.0720	8.90	—	255.9	248-260
Ethylene glycol monobutyl ether (Butyl Cellosolve*)	$C_4H_9OCH_2CH_2OH$	118.17	0.9000-0.9050	7.51	—	171.2	166-173
Ethylene glycol monoethyl ether (Cellosolve*)	$C_2H_5OCH_2CH_2OH$	90.12	0.9280-0.9330	7.75	—	135.1	132-137
Ethylene glycol diethyl ether (Diethyl Cellosolve*)	$C_2H_5OCH_2CH_2OC_2H_5$	118.23	0.842	—	—	121.4	—
Ethylene glycol monomethyl ether (Methyl Cellosolve*)	$CH_3OCH_2CH_2OH$	76.09	0.9630-0.9670	8.04		125.0	122-126
Ethylene glycol monophenyl ether (Phenyl Cellosolve*)	$C_6H_5OCH_2CH_2OH$	138.16	1.1060-1.1110	9.23	—	244.7	240-248
Ethylene glycol monoethyl ether acetate (Cellosolve acetate)	$CH_3COOCH_2CH_2OC_2H_5$	132.16	0.9710-0.9760	8.11	—	156.3	145-165
Ethylene glycol monomethyl ether acetate (Methyl Cellosolve* acetate)	$CH_3COOCH_2CH_2OCH_3$	118.13	1.0030-1.0080	8.38	—	144.5	132-152
Fenchone	$(CH_3)_2C_6H_7C{:}O$	152.22	0.9480	7.89	0.00088	193-195	190-210
Furfural	$(C_4H_3O)CHO$	96.03	1.159	9.64	0.00087	—	110-169
Furfuryl acetate	$CH_3COOCH_2(C_4H_3O)$	140.06	1.119	8.42	0.00094	176	180-186

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* Denotes trade name.

OF SOLVENTS—(*Continued*)

Flash Point °F. (Open cup)	Vapor Pressure at 20° C. mm. of Hg	Surf. Ten. dynes / cm. at 20° C.	Refractive Index at 20° C	Rate of Evaporation (by wt.) *n*-Butyl Acetate = 1.00	Solubility cc./100 cc. at 20° C.		Company Manufacturing Solvent	Solvent Action						Toler. of Cell. Nitr. Sol. for		
					Solvent in Water	Water in Solvent		Cellulose Nitrate	Cell. Acet. (Acetyl Con. 37–42%)	Cell. Ac. But. (Acetyl, 31%, Butyryl, 16%)	Eth. Cell. (Ethoxy Con. 47–48%)	Vinyl Resin	Chlor. Rubber	Toluol	Naphtha	50% Tol. 50% Naph.
280 Cleveland	<0.01	—	1 4776	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
—	<0 1	—	—	—	3.34	—	Carbide, Dow	—	—	—	—	—	—	—	—	—
290	0 01	—	—	—	D	D	Carbide	S	—	—	S	S	—	—	—	—
285	<0 01	—	—	—	D	D	Carbide	S	S	—	—	S	—	—	—	—
20.8	—	—	1 350$^{17°}$	—	V.S.	V.S.	Commercial	—	—	—	—	—	—	—	—	—
75	15 4.	—	—	—	4.33	—	Carbide	—	—	—	—	—	—	—	—	—
75	—	—	1 4052	—	—	—	Sharples	—	—	—	—	—	—	—	—	—
300 (295 Commercial)	<0.01	—	1 5155	—	0 43	1.8	Commercial, Carbide	S	S	I	S	S	S	—	—	—
293	—	—	1 4376	—	<0.3	—	Commercial	S	I	I	PS	S	—	—	—	—
270	0 01	—	—	—	<0.02	0 17	Carbide	—	—	—	—	—	—	—	—	—
—	—	—	-	—	Insoluble	Insoluble	Carbide	—	—	—	—	—	—	—	—	—
425	<0 01	—	—	—	<0 04	<0 07	Carbide	—	—	—	—	—	—	—	—	—
65	29 5	36.9$^{25°}$	1 4232	2 15	D	D	Carbide, Commercial	I	S	S	S	S	S	—	—	—
36	70	—	—	—	D	D	Carbide	—	—	—	—	—	—	—	—	—
122	—	—	1 472-1 477	—	ca. 0 15	—	Hercules	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Insoluble	Insoluble	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	Dow	—	—	—	PS to S	—	—	—	—	—
264	—	—	1 5761	—	Insoluble	Insoluble	Dow			—	PS to S	—	—	—	—	—
—	-	—	—	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
280	0 03	—	—	—	∞	∞	—	—		—	—	—	—	—	—	—
120 A.S.T.M.	5 2	—	1 4072	—	0 43	0 87	Carbide	—	—	—	—	—	—	—	—	—
65 A.S.T.M.	44 0	22 3	1 361; 1 3624$^{18°}$	—	D	D	Carbide, Commercial, Dow, U. S. I., Monsanto	—	—	—	—	—	—	—	—	—
39	65	—	1 3725	—	6 92	11.01	Carbide, Dow, Kessler, Commercial, Monsanto, U. S. I.	—	—	—	—	—	—	—	—	—
<−0.4	866	—	—	—	D	D	Sharples	—	—	—	—	—	—	—	—	—
185	1	—	1 5559	—	Insoluble	Insoluble	Sharples	—	—	—	—	—	—	—	—	—
68 Cleveland	8	-	1 493$^{25°}$	—	0 01	Insoluble	Carbide, Dow	—	—	—	PS to S	—	—	—	—	—
135	1 1	—	—	—	0 43	4 56	Carbide	—	I	I	—	—	—	I	I	I
130	2 3	—	—	—	0 06$^{25°}$	0 57	Carbide	—	I	I	—	—	—	—	—	—
85	—	—	1 3932	—	0 49	0 75	Carbide	S			—	—	—	—	—	—
—	54$^{103°}$	—	—	—	222$^{25°}$	—	U. S. I.	—	—	—	—	—	—	—	—	—
180	—	—	—	—	Decomposes	Decomposes	U. S. I.	—	—	—	—	—	—	—	—	—
97	—	—	1 4242	—	Insoluble	Insoluble	Niacet	—	—	—	—	—	—	—	—	—
160	4	—	1 444	—	S	S	Sharples			—	—	—	—	—	—	—
255	0.2	—	1 4663	—	S	S	Sharples	—	—	—	—	—	—	—	—	—
−40	442	—	1 3542$^{17°}$	—	6 89	1 26	Carbide, Dow, Shell	—	I	—	I	—	—	—	—	—
−4	193	—	1 3597	—	10 5	—	Commercial, U. S. I.	S	S	—	—	—	—	—	—	—
185	0 36	—	—	—	0 10	2 57	Carbide	—	—	—	—	—	—	—	—	—
190	0 40	—	—	—	<0 03	0 55	Carbide	—	I	I	—	—	—	—	—	—
142	2.7	29 9 31 1	1 4118-1 4125	0 22	∞	∞	Amer. Cyanamid, Commercial, U.S.I.	S	S	S	PS to S	S	—	5 3	0 6	2 5
—	—	—	—	—	∞	∞	—	—	—	—	—	—	—	—	—	—
341 5	—	—	—	—	Insoluble	1 0	Commercial	I	I	I	I	I	—	—	—	—
−40	442	—	1.3542$^{170°}$	—	6 89	1.26	Carbide, Dow, Shell	—	—	—	PS to S	—	—	—	—	—
—	—	—	—	—	0 50	—	Carbide	—	—	—	—	—	—	—	—	—
70	43$^{30°}$	—	1 3844	—	1 92	1 22	Carbide	S	I	I	—	—	—	—	—	—
140	5 8	39 8	1 4424	—	∞	∞	Carbide, Commercial	S	S	S	S	I	I	—	—	—
110	11 0	—	1 4540$^{26°}$	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
None	10 4	-	1 5375$^{25°}$	-	0 43$^{25°}$	—	Dow	—	—	—	—	—	S	—	—	—
59	61 1	—	—	—	0 81	0 15	Carbide, Dow, Commercial	I	I	I	S	S	S	—	—	—
240	0 12	—	—	—	∞	∞	Carbide	I to SS	I	I	—	—	—	—	—	—
220	0 38	—	—	—	16 4	7 0	Carbide, Dow	S	S	S	S	S	—	—	—	—
—	—	—	—	—	—	—	Carbide	S	S	S	S	S	—	—	—	—
265	0 02	—	—	—	0 4	18	Carbide	S	S	—	—	S	—	3.0	—	—
165	0.97	—	1 4177$^{25°}$	—	∞	∞	Carbide	S	I	—	—	—	—	—	—	—
130	4 9	—	1 4042$^{25°}$	—	∞	∞	Carbide	S	I	I	—	—	—	4.9	—	—
95	12 0	—	1 3914	—	21.0	—	Carbide	S	I	I	—	—	—	—	—	—
115	8.0	—	1 4025$^{25°}$	—	∞	∞	Carbide, Commercial	S	S	S	—	—	—	4.0	—	—
250	0.03	—	—	—	2.7	10.8	Carbide	S	S	S	—	S	—	—	—	—
140	1.1	—	—	—	23.0	6.0	Carbide	S	Sl. S	Sl. S	—	—	S	2.5	—	—
140	3.7	—	—	—	∞	∞	Carbide, Commercial	S	S	S	—	—	—	2.3	—	—
160	2$^{30°}$	—	1.4647$^{14.8°}$	—	0.2	0.5	Carbide	—	—	—	—	—	—	—	—	—
145	5$^{30°}$	—	1.5261	—	8.3	4.8	Carbide	S	S	S	S	I	I	—	—	—
185	1$^{30°}$	—	1.4627	—	V.S.S.	Insoluble	Carbide	S	—	—	—	—	—	—	—	—

TABLE 43. PROPERTIES

Solvents	Chemical Formula	Molecular Wt.	Sp. Gr. at 20° C./20° C.	Lb. per U.S. Gal. at 20° C. Lb.	Coefficient of Cubical Expansion per ° C.	Boiling Point of Pure Material ° C.	Distillation Range of Commercial Material ° C
Furfuryl alcohol or Furfuryl carbinol	$C_4H_3OCH_2OH$	98.05	1.137	9.46	0.00077	—	152-220
Glycerin or Glycerol	$CH_2OHCHOHCH_2OH$	92.08	1.260^{20}_{4}	10.5	—	290	290
Glycol diacetate	$CH_3COOCH_2CH_2OCOCH_3$	146.14	1.1040-1.1090	9.21	—	190.5	183-195
Glycol diformate	$HCOOCH_2CH_2OOCH_2$	118.09	1.2240	—	—	177	—
Gum Turpentine	$C_{10}H_{16}$	136.23	0.860-0.875	7.22	0.00090	—	154-201
Heptanol-2 (Methyl amyl carbinol)	$CH_3(CH_2)_4CHOHCH_3$	116.20	0.8160-0.8210	6.81	—	160.4	155-165
Heptanone-2 (Methyl-*n*-amyl ketone)	$CH_3CH_2CH_2CH_2CH_2COCH_3$	114.18	0.8160-0.8210	6.80	—	150.6	147-154
Heptadecanol or Heptadecyl alcohol, sec.	$C_{17}H_{36}O$	256.46	0.848	7.1	—	308.5	—
Heptyl alcohol, sec. (Methyl amyl carbinol, Methyl hexanol)	$CH_3CH_2CH_2CH_2CH_2CHOHCH_3$	116.20	0.8160-0.8210	6.81	—	160.4	155-165
Hexalin	$CH_2CH_2CH_2CH_2CH_2CHOH$	100.16	0.962	—	—	161.5	—
Hexalin acetate	$CH_2CH_2CH_2CH_2CH_2CHOOCCH_3$	142.19	0.970	—	–	177	—
Hexandione-2,5	$CH_3COCH_2CH_2COCH_3$	114.18	0.9710-0.9760	8.10	—	191.4	185-195
Hexaethylene glycol	$HOCH_2(CH_2OCH_2)_5CH_2OH$	282.33	1.127	9.4	—	$204^{0.2\text{ mm.}}$	—
Hexahydrocresol	$CH_2CH_2CH_2CH_2CH(CH_3)CHOH$	114.18	0.933	7.6	—	—	169-176
Hexahydro phenol	$CH_2CH_2CH_2CH_2CH_2CHOH$	100.16	0.962	—	—	161.5	—
Hexanol, n	$CH_3CH_2CH_2CH_2CH_2CH_2OH$	102.17	0.8190-0.8230	6.83	—	156.4	153-160
Hexone (Methyl isobutyl ketone)	$(CH_3)_2CHCH_2COCH_3$	100.16	0.7990-0.8040	6.68	0.00112	116.0	112-118
Hexyl (2-Ethyl butyl) acetate	$CH_3COOCH_2CH(C_2H_5)CH_2CH_3$	144.21	0.876	7.29	0.00106	—	157-164
Hexyl acetate, sec. (Methyl amyl acetate)	$CH_3COOCH(CH_3)CH_2CH_2CH(CH_3)_2$	144.21	0.8550-0.8600	7.15	-	146.3	140-150
Hexyl (2-Ethyl butyl) alcohol	$CH_3CH_2CH(C_2H_5)CH_2OH$	102.17	0.833	6.93	0.00089	—	144-156
Hexyl alcohol (isomeric)	$(C_2H_5)_2CHCH_2OH$	102.17	0.833	—	—	148.9	—
Hexyl alcohol, n	$CH_3CH_2CH_2CH_2CH_2CH_2OH$	102.17	0.8190-0.8230	6.83	—	157.2	153-160
Hexyl alcohol, sec. (Methyl isobutyl carbinol, Methyl amyl alcohol)	$CH_3CH_2CH_2CH_2CHOHCH_3$	102.17	0.8060-0.8110	6.72	—	131.8	125-135
2-Hydroxyethyl amine	$HOCH_2CH_2NH_2$	61.08	1.0170-1.0270	8.47	—	170.5	160-176
Hydroxyethyl ethylene diamine	$NH_2CH_2CH_2NHC_2H_4OH$	104.15	1.0280-1.0330	8.58	—	243.7	232-250
Isophorone (see Trimethylcyclohexene)							
Mesityl oxide	$(CH_3)_2C{=}CHCOCH_3$	98.14	0.8520-0.8560	7.13	0.00108	128.0	120-135
Methanol	CH_3OH	32.04	0.7924-0.7929	6.59-6.63	0.00119	64.5	64-65
Methyl acetate	CH_3COOCH_3	74.08	0.9300-0.9400	7.78	0.00140	57.1	55-58
Methyl alcohol (Methanol)	CH_3OH	32.04	0.7924-<0.7929	6.59	—	64.5	64-65
Methylamine	CH_3NH_2	31.02	$0.699^{-10^\circ C.}$	7.7	—	-6.0 to $-5.5^{760\text{ mm}}$	—
Methyl amyl acetate	$CH_3COOCH(CH_3)CH_2CH(CH_3)_2$	144.21	0.8550-0.8600	7.15	—	146.3	140-150
Methyl amyl alcohol	$CH_3CH_2CH_2CH_2CHOHCH_3$	102.17	0.8060-0.8110	6.72	—	131.8	125-135
Methyl amyl carbinol	$CH_3CH_2CH_2CH_2CH_2CHOHCH_3$	116.20	0.8160-0.8210	6.81	—	160.4	155-165
Methyl-*n*-amyl ketone	$CH_3(CH_2)_4COCH_3$	114.18	0.8160-0.8210	6.80	—	150.6	147-154
Methyl benzene	$C_6H_5CH_3$	92.13	0.866	—	—	110.4	—
3-Methoxy butyl acetate	$CH_3CH(OCH_3)CH_2CH_2OOCCH_3$	146.18	0.956	8.37	0.00100	—	135-173
Methyl-*n*-butyl ketone	$CH_3COC_4H_9$	100.16	0.818	6.80	0.00099	127	114-137
Methyl (iso)-butyl ketone	$CH_3COCH_2CH(CH_3)_2$	100.16	0.7990-0.8040	6.68	0.00112	116.0	111-117
Methyl (iso)-butyl carbinol	$(CH_3)_2CHCH_2CHOHCH_3$	102.17	0.8060-0.8110	6.72	—	131.8	125-135
Methyl (iso)-butyl carbinol acetate	$CH_3COOCH(CH_3)CH_2CH(CH_3)_2$	144.21	0.8550-0.8600	7.15	—	146.3	140-150
Methyl Carbitol*	$CH_3OCH_2CH_2OCH_2CH_2OH$	120.15	1.0300-1.0400	8.61	—	194.1	187-197
Methyl Carbitol* acetate	$CH_3COOC_2H_4OC_2H_4OCH_3$	162.18	1.0396	8.7	—	209.1	—
Methyl Cellosolve*	$CH_3OCH_2CH_2OH$	76.09	0.9630-0.9670	8.04	0.00094	125.0	122-126
Methyl Cellosolve* acetate	$CH_3COOCH_2CH_2OCH_3$	118.13	1.0030-1.0080	8.38	—	144.5	132-152
Methyl cyclohexane	$CH_2CH_2CH_2CH_2CH_2CHCH_3$	98.18	0.765^{25°	—	–	101	100-103
Methyl cyclohexanol (Methyl hexalin, Hexahydrocresol)	$CH_2CH_2CH_2CH_2CH(CH_3)CHOH$	114.18	0.933	7.6	–	165-166	169-176
Methyl cyclohexanone	$CH_3CHCH_2CH_2CH_2CH_2CO$	112.17	0.920	—	—	163	160-175
Methyl dioxolane	$OCH_2CH_2OCHCH_3$	88.10	0.982	8.2	—	81	81-82
Methyl ethyl carbinol	$CH_3CH_2CHOHCH_3$	74.12	0.808-0.812	6.72	0.00091	99.5	94-104
Methyl ethyl ketone	$CH_3COC_2H_5$	72.10	0.805-0.809	6.73	0.00130	79.6	72-82
Methyl hexalin	$CH_2CH_2CH_2CH_2CH(CH_3)CHOH$	114.18	—	—	—	—	—
Methyl hexanol	$CH_3CH_2CH_2CN_2CH_2CHOHCH_3$	116.20	0.8160-0.8210	6.81	—	160.4	155-165
Methyl hexyl carbinol	$CH_3(CH_2)_5CHOHCH_3$	130.23	0.8193	—	—	178.5	—
Methyl hexyl ketone	$CH_3(CH_2)_5COCH_3$	128	0.82	—	—	174	—
Methyl lactate	$CH_3CHOHCOOCH_3$	104.10	1.087-1.097	9.09	0.00107	144.8	115-155
2-Methyl-2,4-pentanediol	$(CH_3)_2COHCH_2CHOHCH_3$	118.17	0.922	—	—	—	192-199
4-Methyl pentanol-2 (Methyl amyl alcohol)	$CH_3CH_2CH_2CH_2CHOHCH_3$	102.17	0.8060-0.8110	6.72	—	131.8	125-135
4-Methyl pentanone-2 (Methyl isobutyl ketone)	$CH_3COCH_2CH(CH_3)_2$	100.16	0.7990-0.8040	6.68	0.00112	116.0	111-117
4-Methyl pentyl acetate (Methyl amyl acetate)	$CH_3COOCH(CH_3)CH_2CH(CH_3)_2$	144.21	0.8550-0.8600	7.15	—	146.3	140-150
Methyl propyl carbinol	$C_3H_7CHOHCH_3$	88.14	0.810	6.76	—	119.5	—
Methyl propyl ketone	$CH_3COC_3H_7$	86.13	0.8064-0.8100	6.72	0.00111	102	101-107

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* Denotes trade name.

Flash Point ° F. (Open cup)	Vapor Pressure at 20° C. mm. of Hg	Surf. Ten. dynes / cm. at 20° C.	Refractive Index at 20° C.	Rate of Evaporation (by wt). *n*-Buytl Acetate = 1.00	Solubility cc. /100 cc. at 20° C.		Company Manufacturing Solvent	Solvent Action						Toler. of Cell. Nitro. Sol. for		
					Solvent in Water	Water in Solvent		Cellulose Nitrate	Cell. Acet. (Acetyl Con. 37–42%)	Cell. Ac. But. (Acetyl, 31%, Butyryl, 16%)	Eth. Cell. (Ethoxy Con. 47–48%)	Vinyl Resin	Chlor. Rubber	Toluol	Naphtha	50% Tol. 50% Naph.
175	2^{30°	—	$1.4852^{22.7^\circ}$	—	∞	∞	Carbide	S	—	—	—	—	—	—	—	—
350	—	—	1.4729	—	∞	∞	Dow	—	—	—	I	—	—	—	—	—
226	0.38	—	—	—	16.4	7.0	Carbide, Dow	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	Carbide	—	—	—	—	—	—	—	—	—
110 A.S.T.M.	—	—	1.465-1 478	—	V.S S.	Insoluble	Carbide	—	—	—	—	—	—	—	—	—
160	1 0	—	1.4213	—	0.35	5.07	Carbide	I	I	I	—	—	—	—	—	—
120	3 5	—	—	—	0 43	1.5	Carbide	—	I	I	—	—	—	3.9	—	—
309	<0.01	—	—	—	<0 01	0.46	Carbide	—	—	—	—	—	—	—	—	—
160	1.0	—	1 4213	—	0.35	5.07	Carbide	—	—	—	—	—	—	—	—	—
154	—	—	1.4656^{23°	—	5.4:15	—	Barrett, Du Pont	—	—	—	—	—	—	—	—	—
147	—	—	1 440	—	Insoluble	Insoluble	Du Pont	—	—	—	—	—	—	—	—	—
185	0.68	—	—	—	∞	∞	Carbide	—	S	S	—	—	—	—	—	—
385	—	—	—	—	∞	∞	Carbide	S	—	—	—	—	—	—	—	—
154	—	—	$1\ 4659^{13^\circ}$	—	3 0	—	Barrett, Du Pont	—	—	—	S	—	—	—	—	—
154	1 0	—	1.4213	—	0.35	—	Barrett, Du Pont, Dow	—	—	—	—	—	—	—	—	—
90 Cleveland	0 98	—	—	—	0 58	7.26	Carbide	I	I	I	—	—	—	—	—	—
75	18.1	24 7	1.3959	1 45	1.91	2.81	Carbide, Shell, Dow, Commercial	S	I	I	S	S	—	3.4	1.0	—
135	5^{30°	—	1.4103	—	0 06	0 75	Carbide	—	—	—	—	—	—	—	—	—
110	1.17	—	—	—	0.13	0 58	Carbide	—	I	I	—	S	—	1.7	—	—
145	4^{30°	—	1.4229	—	0.63	4 56	Carbide	—	—	—	—	—	—	—	—	—
135	1.1	—	1.421	—	0 43	—	Carbide	—	—	—	—	—	—	—	—	—
90 Cleveland	0.98	—	1.4161^{25°	—	0.58	7 26	Carbide	—	—	—	—	—	—	—	—	—
130	3 62	—	1 4126	—	1 55	6 28	Carbide	—	—	—	—	—	—	—	—	—
200	0.48	—	—	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
275	0.02	—	—	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
90	9.2	—	1.4558	—	2 8	3 4	Carbide, Dow, Commercial, Shell	S	PS	PS	S	—	S	3.8	—	—
60	98 0	22 6	1.3290	—	∞	∞	U. S. I., Du Pont, Carbide, Dow, Commercial, Shell	PS	I	I	I	S	—	2.5	0.3	—
25	166	25.6	1.3593	10 40	24 2	8.2	Dow, Carbide, Commercial, Du Pont	S	S	S	S	S	—	3.0	0.75	—
60	98 0	22 6	1.329	—	∞	∞	U. S. I., Du Pont, Carbide, Dow, Commercial, Shell	PS	I	I	I	S	—	2.5	—	—
32 5	—	—	$1\ 432^{17.5^\circ}$	—	∞	∞	Commercial	—	—	—	—	—	—	—	—	—
110	1 17	—	—	—	0.13	0 58	Carbide	—	I	I	—	S	—	1.7	—	—
130	3 62	—	1 4126	—	1 55	6 28	Carbide, Shell	—	I	I	—	S	—	I	—	—
160	7 0	—	1 4213	—	0 35	5 07	Carbide	—	I	I	—	—	—	I	—	—
120	3 5	-	—	—	0 43	1 5	Carbide	—	I	I	—	—	—	3.9	—	—
43 7	$36\ 7^{30^\circ}$	—	1 4962	—	0 05	—	Barrett, Koppers	—	—	—	—	—	—	—	—	—
170	3^{30°	—	—	—	6 46	3.72	Carbide	S	I	I	S	S	I	—	—	—
95	10	—	1.4024	—	0 22	2 14	Carbide, Shell	—	—	—	—	—	—	—	—	—
75	18 1	24 7	1 3959	1 45	1.91	2 81	Carbide, Shell, Dow, Commercial	S	I	I	S	S	S	3 4	1.0	1.8
130	3 62	—	1 4126	—	1 55	6 28	Carbide, Shell	—	—	—	—	—	—	—	—	—
110	1 17	—	—	—	0 13	0.58	Carbide	—	I	I	—	S	—	1 7	—	—
200	0 34	—	—	—	∞	∞	Carbide	—	S	S	—	S	—	2.3	—	—
180	0 12	—	—	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
115	8.0	—	$1\ 4025^{25^\circ}$	—	∞	∞	Carbide, Commercial	—	—	—	—	—	S	—	—	—
140	3 7	31 7	—	—	∞	∞	Carbide, Commercial	—	S	S	—	—	S	2.3	—	—
23	—	—	1.421^{25°	—	Insoluble	Insoluble	Barrett, Dow, Eastman	—	—	—	—	—	—	—	—	—
154	—	—	1.4659^{13°	—	3 0	—	Barrett, Dow, Du Pont	I	I	I	PS	I	I	—	—	—
128	—	—	$1\ 4505^{18^\circ}$	—	3 2	—	Dow, Barrett, Du Pont	S	PS to S	S	S	S	S	—	—	—
—	—	—	—	—	59 0	—	Carbide	—	—	—	—	—	—	—	—	—
88	12 1	24 0	1.397	1 0	24.4	56 0	Kessler, U. S. I., Shell	I	I	I	S	I	—	—	—	—
34	77 5	25 0	1.3788-1 3791	4.65	25 6	11 8	Kessler, Shell, Carbide, Dow, Commercial	S	S	S	S	S	S	4.1	0.85	1.7
—	—	—	$1\ 4659^{13^\circ}$	—	3.0	—	Barrett, Dow, Du Pont	—	—	—	S	—	—	—	—	—
160	1 0	—	1 4213	—	0 35	5.07	Carbide	—	—	—	—	—	—	—	—	—
—	—	—	1 4260	—	—	—	Amecco, Resinous	—	—	—	—	—	—	—	—	—
—	—	—	1 4161	—	Insoluble	Insoluble	Amecco, Resinous	—	—	—	—	—	—	—	—	—
142	4.2	34 6	1.4131	0.29	∞	∞	Commercial	S	S	I	S	I	I	3.4	0.2	0.7
201	—	—	—	—	—	—	Commercial	—	—	—	—	—	—	—	—	—
130	3.62	—	1 4126	—	1.55	6.28	Carbide, Shell	—	I	I	—	—	—	I	—	—
75	18.1	24.7	1.3959	1.45	1.91	2.81	Carbide, Shell, Dow, Commercial	—	I	I	—	S	—	1.7	—	—
110	1.17	—	—	—	0.13	0.58	Carbide	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	Shell	—	—	—	—	—	—	—	—	—
55 Tagliabue	30	—	1.3895	—	0.54	3.34	Shell, Carbide	—	—	—	—	—	—	—	—	—

TABLE 43. PROPERTIES

Solvents	Chemical Formula	Molecular Wt.	Sp. Gr. at 20° C./20° C.	Lb. per U.S. Gal. at 20° C. Lb.	Coefficient of Cubical Expansion per ° C.	Boiling Point of Pure Material ° C.	Distillation Range of Commercial Material ° C
Methyl salicylate	$HOC_6H_4COOCH_3$	152.14	1.1840^{20}_{4}	9.9	—	223.3	219-224
Mineral spirits	Naphthenes, etc.	120-140	0.800-0.820	—	—	150-200	—
Morpholine	$CH_2CH_2OCH_2CH_2NH$	87.12	1.0017	8.3	—	128.9	—
n-Morpholine ethanol	$CH_2CH_2OCH_2CH_2NC_2H_4OH$	131.17	1.0724	8.9	—	225.5	—
n-Morpholine ethanol ethyl ether	$C_2H_4OC_2H_4NC_2H_4OC_2H_5$	159.15	0.9648	8.0	—	206.2	—
2-Nitro-1-butanol	$CH_3CH_2CHNO_2CH_2OH$	119.12	1.140	9.48	0.00068	$105^{10\ mm.}$	Decomp.
Nitroethane	$CH_3CH_2NO_2$	75.07	1.052	8.8	0.00111	114	—
Nitromethane	CH_3NO_2	61.04	1.139	9.5	0.00116	101	—
1-Nitropropane	$CH_3CH_2CH_2NO_2$	89.09	1.003	8.4	0.00056	132	—
2-Nitropropane	$CH_3CHNO_2CH_3$	89.09	0.992	8.3	0.00058	120	—
Nonaethylene glycol	$HOCH_2(CH_2OCH_2)_8CH_2OH$	414.48	—	—	—	325 approx.	—
Octanol (2-Ethyl hexanol)	$C_4H_9CH(C_2H_5)CH_2OH$	130.23	0.8320-0.8370	6.94	0.00088	183.5	180-192
Octyl acetate (2-Ethyl hexyl acetate)	$CH_3COOCH_2CH(C_2H_5)C_4H_9$	172.26	0.8700-0.8750	7.27	0.00099	198.6	192-205
Octyl alcohol, sec. (2-Ethyl hexyl alcohol)	$C_4H_9CH(C_2H_5)CH_2OH$	130.23	0.8320-0.8370	6.94	0.00088	183.5	180-192
Octyl amine, sec. (2-Ethyl hexyl amine)	$C_4H_9CH(C_2H_5)CH_2NH_2$	129.24	0.7920	6.6	—	167.5	—
Octyl Cellosolve*	$C_4H_9CH(C_2H_5)CH_2OC_2H_4OH$	174.28	0.8859	7.4	—	228.3	—
2,2′-Oxydiethanol (Diethylene glycol)	$HOCH_2CH_2OCH_2CH_2OH$	106.12	1.1184	9.3	—	244.8	230-270
Perchlorethylene	$Cl_2C{=}CCl_2$	165.84	1.618^{25}	13.50	—	121	120-122
Phenyl Cellosolve*	$C_6H_5OCH_2CH_2OH$	138.16	1.1060-1.1110	9.23	—	244.7	230-240
Phenyl diethanolamine	$C_6H_5N(C_2H_4OH)_2$	181.23	—	—	—	—	—
Phenyl ethanolamine	$C_6H_5NHC_2H_4OH$	137.08	1.097	—	—	285	—
Phenyl ether	$C_6H_5OC_6H_5$	170.13	—	8.9	—	257	257
Phenyl ethyl alcohol	$C_6H_5CH_2CH_2OH$	122.09	—	8.5	—	218	218
n-Phenyl morpholine	$C_6H_5NCH_2CH_2OCH_2CH_2$	163.11	—	—	—	—	—
Phorone	$(CH_3)_2C{=}CHCOCH{=}C(CH_3)_2$	138.20	0.8791	$7.32^{30°}$	—	197.9	—
Phorone, iso	$COCH{=}C(CH_3)CH_2C(CH_3)_2CH_2$	138.20	0.9200-0.9250	7.68	0.00079	215.2	205-220
1,2-Propanediol	$CH_3CHOHCH_2OH$	76.09	1.0370-1.0400	8.64	—	188.2	180-210
Propanol, n	$CH_3CH_2CH_2OH$	60.09	0.804	—	—	97.2	95-102
Propanol, iso	$CH_3CHOHCH_3$	60.09	0.7863-0.7893	6.54	0.00105	82.4	81-83
Propanone (Acetone)	CH_3COCH_3	58.08	0.7915-0.7935	6.59	0.00142-0.00134	56.1	55-58
Propyl acetate, iso	$CH_3COOCH(CH_3)_2$	102.13	0.8660-0.8710	7.27	0.00119-0.00126	88.4	84.5-90
Propyl alcohol, n (Propanol, n)	$CH_3CH_2CH_2OH$	60.09	0.804	—	—	97.2	—
Propyl alcohol, iso or sec. (Propanol, iso)	$CH_3CHOHCH_3$	60.09	0.7863-0.7893	6.54	0.00105	82.4	81-83
Propyl amine, iso	$CH_3CH(NH_2)CH_3$	59.11	0.6875	—	—	31.9	—
Propyl benzene, iso	$C_6H_5CH(CH_3)_2$	120.19	0.862	7.17	—	152.5	152-153
Propyl ether, iso	$(CH_3)_2CHOCH(CH_3)_2$	102.17	0.7252	6.1	—	68.4	63-69
Propyl lactate, iso	$(CH_3)_2CHOOCCHOHCH_3$	132.16	—	8.2	—	—	149-167
1,2-Propylene diamine	$CH_3CH(NH_2)CH_2NH_2$	74.13	0.8732-<0.9400	7.27	—	119.7	112-122
1,2-Propylene dichloride	$CH_3CHClCH_2Cl$	112.99	1.1570-1.1630	9.70	—	96.3	93-99
1,2-Propylene glycol	$CH_3CHOHCH_2OH$	76.09	1.0370-1.0400	8.64	—	188.2	180-210
Propylene oxide	CH_3CHCH_2O	58.08	0.8290-0.8340	6.92	—	34.1	30-40
Propyl benzene, iso (Cumene)	$C_6H_5CH(CH_3)_2$	120.19	0.861^{20}_{20}	7.19	—	152.3	151-154
Tetrachlorethane	$CHCl_2CHCl_2$	167.86	1.600^{20}_{4}	13.30	0.00101	146.3	144-152
Tetraethanolammonium hydroxide	$N(C_2H_4OH)_4OH$	211.18	1.15-1.17	—	—	—	—
Tetraethylene glycol	$CH_2OH(CH_2OCH_2)_3CH_2OH$	194.23	1.1220-1.1270	9.36	—	327.3	—
Tetraethylene glycol dimethyl ether (Dimethoxy tetro glycol)	$O(CH_2CH_2OCH_2CH_2OCH_3)_2$	222.28	1.0110-1.0160	8.43	—	275.8	255-285
Tetraethylene pentamine	$NH_2(CH_2CH_2NH)_3CH_2CH_2NH_2$	189.30	0.9900-1.0000	8.31	—	333	280-360
Tetraglycol dichloride	$(ClCH_2CH_2OCH_2CH_2)_2O$	231.13	1.186	9.9	—	$114^{2\ mm.}$	—
Tetrahydro-Furfuryl alcohol	$C_4H_7OCH_2OH$	102.13	1.0495^{20}_{4}	8.0	—	$177\text{-}178^{743\ mm.}$	175-180
Toluene (Toluol) (Methyl benzene)	$C_6H_5CH_3$	92.13	0.866	7.21	0.00108	110.8	109.4-111.4
Triacetin	$C_3H_5(OOCCH_3)_3$	218.11	1.16-1.17	—	—	258	—
Triamyl amine	$C_{15}H_{33}N$ (mixed isomers)	227.42	0.795	—	—	—	234-260
Triamyl borate	$(C_5H_{11})_3BO_3$	271.69	0.845	—	—	254-255	—
Tri-*n*-butyl amine	$(CH_3CH_2CH_2CH_2)_3N$	185.35	0.78	—	—	—	203-219
Tributyl borate	$(C_4H_9)_3BO_3$	230.16	0.858-0.859	7.14	0.00097	231.0	200-235
Tributyl phosphate	$(C_4H_9O)_3PO$	266.32	0.980-0.985	—	—	270	—
Trichlor benzene	$C_6H_3Cl_3$	181.45	1.574^{10}_{4}	12.20	—	214.8	212-218
Trichlorethane	$CHCl_2CH_2Cl$	133.41	$1.434^{25°}$	—	—	113.5	—
1,2,2-Trichlorethylene	$ClCH{=}CCl_2$	131.40	1.4630-1.4730	12.20	—	86.7	86-87.5
Tricresyl phosphate	$(CH_3C_6H_4O)_3PO$	378.36	$1.180\text{-}1.186^{15°}$	—	—	—	430-440
Triethyl borate	$(C_2H_5)_3BO_3$	146.00	0.863-0.864	7.19	0.00127	114.0	112-121
Triethyl phosphate	$(C_2H_5)_3PO_4$	182.14	1.068-1.072	8.90	—	216	190-220
Triethyl amine	$(CH_3CH_2)_3N$	101.19	0.73	—	—	—	85-91
Triethylene glycol	$HOC_2H_4OC_2H_4OC_2H_4OH$	150.17	1.1220-1.1270	9.37	—	287.3	270-300
Triethylene tetramine	$NH_2(CH_2CH_2NH)_2CH_2CH_2NH_2$	146.24	0.9800-0.9850	8.17	—	277.5	—
Triglycol dichloride	$ClC_2H_4OC_2H_4OC_2H_4Cl$	187.07	1.1950-1.2000	9.97	—	241.3	—
3,5,5-Trimethylcyclohexene-2-1-1 (Isophorone)	$COCH{=}C(CH_3)CH_2C(CH_3)_2CH_2$	138.20	0.9200-0.9250	7.68	—	215.2	205-220
Trimethyl amine	$(CH_3)_3N$	59.11	$0.622^{-8°}$	—	—	$3.2\text{-}3.8^{748\ mm.}$	—
Xylene (Xylol)	$C_6H_4(CH_3)_2$	106.16	0.862	7.17	0.00099	—	135-145

* Denotes trade name.

OF SOLVENTS—(*Continued*)

Flash Point °F. (Open cup)	Vapor Pressure at 20° C. mm. of Hg	Surf. Ten. dynes / cm. at 20° C.	Refractive Index at 20° C.	Rate of Evaporation (by wt.) *n*-Butyl Acetate = 1.00	Solubility cc./100 cc. at 20° C.		Company Manufacturing Solvent	Solvent Action						Toler. of Cell. Nitr. Sol. for		
					Solvent in Water	Water in Solvent		Cellulose Nitrate	Cell. Acet. (Acetyl Con. 37–42%)	Cell. Ac. But. (Acetyl, 31% Butyryl, 16%)	Eth. Cell. (Ethoxy Con. 47–48%)	Vinyl Resin	Chlor. Rubber	Tuluol	Naphtha	50% Tol. 50% Naph.
219	—	—	1.5369	—	0 07	—	Dow	—	—	—	S	—	—	—	—	—
104	$80^{93°}$	—	1.44-1.45	—	Insolubie	Insoluble	Standard Oil N. J. & Calif., Gulf Oil	—	—	—	—	—	—	—		—
100	11.1	—	—	—	∞	∞	Carbide, Dow	—	—	—	—	—	—	—	—	—
210	0.11	—	—	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
—	<0 3	—	—	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
227	$10^{105°}$	37 7	1 4427	—	54 3	88 0	Commercial	S	PS	S	S	I	I	—	—	—
106	15 5	$31\ 3^{28\ 5°}$	1 3916	1.45	4.5	0.9	Commercial	S	S	S	S	S	I	—	—	—
112	27.8	37 0	1 3818	1 80	9 0	2 2	Commercial	S	S	S	I	I	I	—	—	—
120	7 5	30 0	1 4015	1 00	1 4	0 5	Commercial	S	SS	S	S	S	S	—	—	—
103	12 9	30 0	1.3941	1 24	1.7	0.6	Commercial	S	SS	S	S	S	S	—	—	—
—	—	—	—	—	—	—	Carbide	S	—	—	—	—	—	—	—	—
185	0 36	—	1 4300	—	0 10	2.57	Carbide, Dow	I	I	—	PS to S	PS	—	—	—	—
190	0 40	—	1 4300	—	<0 03	0 55	Carbide	—	I	—	—	—	—	1 3	—	—
185	0 36	—	1 4300	—	0 10	2 57	Carbide, Dow	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	Carbide	—	—	—	—	—	—	—	—	—
230	0 02	—	—	—	0 09	5 4	Carbide	—	—	—	—	—	—	—	—	—
290	0 01	—	—	—	∞	∞	Carbide	S	—	—	S	S	—	—	—	—
None	17	—	$1\ 5029^{25°}$	—	Insoluble	Insoluble	Dow	—	I	—	PS	—	—	—	—	—
250	0 03	—	—	—	2 67	10 83	Carbide	—	—	—	—	—	—	—	—	—
136	<0 1	—	—	—	3.34	—	Carbide, Dow	—	—	—	—	—	—	—	—	—
—	<0 01	—	—	—	4 58	—	Carbide	—	—	—	—	—	—	—	—	—
226	—	—	—	—	Insoluble	Insoluble	Dow	—	—	—	V.S.S.	—	—	—	—	—
216	—	—	—	—	1.6	—	Dow	—	—	—	—	—	—	—	—	—
—	<0 1	—	—	—	1 0	—	Carbide	—	—	—	—	—	—	—	—	—
185	—	—	—	—	$0\ 11^{30°}$	$1\ 3^{30°}$	Carbide	—	S	—	—	S	—	2 5	—	—
205	0 31	31 9	1 4777	0 045	1 2	4 3	Carbide, Commercial	S	S	S	S	S	S	6.2	—	—
225	0 18	—	—	—	∞	∞	Carbide	I	I	I	—	I	—	—	—	—
72	14 5	—	1 3854	—	∞	∞	Du Pont	I	I	I	PS to S	—	—	—	—	—
70	35 0	22 0	1.3776	2 05	∞	∞	Carbide, Dow, Commercial, Shell, U. S. I.	I	I	I	S	—	I	I	—	—
15	178 0	24 0	1 3591	7 20	∞	∞	Shell, U. S. I., Monsanto, Carbide, Kessler, Commercial	S	S	S	S	S	PS	4.6	0 65	1 5
54 Tagliabue	48 0	22 8	1 3770	4 35	2 9	1 8	Carbide, Dow, Shell, U. S. I., Commercial	S	I	—	—	S	S	3.0	—	—
72	14 5	—	—	—	D	D	Du Pont	—	—	—	—	—	—	—	—	—
70	35 0	22 0	1 3776	2 05	∞	∞	Carbide, Dow, Shell, U. S. I., Commercial	I	I	I	S	—	I	I	—	—
−32 8	—	—	$1\ 3770^{15°}$	—	∞	∞	Commercial	—	—	—	—	—	—	—	—	—
97	—	—	$1\ 4947^{15°}$	—	V.S S.	Insoluble	Dow	—	—	—	S	—	—	—	—	—
15	118	—	—	—	1 22	0 63	Dow, Shell, Carbide	I	—	—	S	—	—	—	—	—
130	—	—	—	—	∞	∞	Dow	S	S	—	S	—	—	—	—	—
120 (anhyd.)	11 7	—	—	—	∞	∞	Carbide	S	—	—	—	—	—	—	—	—
63 Dow	37 5	—	—	—	0 3	0 07	Carbide, Dow	S	S	S	S	—	—	—	—	—
225	18 0	—	—	—	∞	∞	Carbide	I	I	I	—	—	—	—	—	—
−35	395 0	—	—	—	41 0	13 0	Carbide	S	S	—	—	S	—	2 5	—	—
97	—	—	$1\ 489^{25°}$	—	Insoluble	Insoluble	Dow	—	—	—	—	—	—	—	—	—
None	5 7	—	1 4942	0 75	Insoluble	Insoluble	Dow	I	S	S	S	S	S	—	—	—
—	<0 1	—	—	—	∞	∞	Carbide	I	I	I	I	—	—	—	—	—
345	<0 01	—	—	—	—	—	Carbide	S	I	—	—	—	—	—	—	—
285	<0 01	—	—	—	∞	∞	Carbide	S	S	—	—	S	—	—	—	—
325	<0 01	—	—	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
7250	<0 1	—	—	—	Sl.S.	Sl.S.	Carbide	—	—	—	—	—	—	—	—	—
176	—	—	1 4508	—	∞	∞	Dow	S	—	—	PS to S	—	—	—	—	—
56	22 4	28 4	1.4962	1 95	Insoluble	Insoluble	Barrett, Carbide, Shell, Koppers, Commercial	I	I	I	S	I	S	—	—	—
270	—	—	1 431	—	6 0	$3\ 67^{180°}$	Durrans	S	S	S	S	—	I	—	—	—
216	$7^{26°}$	—	1 4366	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	Decomposes	Decomposes	Sharples	—	—	—	—	—	—	—	—	—
187	0.7	—	1 4310	—	Insoluble	Insoluble	Sharples	—	—	—	—	—	—	—	—	—
—	—	25 6	1 4424	—	Hydrolyzes	Hydrolyzes	Commercial	I	I	—	—	—	—	—	—	—
320	—	—	1.424-1 426	—	$0.6^{26°}$	$7^{28°}$	Durrans	S	S	S	S	—	—	—	—	—
212	—	—	$1.5700^{25°}$	—	Insoluble	Insoluble	Dow	—	—	—	PS to S	—	—	—	—	—
None	20	—	$1.4683^{25°}$	—	Insoluble	Insoluble	Dow	—	—	—	—	—	—	—	—	—
None	60 0	—	$1\ 4749^{25°}$	—	0.10	0.02	Carbide, Dow	I	I to PS	I to PS	I	S	S	—	—	—
419-428	—	—	1.560-1.562	—	$0\ 02^{25}$	$0\ 2^{25°}$	Celanese, Monsanto	S	I	I	—	—	PS	—	—	—
91	—	21.5	1.3742	—	Hydrolyzes	Hydrolyzes	Commercial	I	I	—	—	—	—	—	—	—
240	—	—	1 4055	—	∞	∞	Commercial	S	S	—	—	—	—	—	—	—
19	66	—	1.4003	—	1.5	—	Sharples	—	—	—	—	—	—	—	—	—
330	<0.01	—	—	—	∞	∞	Carbide	S	I	—	—	I	—	—	—	—
290	<0.01	—	—	—	∞	∞	Carbide	—	—	—	—	—	—	—	—	—
250	0.06	—	—	—	1.9	0.83	Carbide	I	I	I	—	S	—	—	—	—
205	0.31	—	—	—	1.2	4.3	Carbide	—	S	S	—	S	—	6.2	—	—
—	—	—	—	—	V.S.	V.S.	Commercial	—	—	—	—	—	—	—	—	—
108	Approx. 11	29.2	1.500	0.68	Insoluble	Insoluble	—	I	I	I	S	I	S	—	—	—

PLASTICIZERS

In the preparation of this subsection on plasticizers research workers at the Ellis Laboratories were given the task of listing all plasticizers appearing in the literature (including the patent office library). When the task was completed the number of plasticizers was close to 20,000. This list, after much discussion, was finally omitted from the handbook because of its length and in its place the following condensed table of some of the important commercial plasticizers was included. More information about most of the items will be found under the general list of chemicals prominent in the plastics industry. Also many of the plasticizers are mentioned under the section describing the manufacture of molding powders.

See page 272 for full names and addresses of manufacturers.

TABLE 44. PROPERTIES

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Acetoacetanilide	$CH_3COCH_2CONHC_6H_5$	177	White, crystalline solid	—	—
Acetoacet-*o*-chloranilide	$CH_3COCH_2CONHC_6H_4Cl$	212	White powder	—	—
Acetoacet-2, 5-dichloranilide	$CH_3COCH_2CONHC_6H_3Cl_2$	246	White, crystalline solid	—	—
Acetophenone or Acetyl benzene	$C_6H_5COCH_3$	121	Colorless liquid or plates	$1\ 026^{20}_{4}$	—
Acetyl tri-*n*-butyl citrate	$(C_4H_9OCOCH_2)_2C(OCOCH_3)COOC_4H_9$	402	Colorless liquid	$1\ 046^{25°C.}$	8.73
Acetyl triethyl citrate	$(C_2H_5OCOCH_2)C(OCOCH_2)COOC_2H_5$	318	Colorless liquid	$1\ 135^{23°C.}$	9.47
Amyl laurate	$C_{11}H_{23}COOC_5H_{11}$	270	Water-white liquid	$0\ 861^{20°C.}$	7.19
Amyl oleate	$C_{17}H_{33}COOC_5H_{11}$	352	Pale straw	$0.862^{20°C.}$	7.20
Amylphenoxy ethanol, *p*-tert	$C_5H_{11}C_6H_4OCH_2CH_2OH$	208	Water-white liquid	$1.015^{20°C.}$	8.48
Amylphenyl-*n*-butyl ether, *p*-tert	$CH_3CH_2C(CH_3)_2C_6H_4OC_4H_9$	220	—	$0.913^{25°C.}$	8.63
Amyl stearate	$CH_3(CH_2)_{16}COOC_5H_{11}$	354	Pale straw liquid	$0.960^{20°C.}$	8.02
Amyl salicylate	$HOC_6H_4COOC_5H_{11}$	208	Water-white liquid	$1.05^{20°C.}$	8.77
Benzophenone	$(C_6H_5)_2CO$	182	Crystalline solid	$1.108^{23°C.}$	9.26
Benzoyl acetone	$C_6H_5COCH_2COCH_3$	162	Colorless solid	$1.090^{60°C.}$	—
Benzyl alcohol	$C_6H_5CH_2OH$	108	Colorless liquid	$1.049^{20°C.}$	8.77
Benzyl benzoate	$C_6H_5COOCH_2C_6H_5$	212	Colorless oily liquid or solid	$1.114^{18.5°C.}$	9.31
Benzyl butyrate	$CH_3CH_2CH_2COOCH_2C_6H_5$	178	Colorless liquid	$1.016^{16/17.5}$	8.49

OF PLASTICIZERS

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water, Per Cent	Compatibility	Manufacturer
83-85	—	—	—	Slight	Cellulose Nitrate	Carbide, U.S.I.
103-106	—	—	—	—	—	Carbide, U.S.I.
92-96	—	—	—	—	—	Carbide, U.S.I.
20.5	202	105	1.53	Insolubl	Cellulose Acetate, Cellulose Nitrate	Givaudan
—	—	—	1.4408$^{25.5°C.}$	<0.002 g.	Cellulose Acetate Cellulose Nitrate Ethyl Cellulose Cellulose Acetate Butyrate Polystyrene, Polyvinyl Acetal	Pfizer
—	127$^{0.7\ mm.}$	—	1.4386$^{23°C.}$	0.72 g.	Cellulose Acetate Cellulose Acetate Butyrate Ethyl Cellulose Cellulose Nitrate Polystyrene Polyvinyl Acetal	Pfizer
−17	275-356	149	1.4380	Insoluble	Ethyl Cellulose	Sharples
< −40	200-240$^{20\ mm}$	186	1.4545	Insoluble	Ethyl Cellulose	Sharples
About −55	297-310	139	1.5192	Insoluble	—	Sharples
−18	282-288	135	1.4958	Insoluble	—	Sharples
30	230-270$^{30\ mm}$	187	1.444	Insoluble	Ethyl Cellulose	Sharples
—	139-143$^{5\ mm.}$	132	1.506	Insoluble	Cellulose Nitrate Cellulose Acetate	Givaudan, Sharples
48.5	306	—	1.602$^{25°C.}$	0.006	Cellulose Acetate Cellulose Acetate Butyrate	Eastman, Givaudan
61	262	—	1.5678$^{25°C.}$	5.0	Cellulose Acetate	Carbide
−15.3	205.8	100	1.54	—	Cellulose Acetate Cellulose Nitrate	Givaudan
18.5	323-4	148	1.570	Insoluble	Cellulose Nitrate	Givaudan
—	240	—	—	Insoluble	Cellulose Acetate	Givaudan

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Benzyl cinnamate	$C_6H_5CH: CHCOOCH_2$	238	Colorless solid	—	—
Benzyl salicylate	$HOC_6H_4COOCH_2C_6H_5$	228	Liquid	1.175	9.82
Benzyl sebacate	$(CH_2)_8(COOCH_2C_6H_5)_2$	368	Viscous liquid	—	—
Bornyl acetate	$C_{10}H_{17}OOCCH_3$	196	Colorless solid	$0.991^{15°C.}$	8.35
Butoxy ethyl stearate	$C_{17}H_{35}COOC_2H_4OC_4H_9$	384	Liquid	$0.888^{20°C.}$	7.40
***n*-Butyl acetyl ricinoleate**	$C_{17}H_{32}(OCOCH_3)COOC_4H_9$	397	Amber liquid	$0.940^{20°C.}$	7.82
Butyl crotonate	$CH_3CH: CHCOOC_4H_9$	142	Colorless liquid	$0.901\text{-}0.903^{20°C}$	7.52
Butyl oleate	$C_{17}H_{33}COOC_4H_9$	338	Colorless liquid	$0.873^{20°C}$	7.26
Butyl phthalyl butyl glycolate	$C_4H_9OCOC_6H_4COOCH_2COOC_4H_9$	336	Colorless liquid	$1.097^{25°C.}$	9.15
***n*-Butyl stearate**	$C_{17}H_{35}COOC_4H_9$	341	Colorless liquid	$0.855\text{-}0.860^{20°C.}$	7.14
Camphor	$CH_2CH_2CHC(CH_3)_2C(CH_3)COCH_2$	152	Colorless solid	$1.000^{25°C.}$	—
"Carbitol" citrate	$C_3H_4(OH)(COOCH_2CH_2OCH_2CH_2OC_2H_5)_3$	540	Yellow liquid resin	1.28	10.7

PLASTICIZERS — (*Continued*)

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
34	244	—	—	—	—	Givaudan
—	$194^{15\text{ mm.}}$	—	—	Slightly soluble	Cellulose Nitrate	Givaudan
—	—	—	—	Insoluble	Vinyl	Resinous Products
29	226	—	1.47	Very slightly soluble	—	Givaudan
16.5	$214\text{-}230^{4\text{ mm.}}$	193	—	Insoluble	Vinyl Ethyl Cellulose Cellulose Nitrate	Ohio-Apex
−32 to −65	$220\text{-}235^{3\text{-}5\text{ mm.}}$	110	$1.4614^{20°\text{C.}}$	Insoluble	Benzyl Cellulose Ethyl Cellulose Cellulose Nitrate Polystyrene Polyvinyl Butyral Polyvinyl Chloride Cellulose Acetate-Propionate	Commerical
—	175-185	—	—	—	Alkyd	Niacet
—	$227^{2\text{ mm.}}$	180	—	—	Benzyl Cellulose Ethyl Cellulose Cellulose Nitrate Polystyrene Polyvinyl Butyral Polyvinyl Chloride	Commercial
—	$219^{5\text{ mm.}}$	199	$1.49^{25°\text{C.}}$	0.0012	Cellulose Acetate Cellulose Nitrate Polystyrene Alkyd Casein Cellulose Acetate Butyrate Ethyl Cellulose Polyvinyl Acetals Polyvinyl Acetate Polyvinyl Chloride	Monsanto
19.5	$220\text{-}225^{25\text{ mm.}}$	180	1.4465	Slightly soluble 0.29	Benzyl Cellulose Ethyl Cellulose Cellulose Nitrate Polystyrene Polyvinyl Butyral Polyvinyl Chloride	Commercial, Kessler
176-177	204-209	93	1.53	0.17	Cellulose Nitrate	Du Pont
—	—	—	—	Soluble	Cellulose Acetate Cellulose Nitrate	Glyco

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
" Carbitol " laurate	$CH_3(CH_2)COOCH_2CH_2OCH_2CH_2OC_2H_5$	316	Orange semi-solid paste	0.94	7.58
" Carbitol " phthalate	$C_6H_4(COOCH_2CH_2OCH_2CH_2OC_2H_5)_2$	398	Pale yellow liquid resin	$1.121^{20°C.}$	9.31
" Carbitol " ricinoleate	$C_{17}H_{32}CHCOOCH_2CH_2OCH_2CH_2OC_2H_5$	410	Light amber liquid	0.96	8.02
" Cellosolve " ricinoleate	$C_{17}H_{32}CHCOOCH_2CH_2OCH_2CH_3$	366	Amber liquid	0.94	7.85
" Cellosolve " stearate	$CH_3(CH_2)_{16}COOCH_2CH_2OCH_2CH$	356	Amber liquid	0.88	7.35
Chloroacetoacetanilide	$CH_3COCH_2CONHC_6H_4Cl$	212	White powder	—	—
Cresyl-*p*-toluenesulfonate,*o*	$CH_3C_6H_4SO_2OC_6H_4CH_3$	262	White solid	$1.207^{15°C.}$	10.06
Diamyl biphenyl	$C_5H_{11}C_6H_4C_6H_4C_5H_{11}$	267	Straw colored liquid	$0.956^{20°C.}$	7.99
Di-tert-amyl cyclohexanol	$[CH_3CH_2C(CH_3)_2]_2C_6H_9OH$	240	Pale yellow liquid	$0.91^{20°C.}$	7.66
Diamyl maleate	$(CHCOOC_5H_{11})_2$	256	Water-white liquid	$0.981^{20°C.}$	8.20
Diamyl naphthalene	$C_{10}H_6(C_5H_{11})_2$	268	Yellow to brown liquid	$0.930\text{-}0.940^{20°C.}$	7.80
Di-tert-amyl phenoxy ethanol	$(C_5H_{11})_2C_6H_3OCH_2CH_2OH$	278	Pale straw liquid	$0.959^{20°C.}$	8.01
Diamyl phthalate	$C_6H_4(COOC_5H_{11})_2$	306	Water-white liquid	$1.027^{20°C.}$	8.61
Dibenzyl ether	$(C_6H_5CH_2)_2O$	198	Colorless liquid	1.0428^{20}_{4}	8.71
Dibutoxy ethyl phthalate	$C_6H_4(COOC_2H_4OC_4H_9)_2$	366	Liquid	$1.063^{20°C.}$	8.88
Dibutyl lactamide,N,N	$CH_3CHOHCON(C_4H_9)_2$	201	Liquid	0.942	7.87
Di-*n*-butyl lauramide,N,N	$C_{11}H_{23}CON(C_4H_9)_2$	311	Liquid	0.860	7.18
Di-*p*-tert-butyl phenyl mono-5-tert-butyl 2-xenyl phosphate	$[(CH_3)_3CC_6H_4O]_2[(CH_3)_3C(C_6H_5)C_6H_3O]PO$	570	Clear, slightly yellowish, soft resin	1.07^{60}_{4}	$9.0^{60°C.}$

PLASTICIZERS — (*Continued*)

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
—	—	—	—	Not dispersible	Cellulose Nitrate	Glyco
<-17	220-255$^{14\text{ mm.}}$	208	—	Partly soluble	Cellulose Acetate Cellulose Nitrate	Glyco
—	—	—	—	Not dispersible	Cellulose Nitrate	Glyco
—	—	—	—	Not dispersible	Cellulose Nitrate	Glyco
—	—	—	—	Not dispersible	Cellulose Nitrate	Glyco
103 106	—	—	—	—	—	Carbide, U.S.I.
51	—	—	1.558	0.0008	Cellulose Nitrate Cellulose Acetate Phenol Formaldehyde Vinyl Polystyrene	Monsanto
-30	364-404	171	1.5335	Insoluble	Polystyrene	Sharples
<-5	288-295	132	1.4873	Insoluble	—	Sharples
<-50	130-145$^{2\text{ mm.}}$	132	1.4463	Insoluble	Ethyl Cellulose	Sharples
-60	326-375	163	1.5535$^{20°\text{C.}}$	Insoluble	Polystyrene	Sharples
-35	318-332	149	1.5074	Insoluble	—	Sharples
<-75	342	171	1.488	0.010	Cellulose Acetate Cellulose Acetate Butyrate Ethyl Cellulose	Eastman, Kessler, U.S.I.
4-5	295-298	134	—	Insoluble	Cellulose Acetate Cellulose Nitrate	Givaudan
<-18	212-232$^{4\text{ mm.}}$	202	—	<0.1	Cellulose Acetate Cellulose Nitrate Ethyl Cellulose Polyvinyl Chloride Acetate	Eastman, Ohio-Apex
<-45	130-131$^{2\text{-}4\text{ mm.}}$	132	1.4545	Insoluble	—	Sharples
-14.5	200-230$^{3\text{ mm.}}$	191	1.4567	Insoluble	—	Sharples
—	300-325$^{5\text{ mm.}}$	270	1.546$^{60°\text{C.}}$	Insoluble	Ethyl Cellulose	Dow

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Di-*p*-tert-butyl phenyl mono-phenyl phosphate	$[(CH_3)_3CC_6H_4O]_2(C_6H_5O)PO$	438	Clear, colorless, viscous liquid	$1.11^{25/25°C.}$	$9.3^{25°C.}$
Dibutyl phthalate	$C_6H_4(COOC_4H_9)_2$	278	Colorless oily liquid	$1.047\text{-}1.050^{15°C.}$	8.75
Dibutyl sebacate	$C_4H_9OCO(CH_2)_8COOC_4H_9$	314	Slightly yellow liquid	$0.933^{15°C.}$	7.83
Dibutyl succinate	$C_4H_9OCOCH_2CH_2COOC_4H_9$	230	Yellowish liquid	$0.974^{25°C.}$	8.13
Dibutyl tartrate	$C_4H_9OCO(CHOH)_2COOC_4H_9$	262	Water-white liquid	1.098	9.17
Di-*n*-butyl toluene-sulfonamide,N,N	$CH_3C_6H_4SO_2N(C_4H_9)_2$	283	Yellowish liquid	$1.054^{25°C.}$	8.77
Di-*n*-butyl urea,N,N	$(C_4H_9)NCONH_2$	172	Water-white liquid	$0.937^{45°C.}$	7.68
Dichloracetonacetanilide (Acetoacet-2,5-dichlor-anilide)	$CH_3COCH_2CONHC_6H_3Cl_2$	246	White crystalline powder	—	—
Di (diethylene glycol mono-ethyl ether) phthalate	$C_6H_4(COOCH_2CH_2OCH_2CH_2OC_2H_5)_2$	398	Pale yellow liquid resin	$1.121^{20°C.}$	9.31
Diethoxyethyl adipate	$C_2H_5OC_2H_4OCO(CH_2)_4COOC_2H_4OC_2H_5$	290	Water-white liquid	$1.036^{25°C}$	8.61
Diethoxyethyl phthalate	$C_6H_4(COOC_2H_4OC_2H_5)_2$	310	Solid	$1.130^{20°C.}$	9.21

PLASTICIZERS — (*Continued*)

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
—	260-275$^{5\text{ mm.}}$	250	1.540$^{25°\text{C.}}$	Insoluble	Ethyl Cellulose Cellulose Nitrate	Dow
−35	325	160	1.490	0.013	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Benzyl Cellulose Ethyl Cellulose Polystyrene Polyvinyl Butyral Polyvinyl Formal Polyvinyl Chloride Acetate Polyvinyl Acetate Polyvinyl Acetal Polyvinyl Chloride	Cyanamid, Carbide, Commercial, Eastman, Kessler, Monsanto, Ohio-Apex, U.S.I., La Pine
−19.5	344-345	178	1.4391	0.005	Acrylics Cellulose Acetate Butyrate Cellulose Nitrate Benzyl Cellulose Ethyl Cellulose Polystyrene Polyvinyl Butyral Polyvinyl Chloride Acetate Phenol-Formaldehyde Urea-Formaldehyde	Commercial, Resinous Products, Amecco, Cyanamid
−19	255	—	1.428$^{25°\text{C.}}$	0.023	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
22	312	—	1.445	0.485	Cellulose Acetate Cellulose Acetate Butyrate	Commercial, Eastman, Kessler
10	200-203	166	1.5094	Insoluble	Cellulose Nitrate	Sharples
22	Decomp.	132	—	Insoluble	—	Sharples
92-96	—	—	—	—	—	Carbide, U.S.I.
<−17	220-255$^{14\text{ mm.}}$	208	—	About 1	Polyvinyl Acetate	Ohio-Apex
<−70	—	—	1.439$^{25°\text{C.}}$	0.248	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
34	345	143	1.492	0.195	Cellulose Acetate Cellulose Nitrate Ethyl Cellulose Polyvinyl Chloride Acetate	Eastman, Ohio-Apex

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Diethyl adipate	$C_2H_5OCO(CH_2)_4COOC_2H_5$	202	Water-white liquid	$1.002^{25^\circ C.}$	8.36
Diethyl lauramide,N,N	$C_{11}H_{23}CON(C_2H_5)_2$	255	Water-white liquid	$0.865^{25^\circ C.}$	7.19
Diethyl phthalate	$C_6H_4(COOC_2H_5)_2$	222	Colorless oily liquid	$1.118^{15^\circ C.}$	9.35
Diethyl sebacate	$C_2H_5OCO(CH_2)_8COOC_2H_5$	258	Slightly yellow liquid	0.9650	—
Diethyl succinate	$C_2H_5OCOCH_2CH_2COOC_2H_5$	174	Pale yellow liquid	$1.048^{25^\circ C.}$	8.69
Diethyl tartrate	$C_2H_5OCO(CHOH)_2COOC_2H_5$	206	Water-white liquid	$1.199^{25^\circ C.}$	9.95
Diethylene glycol diabietate	$(C_{19}H_{29}COOC_2H_4)_2O$	674	Amber solid	1.071	—
Diethylene glycol diacetate	$(CH_3COOCH_2CH_2)_2O$	190	Water-white liquid	$1.116^{20^\circ C.}$	9.30
Diethylene glycol dipropionate	$(CH_3CH_2COOCH_2CH_2)_2O$	218	Water-white liquid	1.075	8.96
Diethylene glycol distearate	$(C_{17}H_{35}COOC_2H_4)_2O$	639	White, waxlike solid	$0.9333^{20^\circ C.}$	7.79
Diethylene glycol monolaurate	$C_{11}H_{23}COOC_2H_4OC_2H_4OH$	288	Pale yellow solid	$1.0354^{20^\circ C.}$	8.65
Diethylene glycol monoöleate	$C_{17}H_{33}COOC_2H_4OC_2H_4OH$	371	Dark red oil	0.96	8.02
Diethylene glycol phthalate	$(C_6H_4COOC_2H_4)_2O$	312	Yellow liquid	1.28	10.7
Dimethoxy ethyl adipate	$CH_3OC_2H_4OCO(CH_2)_4COOC_6H_{10}CH_3$	262	Water-white liquid	$1.075^{25^\circ C.}$	8.94
Dimethoxy ethyl phthalate	$C_6H_4(COOC_2H_4OCH_3)_2$	282	Water-white oil	$1.170^{20^\circ C.}$	9.78
Dimethoxytetraglycol	$O(CH_2CH_2OCH_2CH_2CH_2OCH_3)_2$	222	Pale yellow liquid	1.0132	8.43
Di(methylcyclohexyl)-adipate	$CH_3C_6H_4OCO(CH_2)_4COOC_2H_4OC_2H_5$	338	Water-white liquid	$1.091^{20^\circ C.}$	9.11

PLASTICIZERS — (*Continued*)

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
−14	245	—	$1.426^{25°C}$	0.060	Cellulose Acetate Celllose Acetate Butyrate	Eastman
4	$166\text{-}167^{2\text{ mm.}}$	166	1.4550	Insoluble		Sharples
−3.5	295	140	1.499	0.150	Cellulose Acetate Cellulose Nitrate Cellulose Acetate Butyrate Benzyl Cellulose Ethyl Cellulose Polystyrene Polyvinyl Butyral Polyvinyl Formal Polyvinyl Chloride Acetate	Cyanamid, Commercial, Eastman, Kessler, Monsanto, U.S.I., Givaudan, La Pine
13	308	—	1.435	0.18-0.19	Cellulose Acetate Cellulose Acetate Butyrate	Amecco, Eastman
−22	218	—	1.419	0.19	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
17	280	—	1.445	>50	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
45-50	—	—	—	Insoluble	Cellulose Nitrate Casein Ethyl Cellulose	Hercules
—	250	135	—	∞	Cellulose Acetate	Eastman, Carbide
—	$165^{4\text{ mm}}$	127	$1.429^{25°C.}$	3.6	Cellulose Acetate Cellulose Acetate Butyrate	Ohio-Apex
48	—	—	—	Insoluble	—	Glyco
17-18	193.2	—	—	Insoluble	Cellulose Acetate	Glyco
<0	—	—	–	Insoluble	—	Glyco
—	—	—	—	Insoluble	Cellulose Acetate Cellulose Nitrate	Glyco
−16	—	—	1.439	1.42	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
<−75	$261^{20\text{ mm.}}$	174	1.500	0.838	Cellulose Acetate Cellulose Acetate Butyrate	Eastman Ohio-Apex
—	275.8	140	—	Complete	Cellulose Acetate Cellulose Nitrate Vinyl Acetate	Kessler, Carbide
−45	200-230	189	$1.4685^{20°C.}$	Insoluble	—	Du Pont

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Dimethyl phthalate	$C_6H_4(COOCH_3)_2$	194	Colorless oily liquid	$1.193^{15°C.}$	10
Dimethyl sebacate	$[(CH_2)_4COOCH_3]_2$	230	Slightly yellow liquid	$0.9646^{20°C.}$	8.06
Dioctyl phthalate	$C_6H_4(COOC_8H_{17})_2$	390	Water-white liquid	$0.984^{20°C.}$	8.22
Di-phenyl mono-*o*-zenyl phosphate	$(C_6H_5O)_2(C_6H_5C_6H_4O)PO$	402	Clear, colorless, mobile liquid	$1.20^{60°C.}$	$10.3^{25°C.}$
Ethyl benzoate	$C_6H_5COOC_2H_5$	150	Colorless liquid	$1.0509^{15°C.}$	8.77
Ethyl-*o*-benzoyl benzoate	$C_6H_5COC_6H_4COOC_2H_5$	254	Pale straw solid	$1.155^{20°C.}$	—
Ethyl cinnamate	$C_6H_5CH\colon CHCOOC_2H_5$	176	Colorless liquid	1.049	8.76
Ethyl crotonate	$CH_3CH{=}CHCOOC_2H_5$	114	Colorless liquid	$0.917\text{-}0.919^{20°C.}$	7.65
Ethyl phthalyl ethyl glycolate	$C_2H_5OCOC_6H_4COOCH_2COOC_2H_5$	280	Colorless liquid	$1.180^{25°C.}$	9.84
Ethyl salicylate	$HOC_6H_4COOC_2H_5$	166	Colorless liquid	$1.1362^{15°C.}$	9.44
Ethylene glycol diacetate	$(CH_2OCOCH_3)_2$	146	Water-white liquid	$1.1063^{20°C.}$	9.21
Ethylene glycol dibutyrate	$(CH_2OCOC_3H_7)_2$	202	Water-white liquid	$1.024^{0°C.}$	8.61
Ethylene glycol dipropionate	$(CH_2OCOC_2H_5)_2$	174	Water-white liquid	$1.054^{15°C.}$	8.77
Fenchone	$CH_2CCH_3CH_2CH_2CHC(CH_3)_2CO$	152	Oil	$0.9460^{20°C}$	7.90
Glycerol diacetate	$C_3H_5(OH)(OCOCH_3)_2$	176	Colorless liquid	$1.184^{15°C.}$	9.89
Glycerol monoacetate	$CH_3COOCH_2CHOHCH_2OH$	134	Colorless oily liquid	$1.206^{20°C.}$	10.0

PLASTICIZERS — (*Continued*)

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
0	285	132	1.513	0.305	Cellulose Acetate Cellulose Nitrate Vinyls Benzyl Cellulose Cellulose Acetate Butyrate Ethyl Cellulose	Cyanamid Carbide, Commercial, Eastman, Kessler, Monsanto, U. S. I., La Pine
1	308	—	—	0.008	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Benzyl Cellulose Polystyrene Vinyls	Commercial
—	215-240$^{4\text{ mm.}}$	205	—	Insoluble	Cellulose Esters Vinyls	Ohio-Apex
<0°	250-285$^{5\text{ mm.}}$	—	1.582-1.590$^{60°\text{C.}}$	Insoluble	Ethyl Cellulose Cellulose Nitrate	Dow
−34.6	211-213	—	1.50682$^{17.3°\text{C.}}$	0.08	Cellulose Acetate Cellulose Nitrate	Givaudan
55	355	188	1.573$^{25°\text{C}}$	0.01	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate	Cyanamid, Eastman
6-10	271	—	1.55982	Insoluble	—	Givaudan
45	138	—	—	Slightly soluble	—	Niacet
20°	190$^{5\text{ mm.}}$	196	1.498$^{25°\text{C.}}$	0.0175	Cellulose Acetate Cellulose Nitrate Vinyls Cellulose Acetate Butyrate Ethyl Cellulose	Monsanto
1-1.3	231-234	—	1.5251$^{14.4°\text{C.}}$	Slightly soluble	Cellulose Nitrate Ethyl Cellulose	Hercules
<−78	190.5	104	1.414$^{25°\text{C.}}$	1.815	Cellulose Acetate Cellulose Acetate Butyrate	Eastman, Carbide
<−80	240	—	1.424$^{25°\text{C.}}$	0.05	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
<−80	211	—	1.419$^{25°\text{C.}}$	0.16	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
6	193-198	—	1.4625$^{20°\text{C.}}$	Insoluble	Cellulose Nitrate	Newport
40	176	133	1.4395	∞	—	Eastman
40	158	148	1.4535	∞	—	Eastman, Kessler

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Glycerol monolaurate	$C_{11}H_{23}COOCH_2CHOHCH_2OH$	274	Creamy paste	0.98	8.19
Glycerol monoöleate	$C_{17}H_{33}COOCH_2CHOHCH_2OH$	357	Yellow oil	$0.947^{21°C}$	7.91
Glycerol monoricinoleate	$C_{17}H_{32}(OH)COOCH_2CHOHCH_2OH$	373	Amber liquid	1.02	8.52
Glycerol monostearate	$C_{17}H_{35}COOCH_2CHOHCH_2OH$	359	Waxlike solid	0.97-0.984	8.22
Glycerol phthalate	—	—	Pale yellow solid	1.29	10.8
Glycerol triacetate	$CH_3COOCH_2CH(OCOCH_3)CH_2OCOCH_3$	218	Colorless liquid	$1.161^{20°C.}$	9.69
Glycerol tributyrate	$C_3H_5(OCOC_3H_7)_3$	302	Colorless oily liquid	$1.035^{20°C}$	8.65
Glycerol tripropionate	$C_3H_5(OCOC_2H_5)_3$	260	Colorless liquid	$1.078^{20°C}$	9.01
Hydrogenated methyl abietate	$C_{21}CH_{31}COOCH_3$	318	—	1.02-1 030	8.61
Methoxy ethyl oleate	$C_8H_{17}CH{:}\,CH(CH_2)_7COOC_2H_4OCH_3$	340	Liquid	$0.902^{20°C.}$	7.54
Methyl abietate	$C_{20}H_{29}COOCH_3$	316	Viscous amber liquid	1.02-1.03	8.64
Methyl-*o*-benzoyl benzoate	$C_6H_5COC_6H_4COOCH_3$	240	Pale straw solid	$1\ 190^{25°C.}$	99.4
Methyl cinnamate	$C_6H_5CH{:}\,CHCOOCH_3$	162	Colorless crystals	$1.042^{36°C.}$	—
Methyl cyclohexanone glyceryl acetal	$C[OCH(CH_2OH)CH_2O](CH_2)_4CHCH_3$	172	Pale yellow liquid	$1.074^{20°C.}$	9.00
Methyl oleate	$C_{17}H_{33}COOCH_3$	296	Amber liquid	$0.879^{18°C.}$	7.35
Methyl phthalyl ethyl glycolate	$CH_3OCOC_6H_4COOCH_2COOC_2H_5$	266	Colorless liquid	$1.220^{25°C.}$	10.2
Methyl salicylate	$HOC_6H_4COOCH_3$	152	Colorless liquid	$1.1840^{20.2°C.}$	9.89
Monoamyl biphenyl	$C_5H_{11}C_6H_4C_6H_5$	206	Pale straw liquid	$0.970^{20°C}$	8.10
Monoamyl chloronaphthalene	$C_5H_{11}C_{10}H_6Cl$	233	Yellow liquid	$1.074^{25°C.}$	8.94

PLASTICIZERS — (*Continued*)

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
24-25	—	—	—	Insoluble	—	Glyco
35-38	—	—	—	Insoluble	—	Glyco
<−50	—	—	—	Insoluble	—	Glyco
55-57	—	—	—	Insoluble	—	Glyco
—	—	—	—	Insoluble	Cellulose Acetate	Glyco
−78	259-262	146	$1\ 429^{25^\circ\text{C.}}$	6.69	Cellulose Acetate Cellulose Acetate Butyrate	Eastman, Kessler, Fries & Fries
<−75	315	—	1.4359	0.01	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
<−50	177-182	—	1.431	0.313	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
—	365-370	183	1.517-1.519	Insoluble	Ethyl Cellulose Cellulose Nitrate	Hercules
—	$188\text{-}230^{4\text{ mm.}}$	182	1	Insoluble	Vinyls	Ohio-Apex
—	360-365	180	1.529-1 530	Insoluble	Cellulose Nitrate Ethyl Cellulose	Hercules
40	351	175	$1.587^{25^\circ\text{C.}}$	0.005	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate	Cyanamid, Eastman
36	262	—	$1.5766^{21^\circ\text{C.}}$	Insoluble	—	Givaudan
—	$130\text{-}140^{20\text{ mm.}}$	113	$1.474^{20^\circ\text{C.}}$	Insoluble	—	Du Pont
—	$216^{20\text{ mm.}}$	—	—	Insoluble	Ethyl Cellulose	Glyco
—	$189^{5\text{ mm.}}$	—	$1.504^{25^\circ\text{C.}}$	0.09	Alkyd Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Phenol-Formaldehyde Vinyls	Monsanto
−8.6	222.2	—	1.5369	0.074	Cellulose Nitrate	Givaudan
Ca −60	313-338	149	1.5664	Insoluble	Polystyrene	Sharples
Ca −65	321-333	146	$1.5778^{20^\circ\text{C.}}$	Insoluble	Polystyrene	Sharples

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Monoamyl naphthalene	$C_{10}H_7C_5H_{11}$	198	Yellow viscous oily liquid	0.95-0.96	8.00
Mono-*n*-butyl lauramide,N	$C_{11}H_{23}CON(C_2H_5)_2$	255	—	—	—
Mono-*n*-butyl toluenesulfonamide,N	$CH_3C_6H_4SO_2NH(C_4H_9)$	227	Almost colorless liquid	1.093	9.11
Pentaerythritol diacetate dibutyrate	$C(CH_2OCOCH_3)_2(CH_2OCOCH_2CH_2CH_3)_2$	360	Colorless liquid	—	—
Pentaerythritol diacetate diproprionate	$C(CH_2OCOCH_3)_2(CH_2OCOCH_2CH_3)_2$	332	Colorless liquid	—	—
Pentaerythritol tetraacetate	$C(CH_2OOCCH_3)_4$	304	White solid	—	—
Pentaerythritol tetrabutyrate	$C(CH_2OOCCH_2CH_2CH_3)_4$	416	Colorless liquid	—	—
Pentaerythritol tetraproprionate	$C(CH_2OOCCH_2CH_3)_4$	360	Crystalline solid	—	—
Phenyl N,N-dibutyl carbamate	$(C_4H_9)_2NCOOC_6H_5$	249	Water-white liquid	0.969	8.10
Phenyl ethyl alcohol (Benzyl carbinol)	$C_6H_5CHOHCH_3$	122	Colorless liquid	1.023	8.55
Polyamyl naphthalene	$C_{10}H_8(C_5H_{11})_{11}$	—	Brown liquid	0.93-0.94	7.83
Propylene glycol monolaurate,1,2	$C_{11}H_{23}COOCH_2CHOHCH_2OH$	258	Light orange oil	0.95	7.94
Propylene glycol monoöleate,1,2	$C_{17}H_{33}COOCH_2CHOHCH_3$	341	Orange oil	0.95	7.94
Propylene glycol monostearate,1,2	$C_{17}H_{35}COOCH_2CHOHCH_3$	343	Tan paste	0.93	7.77

PLASTICIZERS — (*Continued*)

Melting Point, °C.	Boiling Point, °C.	Flash Point, °C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
−60° approx.	279-330	124	$1.5727^{20^\circ\text{C.}}$	Insoluble	Polystyrene	Sharples
50-54.5	$200\text{-}225^{3\text{ mm.}}$	191	—	Insoluble	—	Sharples
42-43	$210\text{-}230^{10\text{ mm.}}$	—	—	Insoluble	Cellulose Nitrate	Sharples
—	$160\text{-}165^{2\text{ mm.}}$	—	—	—	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Polyvinyl Acetate	Heyden
—	$173\text{-}180^{2\text{ mm.}}$	—	—	–	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Polystyrene	Heyden
82	$155\text{-}160^{2\text{ mm.}}$	—	—	1.2	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Vinyls	Heyden, Niacet
—	$185\text{-}190^{2\text{ mm.}}$	—	—	—	Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Polystyrene Polyvinyl Acetate	Heyden
25-30	$170\text{-}175^{2\text{ mm.}}$	—	—	—	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Polystyrene Polyvinyl Acetals	Heyden
<−48	160-165	157	1.4927	Insoluble	—	Sharples
—	219-221	—	—	1.6	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate	Givaudan
−45	353-397	182	1.5452	Insoluble	Polystyrene	Sharples
14-15	—	—	—	Insoluble	—	Glyco
6-7	—	—	—	Insoluble	—	Glyco
44-45	--	—	—	Insoluble	—	Glyco

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Sorbitol dilaurate	$(C_{11}H_{23}COO)_2C_6H_8(OH)_4$	547	Brown, soft paste	0.95	7.94
Sorbitol dioleate	$(C_{17}H_{33}COO)_2C_6H_8(OH)_4$	711	Amber oil	0.95	7.94
Sorbitol distearate	$(C_{17}H_{35}COO)_2C_6H_8(OH)_4$	691	Cream colored, wax	0.96	8.02
Sucrose octa acetate	$C_{12}H_{14}O_3(OOCCH_3)_8$	678	White solid	1.28	—
Tetrabutyl adipamide,-N,N,N′,N′	$(C_4H_9)_2NCO(CH_2)_4CON(C_4H_9)_2$	369	White solid	$0.901^{60^\circ C.}$	—
Tetrabutyl urea	$(C_4H_9)_2NCON(C_4H_9)_2$	284	Water-white liquid	0.880	7.35
Tetraethyl adipamide,-N,N,N′,N′	$(C_2H_5)_2NCO(CH_2)_4CON(C_2H_5)_2$	256	White solid	$0.953^{60^\circ C.}$	—
Toluene ethylsulfonamide, *o*- and *p*-	$CH_3C_6H_4SO_2NHC_2H_5$	199	Light amber liquid	$1.188^{25^\circ C.}$	9.9
Toluenesulfonamide, *o*- and *p*-	$CH_3C_6H_4SO_2NH_2$	171	White solid	$1.313^{25^\circ C}$	10.9
Tri-*p*-tert-amyl-phenyl phosphate	$(C_5H_{11}C_6H_4O)_3PO$	537	White powder	—	—
Tri-*n*-butyl aconitate	$C_4H_9OCOCH: C(COOC_4H_9)CH_2—COOC_4H_9$	342	Water-white liquid	$1.018^{20^\circ C.}$	8.50
Tri-*n*-butyl citrate	$(C_4H_9OCOCH_2)_2C(OH)COOC_4H_9$	360	Colorless liquid	$1.045^{20^\circ C}$	8.7
Tri-*p*-tert-butyl-phenyl phosphate	$[(CH_3)_3CC_6H_4O]_3PO$	495	White, crystalline powder	—	—
Tributyl phosphate	$(C_4H_9O_3)PO$	268	Colorless liquid	$0.98^{20^\circ C.}$	8.1
Tri-*n*-butyl tricarballylate	$(C_4H_9OCOCH_2)_2CHCOOC_4H_9$	344	Water-white liquid	$1.004^{24^\circ C.}$	8.38

PLASTICIZERS — (*Continued*)

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
8-12	—	—	—	Insoluble	—	Glyco
<0	—	—	—	Insoluble	—	Glyco
49-51	—	—	—	Insoluble	—	Glyco
79-86	260	—	—	0.09	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate	Niacet
47	238-239$^{1\text{ mm.}}$	185	—	Insoluble	—	Sharples
<−60	305	—	1.4535	Insoluble	—	Sharples
49	195-200$^{4\text{ mm.}}$	>185	—	Soluble	—	Sharples
18	—	—	1.540$^{25°\text{C.}}$	0.13$^{23°\text{C.}}$	Cellulose Acetate Cellulose Nitrate Ethyl Cellulose Casein Vinyl	Monsanto
105	—	—	—	1.0	Cellulose Acetate Butyrate Ethyl Cellulose Cellulose Nitrate Vinyl Acetate Urea-Formaldehyde	Monsanto
62-63	305-345$^{5\text{ mm.}}$	—	—	Insoluble	Ethyl Cellulose	Sharples
—	190$^{3\text{ mm.}}$	—	1.4532$^{26°\text{C.}}$	—	—	Pfizer
−20	233.5$^{22.5\text{ mm.}}$	185	1.4431	<0.002	Vinyls Polystyrene Ethyl Cellulose Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate	Commercial, Eastman, Pfizer
103-105	300$^{5\text{ mm.}}$	-	—	Insoluble	Ethyl Cellulose Vinyl Chloride Acetate	Dow
<−20	140$^{5\text{ mm.}}$	160	1.4248	0.033	Benzyl Cellulose Cellulose Acetate Butyrate Ethyl Cellulose Cellulose Nitrate Vinyl	Commercial, Monsanto
—	305	—	1.4388$^{26.5°\text{C.}}$	<0.002	—	Pfizer

TABLE 44. PROPERTIES OF

Plasticizer	Chemical Formula	Mol. Wt.	Color and Form	Specific Gravity	Pounds per Gallon
Tricresyl phosphate	$(CH_3C_6H_4O)_3PO$	368	Colorless liquid	$1.165^{20°C.}$	9.7
Triethyl aconitate	$C_2H_5OCOCH\colon C(COOC_2H_5)CH_2COOC_2H_5$	258	Water-white liquid	$1.0957^{24.5°C.}$	9.14
Triethyl citrate	$(C_2H_5OCOCH_2)_2C(OH)COOC_2H_5$	276	Colorless liquid	$1.136^{25°C.}$	9.48
Triethyl phosphate	$(C_2H_5O)_3PO$	182	Amber liquid	$1.068\text{-}1.072^{20°C.}$	8.94
Triethyl tricarballylate	$(C_2H_5OCOCH_2)_2CHCOOC_2H_5$	260	Water-white liquid	$1.087^{20°C.}$	9.08
Triethylene glycol diacetate	$(CH_2OCH_2CH_2OCOCH_3)_2$	234	Water-white liquid	$1.111\text{-}1.112^{25°C.}$	9.28
Triethylene glycol dibutyrate	$(CH_2OCH_2CH_2OCOC_3H_7)_2$	290	Liquid	$1.033^{25°C.}$	8.61
Triethylene glycol di-2-ethyl butyrate	$C_5H_{11}CO(OC_2H_4)_3OCOC_5H_{11}$	346	Liquid	$0.9940^{20°C.}$	8.28
Triethylene glycol di-2-ethylhexoate	$C_7H_{15}CO(OC_2H_4)_3OCOC_7H_{15}$	403	Liquid	$0.9679^{20°C.}$	8.06
Triethylene glycol dipropionate	$(CH_2OCH_2CH_2OCOC_2H_5)_2$	262	Liquid	$1.066^{25°C.}$	8.84
Triphenyl phosphate	$(C_6H_5O)_3PO$	326	White solid	$1.185^{25°C.}$	10.5

PLASTICIZERS — (*Continued*)

Melting Point, ° C.	Boiling Point, ° C.	Flash Point, ° C. Open Cup	Refractive Index 20° C.	Solubility in Water Per Cent	Compatibility	Manufacturer
−35	$295^{13\text{ mm.}}$	235	$1.556^{20°\text{C.}}$	<0.002	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose	Celanese, Monsanto, Dow
—	$154\text{-}156^{5\text{ mm}}$	—	$1.4517^{26°\text{C.}}$	0.18	—	Pfizer
—	$150^{3\text{ mm.}}$	155	1.4405	6.1-6.5	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Polystyrene	Pfizer
−56	210-220	116	$1.4055^{20°\text{C.}}$	∞	Benzyl Cellulose Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Polystyrene Vinyls	Commercial
—	$158\text{-}160^{5\text{ mm}}$	—	$1.4324^{26°\text{C.}}$	0.62	Cellulose Acetate Cellulose Acetate Butyrate	Pfizer
<−60	300	—	$1.43^{\sim 25°\text{C.}}$	>50	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
<−70	154-160	—	$1.437^{25°\text{C.}}$	0.8	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
—	358	196	—	0.04	Vinyls	Carbide
—	$215^{5\text{ mm.}}$	207	—	<0.01	Vinyls	Carbide
<−60	$138\text{-}142^{2\text{ mm.}}$	—	1.436	6.7	Cellulose Acetate Cellulose Acetate Butyrate	Eastman
48.5	$245^{11\text{ mm.}}$	235	$1.563^{25°\text{C.}}$	<0.002	Cellulose Acetate Cellulose Acetate Butyrate Cellulose Nitrate Ethyl Cellulose Vinyl Chloride Vinyl Chloride Acetate	Celanese, Dow, Eastman, Monsanto

NAMES AND ADDRESSES OF MANUFACTURERS LISTED IN TABLES 43 AND 44

Advance Solvents & Chemical Corporation, 247 Fifth Ave., New York, N. Y.
Amecco Chemicals, Inc., 75 Rockwood St., Rochester, N. Y.
American Cyanamid & Chemical Corporation, 30 Rockefeller Plaza, New York, N. Y.
American Mineral Spirits Co., 155 East 44th St., New York, N. Y.
Apex Chemical Co., Inc., 225 West 34th St., New York, N. Y.
Barrett Company, 40 Rector St., New York, N. Y.
Carbide & Carbon Chemicals Corporation, 30 East 42d St., New York, N. Y.
Celanese-Celluloid Corporation, 180 Madison Ave., New York, N. Y.
Commercial Solvents Corporation, 17 East 42d St., New York, N. Y.
Dow Chemical Co., Midland, Mich.
E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.
Eastman Kodak Co., Chemical Sales Div., Rochester, N. Y.
Fries & Fries, Inc., 1540 Brewster Ave., Cincinnati, Ohio
Givaudan-Delawanna, Inc., 330 West 42d St., New York, N. Y.
Glyco Products Co., Inc., 230 King St., Brooklyn, N. Y.
R. W. Greeff & Co., Inc., 10 Rockefeller Plaza, New York, N. Y.
Gulf Oil Corporation, 17 Battery Pl., New York, N. Y.
Hercules Powder Co., Wilmington, Del.
Heyden Chemical Corporation, 50 Union Square, New York, N. Y.
Kessler Chemical Corporation, 239 Eleventh Ave., New York, N. Y.
Koppers Co., Tar and Chemical Div., Pittsburgh, Pa.
Arthur S. La Pine & Co., 121 W. Hubbard Street, Chicago, Ill
Metasap Chemical Co., Harrison, N. J.
Monsanto Chemical Co., St. Louis, Mo.
The Neville Co., Pittsburgh, Pa.
Newport Industries, Inc., 230 Park Ave., New York, N. Y.
Niacet Chemicals Corporation, Niagara Falls, N. Y.
Ohio-Apex, Inc., Nitro, W. Va.
Charles Pfizer & Co., Inc., 81 Maiden Lane, New York, N. Y.
Phillips Petroleum Co., Special Products Dept., Bartlesville, Ohio
Plastics Products, Inc., 6473 Georgia Ave., Detroit, Mich.
The Quaker Oats Co., Chicago, Ill.
Resinous Products & Chemical Co., Inc., 22 W. Washington Square, Philadelphia, Pa.
Sharples Chemicals, Inc., 23d and Westmoreland St., Philadelphia, Pa.
Shell Chemical Co., See R. W. Greeff & Co., Inc., Sales agents.
Standard Oil Co. of Calif., 225 Bush St., San Francisco, Calif.
Standard Oil Co. of N. J., 26 Broadway, New York, N. Y.
Union Oil Co. of Calif., Union Oil Bldg., Los Angeles, Calif.
U. S. Industrial Chemicals, Inc., 60 East 42d St., New York, N. Y.

Colors Used in Plastics[3]

To consider this aspect of molding plastics, it will be necessary to subdivide the various classifications of molding compounds and, based on actual experience as developed by the manufacturers of molding powders, molders, manufacturers of colored laminates, etc., indicate those coloring materials which have been used successfully under the particular and peculiar conditions incidental to the type of molding and kind of resin, etc.

Straight Phenolics. Due to the very definite formation of by-products, induced by heat and pressure, the most satisfactory colors for this group are the inorganic blacks, browns, reds, gray (white and black), and a few of the dyestuffs. The combination of dyes and inorganic color pigments tends to produce a more uniform dispersion and a brighter mass tone in the finished molded article. However, the dyestuffs are as a rule subject to color change on prolonged exposure to light and a gradual fading takes place.

The phenol-formaldehyde molding types carry fillers such as wood flour, fabric or mineral type, which, in turn, produce a degree of tinting strength that may be difficult to mask with color sufficiently to obtain a bright, clean-colored finish. Naturally most molding types carrying a filler content will produce an opaque product.

The laminated types of phenol-formaldehyde products also provide the same color limitations.

The phenol-formaldehyde cast resins, however, permit a wide range of color which is obtained by using dyes, pigment colors and combinations of both. These resins are produced in transparent, translucent, and opaque grades, and the colors used depend on the degree of transmitted light involved; i.e., the undertone or the mass tone is secured by color selection.

Phenol-furfural compounds may be considered in the same classification as the phenol-formaldehyde group insofar as coloring possibilities are concerned.

Urea-formaldehyde resins are particularly suited for coloring. All classes, i.e., translucent and opaque, can be colored in an infinite variety of shades, tints, and solid colors, producing beautiful vivid color effects. Dyes, pigments, pigment toners, and lakes may be used separately or in combination.

Polyvinyl chloride and acetate, filled or unfilled, may be considered in the same class as urea-formaldehyde, also methyl methacrylate and styrene types of resins are to be included in the same group, i.e., practically unlimited color possibilities.

Shellac molding compounds permit only limited color possibilities. Some opaque colors may be obtained, but no satisfactory tints.

Chlorinated rubber permits many color possibilities in the translucent and opaque stages. Excellent tints and pastel shades are available.

Modified isomerized rubber compounds may be included in the same classification with the chlorinated rubber.

Hard rubber compounds permit of very limited coloring and these are dark and opaque only.

Casein molding compounds lend themselves very nicely to coloring and permit of a practically unlimited range of solid colors, tints, and pastels.

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[3] Prepared in co-operation with Charles D. Allen, H. Kohnstamm & Co. Inc.

Cellulose acetate and cellulose nitrate compounds are the most satisfactory for coloring. Unlimited colors, shades, tints, and pastels are possible in which pigment colors and/or dyes produce beautiful color effects.

In conclusion it must be borne in mind that many factors influence the behavior of coloring materials when combined with plastics compounds. Resins requiring two-stage molding are considerably more difficult to color uniformly when compared with single-stage products. Molding time and temperature are of prime consideration where color is a constituent part of the powder. The specification covering the use of powder by the molder should indicate that any changes or deviation will cause color change, or in some cases color failure. If a powder is specified to be run at 360° F. for 2 min. it will not yield the same color value if run at 390° F. for 1½ min.

Another feature of coloring plastics may be best described as color beauty versus color permanence. In some cases permanence is the dominant feature, while others sacrifice permanence to secure novel coloring effects or sharp brilliancy.

It must be considered that besides the color value, the dye or pigment should also possess the following qualities to make it entirely satisfactory when used in any molding product:

1. The coloring agent should have good dispersing properties and should be uniformly distributed throughout the mass before actual molding.

2. It might be desirable in some cases to have a soluble coloring material, i.e., soluble dye present to secure desired type and degree of color in the finished, molded product.

3. Where insolubility of the finished molded product is desirable, the color should be selected with this angle considered and colors used must be checked accordingly.

4. Migration, crocking, and powdering may be caused by using colors unsuited for conditions which develop during molding operations.

5. Solvents used with molding resins may also be solvents for the coloring matter present and cause total or partial solution of the color which, in turn, tend toward color irregularities, i.e., lack of uniform coloring effect and other undesirable lack of uniformity in the finished, molded product. This is particularly true when toners or lake pigments are used.

The coloring of plastics is divided into two parts:

1. Surface coloring — after molding, casting or laminating. Done with dyestuffs dissolved in water or in organic solvents or in a mixture of both.
2. Coloring in the mass — uniform dispersion or solution of coloring matter throughout the plastic before or during the process of film formation, molding, casting or laminating.

A definite relationship exists between the solubility of the coloring matter and its applicability with the plastic.

TABLE 45. COLORS FOR PLASTICS

Classifications of Table 45

Pigments and Lakes which are practically insoluble in water and common organic solvents.
Oil-soluble Dyes (soluble in hydrocarbons). (Fair to good solubility in alcohol.)
Spirit-soluble Dyes (practically insoluble in hydrocarbons).
Water-soluble Dyes.

KEY TO SYMBOLS

a **indicates: generally suitable.**
b **indicates:** suitable for special application or for special purposes.

* indicates: readily water-dispersible. See Group 1.
** indicates: fair to good solubility in alcohol. See Group 4.

Pigments and Lakes

	Resins								Cellulose Plastics			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
Yellows												
Helio Fast Yellow 6GL Lumps	a	a	a	a	a	a	a	a	a	a	a	b
Hansa Yellow 10GD Powder	a	a	a	a	a	a	a	a	a	a	a	b
Hansa Yellow 5GD Powder	a	a	a	a	a	a	a	a	a	a	a	b
Hansa Yellow GAD Powder	a	a	a	a	a	a	a	a	a	a	a	b
Hansa Yellow TRAN Powder	a	a	a	a	a	a	a	a	a	a	a	b
Hansa Yellow 3RA Powder	a	a	a	a	a	a	a	a	a	a	a	b
Lithol Yellow GTR Powder	a	a	a	a	a	a	a	a	a	a	a	b
Lithol Yellow GGA Powder	a	a	a	a	a	a	a	a	a	a	a	b
Tapestry Printing Bright Yellow GG*	—	—	—	—	—	—	—	—	—	—	—	—
Orange												
Hansa Brilliant Orange RR Powder	a	a	a	a	a	a	a	a	a	a	a	b
Lithol Fast Orange RLD Powder	b	b	b	b	b	b	b	b	b	b	b	b
Permanent Orange GA Powder	a	a	a	a	a	a	a	a	a	a	a	b
Vulcan Fast Orange GRN	a	a	a	a	a	a	a	a	a	a	a	b
Tapestry Printing Orange Y*	—	—	—	—	—	—	—	—	—	—	—	—
Reds												
Permanent Red 3GA Extra Conc.	b	b	b	b	b	b	b	b	b	b	b	b
Permanent Red GGA Extra	b	b	b	b	b	b	b	b	b	b	b	b
Helio Red RMTA Powder	b	b	a	b	a	b	b	b	b	b	b	b
Helio Fast Scarlet ARD Powder	a	a	a	a	a	a	a	a	a	a	a	b
Phenoform Scarlet T	a	a	a	a	a	a	a	a	a	a	a	b
Permanent Red FRL Extra Powder	a	a	a	a	a	a	a	a	a	a	a	b

TABLE 45. (*Continued*) — PIGMENTS AND LAKES

	Resins								Cellulose Plastics			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
Permanent Red FRLL Extra Powder	a	b	a	b	b	b	b	b	b	b	b	b
Permanent Red F4R Extra Powder	a	a	a	a	a	a	a	a	a	a	a	b
Permanent Red F4RH Extra Powder	a	a	a	a	a	a	a	a	a	a	a	b
Permanent Carmine FB Extra Powder	a	a	a	a	a	a	a	a	a	a	a	b
Helio Fast Pink GL Extra New	a	a	a	a	a	a	a	a	a	a	a	b
Helio Fast Pink RLA Powder	a	a	a	a	a	a	a	a	a	a	a	b
Lithol Rubine BKD Powder	b	b	a	b	b	b	b	b	b	b	b	b
Lithol Red RA Powder New	b	b	a	b	b	b	b	b	b	b	b	b
Lithol Red RB Powder	b	b	a	b	b	b	b	b	b	b	b	—
Helio Bordeaux BLA Special Powder	b	b	a	b	b	b	b	b	b	b	b	b
Vulcan Fast Red G Powder	a	a	a	a	a	a	a	a	a	a	a	b
Vulcan Fast Red BA Powder	a	a	a	a	a	a	a	a	a	a	a	a
Tapestry Printing Pink RL*	—	—	—	—	—	—	—	—	—	—	—	a
Tapestry Printing Scarlet GL*	—	—	—	—	—	—	—	—	—	—	—	a
Tapestry Printing Brilliant Pink RX*	—	—	—	—	—	—	—	—	—	—	—	a
VIOLETS												
Permanent Purple No. 62 Powder	—	—	—	—	—	—	—	—	b	—	—	—
Permanent Purple No. 419 Powder	—	—	—	—	—	—	—	—	b	—	—	—
Helio Fast Violet 4R Powder	a	a	a	a	a	a	a	a	a	a	a	b
Tapestry Printing Violet VR*	—	—	—	—	—	—	—	—	—	—	—	b
BLUES												
Permanent Marine Blue L Powder	—	—	—	—	—	—	—	—	b	—	—	—
Helio Fast Blue GG Powder	a	a	a	a	a	a	a	a	a	a	a	b
Heliogen Blue BKA Powder	a	a	a	a	a	a	a	a	a	a	a	b
Heliogen Blue GN Powder	a	a	a	a	a	a	a	a	a	a	a	b
Permanent Cerulean Blue No. 341 Powder New	—	—	—	—	—	—	—	—	b	—	—	—
Pigment Blue WNL	a	a	a	a	a	a	a	a	a	a	a	b
Heliogen Blue BWS Extra*	—	—	—	—	—	—	—	—	—	—	—	a
Heliogen Blue BWSN Powder*	—	—	—	—	—	—	—	—	—	—	—	a
Heliogen Blue GWS Powder*	—	—	—	—	—	—	—	—	—	—	—	a
GREENS												
Heliogen Green G Powder	a	a	a	a	a	a	a	a	a	a	a	b
Heliogen Green GWS Powder*	—	—	—	—	—	—	—	—	—	—	—	a
BLACKS												
Pigment Deep Black N Extra Conc. Powder	a	a	a	a	a	a	a	a	a	a	a	b
Tapestry Printing Black GN*	—	—	—	—	—	—	—	—	—	—	—	a

TABLE 45. *(Continued)* — OIL-SOLUBLE DYES (SOLUBLE IN HYDROCARBONS)

	Resins								Cellulose Plastics			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
YELLOWS												
Resin Yellow 5GA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Yellow 3GNL	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Yellow GA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Yellow GRA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Yellow RRA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Yellow 7G	b	b	b	b	b	b	b	b	b	b	b	—
Phenoform Yellow RS	a	a	a	a	a	a	a	a	a	a	a	—
Sudan Yellow GRD	a	a	b	a	a	a	a	a	a	a	a	—
ORANGE												
Resin Orange GRA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Orange RR	b	b	b	b	b	b	b	b	b	b	b	—
Resin Orange 4R	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Orange 5R	b	b	b	b	b	b	b	b	b	b	b	—
Phenoform Orange R	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Orange RA New	a	a	b	a	a	a	a	a	a	a	a	—
REDS												
Resin Red DMA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Red R	b	b	b	b	b	b	b	b	b	b	b	—
Resin Red BR	b	b	b	b	b	b	b	b	b	b	b	—
Resin Scarlet BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Rubin BBF	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Scarlet RN	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Red GGA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Red BBN	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Pink BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Pink FF3BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Pink RF	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Rubine 3BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Rubine BA	b	b	b	b	b	b	b	b	b	b	b	—
Phenoform Red 3G	a	a	b	a	a	a	a	a	a	a	a	—
Autol Brilliant Red BND	a	a	b	a	a	a	a	a	a	a	a	—
Autol Red RLPD	a	a	b	a	a	a	a	a	a	a	a	—

TABLE 45. (*Continued*) — OIL-SOLUBLE DYES (SOLUBLE IN HYDROCARBONS)

	Resins								Cellulose Plastic			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
Helio Oil Red G	a	a	b	a	a	a	a	a	a	a	a	—
Helio Oil Red R	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Red GG	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Red BBA	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Red 4BA	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Red B	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Red R	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Red 7B	a	a	b	a	a	a	a	a	a	a	a	—
VIOLETS												
Resin Violet R	b	b	b	b	b	b	b	b	b	b	b	—
Resin Violet 3RA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Red Violet RR	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Red Violet RNA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Violet BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Violet 6BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Purple D	b	b	b	b	b	b	b	b	b	b	b	—
Alizarine Irisol N Powder Solution in Oil	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Violet RR	a	a	b	a	a	a	a	a	a	a	a	—
BLUES												
Resin Blue GA Extra	b	b	b	b	b	b	b	b	b	b	b	—
Resin Blue BG Supra	b	b	b	b	b	b	b	b	b	b	b	—
Resin Blue BB	b	b	b	b	b	b	b	b	b	b	b	—
Resin Navy Blue 3RN	b	b	b	b	b	b	b	b	b	b	b	—
Resin Turquoise MG	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Navy Blue BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Navy Blue BRA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Navy Blue GTNA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Blue 3BF	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Blue BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Blue AF	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Blue FFRS Extra Conc.	b	b	b	b	b	b	b	b	b	b	b	—
Alizarine Sky Blue B Solution in Oil	a	a	b	a	a	a	a	a	a	a	a	-
Sudan Blue GA	a	a	b	a	a	a	a	a	a	a	a	—

TABLE 45. (*Continued*) — OIL-SOLUBLE DYES (SOLUBLE IN HYDROCARBONS)

	Resins								Cellulose Plastics			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
GREENS												
Resin Fast Blue Green BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Dark Green B	b	b	b	b	b	b	b	b	b	b	b	—
Alizarine Cyanine Green G Extra Solution in Oil	a	a	b	a	a	a	a	a	a	a	a	—
BROWNS												
Resin Fast Brown BTA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Brown 3RA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Brown 5RA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Dark Brown B	b	b	b	b	b	b	b	b	b	b	b	—
Phenoform Brown 5B	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Brown 3G	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Brown RRN	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Brown 3RX	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Brown BB	a	a	b	a	a	a	a	a	a	a	a	—
Sudan Corinth B	a	a	b	a	a	a	a	a	a	a	a	—
BLACKS												
Phenoform Black No. 2	a	a	a	a	a	a	a	a	b	b	b	—
Phenoform Black No. 3	a	a	a	a	a	a	a	a	b	b	b	—
Phenoform Black N	a	a	a	a	a	a	a	a	b	b	b	—
Sudan Blue Black B	a	a	a	a	a	a	a	a	a	a	a	—
Sudan Black BN	a	a	a	a	a	a	a	a	a	a	a	—
Sudan Black BT	a	a	a	a	a	a	a	a	a	a	a	—
Sudan Black G	a	a	a	a	a	a	a	a	a	a	a	—
Sudan Black RT	a	a	a	a	a	a	a	a	a	a	a	—
Resin Fast Black 3GA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Black GND	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Black BA	b	b	b	b	b	b	b	b	b	b	b	—
Resin Fast Black BTNA	b	b	b	b	b	b	b	b	b	b	b	—
Induline and Nigrosine Bases	b	b	b	b	b	b	b	b	b	b	b	—

TABLE 45. *(Continued)* — SPIRIT DYES (PRACTICALLY INSOLUBLE IN HYDROCARBONS)

	Resins								Cellulose Plastics			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
YELLOWS												
Azosol Fast Yellow CGG	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Yellow CG	b	a	b	a	b	b	b	b	b	a	a	—
Azosol Fast Yellow GR	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Yellow R	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Yellow RR	b	a	b	a	b	b	b	b	a	a	a	—
Auranine Extra	—	—	—	b	—	—	—	—	a	a	a	—
ORANGE												
Phenoform Orange G	a	a	b	b	b	b	b	b	b	b	a	—
Azosol Fast Orange GA	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Orange RR	b	a	b	a	b	b	b	b	a	a	a	—
REDS												
Phenoform Red G	a	a	b	a	b	b	b	b	a	a	a	—
Phenoform Red B	a	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Scarlet CG	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Scarlet CR	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Brilliant Red BA	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Brilliant Red BN	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Red CB	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Red BB	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Red BBNW	b	a	b	b	b	b	b	b	a	a	a	—
Azosol Fast Red BE	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Red 3B	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Pink B	b	a	b	a	b	b	b	b	a	a	a	—

TABLE 45 (*Continued*) — Spirit Dyes (Practically Insoluble in Hydrocarbons)

	Resins								Cellulose Plastics			Casein
	Phenolic		Urea	Actylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
Violets												
Phenoform Heliotrope No. 10	a	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Violet BB	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Violet R	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Violet RR	b	a	b	a	b	b	b	b	a	a	a	—
Blues												
Phenoform Blue R	a	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Blue GLA	b	a	b	a	a	b	b	b	a	a	a	—
Azosol Fast Blue BLA	b	a	b	a	a	b	b	b	a	a	a	—
Azosol Fast Blue HLD	b	a	b	a	a	b	b	b	a	a	a	—
Azosol Fast Blue 3G	b	a	b	a	a	b	b	b	a	a	a	—
Greens												
Phenoform Green A	a	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Green GG	b	a	b	a	b	b	b	b	a	a	a	—
Azosol Fast Green HL	b	a	b	a	b	b	b	b	a	a	a	—
Brown												
Cubana Brown R	b	b	b	b	b	b	b	b	a	b	b	—
Blacks												
Phenoform Black No. 1	a	a	b	a	a	b	b	b	a	a	a	—
Phenoform Black No. 11	a	a	b	a	a	b	b	b	a	a	a	—
Phenoform Black No. 12	a	a	b	a	a	b	b	b	a	a	a	—
Azosol Fast Black M	b	a	b	a	b	b	b	b	a	a	a	—
Japan Black MBGN (H-1617)	a	a	b	a	b	b	b	b	a	a	a	—
Spirit Nigrosine Jet	a	a	b	a	b	b	b	b	a	a	a	—

TABLE 45. (*Continued*) — WATER-SOLUBLE DYESTUFFS — BASIC

	Resins								Cellulose Plastics			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
Yellows												
Janus Yellow G**	b	b	b	b	b	b	b	b	b	b	b	b
Janus Yellow R**	b	b	b	b	b	b	b	b	b	b	b	b
Auramine DO Conc.**	b	b	b	a	b	b	b	b	a	a	a	—
Euchrysine GGA Conc.**	b	b	b	a	b	b	b	b	a	a	a	—
Orange												
Chrysoidine Y Extra**	b	b	b	a	b	b	b	b	a	a	a	—
Chrysoidine RRS**	b	b	b	a	b	b	b	b	a	a	a	—
Reds												
Safranine Y Extra Conc.**	b	b	b	a	b	b	b	b	a	a	a	—
Magenta BBS Extra Conc.**	b	b	b	a	b	b	b	b	a	a	a	—
Rhodamine 6GY Extra**	b	b	b	a	b	b	b	b	a	a	a	—
Rhodamine B Extra for Lacquer**	b	b	b	a	b	b	b	b	a	a	a	—
Janus Red BB**	b	b	b	b	b	b	b	b	b	b	b	b
Violets												
Methylene Violet 3RA**	b	b	b	b	b	b	b	b	a	a	a	—
Methylene Heliotrope Extra Strong**	b	b	b	b	b	b	b	b	a	a	a	—
Methyl Violet LA Conc.**	b	b	b	b	b	b	b	b	a	a	a	—
Crystal Violet API**	b	b	b	b	b	b	b	b	a	a	a	—
Ethyl Violet AX**	b	b	b	b	b	b	b	b	a	a	a	—
Ethyl Violet GGA Extra**	b	b	b	b	b	b	b	b	a	a	a	—

TABLE 45. *(Continued)* — WATER-SOLUBLE DYESTUFFS — BASIC

	Resins								Cellulose Plastics			
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	Casein
	Molding	Cast					Indene	Styrene				
BLUES												
Victoria Pure Blue BOA New**	b	b	b	b	b	b	b	b	a	a	a	—
Victoria Pure Blue BGO**	b	b	b	b	b	b	b	b	a	a	a	—
Rhoduline Blue 5BA Extra Conc.**	b	b	b	b	b	b	b	b	a	a	a	—
Rhoduline Blue 6GA Conc. New **	b	b	b	b	b	b	b	b	a	a	a	—
Rhoduline Sky Blue 3G Conc.**	b	b	b	b	b	b	b	b	a	a	a	—
Methylene Blue JFA**	b	b	b	b	b	b	b	b	a	a	a	—
Janus Blue GNA	b	b	b	b	b	b	b	b	b	b	b	b
GREENS												
Victoria Green Extra Conc. Fine Powder**	b	b	b	b	b	b	b	b	a	a	a	—
Brilliant Green Crystals**	b	b	b	b	b	b	b	b	a	a	a	—
Janus Green B**	b	b	b	b	b	b	b	b	b	b	b	b
BROWNS												
Bismarck Brown TSS Extra Conc.**	b	b	b	b	b	b	b	b	a	a	a	—
Bismarck Brown B Conc.**	b	b	b	b	b	b	b	b	a	a	a	—
Janus Brown R**	b	b	b	b	b	b	b	b	b	b	b	b
BLACKS												
Janus Black I**	b	b	b	b	b	b	b	b	b	b	b	b
Janus Black BA	b	b	b	b	b	b	b	b	b	b	b	b

TABLE 45. (*Continued*) — WATER-SOLUBLE DYESTUFFS — ACID, DIRECT AND MORDANT

	Resins								Cellulose Plastic			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
YELLOWS												
Fast Light Yellow D3GA**	b	b	b	b	b	b	b	b	a	a	a	a
Naphthol Yellow SXX New	—	—	—	—	—	—	—	—	—	—	—	a
Tartrazine C Extra	—	—	—	—	—	—	—	—	—	—	—	a
Metanil Yellow Extra Conc.**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Yellow G**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Yellow 3G**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Yellow 3GL-CF**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Yellow RA**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Yellow RR**	b	b	b	b	b	b	b	b	b	b	b	a
ORANGE												
Croceine Orange GN	—	—	b	—	—	—	—	—	—	—	—	a
Acid Orange N**	a	a	b	b	b	b	b	b	b	b	b	—
Acid Orange XX**	—	a	b	b	b	b	b	b	b	b	b	a
Fastusol Orange LF3G	—	—	b	—	—	—	—	—	—	—	—	a
Fastusol Orange L5GA	—	—	b	—	—	—	—	—	—	—	—	a
Alcofast Orange GGN Extra Conc.**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Orange GN**	b	b	b	b	b	b	b	b	b	b	b	a
REDS												
Pigment Rubine 3G	b	b	b	—	—	—	—	—	a	—	—	—
Brilliant Croceine 3BA Extra	—	—	b	—	—	—	—	—	—	—	—	a
Carmoisine BA Conc. New	—	—	b	—	—	—	—	—	—	—	—	a
Fast Light Red BA**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Red 3BA**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Red BBLA**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Red GGA New**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Red B**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Red GL-CF**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Bordeaux BA**	b	b	b	b	b	b	b	b	b	b	b	b
VIOLETS												
Acid Violet 6BNOO*	a	a	b	b	b	b	b	b	a	a	a	—
Acid Violet 4RD**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Violet 3RA for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Violet 3RB for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a

TABLE 45. (*Continued*) — WATER-SOLUBLE DYESTUFFS — ACID, DIRECT AND MORDANT

	Resins								Cellulose Plastics			Casein
	Phenolic		Urea	Acrylic	Vinyl	Alkyd	Cumarone		Nitrate	Acetate	Ethyl	
	Molding	Cast					Indene	Styrene				
Fast Violet D for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Violet Powder CF for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Orchid B-CF	—	—	b	—	—	—	—	—	—	—	—	a
Alcofast Violet R**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Acid Violet R**	b	b	b	b	b	b	b	b	b	b	b	—
Fast Acid Violet B**	b	b	b	b	b	b	b	b	b	b	b	—
Fast Acid Violet 10BD Conc.**	b	b	b	b	b	b	b	b	b	b	b	—
BLUES												
Neptune Blue BRA Conc.**	b	b	b	b	b	b	b	b	b	b	b	—
Fast Blue BL Conc. New for Plastics	—	—	b	—	—	—	—	—	—	—	—	a
Fast Blue A for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Blue B for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a
Heliogen Blue SBLA	—	—	b	—	—	—	—	—	—	—	—	a
Alcofast Blue FB**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Blue RA**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Pure Blue BL-CF**	b	b	b	b	b	b	b	b	b	b	b	—
Alcofast Pure Blue GL**	b	b	b	b	b	b	b	b	b	b	b	—
GREENS												
Alcofast Green G**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Green G Extra New for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Green 3G-CF for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a
Fast Green 5G-CF for Plastics**	b	b	b	b	b	b	b	b	b	b	b	a
BROWNS												
Alcofast Brown G**	b	b	b	b	b	b	b	b	b	b	b	a
Alcofast Brown R**	b	b	b	b	b	b	b	b	b	b	b	a
Direct Fast Brown M New	—	—	b	—	—	—	—	—	—	—	—	a
Guinea Brown GRL**	b	b	b	b	a	b	b	b	b	b	b	—
Monochrome Brown BC Conc.**	b	b	b	b	b	b	b	b	a	a	a	—
BLACKS												
Naphthylamine Black 10BR Conc.	—	—	b	—	—	—	—	—	—	—	—	a
Nigrosines	—	—	b	—	—	—	—	—	—	—	—	a
Alcofast Black BRA Extra**	b	b	b	b	b	b	b	b	b	b	b	a

RAW MATERIALS ENTERING INTO THE MANUFACTURE OF PLASTICS

Preparation of Phenols. Phenol is prepared either by the fractional distillation of coal tar, or synthetically. The product obtained from coal tar is usually cheaper, but the phenol may be contaminated with cresols and xylenols which distill with it. Since these react chemically in much the same way as phenol, and form similar resins, their presence does not interfere with the use of the phenol for plastics.

When the price of phenol from coal tar rises too high, one of various synthetic types of phenol can be substituted. An older method involves the preparation of sodium benzene sulfonate by agitating benzene with an excess of sulfuric acid, above room temperature to effect sulfonation, liming out the sulfuric acid with calcium oxide or hydroxide, filtering, and treating with sodium carbonate to convert the calcium benzene sulfonate to sodium benzene sulfonate. The calcium carbonate precipitates and can be filtered out. The sodium benzene sulfonate is crystallized and fused with sodium hydroxide to yield sodium phenolate. When the melt is dissolved in water and the solution acidified, phenol separates out and can be purified by distillation.

A more recent method is the preparation of phenol from chlorobenzene. The chlorobenzene is heated with concentrated sodium hydroxide solution to 350° to 380° C. (662° to 716° F.) under a pressure of 5000 lb. per sq. in. Some diphenyl ether is added as a catalyst, and the reaction takes place in a continuous tubular system of copper. Under these conditions, the ONa group replaces the chlorine, and sodium phenolate is formed. Acidifying produces phenol. If the conditions of the reaction are varied somewhat, ortho and para hydroxydiphenyl are formed.

A still more recent method is to treat benzene in the vapor phase, with or without a catalyst, with not more than one molecular equivalent of oxygen, under at least ten atmospheres pressure. The reaction is carried out in an autoclave at temperatures of 300° to 400° C. (572° to 752° F.). Under these conditions benzene is oxidized directly to phenol.

A process,[4] invented in 1930 by Dr. W. Prahl and Dr. Wm. Mathes of the Dr. F. Raschig G.m.b.H. of Ludwigshafen a/Rh, Germany, functions in two catalytic vapor-phase stages.

In the first, benzene is chlorinated with hydrochloric acid and air, in the presence of a catalyst, with the production of monochlorobenzene. In the second, monochlorobenzene is hydrolized with water, in the presence of a catalyst, with the production of phenol and hydrochloric acid.

The first-stage reaction proceeds at about 230° C. (446° F.), is exothermic, and is represented by the following equation:

$$C_6H_6 + HCl + \tfrac{1}{2}O_2 = C_6H_5Cl + H_2O$$

Since about 10 per cent of the benzene is converted in one pass through the catalyst, since small quantities of polychlorobenzenes are formed, and since a trace of oxidation takes place, the actual products of the first-stage reaction are: C_6H_6, C_6H_5Cl, polychlorobenzenes, CO_2, CO, N_2, and H_2O, so that several orderly steps are required to effect the separation and recovery of the products of the reaction. This is accomplished by continuous fractional condensation whereby the chlorinated benzines

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[4] Durez Plastics and Chemicals, Inc.

and part of the unreacted benzene are collected in liquid form for the separate recovery, by continuous fractional distillation, of benzene, monochlorobenzene, and a mixture of the polychlorobenzenes. A part of the balance of unreacted benzene vapor is condensed for reuse in a final condenser, while the remainder is recovered by scrubbing the tail gases with an organic absorbing liquid from which benzene is continuously distilled and condensed for reuse.

In practice, the first-stage system operates by drawing the reactants in the vapor state, at slight negative pressure, in succession through contact chambers, a fractional condensing tower, and a final condenser. When and as conversion to form first-stage products takes place, these products condense and are removed from the fractional condenser, which operates at a temperature slightly above the boiling point of benzene. The benzene vapors which pass from the fractional condenser are then condensed and recovered from the final condenser and tail gas recovery system.

The second-stage reaction proceeds at about 425° C. (797° F.), is endothermic, and is represented by the following equation:

$$C_6H_5Cl + H_2O = C_6H_5OH + HCl$$

Since but about 10 per cent of the monochlorobenzol is converted in one pass through the catalyst, since more water is present than given by the equation, and since traces of side reaction products are formed, the actual products of the second-stage reaction are C_6H_5OH, HCl, H_2O, oxydiphenyl and diphenyl ether, so that several orderly steps are required to effect the separation and recovery of these products. By heat interchange between the sensible heat of the products of the reaction and the azeotropic vapor mixture of the reactants, the products are first cooled to about 200° C. (392° F.) and then further cooled in a fractional condenser by being required to vaporize a liquid mixture of the reactants. Next, by further fractional condensation, a water solution of HCl (15 per cent), and containing about 5 per cent of the phenol formed, is condensed and recovered. Leaving the fractional condenser the vapors contain about 95 per cent of the phenol formed, together with all the azeotropic mixture of the reactants, and from which the phenol is dissolved by scrubbing with hot water under temperature conditions such that the azeotropic vapor mixture of the reactants remains in the vapor state to be later heated to reaction temperature and passed through the second-stage contact chambers.

The products of the second-stage reaction are thus collected in the form of a recovered HCl solution (15 per cent), containing dissolved phenol and a water solution of phenol. These phenol solutions are separately extracted by benzene in continuous countercurrent fashion, which extraction step constitutes the entry point for the benzene required in the first-stage reaction. After benzene extraction to remove phenol, the recovered HCl solution passes to HCl vaporizers to supply that reactant of the first-stage reaction while the extracted water solution of phenol is reheated, stripped of benzene, which is condensed and recovered, and then cycles back to the phenol scrubber to absorb more phenol.

The combined benzene-phenol solutions from the extraction steps pass to a continuous fractionating still. The distillate from this column delivers benzene vapor to constitute that reactant of the first-stage reaction, while the out-flow from this column consists of crude phenol (97 per cent) which is subsequently recovered in pure state by continuous vacuum distillation.

In practice, the second-stage system operates by cycling the reactants in the vapor state, at slight negative pressure, in succession through contact chambers, heat interchangers, a vapor superheater, a fractional condensing tower, and a scrubbing tower. When and as conversion to form second-stage products takes place, these products condense and are collected from the fractional condenser and the scrubbing tower. Throughout the second-stage system, efficient heat interchange principles are utilized to avoid condensation and re-evaporation of the reactants, and to utilize the sensible heat of the products of the reaction.

Preparation of Formaldehyde. Formaldehyde may be prepared industrially by the direct union of carbon monoxide and hydrogen in the presence of a catalyzer,

$$CO + H_2 \longrightarrow HCHO$$

or by the oxidation of methyl alcohol by passing a mixture of the vapors of methyl alcohol and air through a tube containing copper gauze kept at the desired temperature.

Synthetic methanol is also prepared from carbon monoxide and hydrogen by the use of a catalyst — usually a mixture of zinc oxide and finely powdered copper (produced by reducing cuprous oxide, Cu_2O, by hydrogen).

Preparation of Sulfuric Acid. The concentrated sulfuric acid of commerce is usually prepared by the contact, or catalytic, process in which sulfur dioxide produced by burning sulfur or pyrites in air is oxidized catalytically to sulfur trioxide, which is absorbed in a spray of concentrated sulfuric acid to form pyrosulfuric acid, which can then be diluted with water.

The sulfur dioxide gas first produced is purified by being freed from dust, washed with water, and dried by passing upward through a tower filled with quartz or coke, with concentrated sulfuric acid trickling down it. Arsenic compounds are removed by passing the gas over ferric oxide. The purified sulfur dioxide gas is mixed with air and heated to about 750° C. (1382° F.) in a regenerator by the use of the heat liberated by the oxidation of sulfur dioxide to the trioxide in the contact tower containing the catalyst. At this temperature the reaction is swift but not complete, so it is then completed (99 per cent) in a separate chamber at about 400° C. (752° F.).

The sulfur trioxide, or fine droplets which can be bubbled through water without dissolving, can be absorbed by sulfuric acid to form pyrosulfuric acid,

$$SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$$

and the pyrosulfuric acid diluted to form sulfuric acid,

$$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$$

The catalyst first employed was finely divided platinum, but because this is expensive and has a tendency to be " poisoned " by arsenic and other impurities, other catalysts have been developed, such as ferric oxide mixed with cupric oxide, or mixtures containing vanadium oxide — nearly immune to poisoning.

Preparation of Nitric Acid. Nitric acid is usually produced commercially either by heating a nitrate with sulfuric acid or catalytically from ammonia.

In producing the acid from nitrates, the nitrate and acid are heated in a cast-iron retort holding several tons, the vapors condensed in a water-cooled condenser, forced to pass up through a tower loosely filled with coke or stoneware, and dissolved by a spray of water.

In producing the acid from ammonia, a mixture of ammonia and air is passed quickly over a catalyst such as finely divided platinum or platinum gauze at 750° to 1000° C. (1382° to 1832° F.). Much of the ammonia is oxidized to nitric oxide, which then combines with more oxygen to form nitrous dioxide, which reacts with water to yield nitric acid (if excess oxygen was used) or a mixture of nitric and nitrous acids.

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O \quad \Delta H(25°C.) = -217{,}000 \text{ calories}$$

$$2NO + O_2 \rightleftharpoons 2NO_2$$

$$2NO_2 + H_2O \rightleftharpoons HNO_3 + HNO_2$$

Preparation of Ammonia. Ammonia may be produced either from the direct union of nitrogen and hydrogen, as by the Haber process, or indirectly from limestone, coke, and nitrogen by the Cyanamide process.

The Haber process, which is on the whole cheaper, involves the use of a mixture of hydrogen (from water gas) and nitrogen (from liquid air) under pressures as high as 1000 atmospheres and in the presence of a catalyst, subjected to the action of electric sparks. A mixture of iron and molybdenum makes a satisfactory catalyst, and the compressed gases are passed through chrome steel bombs containing the catalyzer. The ammonia produced is removed by being liquefied and the unchanged gases are again brought in contact. If a considerable excess of hydrogen is used, the reaction is most nearly complete.

A mixture of nitrogen and hydrogen in the right proportions for the synthesis of ammonia can be obtained by passing a mixture of steam and air over white-hot coke, the carbon monoxide so formed being readily removed.

In the Cyanamide process, limestone is first reduced by coke to calcium carbide in an electric furnace. The calcium carbide is then heated to about 800° C. (1472° F.—white heat), at which temperature a stream of nitrogen obtained from liquid air is passed over it, forming calcium cyanamide.

$$CaC_2 + N_2 \longrightarrow CaNCN + C$$

The calcium cyanamide is then heated in autoclaves by high pressure steam to about 800° C., when it breaks down into calcium carbonate and ammonia.

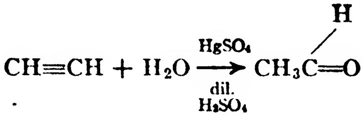
$$CaNCN + 3H_2O \longrightarrow CaCO_3 + 2NH_3 \uparrow$$

Preparation of Hexamethylenetetramine. Hexamethylenetetramine is obtained by evaporating a mixture of an aqueous solution of formaldehyde and ammonia. It is a crystalline solid, used in medicine under the name urotropine.

$$6HCHO + 4NH_3 \longrightarrow (CH_2)_6N_4 + 6H_2O$$

Preparation of Acetic Acid. Since it is expensive to concentrate the dilute solution of acetic acid known as vinegar, obtained by oxidation of alcohol on exposure to air and the action of " mother of vinegar," two other methods are used to produce concentrated acetic acid for chemical processes. In the older method, acetic acid is obtained as a by-product in the destructive distillation of wood. In the production of methyl alcohol or " wood alcohol," the acetic acid is converted to calcium acetate by neutralizing the crude " pyroligneous acid " with lime. Evaporating the solution leaves the crystalline salt which, on heating with sulfuric or hydrochloric acid, yields acetic acid as a distillate. Further purification can be effected by fractional distillation.

The newer commercial method is the synthesis of glacial acetic acid from acetylene by the intermediate production of acetaldehyde. The acetylene is passed into a vigorously agitated suspension of mercuric sulfate in dilute sulfuric acid, at a temperature slightly above room temperature, and the acetaldehyde so formed distills as rapidly as it is formed.



$$CH\equiv CH + H_2O \xrightarrow[\text{dil. } H_2SO_4]{HgSO_4} CH_3\overset{H}{C}{=}O$$

The acetaldehyde may then be oxidized by air, as by mixing the aldehyde with some acetic acid, suspending some metallic oxides in the solution as catalysts, and blowing air through the mixture.

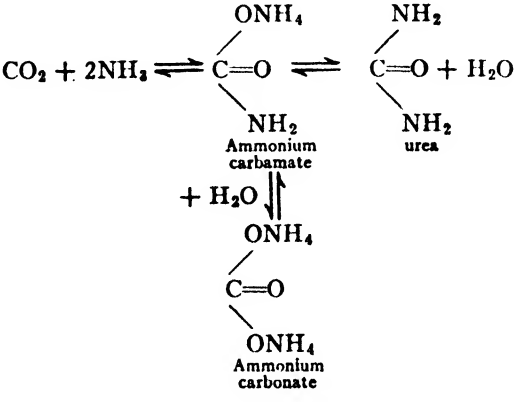
$$2CH_3CHO + O_2 \longrightarrow 2CH_3COOH$$

To trace this synthesis farther back: acetylene (source of the acetaldehyde) is prepared by the reaction of water with calcium carbide, which is in turn prepared by heating lime and coal in an electric furnace.

Preparation of Acetone. Acetone is now prepared by a special type of fermentation, and is considered a by-product of the butyl alcohol industry.

The fermentation of cornstarch by a special bacillus brings about the formation of carbon dioxide, gaseous hydrogen, acetone, and normal butyl alcohol. The carbon dioxide and hydrogen are utilized to prepare methyl alcohol, first reducing the carbon dioxide to the monoxide and then combining the gases catalytically under pressure.

Preparation of Urea. Urea is prepared industrially by heating carbon dioxide and ammonia under pressure. A series of reversible reactions is involved, as indicated by the following equations. Exact control of the temperature and pressure is therefore important and a good yield is obtained only under special conditions.



Preparation of Glycerin. Glycerin, or glycerol, is a by-product of the manufacture of the fatty acids, or their salts, the soaps. It is formed when a fat is boiled with sodium hydroxide until a thick mass is formed which on dilution forms a clear solution.

Sulfuric acid added to this mixture precipitates fatty acids, notably palmitic and stearic acids which are insoluble in water. Evaporating the water solution leaves a viscous, high-boiling clear colorless liquid — glycerol — together with the sodium sulfate formed when neutralized by sulfuric acid.

Glycerin may also be prepared by fermenting sugar by yeast under special conditions — an alkaline preparation, with sodium bisulfite added during the fermentation. During World War I, the fermentation process was widely used in Germany.

Preparation of Acetic Anhydride. Acetic anhydride is prepared industrially by the action of sulfur chloride on acetic acid or sodium acetate.

CHAPTER VI

PLASTICS MATERIALS

ACRYLIC RESINS

Molding Compounds. Methyl methacrylate molding powder is offered in various granulations and in soft and hard compositions for injection and compression molding. It is sold in crystal clear and in many translucent and opaque colors, including delicate pastel shades. Various percentages of plasticizers alter the mechanical and thermal properties, reducing hardness and increasing thermoplasticity.

Bulk density of the molding powder is about 10 gm. per cu. in., lighter than any other molding powder now in general use. The compression ratio is approximately 2 to 1, and molded objects shrink 0.0025 to 0.005 in. per in. of molded section upon cooling. Owing to the absence of residual solvents, however, there is practically no shrinkage in the finished fabricated articles. The finished articles are not discolored by aging or sunlight, negligibly affected by ultra-violet rays (which are transmitted by the clear plastic), and resistant to weathering.

Moldings are resistant to moisture, alkalies, oils, dilute acids and dilute alcohol. Moldings of the "hard" powder will not resist alcohol in excess of 25 per cent and are attacked by ethyl ether. They are readily dissolved by lower ketone and ester solvents, and mixtures of aromatic hydrocarbons with small amounts of alcohols. Moldings from powders containing plasticizers and lubricants are not so resistant as the pure cast materials.

The molding temperature for one grade of the soft type of molding powder is 285° to 295° F., and for a hard type 300° to 315° F. Too high a temperature produces heat marks, giving an "orange peel" surface. Care must be taken to eliminate bubbles in thick sections of a clear molding.

Molds for use with methyl methacrylate molding powders must be specially treated to produce molded articles with highly polished surfaces requiring a minimum of finishing operations. A lubricant incorporated in the resin prevents sticking to the mold, but if no lubricant is used, a very thin coating of olive oil, "Larol," or soap lather may be applied to the surface of the mold which is then wiped clean.

The same molding technique is used as for cellulose acetate molding powders. Compression molds of a positive or semi-positive type are employed, cored for direct heating and chilling. Molds of the flash type may be used where preforms are cut from solid materials and preheated by either wet or dry methods.

Acrylic molding composition is injection molded by the usual technique. The compression molding powder is distinctly different from the injection molding powder. Different types of molding powder are prepared, each to work at an efficient heating and cooling cycle under certain conditions of temperature and pressure.

The powder may be molded into articles completely clear and colorless. Sometimes in the manufacture of the molding powder it is desirable to modify the material with plasticizers and to produce various colors. In that case plasticizers, dyes, and pigments are either added to the monomeric substance dispersed in water or mixed with the finely divided polymer on hot rolls where the polymer softens to a dough and is then calendered off the rolls in sheets. The rough sheets are cut up and reduced to granular form suitable for molding.

Cast Acrylics. Monomeric methyl methacrylate is a clear colorless liquid with boiling point and specific gravity about the same as those of water.

In casting, the monomer is polymerized to a viscous sirup, and then mixed with an amount of catalyst adequate for the subsequent polymerization. The sirup is run into a mold, the filled mold is heated by a hot-water bath, and the solidified contents are afterward ejected as cast forms.

The plastic is crystal clear, light in weight, tough and durable, and flexible in thin sections. It may be cut, turned, sawed, drilled, polished, swaged, or formed. It takes lacquers and pyroxylin stains of the proper type, is not affected by alkalies, oils, dilute acids or dilute alcohols, and is resistant to moisture and the harmful effects of sun and outdoor exposure. It has the property of curving light. A rod, for instance, will carry light through its own curves.

It transmits ultra-violet light, is available in a number of transparent, translucent, opaque, and pearl color effects, is clearer than cast phenolic, not so brittle as polystyrene, and not so tough as the acetates and nitrates.

Cast sheets are available in various thicknesses and sizes up to 27 sq. ft. in area. Massive cylindrical casting 9 by 9½ in. and larger sheet sizes are available by special order. Rods are made ½ to 2 in. in diameter with a maximum length of 48 in. and tubes are made in varying wall thicknesses from ½ to 6 in. outside diameter.

Cast methyl methacrylate is more resistant to chemicals than the solid made from molding powder. The index of refraction is 1.48 to 1.50; the mean dispersion is 0.0088; dispersive power is 0.0174. Plates 2 in. thick transmit 88 per cent of light of 4300 to 7500 Angstroms.

The plastic may be cemented to itself or to pyroxylin plastics by various combinations of active solvents, but a specially prepared cement is recommended.

Cast rods to be bent should be placed in a heated oil bath consisting of a good grade of lubricating oil such as white mineral oil, and heated until the stock is soft enough to be bent without much force.

TABLE 46. HEATING TIME AND TEMPERATURE FOR BENDING ACRYLIC RODS

Regular Acrylic Rods

Rod Size, in.	*Temperature ° C.*	*Approximate Heating Time, min.*
⅜, ½, ⅝	120	15
¾ to 1	120–130	30
1–2	120–130	120 plus
	Boilable Acrylic Rods	
⅜, ½, ⅝	140	30
¾–1	140	60

Laminated Acrylics. Paper and cloth impregnated and laminated with acrylic monomers which are then polymerized find use in the electrical and food packaging industries. Laminated sheets have great possibilities in the aircraft field and in lamp shades. Laminated wood may also be prepared with this resin. Acrylic resin laminated materials may be used for electrical insulation. The first commercial use of acrylic resin was in the manufacture of safety glass, but it has since been replaced by the vinyls.

Sheets and Films. Sheets of the cast resin are available up to 45 by 65 in. in plain and formed shapes. The low density, lack of brittleness, clarity and stability to light adapt them for these uses. Sheets may be formed at a temperature of about 180° to 250° F. Foils are not commonly manufactured from this resin.

Extruded Forms. Acrylic resins may be formed by extrusion, and while other methods are more widely used at present, the trend is toward heavy tonnage production by this newer process.

Extruded rods are available up to 2½ in. in diameter and tubes up to 3 in. in diameter.

The rods leave the dies in highly polished condition requiring no further finishing. This is in contrast to polystyrene and acetate extruded rods which must subsequently be polished if clear finish is desired.

Coatings. Acrylic resins are used in protective coatings and in finishes for leathers. Solutions in organic solvents and aqueous dispersions are used to produce chemically resistant, air-drying enamels, baking enamels, and coating for metal and fabrics. Coating solutions may be brushed, sprayed, or dipped, and then baked. Adhesion to most surfaces is good. Baking is recommended to give a higher gloss, better adhesion, and a harder film.

Various grades and different types of preparation vary considerably in hardness, elasticity, and solubility, but all are water white and transparent, have good electrical resistance, adhesion and flexibility, and resist water, alcohol, alkalies, acids, mineral and vegetable oils and greases, most chemical fumes and weatherings.

Solutions of the resins in organic solvents, such as ethylene dichloride, ethyl acetate, and toluene, are used in surface coatings. The aqueous emulsions are used as coating for metals and finishes for leather.

The specific gravity of clear films is less than that of cellulose acetate, whereas the refractive index (1.48 to 1.49) is similar to that of cellulose esters.

Dried films show 91 to 92 per cent light transmission and do not discolor from age, sunlight, or air. Water absorption after 24-hr. exposure at room temperature in an atmosphere of 100 per cent humidity is practically zero. The electrical properties are favorable for use in insulating coatings. The films are flexible and extensible, sometimes showing an elasticity of 1000 per cent at room temperature, with a remarkable rubbery stretch before breaking.

The coatings resist dilute acids and alkalies better than nitrocellulose films and have good heat resistance, showing no decomposition at 334° to 392° F.

In the case of acrylic resins applied in solution in organic solvents, various solvents such as the following may be used as thinners or to introduce other materials: coal-tar hydrocarbons, chlorinated hydrocarbons, ketones, esters, ether alcohols, ether esters.

Acrylic resins are neutral and may be used with most pigments. Wetting characteristics and compatibility vary. Though some acrylic resins are incompatible with others, nitrocellulose is compatible with them all in any desired ratio if the proper solvent power is maintained. Certain types of cellulose acetate are compatible to a limited extent; benzyl cellulose is not compatible; ethyl cellulose is compatible with some types.

The customary plasticizers for cellulose ester films are readily compatible with acrylic resins: dibutyl phthalate, tricresyl phosphate, triacetin, etc. Drying oils and oleoresinous varnishes are incompatible. (See Coatings, Part II, also.)

Adhesives. Acrylic resins may be used as binders for wood, metal, glass, rubber, textiles and other materials. They show no bacterial or fungus deterioration and give a colorless, transparent bond. When dry they are elastic and extensible.

Solutions of the resins in organic solvents are used as undercoats in difficult adhesion jobs. In the making of safety glass no adhesive other than the resin film itself is necessary.

Impregnating Varnishes. Unpolymerized monomeric methyl methacrylate may be used to impregnate wood, cloth, wallboard, cork, paper, electrical coils, tile or stone, with as much as 60 per cent, and may then be polymerized to form the resin.

Aqueous dispersions of the resin are used to give a permanent finish to textiles. They give greater tensile strength and wear resistance to the impregnated fabrics. These do not require baking, are wash-fast, and give stiffness and body to the fabrics.

Solutions of the resins in organic solvents are also used for impregnating paper and textiles. Colloidal dispersions of acrylates in the absence of solvents or plasticizers give a fine permanent finish to textiles, with no embrittlement.

ALKYD RESINS

Coatings. Alkyd resins are primarily used as coating materials, the largest single outlet being for fender and body finishes in the automotive industry. They were first introduced into nitrocellulose lacquers to give better adhesion and diminish the porosity, but an all-resin lacquer was later developed, characterized by improved durability, retention of luster, and low cost, resulting from the use of cheap solvents in its formation. Varnishes and enamels made from alkyd resins modified by the addition of a drying oil to the reaction mixture may be either air-drying or baking types. The finishes are characterized by rapidity of drying, good gloss retention, excellent flexibility, and tenacious adhesion.

They are modified with mixed esters of rosin, vegetable oil, fatty acids, and plasticizing oils, such as castor oil, interesterified with polyhydric alcohols and polybasic acids. They may also be modified with phenol-formaldehyde-condensation products.

The modifying agents give internal plasticization, because the plasticizing structure is formed as an integral part of the resin molecule. This may largely eliminate the disadvantages of the use of an ordinary chemical plasticizer, which may be lost by evaporation, oxidation, or absorption. Alkyd resins are compatible with many other materials used in the varnish industry. Blended with phenol-formaldehyde or urea-aldehyde, they give great hardness without too great sacrifice in color. Water resistance also is improved by incorporating the heat-hardenable phenolic or urea resins.

Alkyd resins are used as coating for wood, metal, and materials of construction in general, give high gloss, good adhesion, good resistance to weathering, and long-life protection at a reasonable cost. They are used for primers, surfacers, colored enamels, air-drying brushing enamels, furniture finishes, and water emulsion paints.

An average alkyd resin might consist of 50 per cent glycerol phthalate, modified with 50 per cent oil, fatty acid, and natural or synthetic resin. This may be dissolved in such a solvent as coal-tar light oil — toluene, xylol, or a petroleum solvent and pigmented with titanium oxide or other pigment.

Such highly basic pigments as zinc oxide, carbonate white lead, whiting, and aluminum hydrate (all important in conventional finishes), may not be used in alkyd finishes.

Methods of application of alkyd resin coatings are: spraying, roll-coating, hot melt application, dipping, brushing.

Forms available are: oily, viscous drying type resins; oily, viscous, non-drying type resin-plasticizers; air-drying resins in solution form; non-drying resins in solution form; soft, sticky resins without solvent; hard, brittle resins without solvent; resins in aqueous emulsion form.

Alkyd-resin coatings retain their initial good appearance for a long time and have a quick drying and baking schedule.

The solubility of alkyd-type resins varies: those high in alkyd and low in oil constituent are as a rule soluble in aromatic hydrocarbons such as toluene or xylene but have limited solubility in aliphatic hydrocarbons such as petroleum thinners. Those with a high percentage of oil constituent are soluble in mineral thinners. The solvent used is determined by the factor desired in the finish, such as viscosity and solids content, whether finish is to be baked or air-dried and whether applied by spraying, dipping, roller coating, or brushing.

The resins are soluble in a wide range of solvents, such as chlorinated hydrocarbons; esters, such as butyl and ethyl acetate; ketones, and glycol ethers and their esters, such as Cellosolve and Cellosolve acetate. Turpentine is an excellent solvent for grades soluble in mineral thinner. As a rule, alkyd resins are insoluble in alcohols such as ethyl and butyl alcohol. Some proportion of butanol may be added to reduce the viscosity.

The viscosity when further thinned will depend on the solvent used. Aromatic hydrocarbons reduce the viscosity more than petroleum distillates. There is a marked difference in the effects of petroleum thinners of different solvent powers.

Two aqueous emulsions are offered. One contains 50 per cent solids and is a thick viscous paste, suitable for exteriors and interiors for the majority of uses. The other contains 40 per cent solids and is used where its slightly better drying speed, color, and brushing ease are preferred.

Compared with oil paints, alkyd aqueous dispersions have the following advantages: (1) easier application, (2) cleaner shades, (3) less dirt collection, (4) freedom from odor and dangers or organic solvents, (5) equal durability, and (6) may be applied on wet or damp surface.

Alkyd resin coatings from alkyd aqueous dispersions have the following advantages compared with most interior water paints: (1) better gloss and appearance, (2) easier application, (3) better washability, (4) less odor, and (5) better sealing.

Advantages compared with exterior water paints are: (1) better durability, (2) better appearance and gloss, (3) easier application, (4) do not stain on wetting, (5) do not require wetting of surface before application, (6) better sealing, and (7) better spreading capacity.

With all these advantages the fact remains that the alkyds, either in water dispersion or otherwise, find their chief market in interior wall decoration.

Molding Compositions. Alkyd resins are more important as coatings or finishes than as binders, but are used as binders for flake, powder, and split mica to produce insulation materials of good electrical strength. They are also used in the production of linoleum and gaskets. Conversion of the resin to the infusible state is slow, requiring days instead of the usual minutes required for the tar-acid and urea resins. The molded compositions flow under pressure unless the products have been well cured, and their hot strength suffers.

BENZYL CELLULOSE

Molding Compositions. Benzyl cellulose (ether of cellulose and benzyl alcohol) is a plastics raw material of which many things were expected, but it has few applications in plastics today, chiefly because of its low tensile strength.

It can be modified with suitable plasticizers to yield an injection molding powder for the production of articles requiring good water resistance and fair mechanical properties. As plasticizers, tricresyl phosphate, dibutyl phthalate, benzyl benzoate, and dibenzyl phthalate can be used, although only the last two are solvents at ordinary temperatures. Common solvents for benzyl cellulose are 80/20 xylene alcohol, 80/20 chloroform alcohol, cyclohexanone, and benzyl alcohol. The composition is thermoplastic, the molded forms are not very flammable, and they have good electrical properties. As an ether, benzyl cellulose has very high water resistance, the order of water resistance of the cellulose plastics running as follows: benzyl cellulose, celluose nitrate, ethyl cellulose, cellulose acetate.

CASEIN PLASTICS AND OTHER PROTEINS

Molding Compounds. Dried casein comes on the market as a white or yellowish crumbly powder that can be used for plastics molding after suitable grinding. There are several kinds of casein. Rennet is the type generally used for plastics industry.

Sheets and Films. Sheets of casein plastic are usually made by placing freshly extruded rods in frames of the desired size (usually 16 by 20 in.), and pressing them in heated hydraulic presses. They may also be extruded directly.

Sheets 16 by 20 in. are considered standard size and come in 2-, 3-, 4-, and 6-mm. thicknesses. Sheets up to 12 mm. thick and as thin as 1½ mm. are supplied on special orders. Sheets are hardened in formaldehyde and warp considerably. After hardening, they are straightened by heating between hot plates to soften them, pressed flat, and chilled.

Films can be produced from casein solutions and can be hardened and waterproofed by chemical treatment. One method that has been developed uses dried, de-greased casein, brought into colloidal suspension in an alcoholic dispersion liquid of low density and rapid evaporation rate by means of an alkaline salt. The solution is oxidized by hydrogen peroxide, and the alkaline caseinate is coagulated under controlled conditions by the addition of hexamethylenetetramine and poured in a thin layer on a smooth surface, yielding strong, impermeable films containing upward of 80 per cent casein.

Another method of producing transparent casein films is to prepare a 15 per cent solution of casein, filter it under high pressure to remove insoluble mineral salts, add glycerin as a plasticizer, and treat it with formaldehyde before or after coating on the base, and then dry it.

Sheets of protein material similar to casein are pressed from powdered blood albumen. This is treated with water at 65° to 70° C. (148° to 158° F.) for about 2 hr. Then articles are cut and pressed from the moist sheets and tanned with formalin.

Slicing sheets of the desired thickness from blocks of the soft plastic is an alternative method of producing sheets but is not in general commercial use. Disks, however, are commonly sliced from extruded rods.

Molded Forms. Pieces molded to shapes of varying dimensions and thicknesses cure more rapidly in thinner sections in the formaldehyde and will not retain the desired shape. This excessive warping has limited the use of casein for molding materials and the sale of casein molding powders. Granular casein for use in making the plastics is supplied.

Extruded Forms. The softened, kneaded casein mixture is fed into a heated cylinder press fitted with a rotating screw and a nozzle with a bore of the desired size for the production of tubes and rods. The strength of the plastic depends upon the mechanical working and macromolecular orientation of this procedure.

Extruded rods are available approximately 41 in. long and from ¼ to ⅝ in. in diameter, inclusive, in a large range of colors. Some colors are available in ¾-in. diameter. Rods as small as 1/16 in. in diameter are produced by grinding ¼-in. rod in a centerless grinder.

Extruded tubing is made to order in small diameters. The outside diameter is ground to the proper size, but the bore cannot be held to exact dimensions.

Disks may be cut to practically any size from ⅜ to 2½ in. in diameter and as a rule they are not cut thinner than 2 mm. or thicker than 6 mm. Miscellaneous shaped pieces punched from flat stock are also made to order for special fabrication.

All casein articles are hygroscopic and have a tendency to warp under varying conditions of humidity.

Sheets, rods, and tubes are hardened in aqueous formaldehyde of 4 to 5 per cent concentration. Excess moisture and formaldehyde are allowed to evaporate slowly to minimize the formation of strains and cracking. A ¾-in. rod takes 241 days to cure in formaldehyde. On this account rods of greater thickness are no longer made. A 1-in. rod requires a year for forming and drying. Only rods and slabs can be successfully produced on a large scale.

In 1929, Christensen patented the incorporation of a water-soluble aluminum salt in plastic casein to produce the harder, more easily machined product, alumi casein. Buttons ¼ to 2½ in. in diameter are now turned directly from this material into extruded form and, being thin, are hardened in 3 to 5 days.

Casein plastics come in all colors and may be given a fine dip polish by immersing them in sodium hypochlorite solution, which acts on the surface to produce a glaze. Casein articles are attacked by alkalies.

Many substances may be added to casein plastics to aid softening and transparency. It is desirable to use glycerin to the extent of 2 per cent of the weight of the casein, but tricresyl phosphate and methyl diphenylamine aid plasticizing and add transparency.

CASHEW NUT ALDEHYDE PLASTICS

A resin suitable for coatings, adhesives, fiber impregnation and brake linings is made by a phenol-aldehyde reaction with cashew nut shell oil liquid. This material emerged from the laboratory late in 1941 and possibilities of its commercial application are, therefore, still unknown. Successful use has been made of the material for sealing cable joints and for lining laboratory sinks.

Coatings. The reaction product of unfractionated cashew oil and formaldehyde hardens in the air, behaving in some respects as a drying oil. It is not subject to saponification, and varnishes and paints containing it are reported superior in alkali resistance. Hence it is useful for cement paints. Baking gives these coatings the additional properties of solvent resistance, of special importance for surfacing laboratory table tops and in the coating of paper liners in bottle caps. The film has a relatively high flexibility after baking.

In production it is necessary to refine the cashew nut oils to remove materials which are irritating to the skin, causing a rash which is similar to the rash of poison ivy.

When paraformaldehyde is used as a reactant in the polymerization of cashew nut shell oil, the resultant product is hard and somewhat brittle, but if hexamethylenetetramine is used, the product is tough and rubbery and may be milled and mixed with rubber in the manufacture of many metal-backed products such as typewriter platens. Owing to its superior oil resistance, this polymer when used as a blending agent gives greater oil resistance to natural rubber at a cost considerably less than the usual resistant synthetic rubbers. When the softer cashew plastic is calendered on cloth, it produces a so-called " rubberized " fabric that shows no signs of checking or aging at room temperatures.

CELLULOSE ACETATE

Molding Compounds. Cellulose acetate molding powder is furnished in various granulations and different formulas to suit specific molding requirements and finished material properties. It is available in translucent, transparent, and opaque colors, and in mottled and pearl effects and is well adapted to injection or compression molding or extrusion.

The molding powder is rarely preformed, though molding sheets and molding blanks are often used. More pressure is required to preform cellulose acetate than to preform phenolic compounds.

Cellulose acetate molding powder is prepared by first treating cotton linters with acetic anhydride and acetic acid in the presence of a catalyst and precipitating the cellulose acetate with water, after partially hydrolyzing or deacetylating it to the proper acetyl content. It is then washed and dried and mixed in a kneader with suitable plasticizers and with volatile solvents, such as acetone, until a colloidal jell-like mass is obtained. The plasticizers are required to obtain the desired plasticity characteristics of the material. The colloid is worked on heated converting rolls with dye or pigment and then rolled into sheets or slabs, which are taken from the rolls at specified thickness, seasoned at elevated temperatures, and either blanked out into molding forms or ground as required.

The molding compound is a solid solution of cellulose acetate in a plasticizer, and innumerable variations in its physical properties are possible by varying the kind and amount of the plasticizer used and the viscosity and solubility characteristics of the resin itself. The degree of plasticity may be controlled over a wide range.

The useful plastics compositions contain from 60 to 80 per cent of cellulose acetate. With an increase in the amount of liquid or softening plasticizers used, the tensile strength and hardness decrease, and the elongation, impact resistance, and cold flow increase. When solid plasticizers, such as triphenyl phosphate or sucrose octo-acetate, are used in place of part of the liquid plasticizer, the cold flow and elongation are decreased at the expense of the impact strength.

Besides their value as colloidal agents, the plasticizers are used to lower the melting point to a workable temperature and to improve properties such as water resistance, chemical resistance, and hardness.

The thermal properties are relatively unaffected by formulation. The specific heat and conductivity vary less than 10 per cent over a wide range of acetates and formulas Thermal expansion is about 50 per cent, becoming less for the harder plastics.

The cellulose acetate plastics are colored using a variety of coloring agents. In general, spirit-soluble and oil-soluble dyes are used together with organic lakes and toners as well as inorganic pigments.

The crystal or glass-clear plastics are tinted with minute amounts of soluble dye to impart a blue or purple tint in place of the slightly yellowish natural color of the plastic.

As many as seventeen or more different grades of acetate molding powders are available ranging from extra hard to extra soft. In general they are either hard, tough, and high in impact strength, or soft with a high degree of flow.

A special grade of cellulose acetate molding compound with a high acetyl content, which was put on the market recently, has been well accepted in the industry. It has superior water resistance, molds at slightly higher temperatures than the regular, resists warping, but is softer and has less impact resistance than the regular.

Cellulose acetate molding blanks are available from 5/32 to 1⅜ in. thick with a maximum area 20 by 25 in. The blanks, especially the small ones, are more accurately measured in grams and fractions of grams than by dimensional specifications alone. The weight serves as a check. If sample blanks are cut to size, the dimensions should be given and the minimum weight specified.

The minimum weight is 10 per cent more than the weight of the cellulose acetate in the finished piece (10 per cent flash), and a weight tolerance of 10 per cent must be allowed. Hence 15 per cent in excess of the weight of the finished piece must be ordered.

Laminated Forms. Cellulose acetate sheets and films may be laminated to produce decorative effects. Several patents have been taken on cellulose acetate sheets laminated to metal foil and embossed or stamped in a wide variety of patterns. One type is translucent, but light may be directed upon it to give the impression of opacity.

Films or foils may be laminated to produce thicknesses not usually available because of the limitations of the manufacturing process.

Sheets and Films. Sheets of cellulose acetate in various thicknesses are pressed from the orignal plastic mass. Small sheets of molding blanks are sliced from the thicker sheets and from pressed blocks of the material. Standard sheets are available 20 by 50 in. in maximum size, varying from 0.005 to 1 in. in thickness.

Sheets of cellulose acetate are sometimes used for airplane windshields or enclosures. At one time they were sandwiched between sheets of glass to make safety glass.

Thin sheets of cellulose acetate are used as transparent wrapping paper, and somewhat thicker strips are used as safety film for home and hospital use. By law, all amateur or educational movie film, usually 8 or 16 mm., is of this type. Commercial film is usually cellulose nitrate.

Packaging films run from 0.00088 in. in thickness to as thick as desired. The film will not shrink or stretch, is waterproof, germproof and greaseproof, and is unaffected by humidity or temperature changes. It presents a perfect surface for multicolor printing and can be cemented easily and firmly (a weld). It is nonflammable. The material may also be laminated.

Films and foils are made by casting a dope on a polished, moving surface. The volatile solvents are evaporated, and the resulting film is stripped from the support, dried, and wound into rolls. Films from 0.0005 to 0.010 in. thick may be made by this process.

Cellulose acetate dopes are used for casting films to make chicken-wire glass, transparent wrapping sheet, and electrical insulating sheet.

A typical dope for transparent wrapping sheet would comprise:

Medium viscosity type cellulose acetate	15
Triphenyl phosphate	2
Dimethyl phthalate	3
Acetone	60
Alcohol	10
Methyl Cellosolve	10

Sheets and Forms by Block Process. The plastic cellulose acetate mass may be rolled into sheets and baked, or it may be rolled and baked into a block from which sheets or other desired forms are sliced or cut.

If cut sheets are desired, slabs of the material taken from the rolls are stacked and pressed with the aid of heat into solid blocks about 22 by 52 by 6 in. The blocks are then sliced into sheets in thicknesses from 0.005 to over 1 in. The sheets are seasoned to remove residual solvents, and their surface is polished. Standard sheets 20 by 50 in., 0.05 to over 1 in. thickness are highly polished, matte finished, or embossed.

Although this process often results in striated marks or knife lines which cannot be completely removed by surface polishing, it is the method most commonly used in producing decorative sheets.

Molded Forms. Cellulose acetate is produced as molded sheets, rods, tubes, and special stock forms.

Extruded Forms. Slabs of cellulose acetate are taken from the rolls and cut into dice. After conditioning they are extruded in the form of rods and tubes by the aid of heat from hydraulic or screw machines. The residual solvents are removed by seasoning. Later the forms are ground and stretched to size. Rods and tubes are generally made to customers' specifications. Rods may range from 0.050 in. to over 2 in. in diameter; tubes have a minimum wall thickness of about 0.020 in.

Extrusion in screw type dry extrusion machines sometimes is done with acetate—more often with acetate butyrate.

Cellulose acetate extruded filaments go into the making of rayon yarn.

Coatings. Cellulose acetate lacquers are light-resistant and slow burning, have high gloss, hardness, heat resistance, high dielectric strength, toughness, tautening properties, and resistance to mineral oil, alcohol, and gasoline. They may be made into hard and rigid, or soft and flexible, coatings.

Cellulose acetate is made in four grades based on degree of acetylation: triacetate (or high acetyl), film, lacquer, and plastic. The low-viscosity type of higher acetylation has great compatibility, but the choice of solution for high acetyl types is limited, which in lacquers produces films affected by few solvents. The lacquers are used as coating for wallpaper, coating for textiles, leather finishing, making artificial leather, finishing high-grade furniture, coating metal foil, protecting containers, sealing bottles, making capsules, insulating tubing, and the like.

CELLULOSE ACETATE BUTYRATE

Molding Compounds. Cellulose acetate butyrate, a white flaky or granular material, is made up into molding compounds containing a relatively low percentage of plasticizer and containing plasticizers that have greater water resistance and lower vapor pressure than those used in cellulose acetate plastics.

Cellulose acetate butyrate flake and granulations suitable for making solutions are available in a number of types that vary in three ways: (1) total acyl content; (2) relative proportion of acetyl to butyryl; and (3) viscosity.

Cellulose acetate butyrate is thermoplastic, weather resistant, absorbs only about half as much water as cellulose acetate on continuous immersion, and is compatible with many plasticizers and resins.

A common cellulose acetate butyrate composition contains about 37 per cent butyryl and 13 per cent acetyl. The following plasticizers are commonly used: dibutyl phthalate, diamyl phthalate, triphenyl phosphate, tricresyl phosphate, dibutoxyethyl phthalate, dibutyl sebacate.

A much smaller quantity of plasticizer is required with cellulose mixed esters than with cellulose acetate. As the propionyl or butyral content is raised, less plasticizer is required, but compatibility with various plasticizers is greater.

Cellulose acetate butyrate molding compound is available in granular form for injection and compression molding and forming by continuous extrusion, and in sheet or blank form for compression molding only. The molding composition is suited to uses where resistance to distortion under heat and humidity and exposure to weather is desired. The composition is soluble in a wider range of solvents and compatible with more gums, resins, and plasticizers than cellulose acetate.

Coatings. This plastic may be used in lacquers and coating solutions of all descriptions, including airplane dopes, but its possibilities in this field have not been extensively explored. Gums and resins incorporated into a cellulose acetate butyrate lacquer improve its adhesion to metal, glass, and paper.

Extruded Forms. The butyrates are exceptionally well suited to dry extrusion which permits production in any desired length. The product is useful in interior decorating strips (moldings) and when extruded is sufficiently flexible to be bent around sharp corners. The extruded strands may be woven to form radio grilles or may be used to take the place of rattan in furniture making. Colorful furniture for outdoor use is made from this material. The strips are bright and shiny, with no jagged edges. Extruded strips may be flat, round, or of complicated shapes such as wallboard molding. See under Extrusion for further properties.

Adhesives. Cellulose acetate lacquer has some use as an adhesive, especially for fabrics and for sealing bottles.

Impregnating Varnishes. Cellulose acetate lacquers are used to impregnate paper and cloth.

CELLULOSE NITRATE

Molding Compounds. Cellulose nitrate is not well adapted to compression molding because its easy thermoplasticity makes necessary the chilling of the mold before the removal of the molded article. It cannot be used in injection molding presses because of its sensitivity to high temperatures.

Fundamentally, both of these disadvantages, commercially, are due to the difficulty of welding grains of the substances together by heat when only the usual proportion of plasticizer is present. If granules of ordinary cellulose nitrate plastic are molded by heat and pressure they may be made to form what appears to be a solid, homogeneous article, which can, however, be broken down readily into the original fragments. There is no strong weld or fusion between the particles, as there is with cellulose acetate, unless the proportion of plasticizer to cellulose nitrate is increased to such a concentration that the mass is soft and useless for practical purposes.

It is usually formed in blocks from which sheets are sliced but is also available in molding of simple shapes.

Laminated Forms. Cellulose nitrate sheets may be laminated to each other to produce decorative effects. Cellulose nitrate may also be used to laminate other sheet materials including leather, but has certain disadvantages as compared with other similar plastics.

Sheets and Films. Thin sheets and foils as thin as 0.003 in. are produced. Clear films tend to discolor, turning brownish.

Sheet material is compression molded at 160° to 220° F. with mechanical or hydraulic pressure. Sheets may be heated and stretched within the elastic limit and set by cooling to retain stresses which when released by reheating return the material to its original form. Veneering shafts, towel bars, strap hangers is effected as follows: A tube of the plastic is heated in boiling water and while hot is stretched over a metal mandrel and then plunged into cold water. The tube is then removed and placed over the article to be veneered, to which it is shrunk tightly by reheating in hot water or in an air oven.

Certain solvents soften cellulose nitrate without dissolving it, making it soft and pliable. Wooden heels and wooden toilet seats are veneered by softening nitrate sheets in a mixture of 80 per cent wood alcohol and 20 per cent water, then stretching them over wooden forms and allowing the sheets to dry and shrink tightly on the forms.

Sheets and Forms by the Block Process. Cellulose nitrate is mixed in a dough kneader with camphor and alcohol to a jelly-like mass. This is worked on heated converting rolls, temperature 150° to 175° F., with the addition of dyes or pigments to form homogeneous slabs which may be pressed with the aid of heat into solid blocks or extruded as rods and tubes. After having been formed into blocks by hydraulic presses, it may be sliced into sheets of any desired thickness from 0.005 to over 1 in. The sheets and tubes are then seasoned or cured at elevated temperatures to 90° F. to remove the volatile alcohol. The curing period is from 2 hours to 6 months, depending on the thickness of the stock. After seasoning, the material is surface finished in any one of a number of different effects, and is then ready to be fabricated into many articles.

Molded Forms. Cellulose nitrate is among the cheapest plastics and holds its place in spite of flammability and competition. It is not explosive or set off by percussion, but the plastic and its dust or vapors take fire when exposed to flame or spark and burn violently if the plastic has been dried. The flammability is considerably reduced, however, by increased purification to remove unstable by-products and the incorporation of fire-retarding plasticizers such as tricresyl phosphate or triphenyl phosphate.

The plastic may be readily cemented to itself by acetone, ethyl acetate, or butyl acetate, and to many other materials by body cements containing nitrocellulose, plasticizers, and solvents. This property is of advantage in simplifying the fabrication and assembly of many articles.

Cellulose nitrate is practically unaffected by hydrocarbons and chlorinated hydrocarbons, animal, vegetable, and mineral oils, and low concentrations of mineral acids at normal temperatures. It is decomposed by alkalies and acids in any appreciable concentration and dissolved or softened by many alcohols, ketones, and esters. It will absorb water with a slight change in volume from 1.5 to 3.0 per cent of its weight with slight softening and increased plasticity.

In the course of time, cellulose nitrate is decomposed by light and turns yellow and becomes brittle owing to the loss of camphor by sublimation. This has been overcome to a great extent by using dibutyl phthalate or tricresyl phosphate on a mixture of plasticizers. It has a high degree of toughness and flexibility.

Cellulose nitrate is manufactured in standard sheets in thicknesses from 0.003 to 1 in. and in sizes up to 20 by 50 in. Rods vary from 52½ to 60 in. in length and 1/16 to 2 in. in diameter. Tubes are from 30 to 60 in. in length, from ⅛ to 3½ in. in diameters, with a wide range of wall thickness in proportion to the diameter.

The plastic is practically unbreakable, inexpensive, easily worked, readily machined, swaged, blown, and formed. It can be shaped when heated. Practically every color is available, in transparent, translucent, mottle and opaque color effects. The average specific gravity is about 1.41. It can be fabricated by pressure at 160° to 220° F., and also by blowing by placing softened sheets in a mold and forcing air between them. Cutting, sawing, punching, drilling, drawing, turning, printing, embossing, and polishing may be done with ordinary tools, provided there is a stream of cold water running over the material while the cutting, sawing, punching, or drilling is being done.

Extruded Forms. Cellulose nitrates, unlike most thermoplastics, cannot be hot extruded. During the process of manufacture, however, it may be wet extruded continuously as tubes, rods, or sheets. Temperature while extruding should not be above 200° F.

Coatings. Cellulose nitrate in protective coatings lends toughness and quick drying at room temperatures. It is available in lacquers and in emulsions for the coating of paper, where it finds extensive use.

A form of mercurous chloride, incorporated into cellulose nitrate, cellulose acetate, or other plastic gives a pearly effect in molded articles or lacquers. Characteristic porcelain and vitreous enamel effects are produced economically in this manner for fixtures, scales, refrigerators, and other appliances. (See Coatings, Part II.)

Adhesives. Cellulose nitrate in a suitable solvent is used as a household cement. "Liquid Solder" consists of plasticized cellulose nitrate dissolved in suitable solvents and mixed with aluminum powder for a metallic appearance. Both solvents and dried plastic are highly flammable, and the adhesives should not be used for repairing kitchen utensils because heat decomposes them and water loosens them from metals.

CHLORINATED RUBBER

Molding Compounds. Chlorinated rubber is marketed as a white granular powder containing 65 to 68 per cent chlorine.

It is odorless, tasteless, nontoxic, nonflammable, incombustible, stable to dry heat up to 125° C. (256° F.).

Sheets and Films. A commercially produced form of chlorinated rubber is supplied as a white powder with a chlorine content of 65 to 68 per cent and is marketed especially for its valuable film-forming properties. It is soluble in a wide range of industrial solvents and is miscible with many common plasticizers. It can be formed into films comparable with those formed from cellulose acetate and nitrocellulose. It is nonflammable, insoluble in water, and resistant to chemicals.

Molded Forms. Chlorinated rubber has been molded into blocks and simple shapes in the laboratory, but not commercially as far as known.

It is thermoplastic and a dielectric and thus may find use in some branches of the electrical industry.

Coatings. Unpigmented films containing chlorinated rubber, like those of clear nitrocellulose lacquers, break down under direct outdoor condition but are more resistant when pigmented. Paints made with a variety of pigments show excellent protection for metal and may be polished to a good surface.

A film formed from a simple solution of chlorinated rubber is very resistant to chemical action but has poor adhesion, which is much improved by plasticizers. The chemical properties are dependent on the type and amount of plasticizers.

Chlorinated rubber varnishes containing drying oils and aromatic thinners may replace nitrocellulose lacquers for certain applications. In a paint, the chlorinated rubber is dissolved in a 2 to 1 mixture of high-flash naphtha and xylol to give a 30 per cent strength. The acid resistance of the paints is said to be excellent. When properly compounded they can be made to adhere satisfactorily to cement or metal.

Some disadvantages of the material are that it requires pigments to bring out its valuable properties; it tends to increase in brittleness especially when exposed to sunlight. However, chlorinated rubber paints may be applied by spraying, dipping, flowing, or brushing.

Impregnating Liquids. Chlorinated rubber solutions modified by plasticizers, pigments, etc., are used for the impregnation of fabrics for water and flameproofing.

COLD MOLDED BITUMINOUS

Molding Compounds. Cold-molding powders consist of (1) a filler, usually asbestos fibers together with minerals like talc, clay, slate flour, barytes, and the like (sometimes organic fillers such as wood flour), and (2) a binder, (a) bituminous, (b) resinous, or (c) refractory. It is now possible to distribute and market cold-molding powders, although finished articles are more generally sold.

Bituminous Materials. The bituminous binder consists of a varnishlike material made up of various percentages of oils (linseed, tung, castor, oiticica, fish, etc.), natural and synthetic resins (cumarone, indene, copal dammar, ester gum, etc.) and asphalts, gilsonite, steam-reduced and blown petroleum, together with stearine pitch or vegetable pitch.

A typical cold-molding powder of the bituminous type is as follows (U. S. Patent No. 1,671,230; all parts on a weight basis):

Binder (286 parts of this binder are to be used with the filler described)	Stearine pitch	40 parts
	Asphalt	60 parts
	Castor oil	10 parts
	Benzol	25–100 parts
Filler	Asbestos	1100 parts
	Sulfur	66 parts
	Iron oxide	22 parts

Other mixes use asbestos filler up to 80 per cent of total.

After proper aging, about 0.5 to 1 per cent of a lubricant such as a metallic stearate or a neutral soap is usually added to assist the molding operation. Linseed, tung, or fish oil may be used in place of castor oil. Gilsonite, steam-reduced or oxided asphalt, or mixtures of these, may be used wholly or in part to replace stearine pitch.

Driers such as naphthenates or rosin may be added. Other solvents such as mineral spirits, high-flash naphtha, or gasoline may be used in place of benzol to yield a predetermined viscosity requirement.

Molding is done at or near room temperature, usually in a single-cavity mold, pieces being removed and cured in either gas or electrically heated ovens of the air circulating type to drive off the volatile constituents, oxidize or polymerize the oils or resins, and so transform the plastic into a hard and infusible state.

These cold-molded bituminous compounds are used chiefly to mold heat-resistant articles, and their disadvantages are such that, when synthetic resin articles of the same heat resistance (such as phenolic resins with asbestos filler) can be produced to compare with them, the older type will probably be completely replaced.

Because of the presence of volatile solvents and drying oils in the cold-molding compositions, storage and conditioning prior to molding require close attention; hence preparation and molding are usually in the same plant.

Although the cold-molding pressing operation is faster than the hot compression, higher pressures are required, and the greater abrasive action of the mineral filler makes mold maintenance more of a problem. Usually, cold molding is confined to single-cavity molds so that total unit-press output is less than for hot molding where multiple-cavity dies are common.

Cold-molding bituminous materials give good heat resistance, low cost, and rapid molding cycles, but they require wide dimensional tolerance. Their use is limited chiefly to connector plugs on household electrical appliances, handles and knobs for cooking utensils, valve wheels, arc shields, battery boxes, and a few other special uses.

Resin Binder. The usual synthetic resin binder consists of a viscous A-stage phenolic resin of 17° to 18° Baumé gravity. The binder and filler (mostly asbestos) are first thoroughly mixed, then molded and pressed, and finally baked (shorter cycle than with the bituminous materials). The powders are somewhat unstable and must be pressed soon after mixing. The strength of the molded piece is superior to those bonded with bituminous materials. They are used chiefly for molding insulating articles.

Inorganic Binders (*refractory*). In the refractory type of cold-molded materials a binder of Portland cement (high early strength being preferred) lime, or silica is used, with a filler of asbestos, clays (plastic or china) or other mineral, and the proper amount of water to give sufficient flow and density to the piece when it is subjected to pressure in the mold.

Moldings made with Portland cement are usually hardened by soaking in water or in a humidity chamber, whereas those containing sand-lime are processed in steam autoclaves. To reduce the water absorption which may run from 10 to 12 per cent in the finished product, the batch is impregnated with materials such as ceresin, amorphous waxes, creosote or pitches such as coal tar. It is also possible to mix powdered cumarone-indene resin with the asbestos-cement-water mixture before molding. After curing in water this mixture is baked in the usual manner in gas or electric ovens. The resin flows and renders the product impervious to water. Articles impregnated with cumarone-indene resin, moreover, do not track (as do pitches) from the passage of an electric arc.

Like bituminous materials, refractory compounds are not marketed but are molded where they are mixed.

Cumarone–Indene

Molding Compounds. The use of cumarone-indene resins in molding articles is limited because of their brittleness and low tensile strength, but they find application as a modifier in various molding compositions.

Para-cumarone-indene resins are used as a flux with some of the vinyl resins to improve the milling and flowing qualities and to decrease the cost of the finished plastic without too greatly sacrificing its properties.

Cumarone-indene resins are also used in the manufacture of mastic floor tile, in which a thermoplastic binder is employed. The resin is plasticized with various selected pitches or specially processed oils to give a binder of satisfactory physical properties and light color. With it, mineral fillers, including those of the fibrous type and a smaller amount of granular material, and pigments are thoroughly blended on mixing rolls or other standard masticating equipment. When properly prepared the mix flows smoothly at temperatures above the melting point of the binder. Thorough wetting of the filler due to the fluidity of the binder during the mixing provides a dense plastic with good coherence. It is sheeted through rolls, polished, and then cut into standard sizes.

These resins are used to some small extent for making laminates but they are more commonly used as diluents or modifiers for many types of resins ordinarily employed in laminating.

Cumarone-indene resin is compatible with polystyrene, chlorinated rubber, benzyl cellulose, ethyl cellulose, some acrylic ester polymers and a few others. It is also used with heat-hardenable plastics.

Coatings. Cumarone-indene resins are used in varnishes to replace the higher priced natural resins and to some extent ester gum. Their application is somewhat limited by their short durability and lack of elasticity. However, they are neutral, nonoxidizing, and nonsaponifiable, and they impart to varnishes inertness and adhesion, high dielectric strength and shorter drying time than many natural resins. They cannot be used in nitrocellulose lacquers because they are incompatible with them. They are used in paper coatings, artificial leather, linoleum, oil cloth, shoe polish, and printing inks.

Because of their wide compatibility, they are used as a modifier and diluent. They are compatible with:

Waxes

Beeswax
Candelilla
Carnauba
Ceresin
Halowax
Japon
Lanolin
Opal
Spermaceti
Stearic acid

Natural Resins and Derivatives

Batu
Congo
Rosin
Rosin ester
Dammar
East India Elemi
Ester gum
Limed rosin
Lead resinate
Zinc resinate

Synthetic Resins

Alkyd
Chlorinated diphenyl
Methacrylates
Modified phenolic
Oil-soluble phenolic
Petroleum resins
Polystyrene
Some vinyl resins

Rubber

Balata
Chlorinated rubber
Chloroprene
Factice
Gutta Siac
Jelutong
Polysulfide
Resinified rubber
Rubber

Bitumens

Asphalt
Coal-tar pitch
Fatty-acid pitch
Gilsonite
Pine tar
Vegetable pitch

Cumarone and indene are polymerized catalytically or thermally under controlled conditions to yield resin solutions with average molecular size differing according to the melting point desired. When exposed in thin films to oxygen or air and ultra-violet light the resins of this group will undergo oxidation to some extent, resulting in yellowing.

The resins are soluble in all aromatic hydrocarbons and most of the better petroleum diluents up to the fraction boiling above 200° C. (392° F.). In general, the lower melting resins are more readily soluble in petroleum solvents. The resins are also soluble in various common vegetable and animal oils of commerce with the exception of castor oil. In most cases, raw oils are better solvents than bodied, blown, or oxidized oils. Most esters, aldehydes, ketones, and chlorinated hydrocarbons are also good solvents for these unmodified resins.

Solvents that will not dissolve these resins or will only partly dissolve them are alcohols, glycols, glycerol, water, castor oil, and similar hydroxylated compounds, phenol being an exception.

Rubber Compounding. After its use in varnishes, the next largest use for cumarone-indene resins is in rubber compounding. Their effect is to soften the rubber during the milling and to facilitate its handling on the rolls. They do not affect the aging qualities of the rubber and are used as a softener for reclaimed rubber as well as for the new.

They are extensively used as binders and tackifiers in rubber compounding in the automotive industry in tire compounds and for rubberlike resins such as Neoprene and Thiokol.

As a substitute for chicle, as much as 10 per cent of the resin may be incorporated in a chewing-gum mixture.

ETHYL CELLULOSE

Molding Compounds. Ethyl cellulose, the ether of cellulose and ethyl alcohol produced by the reaction of chloride or alkali cellulose, is a thermoplastic white granular powder producing moldings that are tough, lightproof, alkali-proof, acid resistant, flexible, and extensible.

Plasticizers and coloring materials are usually incorporated in the molding compound, but the material can be manufactured without the use of solvents since it can readily be compounded on rolls or in a masticator by the aid of heat. The absence of solvents makes seasoning unnecessary and permits the production in one-half hour of a composition ready for molding.

Zinc oxide is the preferred filler. Less filler is required than in the case of noncellulose plastics. The limit of zinc oxide to be added without sacrificing toughness in the plastic is 30 per cent by weight.

Wide ranges of coloring materials are used since ethyl cellulose will carry as much pigment as paint oils themselves. Other modifying agents commonly used are lubricants, oils, resins, and waxes.

Nearly all plasticizers are compatible with ethyl cellulose, but the following are the most useful: chlorinated diphenyl, aryl phosphates, various phthalates, tributyrin, sulfonamides, butyl stearate, Hercolyn (hydrogenated methyl abietate), phenyl ethers, and vegetable oils. A much smaller proportion of plasticizers is used than with cellulose acetate. The compression-molding mixtures require only 10 to 20 per cent of plasticizer, injection-molding mixtures 15 to 30 per cent, and compositions for flexible extrusions 25 to 50 per cent.

The final molding compound should carry 1 per cent of stearic acid or other stearate to prevent sticking to the molds. Ethyl cellulose is also compatible with rosin, ester gum, Novolacs, uncured phenolics, uncured ureas, cumarone-indene, Vinsol, polymerized cyclic ketones, linseed, cottonseed, soy bean and castor oil and various fatty acids. It is incompatible with polystyrene, vinyl esters, tung oil, or paraffin unless a third mutually compatible ingredient is present in considerable quantity.

The ingredients are mixed dry, rolled on standard friction mills or in a Banbury type masticator at 100° to 130° C. (212° to 266° F.). Usually about 5 minutes are required. If the temperature is too high the plastic will stick to the rolls. The homogeneous plastic is then rolled out in thin sheets and broken up by hand or with an impact pulverizer and then ground. This is the finished molding composition, ready to mold by compression, injection, or extrusion. Usually ethyl cellulose is sold as a white granular powder, unmodified.

Compression Molding. There is a short range of 10° C. between the point where knitting is perfect and where excessive heat causes the appearance of bubbles. Closed type molds help prevent bubbles. If the molding temperature is too low, there is a loss in clarity and toughness. Pieces discharged after cooling should not stick to the molds if enough lubricant has been used. Solvents may be used in compounding if desired, but heat alone is more satisfactory and more economical — especially for opaques.

Injection Molding. Ethyl cellulose is good for injection molding because of its fine thermoplasticity and stability under heat. It may be injected into a hot mold or one of comparatively low temperature.

Typical Compositions

1. For clear compression molding:

Ethyl cellulose	90 parts
Aroclar No. 1260	10 parts
Stearic acid	2 parts

2. For opaque compression molding:

Ethyl cellulose	80 parts
Triphenyl phosphate	10 parts
Dibutyl phthalate	10 parts
Zinc oxide	30 parts
Stearic acid	2 parts
Color	

3. For clear injection molding:

Ethyl cellulose	50 parts
Diethyl phthalate	4 parts
Triphenyl phosphate	2 parts
Camphor	5 parts
Stearic acid	1½ parts

4. Opaque injection molding:

Ethyl cellulose	75 parts
Sancticizer M 17	25 parts
Zinc oxide	30 parts
Stearic acid	2 parts
Color	

5. For flexible extrusions:

Ethyl cellulose	50 parts
Hercolyn	50 parts

Plasticizers Are Interchangeable. All clear compositions carrying more than one-half part of plasticizer to each part of ethyl cellulose have a tendency to cloud when immersed in water. When incorporated in molding materials of other types, especially at low temperatures, ethyl cellulose diminishes tackiness and improves toughness of most resins in which it is soluble.

Petroleum hydrocarbons are the only organic solvents that do not have a marked solvent action on ethyl cellulose.

Grades of ethyl cellulose are differentiated principally by the ethoxyl content. The higher the ethoxyl content, the more soluble, more compatible, and more water resistant the composition.

Ethyl cellulose molding powders are good for injection and compression molding and for forming by dry extrusion.

Sheets and Films. Ethyl cellulose is particularly adaptable for the production of rigid transparent sheeting because of its unusual flexibility, ductility, and toughness. Sheets are available in thicknesses up to 0.020 in. and are particularly well suited to fabrication, swaging, or drawing by high-speed automatic machinery.

Films and foils are available in the same thicknesses and up to 25 in. in width.

Coatings. Specially formulated ethyl cellulose compositions are suited to forming flexible coatings with high adhesion. See under Coatings, page 437.

It is used in varnishes to give toughness, diminish tackiness, and to speed up the drying rate, and in lacquers to give films of great flexibility and toughness. It is excellent in admixtures of nitrocellulose.

Used for leather finishing, it gives excellent, non-tacky, semi-waterproof, moisture-permeable coatings. It is easily worked into most wax emulsions and is suggested for leather adhesives. It is used for making patent leather, because of its flexibility at low temperatures, and as a coating or size for fabric and paper.

Other coating applications of ethyl cellulose are employed as a base for nail polish and as a non-adherent backing coat for adhesive tape. It is used in hot-melt compositions for application either as coatings or as printing inks. Ethyl cellulose compositions have been patented for making pigment chips, colored lacquers, and spirit printing inks.

Nonflammable cellulose ether lacquers are said to result from the use of salts of dimethyl phosphoric acid. Fabric printing with emulsion pastes of both pigments and soluble dyestuffs has made rapid progress. Cellulose ethers are useful as thickening agents of lacquer types of printing pastes for printing fabrics and textiles with pigmented lacquers.

Ethyl cellulose is used to body drying oils and to modify varnishes. Spirit varnishes are improved by incorporating small percentages of ethyl cellulose. Ethyl and benzyl cellulose compositions are about on a par with cellulose esters for aircraft fabric dopes.

FURFURAL

Molding Compounds. Furfural-phenol molding compounds for hot or cold molding usually are brown or black in color, though solid dark colors such as red, green, and yellow are obtainable.

When used as a binder for various fillers and molded, they produce homogeneous moldings that eject from the molds clean, bright, and shining. The color is brilliant, and accuracy of dimension combines with high speed of molding.

Recent experience seems to indicate that the furfurals are of importance for use with phenolics rather than for use alone. Most of the advantageous properties of the furfurals duplicate those of the phenolics, but the phenolics with furfural additions take on some new and interesting properties.

In making cold-molding compounds, furfural resins are used as modifying agents in large-scale production. Furfural is an excellent resin solvent, plasticizer, and hardening agent and is capable of resinification in itself. In preparing the cold-molding compound, the binder containing furfural is mixed with the various fillers until grain surfaces are thoroughly coated. This wet mix is then converted to a dry granular pourable mix. This may be done by lowering the temperature of the composition while it is in motion, solidifying and drying the resin which then may be poured into a mold, leveled, cold pressed, and subsequently cured.

In so-called furfural cold-molding compounds, the binder usually is a phenol-formaldehyde resin. The product has good properties and is used to produce electrical and mechanical parts.

For hot molding, the furfural resins have a restricted flow but otherwise the molding is carried on very much as with phenolics. Unconfined molding of a furfural-phenolic combination is used for flat sheetlike work where the ornamentation varies with every few pieces and the mold offers little compression resistance, as in making printing plates, embossing plates, and flat ornamental products.

The matrices are usually metal faced and backed with non-yielding synthetic resins. The pulverized fusible resin is applied to the face, and heat and pressure are employed for about 2 min. The excess resin flows laterally through the unconfined openings.

Furfural resins were among the first in use for transfer molding. In the phenol combination they are well adapted to this, which provides high production and yields dark-colored products of good strength and infusibility.

Blow molding has been tried using a special rubbery type furfural resin combination in sheet form with or without filler. In this, furfural replaces cellulose nitrate and rubber for some applications. Cast molds or molds of wood or plaster of Paris may be used.

Adhesives. Furfural resins are used as a cement for bonding the brass ferrule of the incandescent lamp to the glass bulb of the lamp. These cements must cure quickly, adhere to both metal and glass, and resist moisture and heat.

Impregnating Liquids. By impregnation with furfural, open porous materials may be hardened, toughened, and strengthened, their moisture absorption reduced and their dielectric properties improved. Soft woods are ebonized in this way for piano keys, cutlery handles, etc.; and plaster of Paris molds are indurated and strengthened for molding and casting.

Impregnating varnishes may be air-dried, heat hardened, or hardened and set with heat and pressure.

LIGNIN PLASTICS

As a rule lignin plastics are sold only as finished articles, mostly as sheets and panels. Several types of the plastics are available. The three principal ones are made by Marathon Chemical, the Masonite Company, and by Mead Paper Company, respectively.

A large part, perhaps most, of the volume of lignin sheet material is modified by the addition of phenol-formaldehyde resins to improve flow and strength properties.

Molded Articles. The manufacture of lignin plastic is based on the release of the lignin bond on woody material by the action of high-pressure steam without removing or destroying the lignin, and then activating the lignins so that their bonding power may again be utilized in the manufacture of board products.

Lignin plastics are made from lignocellulose materials consisting of varying proportions of hemicellulose, cellulose, and lignin. Thermohydrolytic treatment disperses the hemicellulose, makes it soluble or puts it into suspension in water, since its removal is essential to the final product. The cellulose is altered or partly removed, depending on the extent of the heat treatment.

One group of lignin plastics is produced in the following way: Wood chips are fed into a cylindrical steel vessel into which is introduced saturated steam to a pressure of 600 lb. per sq. in., which is quickly increased to 1000 lb. and held for 1 or 2 sec., the contents being then discharged at atmospheric pressure into a cyclone. The chips explode because of the high internal pressure and the fiber falls into a storage tank where it is mixed with water in the ratio of 3 parts fiber to 97 parts water, and then is pumped through refiners, screened, and conveyed to a stock chest. There it is formed into boards, a waterproofing substance being added. The boards are pressed, the time depending on the density desired.

Benalite, another lignin plastic, is produced from either hard or soft woods. The chips are held under steam pressure for long periods under controlled pH conditions and are formed into sheets. The moisture content is then reduced to 5 per cent, and the sheets are put into a flat bed press under a pressure of 1500 to 2000 lb. per sq. in. to convert them to the cured state. Care must be taken to have sufficient moisture present for flow under pressure. The finished product has a specific gravity of 1.44 and may be turned, tapped, or sawed.

Sheets of lignin plastic can be surfaced with synthetic resin in a variety of colors, or left with a natural black finish. The plastic is normally furnished only in flat panels which are, however, adaptable to some further forming. Sheets 0.1 to 1.0 in. in thickness are made. The dielectric properties of the plastic make it suitable for ordinary insulation purposes.

A special lignin composition has been molded in the form of gaskets. For these, the lignin is mechanically mixed with Neoprene or other synthetic rubbers of the butadiene type and then pressure molded. The compression ratio is 25 to 50 per cent, and there is a minimum of cold flow. The scrap is reused, leaving little or no waste. Much research is being done on this composition, so that soon sheets 3 by 4 ft., 1/32 to 1 in. thick will be available.

METHYL CELLULOSE

Sheets and Films. Cellulose is methylated by the use of dimethyl sulfate, the dimethyl sulfate so obtained consisting of a fibrous material that becomes increasingly horny with increased methylation. Cellulose methyl and ethyl ethers swell in water, but this is overcome by treatment with tanning agents and ammonia or organic amines.

Films of methyl cellulose are made by extruding its solutions through slits of the appropriate size into hot water, which coagulates the cellulose derivative. The correct adjustment of the viscosity of the methyl cellulose is of importance for the success of the operation.

Coatings. Methyl cellulose became available in 1939 as a water-soluble, odorless, tasteless, nontoxic substance which yields films that are greaseproof and highly flexible. It is used as a paper coating and sizing and for various other types of coatings.

Modifying Agent. Methyl cellulose is also used as a thickening agent in the textile, soap, cosmetic, and paint fields and as a thickening agent for aqueous dispersions of casein, rubber latex, etc.

Adhesives. Methyl cellulose is used in the preparation of adhesives.

MELAMINE–FORMALDEHYDE

Melamine-formaldehyde resins and molding compounds are probably the newest addition to the thermosetting group of plastics. These materials were first introduced commercially in the United States by The American Cyanamid Company, and the molding compounds are in their early developmental stage insofar as types and applications are concerned. Melamine resins have been used in the laminating industry for over a year and a half.

Melamine resins are practically colorless, are combined with various fillers to form molding compounds, and at this writing, appear to have the ability to combine with any filler normally used in other thermosetting compounds — and several which are not.

Present Developments. Melamine mineral-filled molding compounds are at present entering the electrical field of application. These compounds show great arc resistance, low water pickup, dimensional stability, and excellent dielectric strength at normal and elevated temperatures. Other molding compounds with organic and inorganic fillers are being developed.

The alpha-cellulose filled material has the general appearance of urea-formaldehyde molding compounds. It may ultimately be obtained in many colors. It is more resistant to high temperatures, to boiling water, and to alkaline solutions than the urea-formaldehyde.

Other melamine molding compounds are being developed and tested in the field having impact values ranging from 0.9 to 15 ft.-lb. Izod per inch of notch.

Because of their greater inertness, hardness, and resistance to heat, melamine resins have been used in the laminating industry for the production of translucent laminates and opaque laminates. In the latter instance, melamine is used on the surface lamina. Surface ply of laminates are frequently made with melamine resin to increase the arc resistance of the sheet.

Melamine resin adhesives are being produced for exterior grade plywood and stand up successfully under the boil test.

The material is not available in transparent form.

The molding compounds are handled and molded much the same as the phenolic compounds. Their molding cycle may be slightly longer due to a longer period of flow. This long flow gives excellent results in the transfer molding process. (For information on the use of melamine for coatings see Coatings, p. 437.)

Phenolic Aldehyde Resins

Molding Compounds. Phenolic aldehyde resins are prepared when phenol reacts with formaldehyde or some other aldehyde in huge steam-jacketed vacuum kettles under carefully controlled conditions, until a fusible resin is produced—an intermediate condensation product (solid) that can be softened by heat and cured to the final infusible and insoluble stage. It is poured into flat pans to harden as it cools and is then broken up and ground. It softens under heat and dissolves in solvents such as alcohol.

The resins are usually incorporated with fillers that not only reduce the cost but often impart desirable qualities to the finished products. Pigments or dyes, plasticizers, a lubricant to make molding easier, and sometimes hardening agents, are added. The whole is mixed thoroughly and run between hot rolls to create a homogeneous mass and reduce the bulk. The batch is again broken up, ground, and screened to uniform particle size. This commercial molding powder is packaged in moistureproof containers. Pellets or pills may be formed from the powder by pressure, making the measuring of the powder into molds unnecessary.

The powder may be stored but when the container is open may pick up moisture that is likely to produce mottling or flowmarking. It is best stored at 70° F. If kept in a cold warehouse and used cold it requires a longer curing period, since the molding material must absorb more heat to become plastic.

Coloring agents are coal-tar dyes or pigments such as bone black, carbon black, and iron oxides. Pigments are preferable, although dyes are sometimes used where electrical insulation is called for.

Metallic soaps, stearates and stearic acids are commonly used as lubricants.

The compounds are molded in hardened steel molds by the aid of hydraulic presses with pressures of one or more tons per square inch, and temperatures ranging from about 280° to 350° F. Curing requires 30 sec. to several minutes, depending on the compound used and the size and shape of the molded piece.

Moldings have good dimensional stability, electrical insulating qualities, resistance to heat, water, and chemicals, moldability, and low cost. They are provided in stock colors: black, brown, and mottled effects, and in many brighter colors.

They are supplied in the following grades:

General purpose
Impact resistant
Heat resistant
Nonbleeding
Extrusion
Arc resistant
Sanding and buffing
Closure
Moisture resistant
High dielectric
Low loss
Acid resistant
Alkali resistant
Low friction
Compounds with minimum odor

In addition they are classified as soft, medium, and stiff flows.

Many grades, including general purpose, use wood flour filler, which is the most widely used filler. Common woods are pine, spruce, and fir. The gum content, color, size and shape of wood particles must be considered.

In manufacturing the general purpose materials the resin is finely ground, color pigment and wood flour are added, and the plastic is passed through mixers, sifters, and hoppers.

Pieces rarely require polishing when they come from the mold. Size is limited by the molding presses available, shape only by the molding operations, mold design, and molder's ingenuity.

Impact-resistant grades contain fibrous fillers (scraps of linen or canvas) which increase both mechanical strength and shock resistance.

A small proportion of alkyd resin, incorporated in a finely divided, infusible, and insoluble condition and worked into a phenolic or urea resin at the liquid stage, is said to give an increase in shock resistance.

Long-spun fibered fillers in a resin give shock resistance but lower moldability.

A new type of high-impact phenolic molding material containing a small percentage of graphite, has been developed especially for bumper shoes, refrigerator lock bolts and other parts where minimum frictional resistance is desirable. It has a particle size comparable to dry rice and is said to preform easily and to flow freely through standard feeders. Extrusion grades are especially plasticized for that purpose. (See Fillers.)

Matrix material consists of a fiber board of open structure in which a special phenolic resin has been incorporated. When it is placed in contact with a pattern (type-form or metal printing plate) and subjected to heat and pressure it becomes soft and will readily receive a sharp, clean impression of the original pattern. Further heating makes it hard and infusible, an ideal matrix for forming rubber printing plates used for marking bags and similar articles but suitable for any type of printing.

Phenolic molding sheet sometimes is used in overflow or flash molds where no facilities for tableting are available, or for molding requiring material more plastic than wood flour powder but with the same pressure and time of cure. Unless an exceptionally plastic material is required, molding sheet is not recommended, since it is somewhat inferior to the powdered material in mechanical strength. Hard when cold, molding sheet can be softened or conditioned in a short time, preferably in an oven at 180° to 200° F. or, as a last resort, on a hot plate, a sheet of insulating material such as cotton duck being placed between the sheet and the hot plate. In the softened condition it may be cut or punched into suitable form for charging the mold.

An interesting molding material is produced from a phenol-formaldehyde resin, formaldehyde hardened soybean meal, and wood flour in the proportion 3 to 3 to 2. This is said to produce successful compounds for compression molding.

Cast Forms. Cast phenolics, available in a full range of opaque, translucent, and transparent colors and mottles, are nonflammable, tasteless, odorless and unusually stable to atmospheric conditions. They are moisture resistant and resistant to action of many chemicals and solvents, such as hydrocarbons, cleaner solvents, ethers, and many alcohols.

Aside from the beauty of finish secured by casting some of the clear resins, there is an economical reason back of this method of fabricating. It is less expensive and less time consuming to make an arbor to form a mold to produce cast resin products, even though machining is necessary to bring such products to the desired shape, than it is to build a steel mold and produce the same finished product by hot pressing. This is particularly true where the number of pieces is relatively small, say from 200 to 1000. In such a case the cost of a hardened steel mold would be excessively high per unit.

Cast phenolics are available in the following forms:

Cast polished sheets 12 by 24 in. in various thicknesses
Unpolished sheets, 32 by 72 in. in various thicknesses (cut from cast blocks)
Cast rods, sheets, tubes, and blocks
Special profile castings
Split mold shapes
Resin solutions in organic solvent
Liquid cements
Clear and opaque casting resin for hot or cold setting
Special castings for the production of buckles and jewelry

Standard round rods range from ⅜ to more than 5 in. in diameter. Special rods are available in such forms as square, hexagon, octagon, and fluted. Standard sheets are in sizes 12 by 24 in. to 36 by 72 in. and from ½ to 1 in. thick. Stock cylinders are available in a wide range of inside and outside diameters.

Phenolic resins to be cast usually contain more formaldehyde than the molding resins and are not mixed with fillers. They are poured in a sirupy state into rubber, lead, or glass molds where they are hardened by slow baking. Since considerable period is required for curing (about 48 hr. at 175° F.), the resin is customarily cast in sheets, rods, or tubes and the finished articles machined from blanks.

The opacity is due to the size of the water particles suspended in the resin, hence the greater the dehydration the greater the transparency. Glycerin is often added to aid in rendering the resins transparent. Clear cast material is used to make artificial gems.

In general, cast phenolics have high compressive, tensile, and flexural strengths in the absence of fibrous fillers. They also have good adhesive and electrical insulating properties and are easily machined like wood or metal, giving a glowing luster when polished. They are tough and almost unbreakable.

Development of a special transparent, chemical-resistant cast resinoid, highly heat resistant, nonabsorbent and chemically nonreactive, has extended the applicability of these resins to the manufacture of corrosion-resistant equipment for process industries such as for impeller and rotor parts of pumps and for piping. This resin may be used for containers for hydrofluoric acid.

Cast phenolic can be washed without injury in soaps that do not contain strong alkali cleaners. Certain of the crystal forms are somewhat water absorbent and should not be left to soak. Some modified varieties may be heated in hot water and bent to a desired curve while hot. The material expands when heated but returns to its original dimensions when cooling.

Many special shapes of cast phenolics from straight draw molds without undercuts, and split molds with undercuts, are available.

Uncolored cast phenolic articles may be dyed by the following method:

Make up a mixture of butyl alcohol and glycerin (1 to 1) with the aid of heat. Because the butyl alcohol vapors are inflammable it is best to reflux the mixture. To the liquid mixture add a measured amount of standard dye and then immerse the articles to be dyed, being careful to keep them screened from the bottom of the heated container. Boil for 3 to 5 min. Agitate the mixture, remove the articles from the bath, immerse them in cold water, wash in warm ethyl alcohol solution, dry, and polish lightly on a buffing wheel.

Special phenolic castings such as cutlery handles, gear shift knobs, handles of various types and designs and any other item not requiring a split mold can be made up to order.

New developments in the cast resin field are cold setting of a liquid phenol-formaldehyde resin with acid, and a liquid resin composition that will not harden at room temperature but hardens relatively rapidly at elevated temperatures.

Replacement of hexamethylenetetramine with dimethylol urea during the condensation improves the color of phenol-formaldehyde resins. A glass-clear, transparent condensation product is obtained by reacting phenol with formaldehyde with an alkaline catalyst, lactic acid, and a reactive urea-formaldehyde condensation product. A liquid resin suitable for casting has been produced. It cures in 2 to 3 days at 70° to 80° C. (158° to 176° F.).

Laminated Forms. The outstanding properties of phenolic laminated materials are: chemical inertness, durability, high tensile, compressive, and impact strengths, electrical insulating qualities, resistance to spotting and discoloration, translucency in some grades. They are uniformly dense, tough, resilient, light in weight, non-absorptive. They have low thermal conductivity and a low coefficient of expansion, and are inert to oils, brine, most acids, weak alkalies and many solvents. They are sound absorbing. Resistance to strong alkalies is not completely satisfactory.

Phenolic laminated materials come in two finishes: mirrorlike or dull satin. The commercial grades are provided in two colors, black and natural (tan), though decorative materials are available in a wide variety of colors and designs.

There are four general classes: (1) paper base; (2) canvas base; (3) linen base; (4) asbestos base. Each of these is available in various grades. Wood and glass laminates are considered elsewhere.

Laminated phenolics are prepared by impregnating sheets of cloth or paper with a solution of the A-stage thermosetting resin, drying and bonding with heat and pressure. The layers of material are compressed and consolidated under heat and pressure to sheets, rods, tubes, blocks, and special forms in the infusible stage. The solid, homogeneous, hard, dense product will not delaminate and has excellent mechanical and dielectric properties.

Forms Available. Liquid or powdered phenolic compound for laminating is available.

Laminated Sheets. Sheets are prepared by impregnating special grades of paper, canvas, or linen with phenolic resin, piling them up to the desired thickness, and then pressing in powerful hydraulic presses under controlled heat and pressure to a compact, solid, infusible product.

Laminated phenolic is made in standard-size sheets approximately 38 by 46 in., ranging from 1/32 to 8 in. thick. Gear blanks may be sawed from these, or the blanks may be molded to specifications.

Gears of laminated canvas are silent and outwear those of metal. They may be machined like metal, but more rapidly, are impervious to temperature changes up to 290° F., are practically unaffected by oil and water, and are not affected by oxidation. Laminated gears are one-seventh the weight of brass, one-sixth the weight of steel, one-fifth the weight of cast iron, and one-half the weight of aluminum. The gear blanks may be cut on automatic machines into helical, spur, bevel, or work gears.

Rods. Laminated rods are made by rolling impregnated paper or fabric on mandrels, removing the mandrels, and placing the rolled material in molds which are then subjected to heat and pressure in hydraulic presses.

Tubes. There are three varieties of laminated tubing: (1) molded laminated tubing, made by winding impregnated paper or fabric on a mandrel, applying heat and pressure, and completing the treatment in heated ovens; (2) rolled laminated tubing, rolled between heated rolls (one inside tube and one outside); and (3) spiral-wound laminated tubing (rolled in spiral with lap joining of edge).

All varieties may be punched, threaded, turned, drilled, or fabricated to close tolerances.

Laminated tubing is also supplied in various grades.

Grade X has high tensile strength and is available with high mechanical strength, good punching and machining properties, higher dielectric strength than any other of these tubings, and moisture resistance not so good as that of Grade XX.

Grade XX is made with paper from selected stock raw materials and is manufactured with a higher resin content than Grade X, giving high moisture resistance, better electrical properties and excellent thread strength.

Grade C is made with cotton fabric weighing 6 oz. or more per sq. yd. and is intended for mechanical purposes requiring high impact strength. The moisture resistance and dielectric strength are inferior to those of the other fabric grades.

Grade CE has the same fabric specifications as Grade C, but different impregnation methods are used to improve the electrical properties with moisture resistance. The material is tough and dense, with excellent mechanical properties, but is inferior in electrical properties to the paper-base grades.

Grade L is made with a fine-weave cotton fabric weighing 6 oz. or less per sq. yd. It has excellent machining qualities and good moisture resistance. It is intended for mechanical applications where greater toughness than that of Grade LE or finer machined appearance than that of Grades C or CE are required. It should not be used for high-voltage electrical applications.

Grade LE has the same fabric base as Grade L, but through different treatment of the resin the electrical properties are improved until they compare favorably with those of Grade XX. It has greater toughness and moisture resistance than Grade XX, and electrical properties almost as good. It can be machined with greater precision than any other fabric grade.

Grade A is made from asbestos paper and special resin. It has lower mechanical strength than other grades but considerably higher heat resistance. It should not be used for electrical insulation except for low voltages.

Grade AA has a woven asbestos fabric base and possesses higher mechanical strength than A and some other grades, with high heat resistance. It has excellent dimensional stability. It should be used for low-voltage insulation only. (See tables.)

TABLE 47. PHENOLIC RESINS — LAMINATED TUBES

Grade	Approximate Length	Inside Diameter	Outside Diameter	Wall Thickness
XX X Molded	Up to and including ¼ in. internal diameter, 18 in. Above ¼ in. internal diameter, and ¾ in. outer diameter, 38 in. to 144 in.	⅛ to 9 in., inclusive	To 9½ in., inclusive	No limit, but over 1½ in. wall, annular cracks may develop
XX X Rolled	Up to and including ¼ in. internal diameter, 18 in. Above ¼ in. internal diameter, 38 to 84 in.	⅛ to 4 in., inclusive	To 50 in.	No limit, but over ½ in. wall, annular cracks may develop
Canvas and linen molded	Up to and including ¼ in. internal diameter 18 in. Above ¼ internal diameter and ¾ in. outer diameter 38 in. to 144 in.	⅜ to 9 in., inclusive	To 9½ in.	No limit up to and including 9 in. outer diameter, but thick wall tubing with small internal diameter may not be concentric

PHENOLIC RESINS — LAMINATED RODS

Grade	Diameter	Length
XX	⅛ to 5/16 in., inclusive. Over 5/16 to 3⅞ in., inclusive	18 in. 38 in.
Canvas	⅜ to 6 in., inclusive	38 in.
Linen	⅛ to 5/16 in., inclusive. Over 5/16 to 3⅞ in., inclusive	18 in. 38 in.

Phenolic rods and tubes are ground to close tolerances and come in round, square, and rectangular shapes. Standard lengths are 18 in., 36 in., 24 in., and 48 in. They may be easily sawed, punched, riveted, drilled, reamed, turned, knurled, threaded, tapped, or polished. They resist common solvents and weak acids and will not corrode metal inserts.

Decorative Laminates. Architectural laminated phenolic sheets are made in various colors and in reproductions of marbles, woods, fabrics, designs, patterns, and inlays

The material has a low coefficient of expansion. Architectural sheets for building use come protected with a paper covering in sheets 36 by 42 in., in many colors and types.

Laminated wood in thinner sections than plywood can be produced with the aid of phenolic resin. Beech and birch are the principal woods used. They are obtained in the form of veneer, seasoned, treated to remove volatile matter (mainly water), and finally subjected to a vacuum. The synthetic resin is ther introduced in varnish form, this being the only impregnating and adhesive material used. The solvent is removed by heat in a suitable chamber, and the dried veneer emerges as a pure-wood synthetic-resin-impregnated product. The laminations are built up by arranging alternating sheets in different directions with respect to the grain, and the blocks are cured in presses between platens independently heated and cooled. The laminated-wood product has low moisture content and small capacity for absorbing water.

Wood and phenolic resin are decoratively combined in the form of woven strips of contrasting wood veneering which is extraordinarily thin and uniform throughout in thickness and texture and is impregnated with resin before it is woven. The impregnated veneer is cut into strips of desired thickness, woven, and processed by heat and pressure. The resulting sheet is water- and chemical-resistant and has high resistance to heat and burning cigarettes.

The material is available in a 1/16-in. thickness for veneering to plywood, pressed wood, asbestos board, metal, Masonite and similar backings, and a 0.020-in. thickness that can also be veneered on sharp curves and may be fabricated by stitching, stapling, punching, sawing, and cutting with ordinary shears.

Three standard weave widths, 2-in., 3-in., and 6-in. strips, are supplied and are woven on a diagonal or straight weave pattern.

Beautiful veneers of mahogany, Avodire (a blond wood of even color from Africa), birch (red and white), maple, and walnut are available.

This woven wood veneer is available in sizes 36 by 72 in., 30 by 30 in., and 36 by 36 in. It is shipped with the unfinished side sanded ready for cementing. Smaller weaves of ½- to 1-in. strips are available for small articles. Special weaves are provided on request or individually designed by the styling department of the manufacturing company.

Extruded Forms. Phenol-formaldehyde resin, being a thermosetting material, is not readily extruded and is not commonly formed in this manner. Various thermosetting resins have been extruded in Germany for some years. Experimental work in this country gives promise for this type of material, and some large extrusion machines have been built to handle thermosetting plastics.

PHENOLIC RESINS IN COATINGS[1]

Phenolic resins of many different types are used in coatings today, each type having its own distinctive properties and uses. The general term " phenolic resin " is broad enough to include all resinous materials derived from or containing any one of several hundred known phenolic bodies. As the variety of phenolic resins in commercial use has increased greatly in recently years, a more exact classification seems desirable.

Phenol-Aldehyde Resins. This is the largest and most important class of phenolic

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[1] Prepared in co-operation with Bakelite Corporation.

resins, comprising broadly all the condensation products of phenolic bodies with aldehydes. The phenolic bodies may include unsubstituted phenol, cresols, xylenols and all the numerous alkyl and aryl substituted phenols. The aldehydes may include formaldehyde, acetaldehyde, benzaldehyde, furfural or other compounds containing active methylene groups such as hexamethylenetetramine. As the variety of both phenols and aldehydes in commercial production has increased greatly during recent years, and when it is considered that these may be used in a limitless number of combinations to produce resins, the complexity of the phenol resin field can be realized. Not all of these are suitable for use in coatings, but phenol, some of the cresols and xylenols, p-phenyl phenol, p-tertiary butyl, and p-tertiary amyl phenol are used in large quantities with formaldehyde to yield synthetic resins useful in coatings. These, either alone or suitably modified by combination with drying oils, natural resins, or other synthetic resins such as the alkyds, find their way into millions of gallons of paint, varnish, and lacquer products for almost every conceivable coating use.

Phenol-Terpene Resins. In addition to the phenol-aldehyde resins, there is a newer class of resins also described as " phenolic " which are made by reacting phenols with non-aldehydic substances, such as the terpenes or other similar unsaturated natural products of relatively high molecular weight. Such products may be considered as substituted phenols and may be either oily liquids or solid resinous materials. They may be hardened further by treatment with formaldehyde, though some of the harder materials are useful in oil varnish making without any aldehyde addition. These are described as being particularly resistant to discoloration under the effects of light as compared to the phenol-aldehyde products, and so may be used in white or light-tinted enamels with good results. They are not, however, so resistant to chemical action and to outdoor weathering as the phenol-aldehyde products. They are generally of the permanently fusible type and do not form completely insoluble films on baking.

Heat-Hardening Resins. Phenol-aldehyde resins may be subdivided into two principal classes, the heat-hardening resins and the permanently fusible resins. The heat-hardenable products generally result from reactions made with alkaline catalysts and with an excess of formaldehyde over the equi-molecular proportion, while permanently fusible resins are obtained by the use of acid catalysts and usually a somewhat lower formaldehyde ratio.

Both of these classes may be subdivided again into *oil-soluble* and *spirit-soluble* resins, both of which fill important though different needs in the coatings industry.

The oil-soluble, heat-hardening resins are widely used for improving the performance of lower cost natural resins such as rosin and ester gum (rosin-glycerol ester). When heated with the natural resins in proportions usually ranging from 5 to 25 per cent phenolic resin to 95 to 75 per cent natural resins, a sharp rise in melting point and hardness is produced, and when the resulting modified resin is cooked with drying oils, a marked improvement is obtained in drying rate, moisture resistance, and durability of the varnishes so produced. These resins are also incorporated directly into drying oils without modification, with other resins to produce baking coatings useful as coatings for cans, drums, and tanks and as primers for automobiles and other articles which can be baked to harden the coating.

The *spirit-soluble* or *non-oil-soluble* resins are used without modification with fatty oils to produce exceptionally hard coatings having excellent resistance to moisture.

most solvents, and many corrosive chemicals. These are the oldest form of phenol resin coatings and have been widely used as clear or pigmented baking finishes for food containers, drums, tanks, tank cars, brass fixtures, razor blades, chemical equipment, and many other uses where their unique hardness and impervious nature are required. They are, however, too brittle to withstand extreme flexing or other rough mechanical treatment. Flexibility may be improved by addition of plasticizers, though such additions generally lower the solvent resistance of the coating.

With the development of portable baking equipment designed to apply and bake these heat-hardening coatings on the inside of large tanks, it has become practical to use them for many purposes where high protection against corrosion is needed. The most outstanding has been the coating of the inside of tank cars for the transportation of wine, and the protection of steep tanks in brewing. Several well-equipped commercial concerns are prepared to handle widely varying sizes and shapes of equipment.

Permanently Fusible Resins. Spirit-soluble resins, such as those made from phenol or cresol and formaldehyde with acid catalysts, have had only limited application in the coatings field. Early attempts were made to use them as replacements for shellac which then was expensive and the supply uncertain. However, they were never entirely satisfactory for this purpose due to their lack of toughness and flexibility. They have been used to a limited extent in mixture with shellac or other resins to produce water-resistant lacquers for specialized applications not requiring great flexibility.

The oil-soluble permanently fusible resins are now the most versatile and widely used of all the phenolic resins in the coatings field. They are available in a wide variety of forms, both as unmodified or " 100 per cent phenolic " resins and as modified by combination with rosin or other low cost natural resins. The unmodified resins are based on the use of substituted phenols, such as p-tertiary butyl phenol, p-tertiary amyl phenol, p-phenyl phenol or other octyl phenol, the degree of oil solubility depending largely upon the nature of the substituent group and its position in the phenol nucleus. The modified resins may be made from either substituted or unsubstituted phenol. An especially important class of rosin modified resins has been made in large quantities from unsubstituted phenol resins of the heat-hardenable type modified with rosin to secure the necessary oil solubility. These are unusually hard resins, useful in quick drying varnishes and enamels of the so-called " 4-hr. drying " type. Varnishes produced from them are markedly better in water resistance, alkali resistance, and durability than similar varnishes produced from rosin or ester gum, but are not so good as those produced from the unmodified phenolic resins.

The unmodified resins have become well established in the production of air-drying oleoresinous varnishes and enamels for withstanding severe moisture conditions, weak alkalies and acids, and exterior weathering. They are cooked with drying oils, such as tung, linseed, oiticicia, dehydrated castor, soya or other oils in various proportions, depending on the use to which the coating is to be subjected. Spar varnishes, or coatings for exterior use on wood, generally contain from two to three parts drying oil to one part of resin, while coatings designed for use on metal may contain a larger proportion of resin. Such coatings are used as anti-corrosive primers for automobile bodies, structural steel, bridges, dams, ships, railway equipment, and numerous similar uses. (See Coatings for general discussion.)

A material which seems to hold promise for coating of so-called creaseproof fabrics is formed by reacting a phenol, an aromatic sulfonamide, and a halogenated aliphatic group.

Adhesives. Phenolic heat-hardenable cements are used to seal incandescent lamps and radio tubes in their bases, bristles in brushes, and to furnish a strong durable bond for joining metal, porcelain, wood, fiber, and glass. For the latter purpose a lump resin is supplied.

Phenolic plybonds, or adhesives in film form, make enduring synthetic resin bonds for veneers or plies of wood or other porous materials. They are made by impregnating a very thin sheet of paper with the resin. Phenolic plybonds are generally used instead of urea because of their greater permanence.

The best conditions for curing are a temperature of 135° F. with a minimum pressure of 5 kilograms per square centimeter. The humidity of the wood should fall between 8 and 10 per cent.

Plywood laminated with phenolic plybonds must be immersed in water after leaving the press and then dried to the required degree of humidity. When this is done they form one of the strongest bonds yet developed. Cold-setting plybonds requiring pressure but no heat are also available. Urea adhesives are often used instead of phenolic for airplanes and furniture.

Phenolic liquid resin is used for bonding ground cork to form a flexible and water-resistant lightweight material.

Modified Phenolics. Phenol-aldehyde condensation resins, modified by dispersion in abietic acid or natural copals — or reacted with fatty resin acids — are one of the most widely used type of commercial phenolics. The substituted phenolics have had wide acceptance owing to improved color retention, coupled with other good properties.

In general, these resins improve the properties of varnishes in a manner similar to the straight phenolics, and in two main exceptions gloss and greater hardness show improvements.

Certain oil and resin acid-modified phenolics are advantageously incorporated into nitrocellulose lacquers. Such combinations can be made to rub just as quickly as dammar, but to a clearer and brighter film that has much less tendency to bloom after long aging periods. In addition, an appreciable increase in film strength (as demonstrated by hot-and-cold check tests) is obtained.

Modified phenolics are present in many interior decorating finishes such as the 4-hr. drying type, architectural coatings, quick drying primers and baking enamels for metal, rubbing varnishes for wooden furniture, long-oil exterior varnishes, perspiration-resistant wrinkle finishes for office equipment and many other applications.

POLYAMIDES (NYLON)

Extruded Forms. Nylon (see under Fibers, p. 344) is the generic name for materials defined as " synthetic fiber-forming polymeric amides having proteinlike chemical structure derivable from coal, air, and water, or other substances and characterized by extreme toughness and strength," produced by du Pont. As a single extruded filament, it is used as fishing leader material, non-irritating surgical sutures, and industrial brush bristles. It may be injection molded, but at the present time the demands for extruded nylon is so great that its possibilities for other types of molding have not been fully explored.

Nylon bristles wear twice as long as natural bristles, and are tough, resistant to deformation, and superior in moisture resistance. They are used for toothbrushes, hairbrushes, nailbrushes, and other toilet brushes. Nylon has high elasticity and tensile strength, the yarn (first spun in 1939) having a higher factor of combined tensile strength and elasticity than any other commonly used textile yarn, weight for weight.

Polyamides are prepared by first condensation reaction in which low molecular weight polyamides are built up to form large molecules. With an advanced degree of polymerization a tough, hornlike polymer is obtained. The molten mass is extruded as a ribbon and ground to granular or flake form. It has a crystalline structure, melts sharply, is completely stable and may be stored for any length of time until used for spinning yarn.

Flake to be spun is melted and then extruded from a spinneret. The resolidified filaments are collected but must be drawn before they can be spun. Before drawing, the molecules of the filaments are distributed in a disorderly or random manner, the long-chain molecules lying in all directions, twisted and coiled. It is necessary to orient the molecules along the axis of the fiber by stretching the fiber. Little force is required to stretch the fiber to a fourfold increase in length, proportionately reducing the diameter. The drawn yarn shows slight changes in dimensions with variations in moisture content and will shrink a few per cent when first immersed in hot water, but it will not return to its disoriented state. The drawn yarn is strong, elastic, and tough.

The principal use of Nylon yarn so far has been in the manufacture of full-fashioned stockings. In the handling of these, a special sizing must be applied to the yarn to take the place of sericin in natural silk. This sizing must adhere to the yarn, soften in water without becoming tacky or sticky, and redry to give firm positioning of the loops. It must protect the fabric during handling and be easily removed after it has served its purpose.

Under heat and moisture Nylon takes a permanent set. If dyed loose in a hot dye bath, like silk or other fibers, and dried on a form, the result is a wrinkled, misshapen stocking. It must be placed on a form and subjected to steam at 5 lb. gauge pressure (282° F.) for 5 min. before being dyed, and it then retains a permanent "set." Wrinkles set in may be removed by a later treatment at a higher temperature for a longer time.

Common dry-cleaning solvents are without effect on Nylon. It is practically non-flammable, fairly resistant to mineral acids and highly resistant to alkalies in fairly concentrated solution and at elevated temperatures. It is completely inert physiologically and may be used for surgical sutures. It resists enzymes, mildew, molds, and moths. It is soluble in phenols and formic acid.

Nylon yarn has an affinity for many classes of dyestuffs, but the best results are obtained with colors developed for the coloring of cellulose acetate yarns and fabrics. There is an infinite number of possible kinds of polyamide materials, differing widely in physical properties. The material commonly offered as an extruded yarn has a high melting point (253° C. or 487° F.).

POLYSTYRENE[2]

Polystyrene is a thermoplastic resin which has been in commercial production in the United States since 1937. Because this resin has many unique properties it is being used extensively for a variety of purposes.

As the name implies, it is made from styrene ($C_6H_5—CH=CH_2$), or vinyl benzene, and thus is related to the other vinyl compounds, such as vinyl chloride, vinyl acetate, and the acrylates. The presence of the phenyl group attached to the vinyl radical gives rise to the properties which distinguish it from the other vinyl types. Thus, polystyrene is made by " hooking " together a large number of the above monomeric units. This is usually written $(C_6H_5—CH=CH_2)_n$; the literal number *n*, representing the monomeric units in a polymer unit, may be as high as 100 to 200.

The starting material, monomeric styrene, has long been known to occur in coal tar in small quantities. Recent work has shown the possibility of commercial recovery from this source. However, the major portion now on the market is made synthetically. The polymerization reaction, by which the polymer is formed from the monomer, takes place slowly at room temperature, unless it is stopped by an inhibitor. The reaction, however, is relatively slow at this temperature. Heating and catalysts speed up the reaction. The polymerization is exothermic and some care must be exercised in its control.

The product thus formed is a crystal clear, colorless resin of high refractive index (1.59). It is the base for the almost unlimited variations of colors in transparent, translucent, or opaque effects available today. In commercial use it is, for the most part, injection molded or extruded. The physical strength properties by injection molding are shown below. All values are by A.S.T.M. unless otherwise specified.

TABLE 48. POLYSTYRENE — PHYSICAL PROPERTIES BY INJECTION MOLDING

Tensile strength (lb./sq. in.)		6000–8000
Flexural strength (lb./sq. in.)		16,000–19,000*
Modulus of elasticity (lb./sq. in.)		0.4–0.55 × 10^6
Izod impact (ft. lb./in. notch)		0.6–1.2**
Elongation		1–2.5%
Heat distortion		77°–80° C.
Water absorption		None
Index of refraction		1.592–1.597
Light transmission		90%
Thermal coefficient of linear expansion		65–75 × 10^6 per ° C.
Specific heat		0.32 gm. calories/° C.
Rockwell hardness		M85–M92
Cold flow		Negligible at ordinary temperatures and pressures
Dielectric strength 60 cycles (specimen 0.125 in. thick)		500–525 volts/mil (step by step)
Power factor	60 cycles	0.0002–0.0003
Power factor	1000 cycles	0.0002–0.0003
Power factor	1,000,000 cycles	0.0002–0.0003
Power factor	50,000,000 cycles	0.0002–0.0003
Dielectric constant	60 cycles to 50,000.000 cycles	2.5–2.6
Loss factor	60 cycles to 50,000,000 cycles	0.0005–0.0008

* 5 by ½ by ½ in. specimen.
** 5 by ½ by ½ in. specimen—broken four at a time to give 5 by ½ by ½ in.

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[2] Prepared by Virgil Meharg of the Bakelite Corporation.

Chemically, polystyrene is not attacked by weak or concentrated acids, although it may show slight discoloration in the presence of oxidizing acids. Alkalies also have no effect on it. Bleaching solutions, photographic chemicals, the lower alcohols, and most fats, animal and vegetable oils do not attack the resin. Polystyrene is dissolved by aromatic chemicals, such as benzene, toluene, and coal tar solvents generally. Other solvents such as acetone and other ketones attack it but do not completely dissolve it. Chlorinated solvents usually give complete solution.

The properties just given will suggest the general uses of the resin, while the following list will illustrate some of these.

Application	*Properties*
Radio and electronics generally	Excellent electrical properties maintained at all frequencies and under highly humid conditions.
Refrigerator parts	Retains strength at low temperatures — highly decorative — dimensionally stable.
Combs	Strength, rigidity, and color.
Instrument parts and panels	High light transmission which may be utilized to pipe light around bends — good dimensional stability which is maintained on aging.

This abbreviated list shows the diversity of applications possible with polystyrene. One outstanding property to be noted is dimensional stability. Changes in dimensions after molding may be due to several causes, the most important of which are a shrinkage due to loss of a volatile constituent, such as plasticizer, or change due to absorption or loss of moisture. As polystyrene is usually molded without plasticizers, the first of these causes is removed automatically. Since moisture absorption is nil, the second is also eliminated. Thus, parts from polystyrene retain their dimensions over long periods of time with changes which can hardly be measured. Strength also is retained, since no embrittlement occurs due to loss of a plasticizer.

The use of polystyrene at low temperatures is mentioned in connection with refrigerator parts. This point also needs further emphasis since it has been found that there is no loss in strength of molded parts from room temperature down to − 40° C. While this property has enabled polystyrene to be widely used in the manufacture of refrigerator for the home, it is certain that further large uses will be found when the material's unique chemical and electrical properties are considered in addition to its strength properties.

The greater portion of present production goes into molded parts. For this purpose polystyrene comes to the molder in granular form with the dyes, pigments, etc., already added by the manufacturer. More than ordinary care is necessary in handling to avoid contamination, since this condition shows up very quickly in parts molded of transparent polystyrene. Injection molding, as compared with compression, gives a faster cycle, stronger parts, and generally superior results.

The actual molding procedure is similar to that for other thermoplastics. However, polystyrene is less flexible than most thermoplastics and, in addition, it takes the details of the die very accurately. It is, therefore, essential that dies should be designed without undercuts, and that they have a good finish. Although polystyrene will fill a die through long runners and through a smaller gate than is necessary for most thermoplastics, long runners should not be employed except when necessary. Large gates and short runners yield molded parts which have much greater strength. High ram pressures also tend to give higher strength. Temperatures in the heating cylinder run slightly higher than is required for such plastic materials as cellulose acetate, and molding at higher temperatures is an advantage. The combination of high ram pressure, short runners, large gates, and elevated temperatures requires that the mold be well aligned, and that high clamp pressures be available. Gates and welds tend to be weak points in parts molded of polystyrene. Consequently, in designing parts, these sections should not be placed at positions where they are likely to be subjected to high stress.

At the present time, polystyrene is furnished almost entirely without fillers other than the small amounts of pigments necessary for coloring and opacity. Finely ground inorganic fillers can be added up to 10 to 20 per cent without serious impairment to flow or strength. Filler contents up to 50 per cent have been made, but there is considerable loss of other properties, such as shock resistance and plastic flow.

Parts molded of polystyrene possess all the strength usually required in molded parts, if they are properly molded from prime grade polymer. If this prime grade polymer is not used, however, the parts may be brittle. Various efforts to overcome this deficiency by addition of placticizers have generally been rejected, due to the fact that the plasticizers adversely affects properties, such as strength, softening point, and dimensional stability, to such a degree as to overbalance the advantages of increased flexibility. Nevertheless, there are some applications in which plasticizer addition may be advisable.

The price of the granular powder has dropped rapidly as sales volume increased. Thus, from about $2.00 per pound a few years ago it is now (1942) offered at about $0.30–$0.40 per pound.

Films. Polystyrene is available in film form of from 1-mil thickness upward. This film is used mainly in high quality condensers. This use will increase as higher frequencies are employed by the radio industry. As the quality and particularly the strength of polystyrene film improve, other uses will be found in applications similar to those common to foil materials.

Extruded Forms. Extruded sheets, rods, and tubes of polystyrene are also produced. While these are mostly for electronic applications, other uses based on chemical resistance, dimensional stability, and strength at low temperatures, will undoubtedly be found.

Cast Forms. Although casting of polystyrene is possible, little commercial use of such a product has developed. This is principally due to the high shrinkage during polymerization from the monomer to the polymer. Nevertheless, simple forms can be expected as the price is lowered.

Coatings. Possible application of polystyrene resins (not yet commercially developed) is in metal lacquers and light-colored enamels. The toughness, light color, and solubility in inexpensive solvents possessed by these resins suggest these uses. These lacquers are said to be quick-drying, resistant to water, and moderately resistant to acids and alkalies.

SHELLAC

Shellac is sold as a resin either in liquid or in flake or chip form coatings, molding compounds, or laminated materials.

Molding Compounds. In making the molding compound, diluents and fillers such as rosin, wax, talc, mica, asbestos, clay, and wood flock, are added to powdered shellac and mixed on rolls. Coloring agents are added on the rolls.

A typical mixture would consist of three parts of clay filler to one part shellac. With the use of rosin, which also acts as a bonding agent, the amount of shellac may be reduced. The mixed material is run through blanking rolls for cooling and ground to powder for molding. Before molding, the compound is softened on a steam table. It is compression molded at 250° to 275° F. at 1000 to 3500 lb. per sq. in. pressure. The mold is chilled to about 100° F. before pressure is released.

Injection molding at 230° F. is also possible.

Shellac molding compositions have an unusual evenness and smoothness of flow and the finished pieces have a high gloss and hard surface. The price of the compositions is very low.

Shellac is used as an important constituent of many proprietary organic molding compounds, in addition to being used as a plastic binder itself. Many new types of molding powders are prepared from polymerized shellac, from high phenolic-lac resins, and from shellac-urea-formaldehyde resins. They can be pressed at the usual elevated temperatures used for thermosetting resins — some degrees higher than that used for unmodified shellac compositions or most other thermoplastic materials. Most of these modified compounds can be ejected from the molds while hot. The molding powders are available in a wide variety of colors and mottles. They are compatible with ethyl cellulose, with which they make up a coating for an aluminum type of phonograph record. The combination of shellac with urea and other chemicals increases the polymerization rate and improves the impact strength, heat resistance, and water resistance of the molded articles.

Other improvements have been made by extraction of the soft lac with solvents, leaving the hard lac which shows great water resistance and a 20° F. higher softening point. Films of hard lac can be baked without developing blisters or pinholes. Articles can be molded with hard lac to have softening temperatures above 212° F., instead of showing deformation below 170° F. as do the articles molded with the untreated shellac.

Laminated Forms. An important comparatively recent use of shellac is as a resinous binder for cloth, paper, silk, mica and other insulating materials. As such it is used to form thermal and electric insulating board.

The molten shellac is applied to the base by a hot-spray process. This technique has been used in the production of laminated electrical tubing and sheets.

In recent years shellac-coated paper has been marketed in several varieties — many thicknesses in sheets, strips, and rolls. These papers may be used to build up laminated board or to stamp out washers or separators. A pack can be made in the requisite thickness by heating with a hot iron, causing the lamination to adhere. The strips can be used in small transformers or for interleaving coil windings, and may replace tacky oiled cambric, having the advantage of not being subsequently affected by oils or varnishes.

Laminated compositions are prepared by coating a paper or fabric base with molten resin by dusting it on the fabric as it passes over a hot plate or by coating it with an alcoholic solution or with an aqueous varnish made by dissolving the lac in alkaline solution.

Shellac is molded into electrical insulating parts and phonograph records. Its high insulating ability, good arc resistance, high scratch resistance, and resiliency make it an excellent material for these applications. It is also used for molding dental blanks for taking jaw impressions.

Coatings. Shellac coatings are provided in the form of alcoholic varnishes and alkaline aqueous emulsions.

Shellac is also used in rubber mixtures as a modifier.

UREA–FORMALDEHYDE RESINS

Molding Compounds. Urea-formaldehyde thermosetting molding powders are supplied in an intermediate stage of polymerization, with curing in the molds under heat and pressure necessary for the completion of polymerization. The molded product is insoluble, infusible, tasteless, odorless, hard, and tough. It has excellent light-diffusing qualities and electric-insulating qualities, including nontracking characteristics. It is completely resistant to oils and greases, though attacked by concentrated acids and alkalies.

The first research on urea resins was done to find a transparent substitute for glass, but the urea-formaldehyde products absorbed moisture, and condensation continued, causing cracks and fissures in the molded articles. In 1926 a successful commercial product using thiourea was developed in England. This had greater strength and water resistance, but the cost of production was high, and the sulfur present attacked the steel molds necessitating the use of expensive chromium plated or stainless steel molds.

In 1929 the first successful straight urea product was perfected in the United States, using a hygroscopic filler such as highly refined alpha cellulose. Usually 30 to 40 per cent filler is added, which destroys the transparency but gives better molding characteristics. It allows the production of translucent articles in permanent pastel colors. Almost 1800 color shades have been made up to the present time. The molded articles are resilient though not unbreakable, and have unusual flexural and tensile strength, resistance to alcohol, and good dielectric properties. They have a lower power factor at high frequencies than the tar-acid resins.

During the molding a catalyst in the urea-formaldehyde resin mix accelerates the conversion to the final hardened state. Thiourea may be used to replace the urea entirely or in part for certain purposes.

Urea is molded in the same type of molds as phenolics. It is recommended that the molds be slightly positive. Somewhat higher pressures are required than for phenolics. With highly polished molds an excellent, smooth glossy surface is obtained.

Cast Forms. Urea cast resins are not produced in the United States.

To produce urea cast resins, the urea and formalin are reacted in an alkaline medium to the dimethylol stage in a manner similar to that used in the production of molding compositions. The resulting liquor is vacuum distilled at about 60° C. (140° F.) in the presence of a plasticizer such as glycerol. Prior to and during distillation the liquor is acidified to a predetermined pH and maintained at that value. When most of the water has been distilled off and a sirup of appropriate viscosity has been obtained, the sirup is cast into lead or glass molds and baked at about 60° C, until hard. Transparent colorless products should result, although opaque and colored effects may be produced with dyes and pigments, and special mottles are obtainable.

Urea cast resins have not been developed commercially to a great extent because of the difficulty of hardening them without the development of bubbles and cracks. In the making of the English Pollopas, or urea organic glass, the condensation liquor undergoes an appropriate adjustment of the pH value and after the addition of such substances as glycerol, is distilled to a thick sirup and then cast into sheets or blocks from which sheets or forms may be sliced or machined.

Laminated Forms. To produce laminated material the mixed urea, thiourea-formaldehyde liquor, is prepared as for the production of molding powders and is then made slightly acid. High-grade paper or other material suitable for laminating is impregnated with the liquor and dried at 200° F. (93° C.) to a predetermined stage. The sheets to form the outer surfaces of the laminate may be given a double impregnation, raising the resin content to give a glossy finish. The treated paper, after drying, is cut to size and assembled in bundles, the number of sheets in each bundle determining the thickness of the finished lamination. The bundles are then hot pressed between polished metal sheets at about 140° C. (286° F.) in a multiple daylight press, cooled under pressure, ejected, and trimmed. Translucent sheets in a pearl-white color result. White opaque and colored sheets may be obtained by having the appropriate filling and coloring substances in the impregnating liquor. The outside sheets may be specially treated before lamination to give variegated patterns.

Wood laminated with urea resin is now used in thick sections where only solid woods were formerly used, as in beer barrel staves, skis, etc.

Molded Forms. Urea resins are produced in large quantities as molded articles, such as buttons and buckles, knobs and handles, boxes and containers, clock and radio cases, bottle closures, instrument housings, tumblers and tableware, wiring devices, and molded shades and reflectors. In lighting equipment, translucent urea-formaldehyde is replacing opal glass.

The unpigmented resin is highly translucent and gives a high light transmission with an exceptional degree of light diffusion in all sorts of shades and reflectors for direct and indirect lighting fixtures. Many of the shades used in railway cars are made of this material. The resin is available in degrees of denseness and opacities to give particular ratios of reflection and transmission. Reflectors as large as 28 in. in diameter are on the market.

Coatings. Urea resins are used in combination with alkyd resins in surface coatings. Until recently their use in paints and varnishes was discouraged by their insolubility in organic solvents and their instability although their lack of color, high transparency, hardness, and freedom from after-yellowing were desirable characteristics. Methods for preparing condensates have been developed to overcome the undesirable properties.

Water-soluble urea resins are used in the manufacture of urea molding compounds, the lamination of paper and fabric, the treatment of textiles, for adhesives, but are unsuited for use in varnish, lacquer, or similar coatings. The resins are marketed either as plain urea resin soluble in non-aqueous solvents and adapted for use in lacquer and similar type coatings or in combination with a proportion of alkyd resins.

The organic solutions are clear, water white, and viscous. The resin is thermosetting, convertible by heat to a practically colorless, non-yellowing, extremely hard, brittle film, with excellent resistance to solvents and many other chemical agents. Since it is supplied in a reactive state, it will exhibit a gradually increasing viscosity when stored over long periods of time or at elevated temperatures. The coatings are intended for baking finishes, and are too soft and lacking in water resistance to be of value in air-drying finishes. It is cured only by heat.

Adhesives. Several brands of urea adhesives now on the market meet the need for a hot-press adhesive which is applied in liquid form, cures rapidly at moderate temperatures, and is economical. For greater economy, the urea adhesive may be mixed with various proportions of flour (up to 50 per cent) without having its water-resistance affected. Thus diluted it comes within the cost range of animal and vegetable glues and is more durable.

A new adhesive is composed of two different substances: (1) a urea-formaldehyde condensation product with starch added for pliability, and (2) a 15 per cent solution of ammonium chloride. Gluing is done under heat and pressure. The adhesive is said to be less resistant to traction and stripping than bone or casein glue, but much more resistant to moisture and cold water.

The first one-part plastic resin adhesive is now introduced as a new urea-formaldehyde cold-setting glue. It dissolves instantly when mixed with cold water, and no separate hardener, catalyst, or heat are necessary after application. Hardening in 4 hr., it produces a bond whose strength has not yet been determined because all tests showed 100 per cent wood failure, not glue failure. Tests on gluing mahogany to pine, calling for a 250-lb. reading on the test machine, showed up to 2400 lb. before the wood gave way.

The bond formed is permanent and waterproof, not attacked by fungus or bacteria. The glue will not stain and may be used with rare wood, veneers, and dyed materials. Jobs glued with this material may be handled and worked in 2 hr. The bond takes on waterproof characteristics in 48 hr. and becomes completely waterproof after 2 weeks' aging.

Urea adhesives in film and liquid form are among the strongest and most durable bonds yet developed. After curing under heat and pressure they are tough, heat- and moisture-proof.

A urea adhesive has recently been developed which is sold in powdered form and is particularly valuable for use in hot climates as the solution may be made up as required.

The best conditions for applying the urea resins are a temperature of 100° C., a minimum pressure of 5 kg. per sq. cm., and humidity of the wood between 6 and 15 per cent. After pressing, the urea plywood may be used immediately.

An adhesive in foam form has also been introduced, which requires the use of only 80 gm. of actual adhesive per sq. m. of wood surface. The composition consists of:

	Parts
Urea plastic	150
Water	82
Wood flour	20
Liquid froth hardener	20
Casein	18
Total	290

The casein is a necessary part of the composition and acts as a stabilizer.

In preparing the composition, the casein is placed in a mixing machine, heated with about three times its weight of hot water, and stirred. The " liquid froth hardener " is then added, and stirring is continued until the casein is well swollen, when the balance of the water is added cold. The whole solution is then cooled to about 30° C. (86° F.) and wood flour added. The urea plastic in liquid form is then added and agitation continued for 15 to 20 min. until the solution becomes three times its original volume. The frothy or spongy product so obtained is distributed by a sizing machine over the wood which is to form plywood. Pressing requires 6 min. and 1 min. for each millimeter of thickness.

The urea resin in adhesive form is used almost exclusively in the furniture. This adhesive usually consists of about 100 parts of urea plastic and 10 parts of hardener. The time of setting varies from 30 to 90 min., according to the nature of the hardener used. The time of pressing is 3 to 12 hr. at 15° C. (59° F.). The froth or foam process is also being used by furniture manufacturers.

These adhesives are widely used in airplane construction.

Urea resin adhesives are provided in hot-press and cold-press types.

The *cold-press* glue represents the achievement of long experimentation. By a new method of chemical control of the hardening process, the resin adhesive is allowed to set in a thin layer of plastic with all the strength and permanence which this implies. The bond is strong, moistureproof, waterproof, unaffected by stains, solvents, and fungus. It does not stain wood. A few hours after gluing, the pieces can be machined, but the maximum strength and water resistance are not attained for several days. This plastic glue is reported to be stronger than the wood it bonds. Composition is:

Cold-press

100 lb.	urea-formaldehyde powdered glue
65 lb.	water
2 lb.	cold hardener

At normal room temperature, 70° F., a solution of cold-press glue with hardener has a working life of about 4 hr. At higher temperatures the life of the mix is shorter, and at lower temperatures substantially longer. As the glue solution without hardener is quite stable, it is sometimes desirable to mix up a batch of glue sufficient for several days' work and add the proper amounts of hardener to small lots drawn off as needed. The wood requires no special preliminary treatment before applying the glue.

The glue is applied with any modern glue spreader, grooved rubber rolls being preferred because they give the most economical and even spread for this type of glue, though finely grooved metal rolls are satisfactory. The glue may be applied by spraying, brushing, or dipping. The required spread for this type of glue is substantially less than for animal, vegetable, and casein glues. A spread of from 30 to 40 lb. per 1000 sq. ft. of single glue line should be sufficient.

Pressure must be applied while the glue is wet. The pressures for plywood construction are 150 to 300 lb. per sq. in., depending on the amount of spread used and the type and cutting of veneer. With simple laminations and tight-fitting joints, the pressure may be released before the glue has completely set. When it is desired to speed up production, the application of moderate heat (temperature from 120° to 200° F.) is recommended, the exact temperature used depending on the heating interval and type of construction. Because of the relatively small quantity of water in a urea-formaldehyde glue line as compared with other types of glue, no special treatment of panels or other products after pressing is necessary.

For purposes of economy the glue may be extended with flour, preferably wheat. For general practice it is recommended that this should not exceed 50 lb. of flour per 100 lb. of powdered glue. The required spread for extended glue is somewhat higher than for straight urea-formaldehyde glue. Spreads of 35 to 45 lb. per 1000 sq. ft. of single glue line should be sufficient. Extension with flour tends to retard slightly the setting of cold-press glue.

For *hot-press* glue an aqueous solution is prepared by dissolving 100 lb. of the solid material in 60 lb. of water. The setup of the resin in the hot press is created by the action of a hardener supplied in dry crystalline form and dissolved in a glue solution. In each case, regardless of the quantity of filler used, 12 lb. of hot hardener should be used with each 100 lb. of urea-formaldehyde dry resin.

In the manufacture of the glue, dry resin is put into the mixer and agitation is begun. Approximately three-fourths of the necessary water is then added quickly and the mixture stirred to a smooth paste. The specified quantity of hardener is dissolved in the remaining water. The hardener solution should then be added slowly to the mixture and the stirring continued for several minutes at room temperature. A solution of urea-formaldehyde resin with hot hardener has a liquid life of approximately 24 hr. Enough mixture may be prepared at one time for a normal day's run,and at the end of the day any leftover material should be removed from the spreader and mixer (which should then be washed thoroughly) and kept in a closed container overnight, to be added to the first batch mixed the following morning.

The required spread is from 25 to 40 lb. per 1000 sq. ft. of single line. Normally, good results are obtained with an assembly period of 1 hr. or less. When a high percentage of filler is used, the panel should be pressed while the glue line is wet. With straight resin the assembly period may be extended to 48 hr.

The recommended pressing temperature is from 220° to 240° F., though a temperature as high as 300° F. may be employed in special cases such as seven-ply construction or where a rapid cure is required. When using resin without filter, for panels with core up to and including 1/8 in., the minimum pressing time is 2 min. plus 1 min. for every 1/20 in. from the platen to the deepest glue line. Using urea resin with flour filler, add to the periods above 1 min. for each 50 lb. of filler used per 100 lb. of resin. No special treatment of the panels is necessary after pressing. The panels removed from the presses may be sanded to the exact required dimensions or otherwise finished. They may be stacked without strips or finished immediately.

Impregnating Liquids. Urea-formaldehyde resins are supplied in various stages of condensation for impregnation of cloth or paper for use in laminating. The urea resins are used both as the chief binding material for the sheets and on the surface laminae of sheets where phenol is used as the principal binder. This gives a wide color range in decorative materials without loss of strength or other characteristics of the tar-acid resins.

A resin in one of the earliest stages of condensation is supplied as a solid, crystalline product which may be dissolved in water under heat to give a solution of 25 per cent resin or less. After drying the material impregnated, the resin is normally cured at 285° to 300° F. for 2 to 10 min., depending upon the particular conditions of application. It is customary to use 3 to 5 per cent catalyst, depending on the weight of the resin, to secure a satisfactory cure under these conditions. When that curing temperature cannot be attained, 8 to 10 per cent of some catalyst is used.

A somewhat more highly condensed resin is supplied as a 35 to 38 per cent solution in water and may be further diluted with water to reduce the solids content. The solutions of this resin are more viscous than those of the above-described material, and are less effective in penetrating the material to be impregnated. They are used where a surface effect is desired.

Another resin of this general type is supplied as a 70 per cent solution in water. It finds use primarily as an adhesive for the bonding of plywood by hot pressing but also lends itself to a variety of impregnating operations where adhesion and water resistance are desired.

For the production of laminated panels a 50 per cent solution of urea resin in water is supplied as a relatively thin, free-flowing liquid. In the typical molding operation a filler sheet of paper or cloth is impregnated with laminating solution so that the ratio of resin to filler is approximately 1 to 1. The sheets are then dried in a treater, and the dried sheets laminate under heat and pressure to give rigid, water-resistant panels of excellent appearance. The drying operation is generally accomplished in from 3 to 15 min. at 100° to 125° C. (212° to 257° F.). The molding conditions may be adjusted to the particular circumstances, but a typical molding cycle might be 20 min. at 140° C. (284° F.) and 1100 to 1400 lb. per sq. in. pressure, with a suitable time interval before and after the curing temperature is reached. Laminations must be cooled under pressure before removal from the press.

A new use of synthetic resins in the textile industry is improving the luster, strength, resilience or crease resistance of fabric by impregnation with urea-formaldehyde resin. The appearance of the fabric is not changed, and it retains its textile properties of absorbency, porosity, elasticity, flexibility, and serviceability. Today fabrics produced from 30 per cent synthetic resin and 70 per cent fiber have all the appearance, feel, and microscopic characteristics of the 100 per cent fiber yarns. The resins best adapted for fabric impregnation are clear, colorless, light-stable resins which can be dispersed or dissolved in water. Urea-formaldehyde seems to be particularly successful.

Unpolymerized urea-formaldehyde can be impregnated and squeezed into the core of cotton and linen fabrics, and when polymerized in this position, produces fabrics with tremendously improved resilience. The resulting fabric is not stiffened, but retains all its initial suppleness, fullness, and drape. This was developed at first as an anti-crease process, and though the development was slow in this country, millions of yards of spun rayon fabric containing 10 to 15 per cent urea-formaldehyde resin are on the market today. No evidence of the resin coating is visible, and the treated fabric is as soft or softer than the untreated type. The color is unchanged, the resilience may be more than doubled, and abrasion resistance in some instances is increased fivefold.

Urea-formaldehyde may be applied from aqueous solution in low or high degree of polymerization. This impregnating process may be used to give rayon fibers the resilience of wool, cotton fibers the luster of silk and the stability of high-grade worsted, spun rayons the character and quality of high-grade woolens, and cotton and rayon the coolness and absorbency of linen. It is possible to improve the tensile strength of the fabric, double or triple its wearing qualities, increase or decrease the luster of the fabric, and improve the wearability and serviceability.

Foamed Forms. One of the newer plastic products just emerging from the laboratories is known as foamed urea plastic. This material looks like rigid marshmallow and appears to be an excellent insulator for heat and sound. It has an apparent density of 0.83 lb. per cu. ft. It has a heat conductivity of 0.238 B.t.u. per sq. ft., per hr., per ° F., per in. Acoustical sound absorption is medium using the box method. The following factors were obtained:

Thickness	*Frequencies*		
	256	512	1024
¾ in.	0.27	0.48	0.80
1 in.	0.30	0.53	0.90
1½ in.	0.41	0.75	0.80

It has remarkable resistance to bacterial growth upon aging; there is a slight shrinkage. It is unaffected by temperatures below 185° F. It has low hygroscopicity.

VINYL RESINS

The vinyl resins are discussed by type as follows: polyvinyl acetate, polyvinyl chloride, polyvinyl chloride-acetate, polyvinyl acetals or polyvinyl aldehyde reaction products (polyvinyl acetal, polyvinyl butyral, polyvinyl formal), and vinylidene chloride.

POLYVINYL ACETATE

Polyvinyl acetate is commercially available as granular powder or solution in five standard grades. It is used as resin base for paints, varnishes and lacquers, for adhesives, and for inks, particularly metallic inks. The resin may be molded in intricate shapes, used as a binder for heavily filled plastics, applied to textiles as a stiffening agent, or paper as a high-gloss coating.

It is used as a component of paints, varnishes, and lacquers. Films of the resin are not discolored by exposure, and after irradiation become opaque to ultra-violet light. They are hard and tough and have good adherence and endurance. Their dielectric strength is good, and they have high arc resistance. Grades with softening points from 80° C. to 200° C. (176° to 392° F.) are available.

Polyvinyl acetates are colorless, odorless, tasteless, and thermoplastic, the softening point and viscosity increasing with higher polymerization. They are soluble in coal-tar solvents, and compatible with certain alkyd resins, tar-acid and natural resins. Their properties of compatibility, durability, resistance to abrasion, and rust inhibition make them desirable for surface coatings. Added to nitrocellulose lacquers they improve the adhesion, luster, and toughness.

They are compatible in all proportions with nitrocellulose and certain glycerol-phthalate and phenol-formaldehyde resins and in fair amounts with shellac, dammar, elemi and ester gum. They are not compatible with cellulose acetate, rubber, and most other gums. They resist dilute salt, acid, and alkali solutions. They burn slowly with a smoky flame.

Polyvinyl acetate is plasticized by most of the common lacquer types of solvents such as phthalates, tartrates, phosphates, abietates, and glycollates. It may be plasticized to any degree of flexibility, much less plasticizer being required for flexibility than with cellulose nitrate.

Polyvinyl acetates are soluble in most alcohols, ketones, esters, ether-alcohols, chlorinated hydrocarbons, or in mixtures of these. They are insoluble in petroleum naphthas, glycols, turpentine, and vegetable and mineral oils. They are insoluble in water, although 5 to 20 per cent of water mixed with the lower alcohols improves the solubility characteristics. In making up solutions, nonsolvents such as xylene may be used as diluents in the presence of active solvents. Solutions of these resins have a very low tolerance for petroleum thinners.

Adhesives. Because of good adherence and endurance, polyvinyl acetates form an extremely satisfactory adhesive for cloth, paper, cardboard, porcelain, metal, mica, stone, wood, leather, glass, and plastic sheets and films. They are used in both solvent and thermoplastic types of adhesives. They are particularly good for making paper-to-metal laminations. They have the same refractive index as Pyrex glass and leave no line of demarcation when used as a cement for that material.

When solutions of polyvinyl acetate are to be used as adhesives, the thermoplastic properties of the resin should be utilized, because of difficulty in controlling the amount of solvent necessary to secure the desired tackiness at the time the bond is to be made. The solution should preferably be applied to both surfaces to be bonded and the solvent allowed to evaporate completely. A force dry of 3 to 5 min. at 200° F. is generally sufficient and the surfaces may then be laminated at approximately 250° F. under as much pressure as the material to be bonded will stand. The resulting bond will be unaffected by moisture or oil.

Polyvinyl acetate impregnations have been used to stiffen toe caps in shoes and articles made of paper pulp suspensions. The resins also are used as a substitute for chicle in chewing gum. Another use is as an ingredient of printing ink.

Molded Forms. The polyvinyl acetate resins may be molded at temperatures from 250° to 275° F. and under pressure of 1000 to 2000 lb. per sq. in., but have a tendency to cold flow. They are used as a binder material with ground mineral filler in advertising signs and with wood flour in molded artificial wood " carvings."

Another and more promising application is in making transparent papers, foils, and glassine papers for food packaging.

POLYVINYL CHLORIDE

Polyvinyl chloride is available as a granular powder, plasticized sheets, extruded tubes, and special shapes. Normally it is a rigid material and is highly plasticized for most uses.

It is a nonflammable resin, practically insoluble at ordinary temperatures. It is moisture resistant, nontoxic, odorless, and tasteless. Straight polyvinyl chloride is almost infusible and, accordingly, is very difficult to fabricate. Combined with proper plasticizers, however, it is a very versatile plastic.

Polyvinyl chloride may be molded at temperatures from 225° to 275° F. and pressures from 1000 to 2000 lb. per sq. in.

Sheets and Pipes. Clear sheets of polyvinyl chloride can be made. In Europe, pipes and pipe fittings are made of rigid polyvinyl chloride compounds, i.e., slightly plasticized resin. They are light, strong, and can be heat-sealed or shaped.

Polyvinyl chloride is used for packaging because of its physical properties, heat-sealability, and good moisture resistance.

Extruded Forms. One of the most recent and widest uses for polyvinyl chloride is as highly plasticized, extruded wire coverings providing electrical insulation and waterproofness for electric wires.

Extruded polyvinyl chloride is gaining considerable popularity as a reinforcing agent in concrete. The fiber has great strength, is light in weight, resistant to water, alkalies, acids, and rust, and has good insulating properties. Plasticized polyvinyl chloride is extruded as cable coverings and calendered in the form of tape.

Bristles and textile fibers of polyvinyl chloride are extruded. Polyvinyl chloride bristles for brushes resist moisture, alcohol, gasoline, and many other chemicals.

Coatings. This vinyl material is used occasionally for chemical plant construction of cooling coils, ball floats, and valve balls. Iron tanks are coated internally with the same material in foil form. It is stable to acids, alkalies, and salt solutions, may be safely used at a temperature of 60° C. (140° F.), and is nonflammable.

Polyvinyl chloride is used for tank linings and fabric coatings. Solutions of the plasticized resin are used in special types of varnishes. Polyvinyl chloride is used in a cloth-coating preparation to make artificial leather.

Polyvinyl Chloride–Acetate

Properties. *Effect of water.* Water absorption is only 0.05 per cent in 24 hours' immersion.

Warping. Articles retain their dimensions and shape at normal temperatures.

Shrinkage. The materials are nonshrinking and therefore have a distinct advantage in use in that no " seasoning " period is required.

Flammability. The materials will not support combustion, therefore, they have distinct advantages in wiring and conductors where nonflammability is of importance.

The materials are odorless and tasteless and therefore have much promise for food containers both in the molded form and as coatings.

Chemical Inertness. The various copolymers are highly resistant to acids and alkalies and show no staining or softening of surface in the presence of greases and oils.

Rigidity. The molded parts are considerably more rigid than many other thermoplastics of equal cross section. Their strength and toughness are retained over a wide temperature range.

Applications. The material is available as:

Injection molding powders
Compression molding powders
Sheets unplasticized
Coated paper
Calendered film, 3 mils to 15 mils in thickness
Rods, tubes, and special extruded shapes
Highly plasticized sheeting permanently flexible over a wide range of temperatures and in a variety of thicknesses

Molding Compounds. Molding compounds are prepared from copolymers of vinyl chloride and vinyl acetate. Their plasticity is controlled by varying molecular weights or the ratio of the vinyl derivatives. Resins of approximately 90 per cent chloride equivalent are best suited to molding.

The outstanding properties of the finished product are strength, good dielectric properties, and resistance to water, soap, acids, alkalies, and alcohol. Their stability to light may be improved by adding ultra-violet absorbing compounds, and their stability to heat improved by the addition of lead oleate, calcium stearate, or other bases. As the acetate content increases, so does the water absorption and compatibility with other resins. Injection and compression molding powders are available.

Some of the principal types of copolymers (under the trade name of " Vinylite ") are:

1. A resin of high molecular weight, above 90 per cent chloride, used largely in plasticized form for electrical insulation, sheeting, etc.
2. A resin of high molecular weight (85 to 88 per cent chloride) which finds use in dentures where good fatigue resistance, impact strength, and tensile strength are required.
3. A resin of medium molecular weight (chloride content averages 85 per cent) suitable for general molding and extending applications including the production of sheets, rods, and tubes.
4. A resin of comparatively low molecular weight (85 to 88 per cent chloride) used in moldings, coated paper, lacquers, floor tile, cable insulation, and phonograph records.

The molded products are thermoplastic, with low softening points [60° C. (140° F.) up]. They have a wide color range and high dimensional stability. Their transparency, toughness, and slight absorption of water are important in the making of dentures, and their flexibility and excellent grooving characteristics make them useful for making phonograph records one and one-half times as heavy as those made of shellac.

Polyvinyl chloride-acetate resins shrink very little during processing and hence are applicable to large moldings. They may be used in extrusion processes such as toothbrush preforms. Fillers and pigments may be added, though pigments containing iron or zinc have harmful effects on the stability of the resin. Fillers used are wood flour, mica, talc, and alpha cellulose. In general, the fillers reduce the mechanical strength of the resin and lessen its water resistance. Plasticizers like dibutyl phthalate or tricresyl phosphate give a softer, more flexible resin. These copolymers resemble the cellulose derivatives in their molding characteristics, mechanical strength, and appearance.

These resins mixed with slate flour or other filler can be used for making floor tile with excellent properties

Polyvinyl chloride-acetate plastics darken on exposure to heat or direct sunlight, though they are improved in this respect by addition of 1 to 2 per cent of stabilizers such as lead stearate, lead oleate, calcium stearate, slaked lime, or somewhat larger proportions of the commonly used lead pigments.

Films. Films are made of polyvinyl chloride-acetate, calendered, 3 to 5 mils in thickness.

Molded Forms. Dentures, phonograph records, radio parts and parts for storage batteries are some applications. The resins are suitable for machining, extruding, blowing, shearing, spinning, swaging, and transfer molding.

Copolymer vinyl resins are outstanding as compounds for injection molding. Resistance to chemicals, beautiful colors, rigidity, strength, and accuracy of molding make these injection molding compounds outstanding in pocket combs, toothbrush handles, fountain pen parts, and the like.

Extruded Forms. Polyvinyl chloride-acetate plastics are extruded in a variety of shapes and as electrical insulation. The newest development is the extrusion of minute fibers to form a synthetic yarn woven into a new fabric — Vinyon. This process and the resultant material are described at length under Multifilaments, page 344.

TABLE 49. PROPERTIES OF EXTRUDED POLYVINYL CHLORIDE-ACETATE

Yarn	Dry (relative humidity 65%)		Wet	
	Tenacity Gm./denier	Elongation %	Tenacity Gm./denier	Elongation %
Silk (degummed)	4.22	16	3.4	26.3
Viscose rayon	2.00	18	1.0	25
Acetate rayon	1.40	27	0.85	36
Vinyon:				
High stretch	—	—	4.00	18
Medium stretch	—	—	2.30	25
Unstretched	—	—	1.00	120

Vinyon fish nets and lines tried along the Florida coast are reported to have caught twice as many fish as the ordinary tar-impregnated cotton nets and showed no signs of deterioration after six months though all other types showed partial or complete disintegration.

Other suggested uses for the new material are: shower curtains, bathing suits, waterproof acid- and alkali-resistant clothing, full-fashioned hosiery, fireproof awnings, curtains, sail cloth, umbrella fabrics, tent and tarpaulin materials, shoe linings, braids and various knit fabrics.

Coatings. Polyvinyl chloride-acetate resins find wide use in surface coatings. In general, those high in vinyl acetate are better lacquer ingredients than those high in vinyl chloride.

Two types of resins used in surface coatings are as follows:

1. A resin of low molecular weight, containing 85 to 88 per cent chloride, used in coating paper, in lacquers, and in floor tile.

2. A resin of low molecular weight, compatible with nitrocellulose and used in lacquers and finishes for industrial applications.

In lacquers these resins give high resistance to water, oils, and chemicals. Drying is by evaporation rather than by oxidation. They are suitable for lining food containers, coating concrete, coating metal, lining plating tanks, coating paper for bottle cap liners, and making wallboard coatings. The most successful application at present is as an inside coating for beer cans.

Polyvinyl chloride-acetate coatings are used extensively as finishes for sheet metal. Their exceptional toughness and flexibility make them especially well suited for this, as metal stock is often punched, spun, drawn, or otherwise fabricated after coating; nontoxic finishes, free from taste and odor, result. The coatings usually are baked at a relatively high temperature to secure the proper adherence. The coatings have unusual resistance to moisture, grease, alcohol, acids, alkalies, and most other reagents. These properties explain the present wide use and rapidly increasing demand for finishes made from them.

The solvents are primarily ketones or mixtures of ketones and coal-tar hydrocarbons. The required proportion of ketone to hydrocarbon depends on the concentration of the resin in solution and is determined by the viscosity characteristics of the resin solutions. At relatively low concentrations (8 to 10 per cent), very lean thinner mixtures may be employed, but higher solids requirements need a greater proportion of ketone.

The resins are neutral, chemically inert, and not compatible with nitrocellulose or other resins or drying oils, hence in surface coatings they are the only film-forming constituents. They have high internal plasticity, permitting the incorporation and use of a large number of different types of fillers and pigments. They darken on exposure to direct sunlight or heat, but this is lessened by the incorporation of 1 or 2 per cent of stabilizers such as lead stearate, lead oleate, calcium stearate, slaked lime, or somewhat larger proportions of the commonly used lead pigments. The stabilizers should be added to the powdered resin before fluxing on the mill or in an internal mixer. Where flexibility is a factor, plasticers such as dibutyl Cellosolve phthalate, dibutyl phthalate, tricresyl phosphate, and Santicizer B-16 are recommended. The amount added depends on the degree of flexibility desired.

The resin itself is supplied as a white, fluffy powder, yielding transparent, translucent, or opaque coatings in many shades and tints. It is soluble in ketones and related compounds, esters, chlorinated hydrocarbons, dioxane, propylene oxide, and mesityl oxide. It swells or dissolves in dichloroethyl ether and in aromatic hydrocarbons.

The presence of pigments, wax, stabilizers, and the like in filled compounds or coatings generally decreases the resistance to chemicals and solvents. Baking at a high temperature generally makes surface coatings of polyvinyl chloride-acetate resin less susceptible to attack by solvents.

Impregnating Liquids. Polyvinyl chloride-acetate impregnating varnishes are used for impregnating paper, felt, and various fabrics. Since the resin is thermoplastic, fabrics impregnated with it may be formed by heat and pressure into shapes which they will retain.

Polyvinyl Acetals (Polyvinyl Aldehyde Reaction Products)

Polyvinyl acetate becomes polyvinyl acetal by a process in which the acetate is hydrolyzed to an alcohol, which is in turn partially replaced by an aldehyde. This may be acetaldehyde, formaldehyde, or butyraldehyde, resulting in polyvinyl acetal, polyvinyl formal, or polyvinyl butyral, respectively.

In each case properties are partially controlled by the extent of replacement of the acetate groups with aldehyde. Viscosity varies with the degree of polymerization.

Polyvinyl acetal is available in compositions for injection and compression molding and the binding power of the resin is such that large percentages of filler may be used without the loss of many desirable properties. The resins show little cold flow when molded and are tougher and harder and have better adhesion than the vinyl acetate types, but are less resistant to weathering. The moldings may be machined and polished, and they take inserts. An acetal-base molding compound with 85 per cent acetate replaced has good impact strength and is used in toilet articles.

Polyvinyl acetal with 70 to 80 per cent acetate group replacement are used chiefly in spirit type varnishes, lacquers, and enamels that must stand exposure to weather.

POLYVINYL ACETAL

Sheets or Films. Sheets of the resin are used as photographic film base and for decorative and other articles. The films are made by spreading a solution of the resin (in a non-corrosive, low-boiling solvent) onto a glass or metal plate or onto a revolving drum, then evaporating, stripping, and curing by heating with warm air.

POLYVINYL BUTYRAL

Cast Forms. Polyvinyl butyral resins are available in England as granular powders and molding compounds, in the United States as calendered and extruded sheets. However, it is in the form of safety glass interlayer sheet that polyvinyl butyral resins have found their greatest field and met their greatest success — in fact, have revolutionized the safety glass industry. The 1941 production for this use was about 100,000,000 sq. ft.

Plasticized polyvinyl butyral resins, sold in sheet or roll form, are the outstanding plastic for safety glass manufacture. A number of different plasticizers may be used and the properties of the interlayer varied accordingly, but all commercial sheets form safety glass with high impact strength and toughness and with little tendency toward flying splinters. These safety values are particularly noticeable at low temperatures because the adhesive strength of highly plasticized butyral resin decreases less at lower temperatures than that of plastics previously used, e.g., cellulose nitrate and cellulose acetate.

POLYVINYL FORMAL

Molding Compounds. Polyvinyl formal is available in molding compounds of different types for various kinds of molding or extrusion. Cast forms also can be made. The 95 per cent acetate replacement type has possibilities in the manufacture of phonograph records and in photographic film. In the field of extrusion there are possibilities for artificial silk production.

The resin is resistant to alcohols, coal-tar solvents, fats, oils, and water. Films of the resin are produced having one-tenth the moisture transmission rate of regenerated cellulose and one-fourth that of cellulose acetate.

VINYLIDENE CHLORIDE

Molding Compound. Vinylidene chloride is a white, crystalline, thermoplastic substance produced as a powder and used principally for extrusion. It has the peculiar property of existing in two states — the amorphous and the crystalline. In the amorphous form the material is flexible, and when extruded is tough and can be stretched to a limited extent. The transformation from the amorphous to crystalline is brought about by orientation either from mechanical working such as drawing or stretching or from heating. In the crystalline state it assumes maximum toughness and rigidity at the sacrifice of flexibility.

The longer injection cycles and the high specific gravity — 1.70 — of the unfilled material may limit it to special applications where the inherent properties are essential.

Extruded Forms. The molecules of the filaments formed by extrusion are aligned in an orderly manner during extrusion and fabrication and large filaments with a tensile strength of 60,000 lb. per sq. in. are possible. The extruded material is nonflammable, resistant to water and many chemicals, though affected by inorganic salts, acids, and alkalies. It is used as a substitute for reed and rattan in weaving subway seats, where its ease of cleaning and resistance to splitting or cracking make it ideal. Special rubber foam inner cushions are used in these seats so that advantage may be taken of the long wearing qualities of the vinylidene chloride.

Extruded strands for use in fishing tackle are provided in a soft twist, which will unravel at the cut ends, and a hard twist, which will not do so. Strands and coils in cut lengths for leaders, trolling lines, and snells are produced, and compare favorably with Japanese synthetic gut. It is not necessarily soaked in water to give the proper flexibility, and water does not lessen its strength. It does not become weak or fray with continued use, but knots must be tied with care. The material does not stand up under snapping as well as the more expensive silkworm gut.

Experimental fly screens, cordage, and tape plastics have been made from vinylidene chloride.

Adhesives. Vinylidene chloride may be made to adhere when heat-bonded to smooth metal surfaces if it is blended with a high proportion of fibrous, non-thermoplastic filler. The unfilled plastic, however, shows inferior adhesion. Useful fillers are asbestos, sisal, hemp, and short staple cotton. Copolymerizing may be done with a number of materials such as vinyl acetate, vinyl chloride, or methyl methacrylate.

Wallboard may be made by using parts of asbestos and vinylidene chloride-vinyl chloride copolymer, then masticating the mixture with acetone and subsequently driving off the solvent. A small percentage of plasticizer is usually incorporated in the mixture.

Bonding to the smooth surface of metals such as stainless steel, nickel, copper, and monel metal is effected in molds at a temperature of from 130° to 170° C. (266° to 338° F.) and at pressures of from 1000 to 5000 lb. per sq. in. The curing time is 30 sec. to 10 min. The bond so formed is not easily broken by hammering, bending, or the action of common solvents.

VULCANIZED FIBER

Vulcanized fiber is prepared from fine cotton fibers, chemically hydrolyzed, usually by zinc chloride solutions. It forms a hard, dense, bone-like material — tough, pliable, and strong, with great physical strength and high dielectric strength. It is easily machined.

Vulcanized fiber is made from special high alpha-cellulose content paper. It also may be prepared by converting cotton rags to absorbent paper. The blends of rag stock are adjusted on the basis of the properties demanded in the finished product. After treatment in a paper mill, the material is rolled on cylinders and unreeled in strips into zinc chloride solution. A finishing process consists in soaking in successive zinc chloride solutions diminishing in strength to pure water, removing the zinc chloride from the jelly-like material by osmosis, washing and treating with steam heat and high pressure. The material may be wound on drums or mandrels to the desired thickness for rods or tubes. It is formed as soon as prepared. The forming operation is somewhat similar to that of casein.

Vulcanized fiber is made in rods and tubes and other unfinished forms, hollow ware (boxes, cans, and pails), laminated sheets and plates. The sheets, rods, and tubes are made in standard size in red, gray, and black.

The fiber is tough, and resists heavy impacts without cracking or shattering. Its hard, smooth surface is not easily scuffed, scarred, or splintered. It is noncorrosive, greaseproof, and oilproof. The hollow ware is made in standard sizes and special sizes to meet particular requirements.

Articles of vulcanized fiber may be turned, sawed, sheared, punched, drilled, tapped, bored, and formed. They may be machined in any way it is possible to machine metal. They resist dry heat but become brittle at high temperatures and char at about 180° C. (356° F.). They absorb moisture readily and must have a varnish or protective coating. Curved articles show superior mechanical strength. The material has important electrical applications.

ZEIN PLASTICS

Maize protein is isolated as a white granular powder, and a mixture of this and formaldehyde is put through a dough mixer, worked on hot rolls, and cured under pressure. It resembles casein and is formed in a similar way. It may be made more flexible by incorporating an ester of lactic and tartaric acids, an aromatic sulfonalkylamide, or dibutyl phthalate. Sheets are sliced and forms are machined from pressed blocks.

Zein differs from casein in being soluble in many solvents (glycols, glycol ethers, alcohol-hydrocarbons mixtures), especially when warm. It is also compatible with many synthetic resins, notably glyptals.

Zein filaments are made by extrusion through spinnerets of solution of zein in an aqueous organic solvent containing formaldehyde and using aqueous formaldehyde as a coagulating bath. These filaments may find application in textiles.

Zein-impregnated cloth may be formed in a hot-molding operation in such shapes as hats, although a coat of varnish, lacquer, or paint is required to prevent absorption of moisture.

CHAPTER VII

SYNTHETIC TEXTILE FIBERS

MULTIFILAMENTS

The development of the synthetic fibers industry has been intimately associated with the growth of plastics as a whole. New types of materials produced in one field aided progress in the other. More recently, work with new fibers has made available for moldable plastics a wide selection of potentially valuable raw materials.

The most important synthetic fibers occupying the attention of the textile trade, at present, are classified in groups in Fig. 7.1.

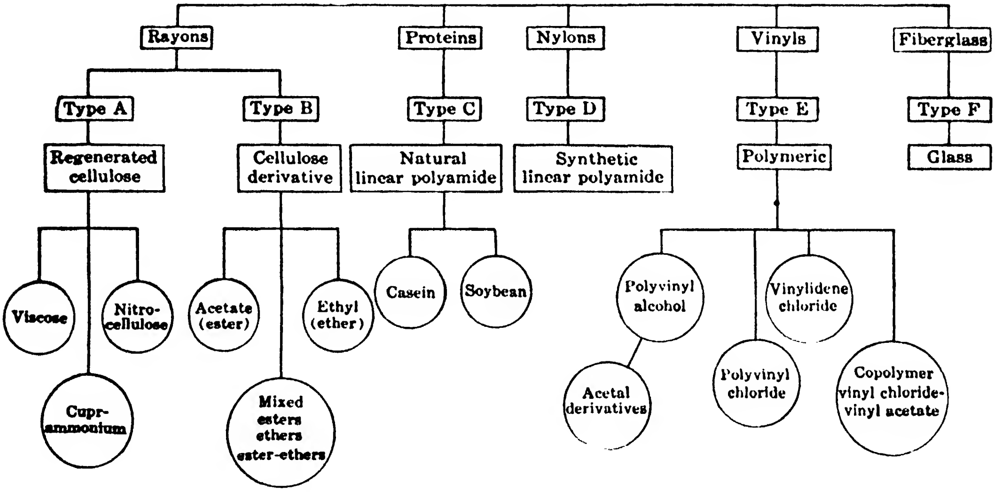


FIG. 7.1 — Types of synthetic fibers.

In this section attention is devoted to continuous multifilament yarns. " Multifilament " denotes that a continuous thread of yarn is actually made up of several individual filaments.

Rayon Manufacturing Methods. Four manufacturing methods have been used for commercial production, as indicated in Fig. 7.2.

TYPE A RAYONS

Viscose Process. Slightly less than 66 per cent of the rayon manufactured in the United States during 1940 was prepared by this process. Cross, Bevan, and Beadle discovered the reactions involved in the preparation of cellulose xanthate and obtained their patents in 1892. In 1910 the first American plant was established.

Cellulose in the form of a high-grade wood pulp (mostly from spruce and western hemlock), or cotton linters, or a mixture of these materials, is used for the viscose process. The first step consists of " steeping " in 18 per cent caustic 150 to 200 lb. of pulp in the form of sheets. This step requires from 30 to 90 min., and the temperature of the solution is maintained around 18° C. (64.5° F.). The excess caustic liquor is removed and the sheets pressed until their final weight is approximately three times their original weight. Except for dampness there is no evidence of a chemical reaction after this step; however, the cellulose has undergone the reaction shown in Fig. 7.3, page 347.

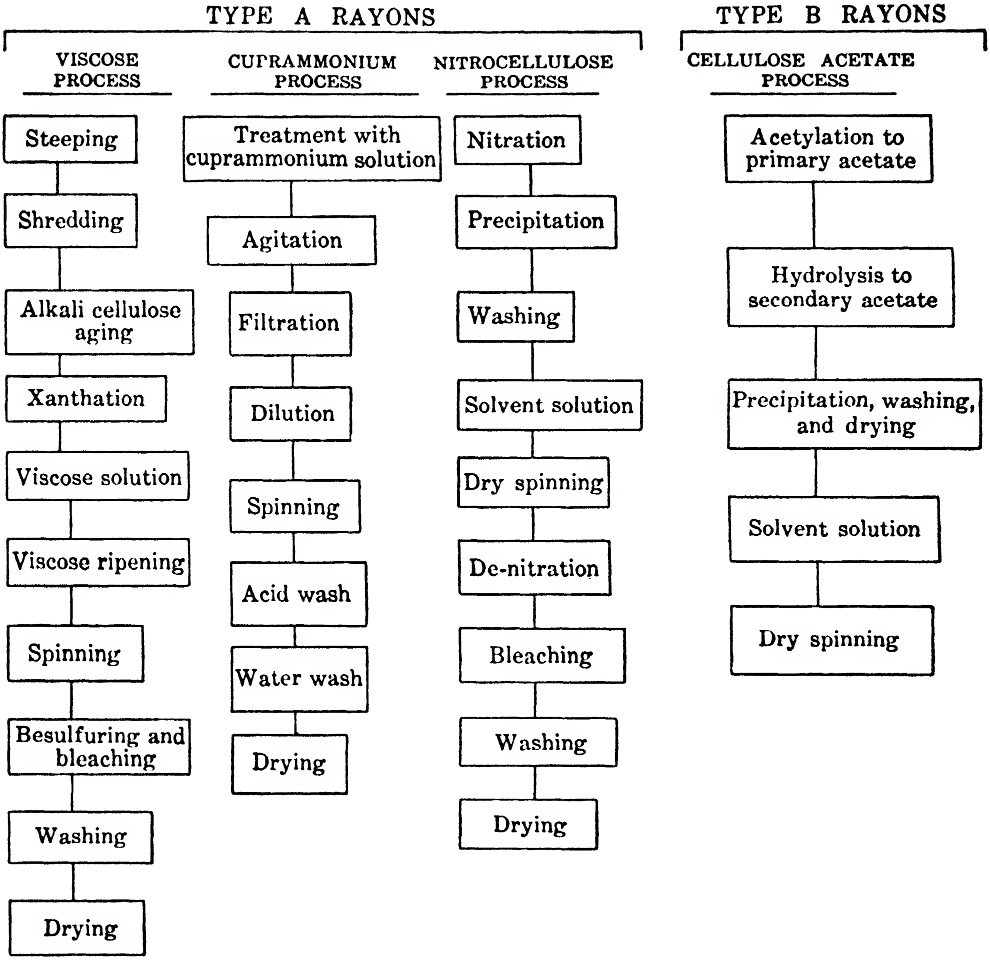
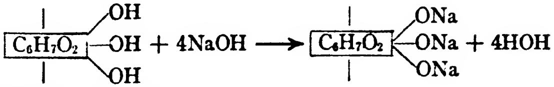


FIG. 7.2 — Conversion of wood pulp and cotton linters.

After steeping and pressing, 350 to 700 lb. of the wet pulp sheets are immediately transferred to powerful shredders where they are milled and disintegrated into a fluffy condition. The temperature of this step is controlled between 68° and 86° F. (20° to 30° C.), since the pulp is quite alkaline and the caustic continues to react with

TABLE 50. VISCOSE PROCESS

Operation	Quantities* of Materials Reacted	Approx. Time Consumed	Approx. Temperature of Reaction	Reaction†
1 Steeping	150–200 Wood pulp or cotton linters, 18–19 per cent sodium hydroxide	30–90 minutes	18° C. (64.4° F.)	 $\boxed{C_6H_7O_2}\begin{matrix}-OH\\-OH\\-OH\end{matrix} + 4NaOH \longrightarrow \boxed{C_6H_7O_2}\begin{matrix}-ONa\\-ONa\\-ONa\end{matrix} + 4HOH$
2. Shredding	350–700 Alkali cellulose per charge	2–3 hours	20°–30° C.(68°-86° F.)	Mechanical disintegration
3. Aging	—	48 hours	25°–30° C.(77°-86° F.)	Cellulose chain length becomes shorter. Viscosity of alkali cellulose decreased. Viscosity of original pulp determines length of aging
4. Xanthation	100 Alkali cellulose 50 or less — carbon bisulfide	2–4 hours	25°–30° C.	Xanthation reaction
5. Mixing	Cellulose xanthate, 4 per cent sodium hydroxide	4–6 hours	20° C.	Xanthate dissolved in caustic to form " Viscose " solution
6. Blending	—	Continuous	20° C.	Mixer charges blended for uniformity
7. Viscose ripening	—	48 hours	18°–22° C.(64.4°–71.6° F.)	Hydrolysis reaction
8. Spinning	Viscose extruded into excess of bath containing H_2SO_4 and $NaHSO_4$ to coagulate and regenerate	20–30 seconds	40° C. (104° F.)	Reaction Viscose solution + H_2SO_4 + H_2O $\longrightarrow$ Side reaction
9. Preliminary wash	—	—	—	To remove excess acid
10. Desulfuring	Treatment with dilute caustic solutions	—	85°–95° C. (185°–203° F.)	To wash out sulfur compounds resulting from xanthation step
11. Bleaching	Dilute sodium hypochloride, chlorine water or peroxide	—	20°–30° C.	To oxidize remaining sulfur compounds and to improve " whiteness " of yarn
12. Washing	Soft water	—	—	To remove chemicals from desulfuring and bleaching steps and remaining sulfur compounds
13. Drying	—	—	—	—

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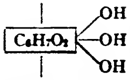
* Pounds.

† Form  $\boxed{C_6H_7O_2}\begin{matrix}-OH\\-OH\\-OH\end{matrix}$ is written to indicate a chain and not a single glucose unit. Each cellulose chain is composed of a large number of glucose units and there are a great number of chains. Each glucose unit should be enclosed and taken *n* times. *N* would represent the " degree of polymerization," i.e., the average chain length (number of glucose units) of the sample at hand.

the cellulose, shortening the length of the cellulose chains now known to be made up of recurring glucose units. A high temperature would accelerate this reaction to a harmful degree.

The fluffy alkali cellulose is then placed in cans and stored at a temperature ranging generally between 77° and 86° F. (25° to 30° C.). All during the storage period of approximately 48 hr., chemical reaction continues, the cellulose chain length becoming shorter. This is a very important step because the chain length of the cellulose molecule controls the viscosity of the subsequent viscose solution and in turn the ultimate strength of the regenerated cellulose fiber. Aging time and temperature, therefore, must be rigidly controlled if uniform quality of the rayon is maintained.

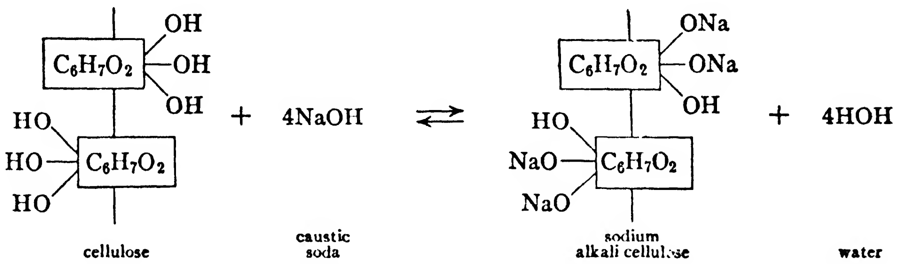


Fig. 7.3 — Rayon viscose process.

The alkali cellulose is transferred to revolving drums called barrattes which are capable of holding 500 to 1000 gal. Carbon bisulfide is added and reacts with the alkali cellulose complex to form a thio-carbonate of cellulose. This carbonate is hydrophilic, and as the reaction proceeds, the fibers become swollen in the water always associated with the alkali cellulose. The fibrous alkali cellulose now changes to granular or jellylike masses, bright orange in color. Two to 4 hr. are permitted for this step. The principal reaction can be expressed as in Fig. 7.4.

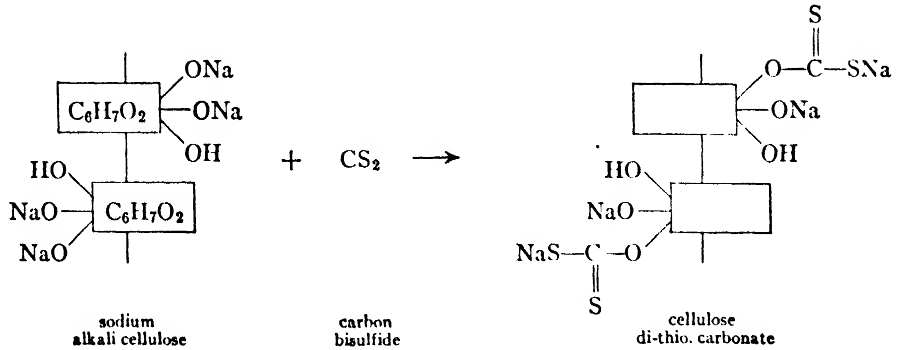


Fig. 7.4 — Rayon viscose.

Fifty pounds or less of carbon bisulfide are needed for 100 lb. of sodium alkali cellulose. Heat is generated during the reaction so the barrattes are equipped with controlling devices and held at a temperature of 77° to 86° F. A means is also provided for removing from the equipment both the gases formed during the reaction and any excess carbon bisulfide.

The xanthate is now transferred to water-jacketed mixers or dissolvers where it is mixed with dilute caustic soda to provide the proper cellulose-caustic ratio. The cellulose content generally ranges between 6 and 9 per cent and the caustic between 4 and 7 per cent. During mixing, the temperature is maintained at about 62° F. (16.7° C.). The resulting orange-colored solution is known as viscose.

Rayon made from this viscose is known as the " Bright " type because of the high luster of the finished yarn. " Dull " or " Semi-dull " rayon yarns are also made. The conventional method for making these latter yarns is by adding a " delustering agent " (a material having a refractive index differing from that of cellulose) during the mixing operation. Titanium oxide and white mineral oil are representative delustrants. Certain organic salts are also employed.

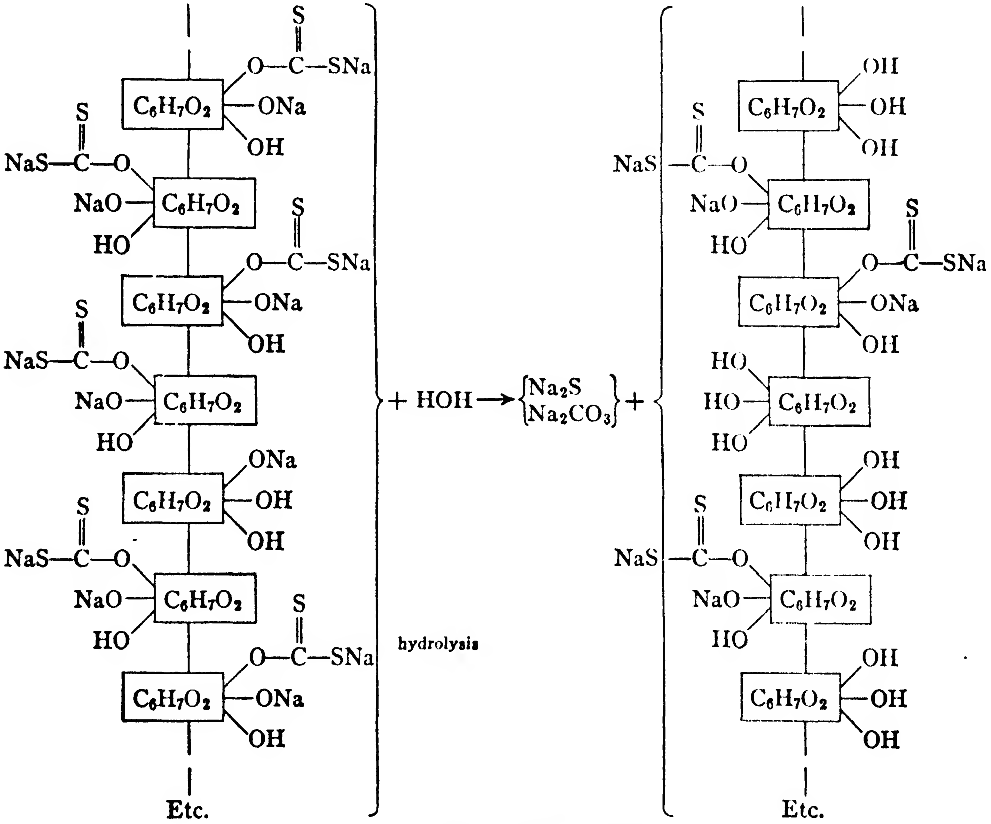


Fig. 7.5 — Rayon viscose, ripening.

Another method of preparing " Semi-dull " or " Dull " yarns consists in adding the delustrant in the form of an aqueous dispersion to the viscose just before the viscose solution is pumped to the spinning machine. The viscose and delustrant enter a " mixing head " and from these the delustered viscose is pumped to the machines.

The amount of delustrant added to the viscose depends upon the dullness desired. This can be determined only by experience and caution must be exercised not to impair the strength of the yarn.

Cellulose xanthate, being essentially a dithiocarbonate, is similar to the familiar soluble carbonates. Hydrolysis occurs in aqueous solution. After thorough mixing, the viscose solution is transferred to large blending or storage tanks, the air removed by evacuation, filtered to remove undissolved particles and foreign matter, and allowed to " ripen " until ready for the spinning operation. Hydrolysis, which continues during the ripening period, is controlled by temperature and time. High temperatures accelerate ripening. In time, the viscose solution would spontaneously set to a gel and would finally become a dense block. Before reaching the gel stage, however, the viscose solution (generally after about 48 hr. at 64° to 72° F.) is pumped to the spinning machines. The reaction taking place during ripening can be represented as in Fig. 7.5.

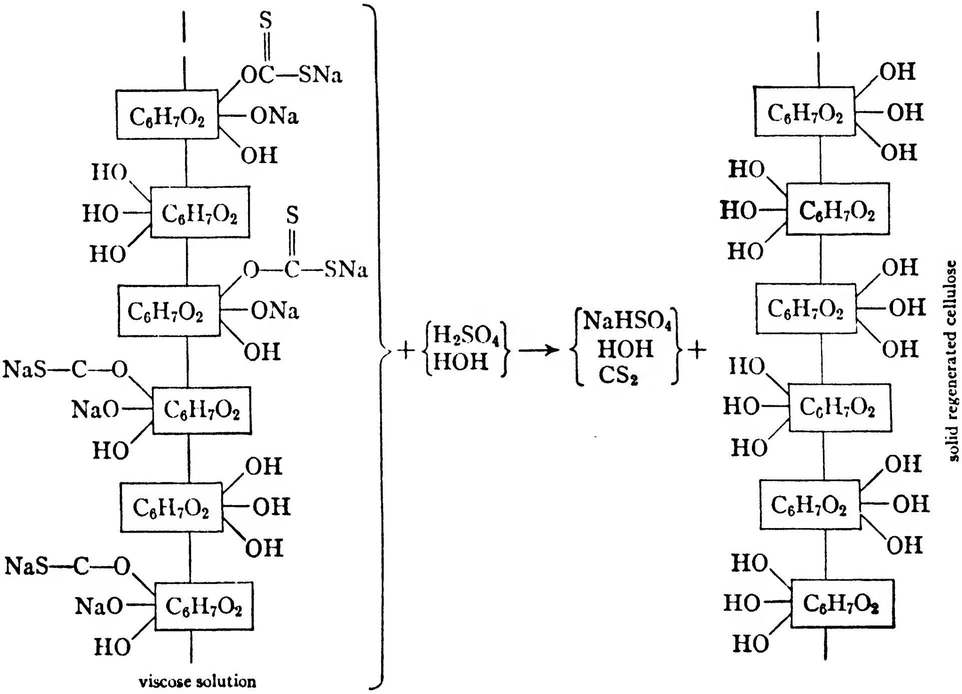
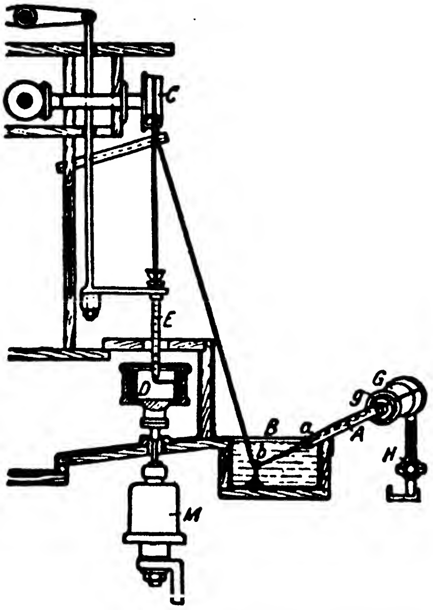


Fig. 7.6 — Regeneration in rayon production.

The viscose solution upon reaching the spinning machine is filtered and extruded by pressure through spinnerets. Spinnerets (made of platinum-gold or platinum-iridium alloys, unaffected by the acid bath) are circular and cup-shaped and contain a number of small round holes (0.002 to 0.006 in. in diameter) depending upon the number of individual filaments (filament count) desired to make up the single strand of yarn.

Considerable choice can be exercised in the bath used to coagulate (precipitate) and regenerate the cellulose from the viscose solution. One popular type is an aqueous solution of sulfuric acid, sodium sulfate, zinc sulfate, and glucose. The sulfuric acid, which is responsible for regeneration, in most cases is maintained between 8 and 12 per cent, although in the Lilienfeld process, baths of 55 per cent acid at a temperature of 77° F. (25° C.) are recommended. Normally, the precipitating baths are maintained at about 104° F. (40° C.). Glucose is used in small amounts to prevent the salt formed during the precipitating reaction from crystallizing on the spinning machinery. Sodium sulfate or sodium acid sulfate is always formed in baths using sulfuric acid, owing to the presence of sodium hydroxide in the vicose. The concentration is maintained between 15 and 20 per cent.

The acid in the coagulating and regenerating bath precipitates the cellulose xanthate and further breaks down the xanthate, releasing cellulose. This cellulose is known as "regenerated cellulose," and at this point we have, for the first time, the regenerated cellulose fiber. Chemical reactions taking place during regeneration are given in Fig. 7.6 on page 349.



Courtesy of News Edition of Industrial and Engineering Chemistry.

FIG. 7.7 — Bucket rayon spinning machine.

Two main types of spinning equipment used commercially are known respectively as "bucket system" and "bobbin system." Figure 7.7 shows diagrammatically a cross section of a bucket rayon spinning machine. The viscose is passed through the pump *H*, filter *G*, pipe *A* and spinneret *a*, precipitated and regenerated into continuous fibers in the bath *B*, passed under a guide *b*, up and around a feed wheel *C* and then through a glass funnel *E* into a revolving, acid-resistant fabric-reinforced plastic type of bucket *D*. Each bucket has an individual motor *M* and a single commercial machine has 50 to 100 spinning positions. The speed of the bucket ranges between 2000 and 7000 r.p.m.

The funnel moves up and down giving the traverse required to build up an annular cake against the walls of the bucket. During this type of spinning, the required twist can be given the thread and subsequent twisting is unnecessary. Tension on the yarn between the feed wheel and the point where it enters the bucket is determined by the effective radius of the bucket. The tension grows less as the cake builds up, and is compensated by applying a counterchange in tension at some point in the cycle; that is, the bucket speed can be changed or the tension on leaving the bath can be altered continuously.

For the bobbin system, the procedure is the same up to the point where the rayon passes around the feed wheel. At this point, a round revolving bobbin is used and the rayon wound directly upon the bobbin. No opportunity is provided for putting a twist into rayon during spinning when using this system, and a separate twisting step must be provided later.

One manufacturer has eliminated winding the wet unpurified yarn. Each thread is purified and dried individually after passing from the spinning bath to the final wind-up package.

After spinning, the cakes or bobbins of rayon are given a wash to remove the excess acid. The rayon can be skeined either before or after purification. The purification treatment consists of removal of the sulfur compounds (resulting from the xanthation step) and bleaching. Desulfuring is carried out by subjecting the rayon to showers of hot alkaline solutions. Some manufacturers use hot sodium sulfide, or a combination of hot dilute caustic soda and sodium sulfide. Others employ a hot solution of sodium carbonate and sodium cyanide. Heat is important during the desulfuring treatment since it steams out the volatile sulfur derivatives entrapped in the rayon. The rayon is later bleached with dilute chlorine water, dilute sodium hypochlorite, or weak hydrogen peroxide. Great care must be exercised during this step because if the rayon is over-bleached, oxycellulose is formed, and the strength of the rayon is impaired. In some cases where chlorine types of bleach are used, an " anti-chlor " treatment of dilute sodium sulfite is given. The purified rayon is dried and conditioned, then skeined or coned in an atmosphere of 60 per cent relative humidity at 70° to 72° F.

High Tenacity Rayon Yarns.[1] Viscose rayon yarns of extremely high strength have been used in the construction of fabrics for automobile tires. Some of these yarns have a tensile strength of 70,000 lb. per sq. in. — a strength as great as some forms of steel. One of the processes for making this yarn employs cotton linters of the highest purity in place of wood pulp.

The astonishing strength is brought about in part by stretching the wet swollen viscose filaments directly following the coagulating and regenerating operation.

Cuprammonium Process. In the cuprammonium process, cotton linters are used as the source of cellulose. Into a larger mixer are added measured amounts of (1) ammonium hydroxide (approximately 26° Baumé), and (2) copper hydroxide. The latter can be anhydrous, but since the copper is recovered in the operation, for economy the salt with a measured amount of water is generally used. The copper hydroxide is kept free from other metallic impurities. After mixing, cotton linters are added, and with proper agitation, solution of the cotton can be accomplished in about 1 hr. If low-viscosity cellulose (shorter cellulose chain length) is used, the cellulose concentration can be permitted to reach 15 to 20 per cent without gelation. If high-viscosity cellulose is used, the concentration must be reduced.

After dissolving the cotton, the solution is pumped to a second mixing tank and water added until the cellulose concentration is approximately 4 per cent. The dilute solution is then sucked through a vacuum filter into a tank where it is blended with other charges for uniformity. After de-aeration, the solution is pumped through a plate and frame filter press, using canton flannel and cotton batting dressing, onto a storage tank for the spinning solution. Up to this point, 10 to 12 hr. are required.

Spinning can be accomplished by extruding the solution through spinnerets into a sodium hydroxide solution (4 per cent or stronger) maintained at room temperature. The bobbin type or bucket type of spinning can be used. A means is provided for giving the thread a slight stretch before winding. Continuous purification and drying of the coagulated thread, thereby eliminating winding the wet yarn on a bobbin or in a bucket, has been used with success. If a continuous purification of the individual filaments is not employed, the yarn is skeined. The skeins are treated with cold dilute sulfuric acid (1 to 3 per cent), followed by thorough washing with soft water and drying.

Ammonia is recovered in the process by conducting into the bottom of an ammonia scrubber (water enters top) the fumes from the tank used for dissolving the cotton; the ammonia solution formed is conducted to the ammonia make-up tank. If dilute

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[1] See also under Physical Properties of Rayon.

sodium hydroxide is used for the coagulating bath, the ammonia dissolved during spinning is also recovered by heating the bath and sending the ammonia fumes to the ammonia scrubber. The copper from the coagulating bath is recovered by precipitation. Copper is also recovered from the acid and water purification solutions.

It has been estimated that 0.57 lb. of ammonia (26° Baumé), 0.80 lb. 50 per cent caustic soda, 0.75 lb. copper sulfate, and 0.92 lb. of cotton linters are essential for 1 lb. of rayon made by the cuprammonium process.

Nitrocellulose Process. This process was used to produce the first rayon on a commercial scale. It was invented by Count Hilaire de Chardonnet who obtained his first patent in 1884 and exhibited his product in Paris in 1889.

The nitrocellulose or " nitro " process, as it was commonly called, has not been used in the United States since 1934, therefore very little attention will be given to the manufacturer of the yarn. For the chemical steps involved in converting cotton linters into cellulose nitrate see Flow Chart section; also Cellulose Nitrate.

Cellulose nitrate has the general appearance of cotton but is more granular and feels harsh to the touch. To convert it into filaments it is dissolved in solvents, such as a mixture of ether and alcohol, or other low-boiling solvent mixtures, filtered to remove impurities and undissolved particles, and transferred to large aging tanks where entrapped air is released in the form of bubbles. The dissolving process takes from 4 to 8 hr. The temperature is maintained at about 60° to 65° F. (15.6° to 18.3° C.).

The solution, free of air, is extruded through spinnerets into a current of warm air which evaporates and carries off the solvents, thus solidifying the filaments. This is called " dry spinning " since it involves only the evaporation of solvents. The filaments are combined and wound on bobbins. After giving the yarn a slight twist it is skeined and denitrated by immersion in ammonium sulfide or sodium sulfide solution. The yarn during denitration has been converted into cellulose again. It is washed, bleached slightly, given a final wash, dried, inspected, packed, and shipped.

This process is more hazardous and more expensive than the viscose process.

TYPE B RAYONS

Cellulose Acetate Rayon Yarns. The chemical steps involved in the manufacture of cellulose acetate are explained in Chap. XIII; see also Cellulose Acetate.

Cellulose acetate rayon differs from the viscose, cuprammonium, and nitrocellulose types in that it is a cellulose ester and not regenerated cellulose. In other words, in the Type A rayons, the final yarns all have the same chemical composition — fibers made up of chains of recurring glucose units, having the accepted formula. See Fig. 7.8.

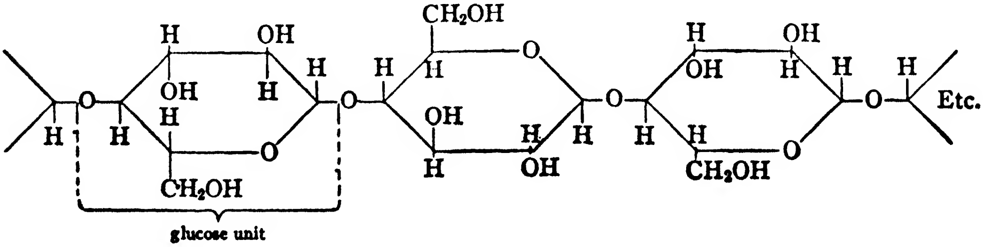
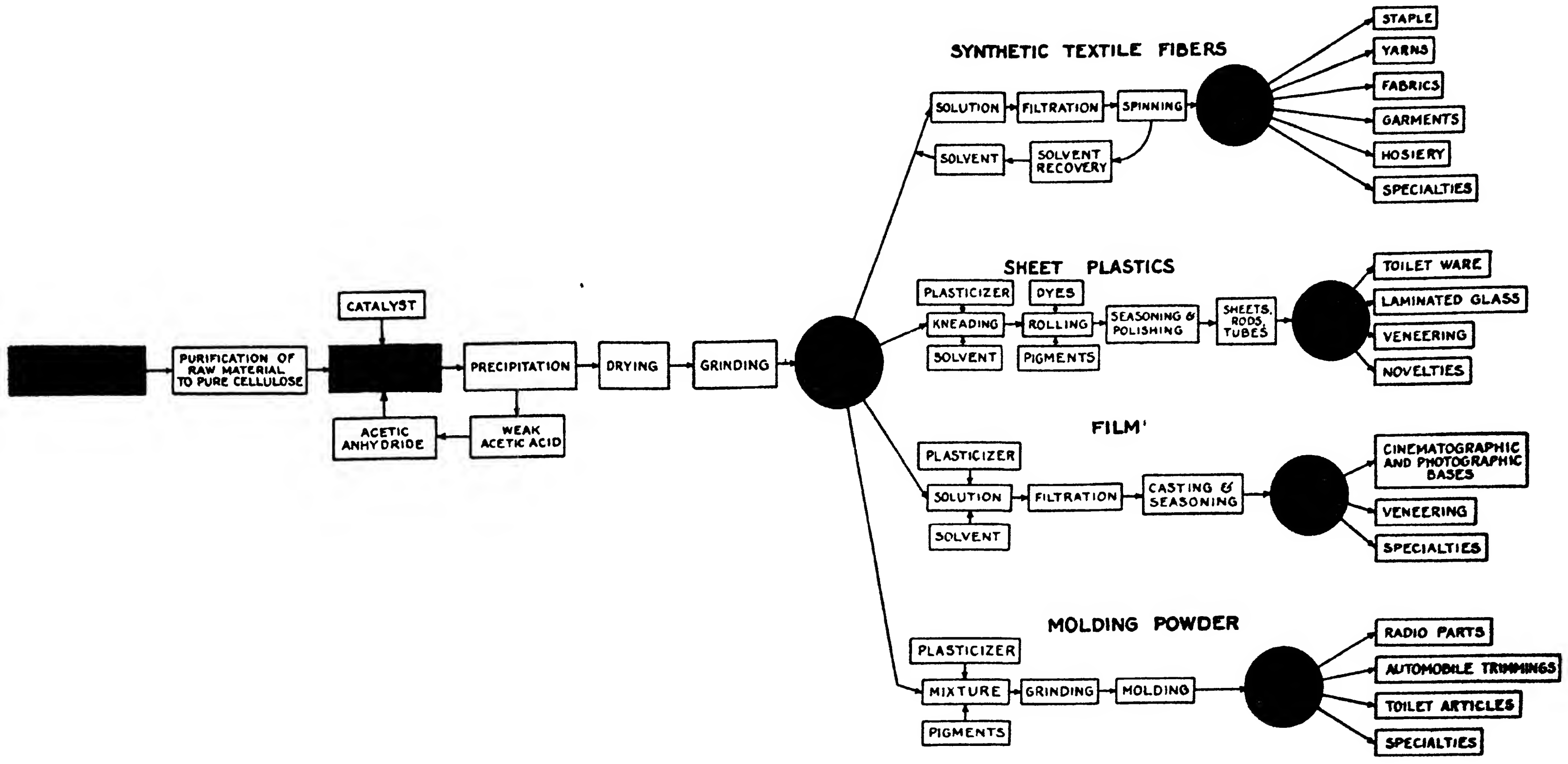
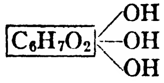


Fig. 7.8 — Cellulose acetate rayon.



Flow of cellulose materials through various manufacturing processes to the finished articles.

Theoretically, when considering the structure of a single glucose unit,



$$\boxed{C_6H_7O_2}\begin{matrix}\diagup OH\\ -OH\\ \diagdown OH\end{matrix}$$

it would appear possible to prepare true mono-, di-, and triacetates. Actually, with the exception of the triacetate, where all three hydroxyl groups are known to be replaced, distinct compounds do not exist but mixtures of acetates of various degrees of esterification are formed. In the acetylation of cellulose it is important to keep in mind that the chains which make up the cellulose fiber contain a great number of glucose units and that there are a great number of chains. In preparing acetates below the triacetate, the hydroxyl groups of each individual glucose unit along the chain are not replaced by acetyl groups to the same extent. Therefore, when the resulting material is analyzed for combined acetic acid, and the degree of substitution is calculated, an average value is obtained. If, by chance, the degree of substitution is found to be exactly 2.0, it does not mean that two hydroxyl groups of each glucose unit all along the cellulose chain have been replaced, but that this value is an average of the extent of reaction of all the glucose units of all the chains making up the sample.

In the manufacture of cellulose acetate, the purified cotton linters are acetylated to the tri- or primary acetate, having the formula in Fig. 7.9, where *n* represents the average " degree of polymerization," i.e., average number of acetylated glucose units making up the cellulose acetate chains.

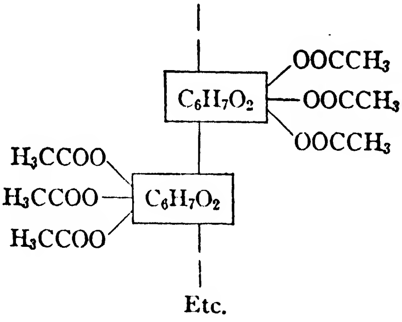


FIG. 7.9 — Rayon.

This type theoretically contains 62.5 per cent combined acetic acid and is soluble in chloroform. It is, however, insoluble in acetone and unsuited for the manufacture of yarn because of its limited solubility and the fact that it is not easily wetted by water, making it difficult to dye and finish.

The type of cellulose acetate being supplied the trade in the form of yarn today contains around 54.5 per cent combined acetic acid, corresponding to an average degree of substitution slightly over 2.0. This emphasizes again that the material is not made up of molecules all having the same acetic substitution, but rather that it is a mixture of molecules having various degrees of acetic substitution.

Acetates with less than 50 per cent combined acetic acid are not suitable for textile purposes.

The primary acetate is treated with water in the form of dilute acetic acid and allowed to remain for a period of time under controlled temperature conditions. The water reacts with a part of the acetyl group of the triacetate with the liberation of acetic acid. Samples are taken periodically, washed and tested for solubility, and combined acetic acid. When the hydrolysis has proceeded to around 54.5 per cent combined acetic acid, the entire mass can be precipitated by diluting with water and agitating vigorously. If the temperature is raised to 104° to 140° F. the hydrolysis step can be carried out in a few hours. We have now an acetone-soluble acetate termed the " secondary acetate." This material is washed thoroughly with carefully purified water until neutral and free of uncombined acetic acid.

The concentration of the cellulose acetate in solution generally varies between 18 and 25 per cent, depending upon the viscosity desired. The acetate flake is dissolved in the solvent in large closed mixers having heavy stirrers because of the high viscosity of the dope. This operation takes from 12 to 24 hr. When solution is complete the charge is pumped to blending tanks which hold several batches, and again mixed in order to ensure uniformity. The material is filtered several times under high pressure through thick cotton filters and then stored to remove dissolved air bubbles. After de-aeration it is transferred to feed tanks.

The spinning operation is similar to that used for the nitrocellulose process. It consists of extruding the viscous acetate solution through fine holes (0.002 to 0.005 in. in diameter) in a nickel or other noncorrodible metal spinneret into a tube or box (generally known as a spinning cell) through which warm air flows for the evaporation of the solvent. As the filaments leave the cell, they are drawn together and led to some form of winding device. This yarn, known as " Bright " does not require a purification treatment. It is now ready for twisting and packaging.

The size of the holes in the spinneret has an effect on the size of filaments extruded but for the most part filament denier is determined by the relation between the rate of delivery of spinning solution and the windup speed.

So-called dull or delustered acetate yarns are made by incorporating certain pigments such as titanium oxide in the acetate solution during the mixing operation. The degree of dullness is controlled by the quantity of pigment added.

Ethyl Cellulose Rayon. Ethyl cellulose is a cellulose ether manufactured commercially by treating alkali cellulose (see Steeping Step — Viscose Rayon Process) with ethyl chloride. For details concerning the manufacturing steps see the Flow Chart section.

After reacting the alkali cellulose with ethyl chloride, ethyl celluloses of different degrees of substitution are formed. As in the case of cellulose acetate, uniformly etherified cellulose molecules are not formed. The extent of reaction can be obtained by analysis, showing the average degree of substitution of ethoxy groups (OC_2H_5) along the cellulose chain. Under controlled concentration and temperature conditions, different degrees of substitution may be duplicated.

There are several grades of ethyl cellulose available. The following tabulation demonstrates the effect of the degree of etherification on softening and melting points.

Ethyl cellulose with 48.0 to 49.5 per cent ethoxy is the most soluble in single solvents. Different viscosity flakes are available and, generally, the higher the viscosity, the stronger the yarn.

TABLE 51. ETHOXY CONTENT OF ETHYL CELLULOSE[2]

Type	Mols per C6 Unit	Per Cent	Softening Temperatures, °F.	Melting Temperatures, °F.
Low	2.15–2.25	43.5–45.0	356.0–320.0	392.0–410.0
Medium	2.25–2.46	45.0–48.0	320.0–284.0	392.0–410.0
Standard	2.46–2.58	48.0–49.5	284.0–320.0	392.0–410.0

Although produced and sold in commercial quantities in flake form, the material has never been used on a commercial scale to produce rayon. Its solubility in a wide variety of solvents, some of them well known dry-cleaning solvents, and its comparatively low softening point restrict its use in the textile industry. Ethyl cellulose yarn has, however, been investigated on an experimental basis and may be made available in the future for textile articles. Care will have to be exercised during cleaning.

With the exception of the use of different solvents, ethyl cellulose flake may be converted into yarn using the procedure and process described for cellulose acetate. The concentration of the spinning solution would depend upon the viscosity of the flake used. " Semi-dull " and " Dull " types of yarn could be produced by incorporating pigments in the spinning solution during the mixing operation.

One satisfactory solvent for ethyl cellulose consists of a mixture of 80 per cent toluene and 20 per cent alcohol. It is also soluble in a variety of alcohols, esters, aldehydes, and ketones. In concentrations up to around 16 per cent, ethyl cellulose is soluble in ethyl ether, but in higher concentrations, e.g., around 50 per cent, it is simply swollen.

Some indication of the relative physical properties[3] of cellulose ether and cellulose ester types of yarn can be obtained from the following tabulation, showing results on two yarns, both of the pigmented type.

TABLE 52. PHYSICAL PROPERTIES OF CELLULOSE ETHER AND CELLULOSE ESTER

Yarn Tested at 60% Relative Humidity and 70° F.

	Ethyl Cellulose	Cellulose Acetate
Softening point (° F.)	284–293	446
Melting point (° F.)	356–374	464
Denier	175	150
Filament count	40	40
Dry tenacity (grams per denier)	0.83	1.26
Dry elongation (per cent)	28.9	24.0
Wet tenacity (grams per denier)	0.70	0.80
Wet elongation (per cent)	29.6	33.6

Mixed Cellulose Esters, Cellulose Ethers, and Ester-Ethers. A large number of mixed cellulose esters, mixed ethers and mixed ester-ethers have been prepared and

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[2] From Dow Chemical Co.

[3] See section under Physical Properties for explanation of test terms.

studied but none is used at present in the commercial manufacture of continuous filament yarn. Some of the mixed esters, such as cellulose acetate-butyrate and cellulose acetate-propionate, are finding application in the production of transparent films. (See section on Synthetic Films.)

RAYON STAPLE FIBER

This type of fiber is prepared from both Type A and Type B rayons. It is prepared by cutting continuous fiilaments to specified short lengths. The chemical processes are the same as those explained for the rayons. The spinnerets, however, are larger and contain a greater number of holes.

For viscose staple, several spinnerets are placed in the same coagulating and regenerating bath. The regenerated cellulose fibers are converged prior to the windup and the material at this stage has the appearance of a rope. This rope can be purified by draping over rods on a movable conveyor where it is subjected to the desulfuring, bleaching, washing, and finishing solutions. It is then cut to the desired length (generally 1½ in. to 6 in.) and dried. In some processes the staple rope is cut before purification. The " chips " are placed on an endless belt and subjected to the purification treatment. The dried staple is shipped in large bales similar to cotton.

Type B rayon staple fiber, converged after the dry-spinning operation, does not require the purification treatment. The filaments are merely cut to desired lengths immediately and subjected to a finishing treatment which aids in processing on textile equipment.

Staples having a " crinkly fiber " are on the market and are being used extensively in the manufacture of carpets and rugs. After weaving, this type has the appearance of wool and is very serviceable.

The rayon staples can be spun alone or mixed with cotton, silk, or wool on standard textile equipment. Fabrics produced from the mixed fibers provide novel texture effects. See section under The Rayon Industry for production and price figures.

Physical Properties of Rayon Yarns. Physical properties of representative types of continuous filament rayon yarns are tabulated in Table 53 and Table 54. Although the dry tenacity (tensile strength) of cellulose acetate yarns is on an average lower than that of the regenerated cellulose types, the wet tenacities are about the same. In the wet tests, viscose and cuprammonium textile type rayons retain about 45 to 50 per cent of their strength. Under like conditions, cellulose acetate retains about 60 to 70 per cent of its strength. " High tenacity " viscose rayon yarns retain their strength after saturation to a higher degree than the viscose textile yarns.

EXPLANATION OF TERMS USED IN TABLES 53 AND 54

Denier: The unit of weight (0.05 gram) used to express the number (fineness) of rayon yarns. The denier of yarn is the weight of 450 meters of yarn at standard conditions expressed in units of 0.05 gram. Denier is also equal numerically to the weight in grams of 9000 meters of yarn at standard conditions.

Filament or Filament Count: Number of individual filaments making up one strand of yarn.

Tenacity and Elongation: A standard length of yarn (18 in.) is stretched until it breaks. The tension necessary to cause a filament of the yarn to break is calculated to grams per denier (based on original denier), and reported as tensil strength (tenacity). The amount the sample has stretched at the time of rupture is calculated as a percentage of the original length and reported as elongation.

Calculations:

$$\text{Tenacity in grams per denier} = \frac{\text{Sum of breaking strength of all observations}}{\text{Number of observations} \times \text{average denier}}$$

$$\text{Elongation in per cent} = \frac{\text{Sum of elongation of all observations}}{\text{Number of observations}}$$

Dry Tests: Atmosphere of 60 per cent relative humidity and 70° F.
Wet Tests: After soaking yarn in water for at least 2 min.

TABLE 53. PHYSICAL PROPERTIES—REPRESENTATIVE TEXTILE TYPE RAYON YARNS

Test conducted at 60% Relative Humidity and 70°–72° F.

Average

Company	Type	Denier (Yarn)	Filaments (Number)	Dry Tenacity (g. per d.)*	Dry Elongation (Per cent)	Wet Tenacity (g. per d.)*	Wet Elongation (Per cent)	Twist (Turns per inch)
	Viscose Process							
A	Bright	100	40	1.94	21.1	0.97	23.4	4.9
	Bright	100	60	2.00	20.0	1.00	23.5	4.3
	Bright	150	60	2.00	21.9	1.01	30.7	7.1
	Semi-dull	75	30	1.75	21.1	0.90	23.8	4.2
	Bright	75	45	1.82	20.3	0.93	23.1	4.3
	Bright	100	20	1.59	18.8	0.73	20.7	2.5
	Bright	150	40	1.83	18.2	0.86	23.4	2.7
	Bright	200	55	1.78	18.7	0.80	23.2	2.8
	Bright	150	90	1.76	18.9	0.81	22.8	2.8
	Bright	200	80	2.70	15.3	1.48	18.6	6.1
B	Bright	150	40	1.89	23.2	0.95	33.6	2.9
	Semi-dull	150	40	1.62	23.8	0.80	37.5	2.8
	Dull	150	90	1.79	18.8	0.85	26.1	2.7
	Semi-dull	250	60	1.69	21.1	0.84	36.6	3.0
	Semi-dull	300	60	1.75	22.7	0.88	35.2	2.9
	Bright	300	60	1.96	23.4	0.99	34.1	2.9
	Dull	75	45	1.73	23.1	0.84	30.2	5.5
	Dull	50	18	1.60	21.2	0.81	31.8	5.7
	Bright	100	40	1.92	19.7	0.96	27.5	2.9
C	Bright	100	40	2.11	12.7	1.33	12.1	13.9
	Dull	100	100	1.68	18.6	0.74	17.6	5.0
	Cuprammonium Process							
D	Bright	65	45	1.43	14.4	0.85	24.6	0
	Dull	100	75	1.62	14.4	0.85	21.6	0
	Cellulose Acetate Process							
E	Dull	300	100	1.37	26.3	0.84	36.2	2.9
	Bright	100	40	1.36	24.7	0.90	36.0	2.8
	Bright	150	40	1.36	27.9	0.85	36.4	2.8
	Dull	75	24	1.32	22.7	0.80	33.5	3.9
	Bright	75	50	1.53	23.0	0.99	31.7	2.9
F	Dull	300	104	1.52	24.8	0.97	32.2	2.7
	Bright	100	34	1.47	24.6	0.97	34.0	3.7
	Bright	150	38	1.44	27.4	0.92	36.8	3.7
	Dull	75	26	1.36	26.2	0.90	33.2	2.8
	Bright	75	49	1.44	21.9	0.93	28.0	3.4
G	Bright	75	52	1.35	26.0	0.80	32.4	4.2

* Grams per denier.

TABLE 54. PHYSICAL PROPERTIES—HIGH TENACITY VISCOSE RAYON YARNS (TIRE CORD TYPE)

Test conducted at 60% Relative Humidity and 70°–72° F.

Company	Sample	Denier (Yarn)	Filaments (Number)	Dry Tenacity (g. per d.)*	Dry Elongation (Per cent)	Wet Tenacity (g. per d.)*	Wet Elongation (Per cent)	Twist (Turns per inch)
A	(1)	1100	300	3.37	7.9	2.13	17.8	2.5
	(2)	1100	300	3.48	8.6	2.14	17.0	2.0
B	(1)	1100	480	3.82	13.4	2.41	16.2	2.9
	(2)	1100	480	3.44	12.6	2.26	18.4	1.3
C	(1)	1100	480	3.56	9.4	2.12	19.1	3.0
	(2)	1100	480	3.72	9.4	2.24	19.4	3.0
D	(1)	275	120	3.17	11.7	1.78	18.2	4.0

* Grams per denier.

EFFECT OF VARIATIONS IN ATMOSPHERIC CONDITIONS IN THE TESTING OF RAYON

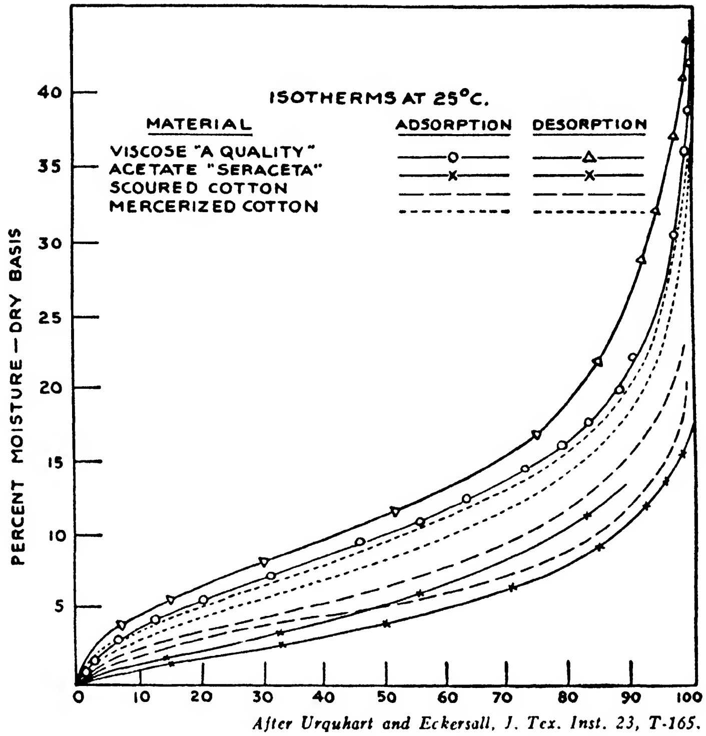
Effect on Moisture Content. Probably the most significant effect of change in relative humidity is the change in moisture content. This change is not a straight-line relationship, but forms a typical " s " curve, as shown in Fig. 7.10. This figure shows the relationship between relative humidities and regain of rayons for a viscose type of yarn, for a cellulose acetate type of yarn, and for scoured and mercerized cotton.

Note the difference in moisture regain when yarns are allowed to reach equilibrium by approaching a given relative humidity from a higher moisture content or from a lower one. This difference is known as hysteresis. Due to hysteresis it is important that all samples tested for physical properties be permitted to reach equilibrium from the same side. It has been suggested by various investigators that an approach from the lower side be employed.

From work on cotton it is believed that in the range 59° to 77° F., temperature has little effect on the amount of moisture absorbed by regenerated cellulose at any given relative humidity.

Effect on Denier. Change in moisture content of a yarn changes the physical properties (strength, elongation, etc.). This also changes denier, or in other words changes the volume of the yarn and its apparent density. Figure 7.11 represents the change in denier of viscose and acetate rayon within the relative humidity range of 57 to 73 per cent. Within this narrow range, the curve holds for both viscose rayon and acetate rayon.

Effect on Tensile Strength. The tensile strength of rayon increases with a decrease in moisture content. This does not hold true for cotton. The change in cuprammonium and viscose types of rayon is slightly greater than the change for the cellulose acetate rayon type. The effect of moisture content on tensile strength has been recorded in Fig. 7.12. Curve 1 shows tensile strength in grams per denier. Curve 2 records the breaking strength. These curves are not the same, because, while the strength decreases



After Urquhart and Eckersall, J. Tex. Inst. 23, T-165.

FIG. 7.10 — Per cent of relative humidity.

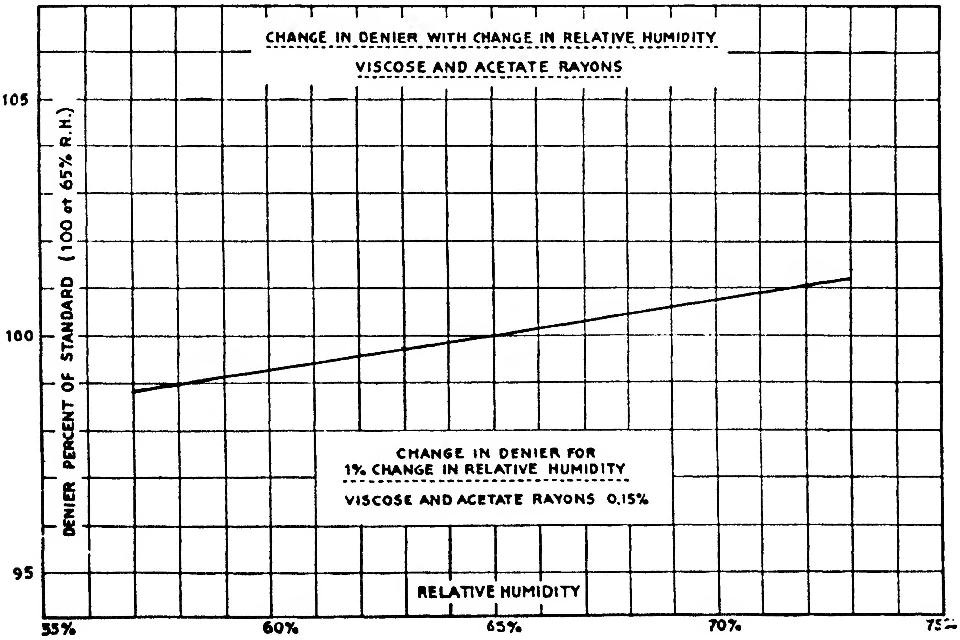


FIG. 7.11 — Relative humidity.

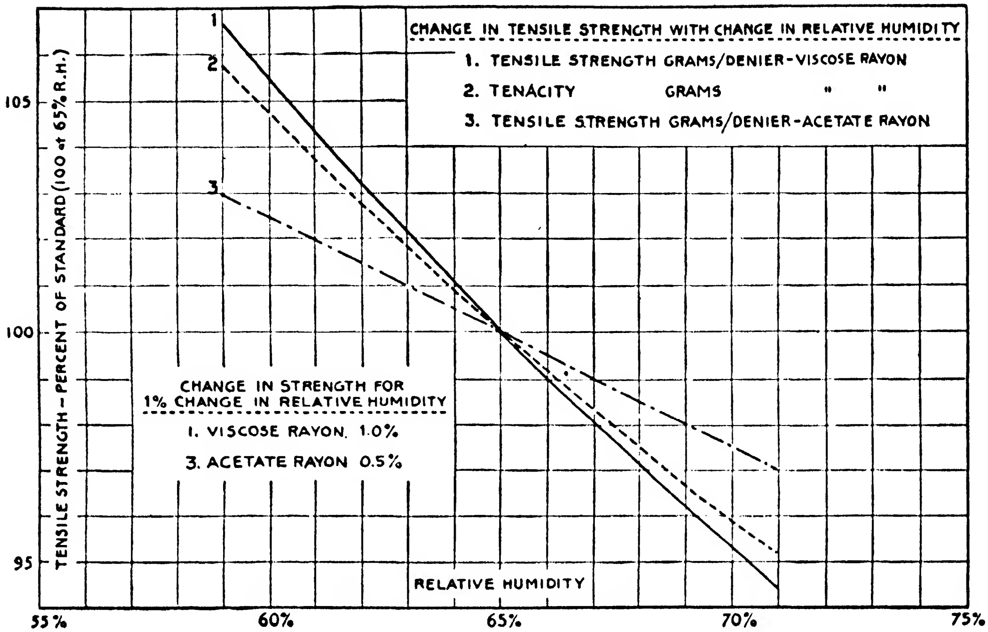


FIG. 7.12 — Relative humidity.

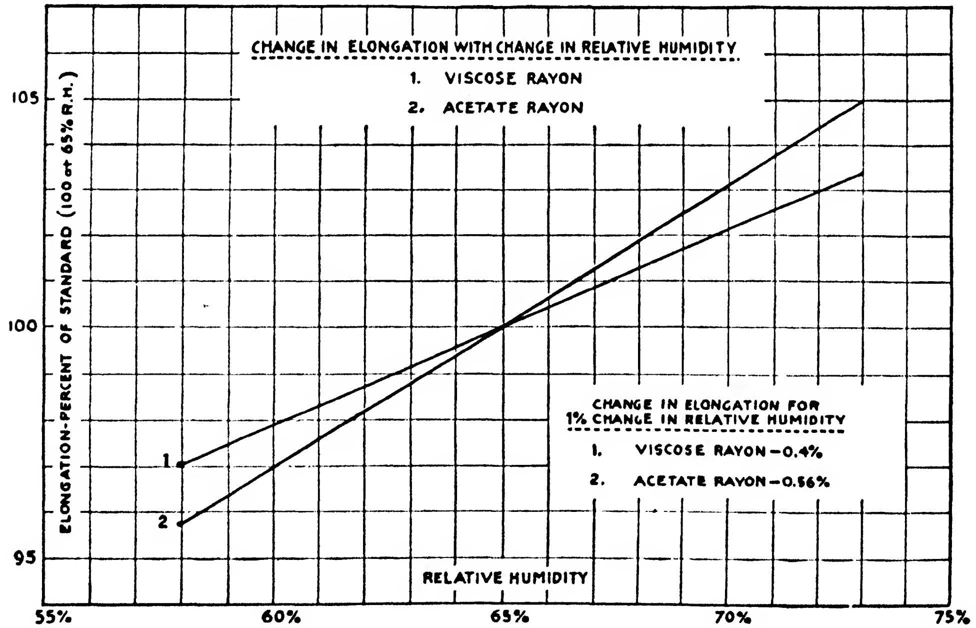


FIG. 7.13 — Relative humidity.

as moisture content increases, denier increases. Accordingly, the change in grams per denier tensile strength is not quite the same as the change in observed breaking strength. Curve 3 shows the relationship between tensile strength of cellulose acetate expressed in grams per denier and relative humidity.

Effect on Elongation at Break. The relationship between elongation (stretch) of a representative viscose type and acetate type of rayon is shown in Fig. 7.13.

THE RAYON INDUSTRY

Of all the synthetic fibers, the rayons have reached the greatest importance from the standpoint of pounds manufactured, diversification of uses, and cost. Today, this branch of the synthetic fiber field is producing in the United States an all-time record amount, limited only by plant capacity. According to The Textile Economics Bureau, Inc., the rayon industry of this country consists of fifteen companies operating twenty-seven plants, plus three companies whose plants were idle as of May, 1941. Of the fifteen companies operating, eleven have twenty plants manufacturing rayon by the viscose process, five companies have six plants manufacturing cellulose acetate rayon, and two companies have two plants manufacturing rayon by the cuprammonium process. No rayon has been produced by the nitrocellulose process since 1934.

Virginia is first in the number of plants, having six, while Tennessee has four, Pennsylyania three, Ohio two, West Virginia two, and New York two. The remaining eight plants are located in eight other states.

In Tables 55, 56, 57, and 58, are listed the United States and world production of continuous filament yarns and staple fiber.

TABLE 55.[4] PACKAGED RAYON YARN PRODUCTION IN UNITED STATES

Acetate, Viscose, Cupra[5] and Total

(Values in thousands of pounds)

Viscose	Viscose plus Cupra		Acetate		
	Pounds	Per Cent	Pounds	Per Cent	Total
1930	117,543	92.3	9,790	7.7	127,333
1935	202,010	78.4	55,547	21.6	257,557
1938	181,470	70.4	76,155	29.6	257,625
1939	231,283	70.4	97,342	29.6	328,625
1940	257,124	65.9	132,947	34.1	390,071

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[4] This and the following tables covering rayon are from the Journal of the Textile Economics Bureau, Inc., The Rayon Or'ganon.

[5] Includes " nitro " for 1930.

TABLE 56. RAYON YARN — WORLD PRODUCTION

" Nationalistic " Countries vs. " Other " Countries
(Values in millions of pounds)

	1933		1937		1938		1939		1940	
	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent
Germany	62.9	9	125.0	10	140.0	14	160.0	14	250.0	22
Japan	98.3	15	334.4	28	209.6	21	239.4	21	225.0	20
Italy	73.4	11	106.6	9	101.4	10	119.0	10	100.0	9
Total " Nationalistic " Countries	234.6	35	566.0	47	451.0	45	518.4	45	575.0	51
All " Other " Countries	428.8	65	634.0	53	537.0	55	627.1	55	569.0	49
World Total	663.4	100	1200.0	100	988.0	100	1145.5	100	1144.0	100

TABLE 57. RAYON STAPLE FIBER[6] PRODUCTION IN UNITED STATES

(Values in thousands of pounds)

1934	2,200
1935	4,600
1936	12,300
1937	20,244
1938	29,861
1939	51,314
1940	81,098

TABLE 58. RAYON STAPLE FIBER — WORLD PRODUCTION

" Nationalistic " vs. " Other " Countries
(Values in millions of pounds)

	1933		1937		1938		1939		1940	
	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent	Pounds	Per Cent
Germany	8.8	31	219.2	35	330.0	35	440.0	41	575.0	47
Japan	1.0	3	174.2	28	375.0	39	309.5	28	300.0	24
Italy	11.0	39	156.4	25	166.9	17	191.0	18	225.0	18
Total " Nationalistic " Countries	20.8	73	549.8	88	871.9	91	940.5	87	1100.0	89
All " Other " Countries	7.1	27	69.4	12	85.7	9	141.5	13	136.9	11
World Total	27.9	100	619.2	100	957.6	100	1082.0	100	1236.9	100

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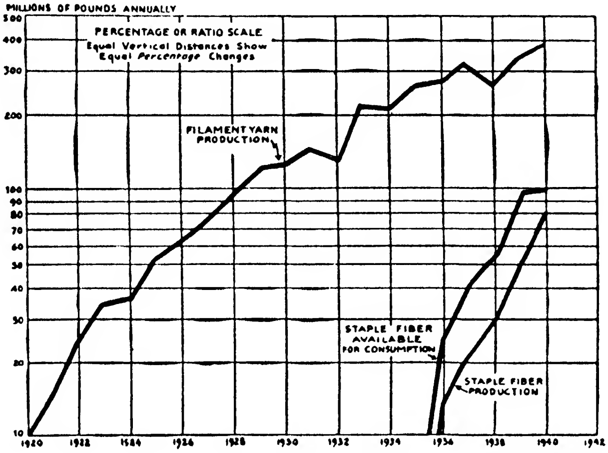
[6] All processes.

These tables show an astonishing world increase in the production of staple fiber — from a small showing of 27,900,000 pounds in 1933 to an estimated 1,236,900,000 pounds in 1940. In a like period, continuous filament rayon yarn has increased from 663,400,000 pounds to 1,144,000,000 pounds. From Tables 55 and 56, it is interesting to note that the United States had the largest production of continuous filament rayon of any country in the world during 1940 with a volume of 390,071,000 pounds or 34 per cent of the total. The production of filament yarns and staple fiber for periods of 20 years and 4 years, respectively, are plotted on Fig. 7.14.



Courtesy of Textile Economics Bureau, Inc.

Fig. 7.14 — United States rayon production.

Commercial Types of Rayon. Table 59 gives the types of rayon yarns sold in the United States. Names of suppliers and trade names are also provided.

Rayon Prices. Table 60 gives a comparison of the spot prices of cotton, wool, silk, and rayon for the past 28 years.

PROTEIN FIBERS (TYPE C)

For several years, considerable research has been carried out on the development of a suitable textile fiber from animal and vegetable proteins. Many potential sources exist from which proteins can be obtained. Some of the possibilities are: milk, soybean, corn, cottonseed, peanuts, wheat, and slaughterhouse refuse. Protein fibers from milk and soybean have reached the greatest importance and their manufacture will be considered here. Casein fiber from milk is being manufactured in the United States on a commercial basis and a small-scale plant unit (estimated at 1000 lb. per day) is being equipped for further investigation and production of the soybean fiber. For the basic chemical steps used in obtaining casein from milk see Fig. 13.26, page 517. For the preparation of filaments from soybean see Fig. 7.16, page 367.

Protein Structure. The protein molecule is made up of a number of amino acids joined by a peptide linkage.[7] The study of the complex chains of amino units and how

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[7] Protein Structure V, *Silk & Rayon*, p. 380, June, 1941.

TABLE 59. TYPES OF RAYONS SOLD IN UNITED STATES

Company	Executive Office	Plant	Trade Name
American Bemberg Corporation (Cuprammonium)	261 Fifth Ave., New York City	Near Elizabethton, Tenn.	Bemberg, Matesa, Aristocrat, Star Breeze
American Enka Corporation (Viscose)	206 Madison Ave., New York City	Enka, N. C.	Perlglo, Briglo, Englo, Tenpra
American Viscose Corporation (Viscose and acetate)	Wilmington, Del.	Fort Royal, Va. Lewiston, Pa. Marcus Hook, Pa. Nitro, W. Va. Parkersburg, W. Va. Roanoke, Va. Meadville, Pa.	Crown, Dulesco, Filenza, Chalkelle, Tenasco, Rayflex and Durafil. Fibro and Avisco, Staple, Visca, Straw, Seraceto and Sombraceta, Acetate
Celanese Corporation of America (Acetate)	180 Madison Ave., New York City	Cumberland, Md. Narrows (Celco), Virginia	Celanese Yarn and Staple
E. I. du Pont de Nemours & Company, Incorporated (Viscose and acetate)	Wilmington, Del.	Buffalo, N. Y. Old Hickory, Tenn. Richmond, Va. Waynesboro, Va.	Dupont Rayon, Yarn and Staple, Cordura, Acele (acetate)
Industrial Rayon Corporation (Viscose)	W. 98th St. & Walford Ave., Cleveland, Ohio	Cleveland, Ohio Painesville, Ohio Covington, Va.	Spun-lo, Premier, Dul-tone, Spun Black Yarn and Staple
North American Rayon Corp.	261 Fifth Ave., New York City	Near Elizabethton, Tenn.	North America, Xtra Dull, Watanga, Nardura, Super-Narco, Key to Quality
Tennessee Eastman Corporation (A. M. Tinney Associates) (Acetate)	Kingsport, Tenn.	Kingsport, Tenn.	Eastman Acetate Rayon, Koda (filament yarn), Teca (staple)
Tubize Chatillon Corporation (Viscose and acetate)	2 Park Ave., New York City	Rome, Georgia	Viscose-Tubize, Chardonize — Acetate-Tubize
Acme Rayon Company (Viscose)	1294 W. 70th St., Cleveland, Ohio	Cleveland*	Acme
Delaware Rayon Co. (Viscose)	171 Madison Ave., New York City	New Castle, Del.	Delray
Hampton Company (Viscose)	Easthampton, Mass.	Easthampton, Mass.*	Hampton
Hartford Rayon Corp. (Viscose)	Rocky Hill, Conn.	Rocky Hill, Conn.	Hartford (Yarn-Staple)
Imperial Rayon Corp. (Cupra)	Gloucester, N. J.	Gloucester, N. J.	Imperial (Yarn-Staple)
New Bedford Rayon Co. (Viscose)	New Bedford, Mass.	New Bedford, Mass.	Newbray, Newlow, New-dull
Skenandoa Rayon Corp. (Viscose)	Utica, N. Y.	Utica, N. Y.	Skenandoa
Sylvania Ind. Corp. (Viscose)	122 E. 42nd St., New York City	Fredericksburg, Va.*	Sylph — Staple fiber
Woonsocket Rayon Company (Viscose)	Manville, R. I.	Woonsocket, R. I.	None — output taken by parent co. Manville, Jenckes Corporation

* Idle as of May, 1941.

TABLE 60. AVERAGE SPOT COTTON, WOOL, SILK, AND RAYON PRICES

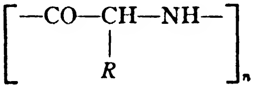
Raw cotton, scoured raw wool, raw silk, and rayon filament yarn

(Dollars per pound)

	Cotton	Wool	Silk	Rayon
1912	0.115	0.64	3.45	1.85
1915	0.102	0.71	3.32	2.08
1920	0.339	1.66	9.08	4.60
1925	0.234	1.40	6.57	2.05
1930	0.132	0.76	3.41	1.06
1935	0.121	0.74	1.63	0.57
1940	0.102	0.96	2.77	0.53

they are held together have been subjects of extensive research. Physical and chemical methods have been used and valuable information has been obtained from X-ray analysis.

It is thought that the protein molecule is built up of units having the structure[8, 9]:



$$\left[-\mathrm{CO}-\underset{\substack{|\\ R}}{\mathrm{CH}}-\mathrm{NH}-\right]_n$$

where R may be hydrogen or a complicated ring structure based on the particular type of protein. According to the literature,[9] X-ray studies show that two types of protein structure exist, fibrous and globular. In the globular form, the side chains have inter-reacted (cross-linked) to change the molecule from its natural fiber structure, and reaction takes place in the side chain unless the reactions are violent enough to convert the protein into its amino acid residues.

Protein Fiber from Casein. Casein used for fiber production is precipitated from sweet skim milk by means of sulfuric acid. The amount of acid is carefully controlled. After washing the precipate free from acid, the casein is generally redissolved in dilute sodium hydroxide and reprecipitated with sulfuric acid to reduce the mineral content. The reprecipitated casein may be converted into fibers by the method diagrammed in the flow chart, Fig. 7.15.

Manufacturing Details. A temperature of 50° C. (122° F.) and a casein concentration of 10 per cent are recommended[10] for preparing the alkaline casein solution. Temperature and concentration have a bearing on the character of the thread formed. Other alkalies such as potassium hydroxide, trisodium phosphate, ammonium hydroxide, and triethanolamine may be used in place of sodium hydroxide. Agents to strengthen the fiber and increase its flexibility may be added to the casein solution. For strengthening, small amounts of compounds of calcium, barium, or aluminum are recommended.[10] For increasing flexibility, 1 per cent of glycol phthalate, Turkey red oil, urea, sodium glycerol phosphate, or ethyl glycolate are suggested.

The solution is de-aerated and ripened (aged) similarly to the viscose solution used for the viscose rayon process. Ripening (hydrolysis) is carried to a point where it is

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[8] Protein Structure IV, *Silk & Rayon*, p. 315, May, 1941.

[9] *Modern Plastics Catalog*, 1941, p. 94.

[10] Whittier and Gould, *Ind. & Eng. Chem.* 32, 906–907 (1940).

thought the cross-linkages in the side chains are broken, assuring a protein molecule having the fiber, rather than globular structure.

The ripened solution is then extruded through spinnerets (similarly to the rayons) into a coagulating bath. The coagulating bath may contain from 2.0 to 20 per cent of the acid chosen. Coagulating baths consisting of (1) 18 per cent sulfuric acid — 27 per cent sodium sulfate, or (2) 20 per cent sulfuric acid — 14 per cent aluminum sulfate — 5 per cent sodium chloride, may be used. In the presence of strengthening and flexing agents, baths consisting of (1) 2.0 per cent sulfuric acid — 5.0 per cent formaldehyde — 20 per cent glucose, or (2) 5.0 per cent phosphoric acid — 10 per cent monocalcium phosphate monohydrate — 5.0 per cent formaldehyde — 20 per cent glucose, have been recommended depending upon the strengthening and flexing agents used. Glucose assists in " setting-up " or dehydrating the fibers. Spinning speeds up to 5000 in. per minute have been used.

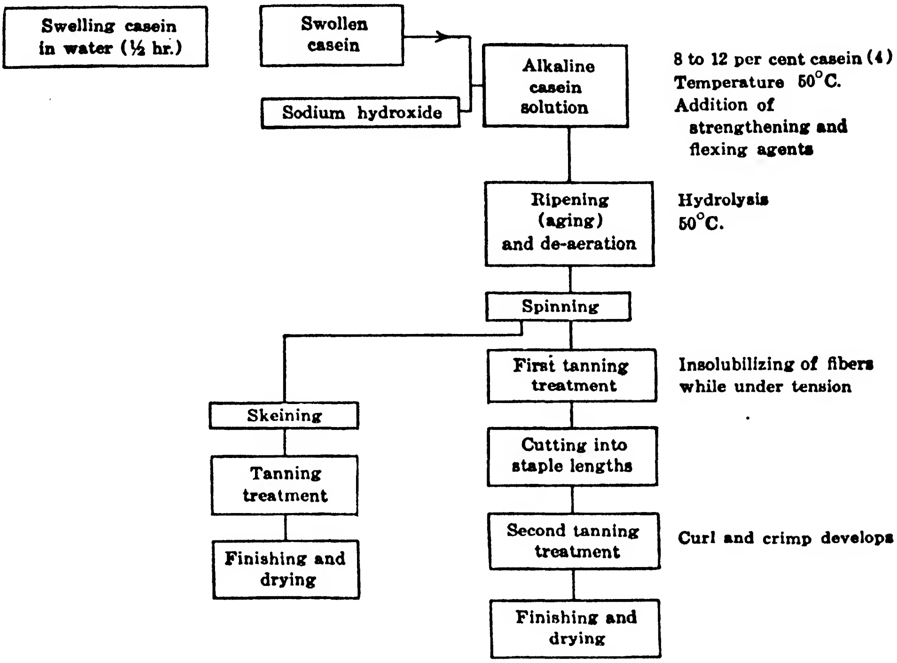


FIG. 7.15 — Flow chart for casein filaments.

After spinning, the coagulated yarn is collected on bobbins. The insolubilizing treatment is then carried out using the two schemes outlined in the flow sheet (Fig. 7.15). The insolubilizing treatment can be accomplished by immersing the coagulated fibers in 5 per cent formaldehyde for approximately 16 hr. They are then immersed in oil emulsions (5 per cent) and dried. Many of the commercial oils sold for preparing emulsions for finished rayon are satisfactory for casein.

Protein Fibers from Soybeans. To obtain protein fiber from soybeans, the beans are crushed and the oil extracted by means of an organic solvent; hexane is a suitable solvent. The soybean meal remaining after extraction is further extracted with sodium sulfide and reprecipitation with acid (accurately controlled). The protein is then washed and dried.

The dried protein may be converted into fibers according to the steps outlined in the following flow sheet (Fig. 7.16).

Manufacturing Details. The alkaline protein solution is extruded through spinnerets similarly to viscose solution into a coagulating bath. This bath contains sulfuric acid and generally some aluminum sulfate. Spinning may be accomplished on the " bobbin-type " or " bucket-type " spinning equipment. The coagulated protein filament may be subjected to the hardening (insolubilizing) treatment in skein form, or continuously in the single strand form. A slight stretch is generally given the wet filaments after leaving the coagulating bath. If desired, a subsequent stretching may be given the filaments after the hardening treatment. The specific gravity of the protein fiber is about 1.3.

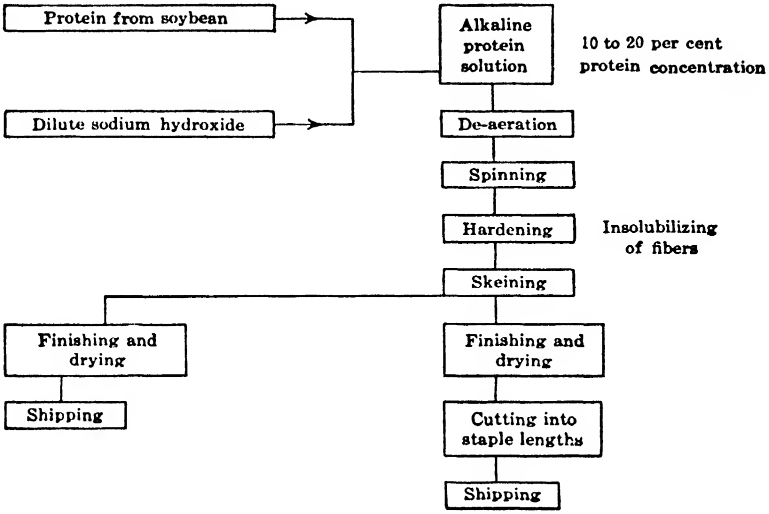


FIG. 7.16 — Flow chart for soybean filaments.

Physical Properties. Protein fibers have certain of the characteristics of wool, but lack its strength, especially its wet strength. Tests conducted on samples of fibers have shown results as in Table 61.

TABLE 61. PHYSICAL PROPERTIES OF PROTEIN FIBERS

Tensile Strength (g/d)[‖] 60 per cent Relative Humidity and 70° F.

Sample	Bundle Test[*]		Dynamometer Test[†]		Denier per Filament
	Dry	Wet	Dry	Wet	
Wool	1.07	0.71	1.29	1.02	3.89
Casein Fiber	0.87	0.21	0.75	0.26	3.19
Soybean Fiber[‡]	0.73	0.15	0.75	0.36	3.03

[*] Involves combing out sample of staple fiber, placing a known number of fibers in parallel arrangement, taping the ends, and measuring strength of resultant bundle.

[†] Single fibers with Richards Dynamometer.

[‡] Other sources have reported the tensile strength as " about 80 per cent, as compared to wool, while its dry elongation of 40 per cent and wet elongation of 60 per cent are much higher." It is further stated, " the tensile at the break is approxi- the same dry and wet; however, the yield point is lower on the wet "

[‖] Grams/denier.

Uses. The greatest use to date of protein fiber in the United States has been in the manufacture of felt hats. It is mixed to an extent of 10 to 20 per cent with the fur. It is also mixed to about the same extent with wool for certain felts. Wool and fur dyes will also dye protein fibers.

In Europe, casein fibers are mixed with other fibers, principally wool, and spun into yarn for making clothing.

Nylon (Type D)

History. As a result of fundamental chemical research started in 1928 by Dr. W. H. Carothers and collaborators for E. I. du Pont de Nemours & Company, Inc., announcement was made on October 27, 1938, of the successful development of a group of new synthetic, protein-like materials — polyamides — somewhat similar in chemical composition to silk and wool, yet having a chemical structure not found in nature. Among other things these linear polyamides were suitable for spinning into strong and elastic fibers. The family of materials was called nylon. Commercial manufacture of nylon yarn was started in January, 1940, in a plant with an annual capacity of 4,000,000 lb.

General. Nylon is a generic name coined by the du Pont Company to describe the synthetic linear polyamides of the types obtained by polymerization of diamines with dibasic acids or their amide-forming derivatives, or of amino-acids, or of a mixture of bifunctional compounds containing complementary amide-forming groups such that appreciable numbers of amide linkages are produced in the molecular chain of the polymer formed. There are numerous types of nylons obtainable, the natures of which depend on the types of reactants chosen, the proportion of the reactants, and the method and extent of polymerization.

The name nylon does not refer to yarns, monofilaments, films, or any other particular form of the polyamide, but rather to the polyamide itself.

Raw Materials. Basic substances, coal, air, and water, yield the following materials used in the manufacture of nylons:

Coal	Phenol, etc.
Water	Hydrogen
Air	Nitrogen, Oxygen

From these materials, dibasic acids, diamines, and amino-acids are made. The reaction indicated below illustrates how the above intermediates may be utilized in making nylons. The properties of the final product depend in part, however, upon the diamine and dibasic acid chosen.

Dibasic Carboxylic Acid and Diamines.

$$\mathrm{HOOC{-}(CH_2)_{\mathit{x}}{-}COOH + NH_2{-}(CH_2)_{\mathit{y}}{-}NH_2} \xrightarrow{\text{Heat}}$$

$$\mathrm{{-}NH{-}(CH_2)_{\mathit{y}}{-}NHCO{-}(CH_2)_{\mathit{x}}{-}CO{-}NH{-}(CH_2)_{\mathit{y}}{-}NHCO{-}(CH_2)_{\mathit{x}}{-}CO{-}etc.}$$

$$+ \mathrm{(H_2O)_{\mathit{n}}}$$

Repeating Structural Unit:

$$\mathrm{{-}NH{-}(CH_2)_{\mathit{y}}{-}NHCO{-}(CH_2)_{\mathit{x}}{-}CO{-}}$$

Manufacturing Process. In general, commercial manufacture of nylon utilizes the type of reaction illustrated. Again we have a wide choice in starting materials, some of which are represented in Table 62. The diamines and acids are reacted first to form salts and are subsequently heated under pressure to form the polyamides.

TABLE 62. DIAMINE-DICARBOXYLIC ACID SALTS

Diamine	Derived from following Acids
Tetramethylene	Azelaic
Pentamethylene	Sebacic
Hexamethylene	Adipic
Hexamethylene	Sebacic
Octamethylene	Adipic
Octamethylene	Sebacic
Nonamethylene	Adipic
Nonamethylene	Sebacic
Decamethylene	Adipic
Decamethylene	*p*-Phenylene diacetic
Undecamethylene	Sebacic
Dodecamethylene	Adipic
Dodecamethylene	Sebacic
p-Xylylene	Sebacic
p-Xylylene	*p*-Phenylene diacetic

A flow sheet is shown in Fig. 7.17 outlining nylon manufacture from aqueous solution to the finished yarn.

Manufacturing Details. One dibasic acid can be made to react with two different diamines simultaneously, or two dibasic acids with one diamine. Also two or more different nylon polymers may be blended and extruded in the molten condition from the spinning hopper.

After polymerization, a hornlike, tough polymer is obtained. The molten polymer is extruded in the form of a thick film on a revolving drum, solidified, stripped, and broken up into fine chips.

The polymer is remelted, prior to spinning, in a specially heated vertical hopper and from this hopper the molten material is forced through a spinneret. After extrusion, the filaments immediately cool and solidify. The filaments are converged and wound on bobbins.

After spinning, X-ray diagrams show the nylon fibers to be crystalline, and the crystals to have random orientation. In this form the yarn is unsatisfactory for most uses, but by relatively little force it is cold-drawn (stretched) as much as seven times its original length (commonly four). During the drawing operation, the molecules are oriented (lined up) parallel to the fiber axis and the yarn becomes tough and elastic. Indeed, the elasticity as shown in Table 63 is superior to that of silk or the rayons. This property, in addition to its high strength, has greatly aided its wide acceptance by the textile trade.

The size of nylon filaments is controlled during the spinning operation by accurate adjustment of the rate of delivery of the molten polymer and by the rate at which the solidified yarn is drawn away from the spinneret. The size of the yarn before drawing is, of course, determined by the size and number of individual filaments making up one strand. The number of filaments is determined by the number of holes in the spinneret. The size of the yarn after the cold-drawing operation depends upon its original size and the degree of stretching. If given a four fold stretch, the final diameter is one-half the original diameter. The drawing operation is accomplished by unwinding the yarn from one spool or bobbin and winding it up at a faster rate of speed on another spool or bobbin.

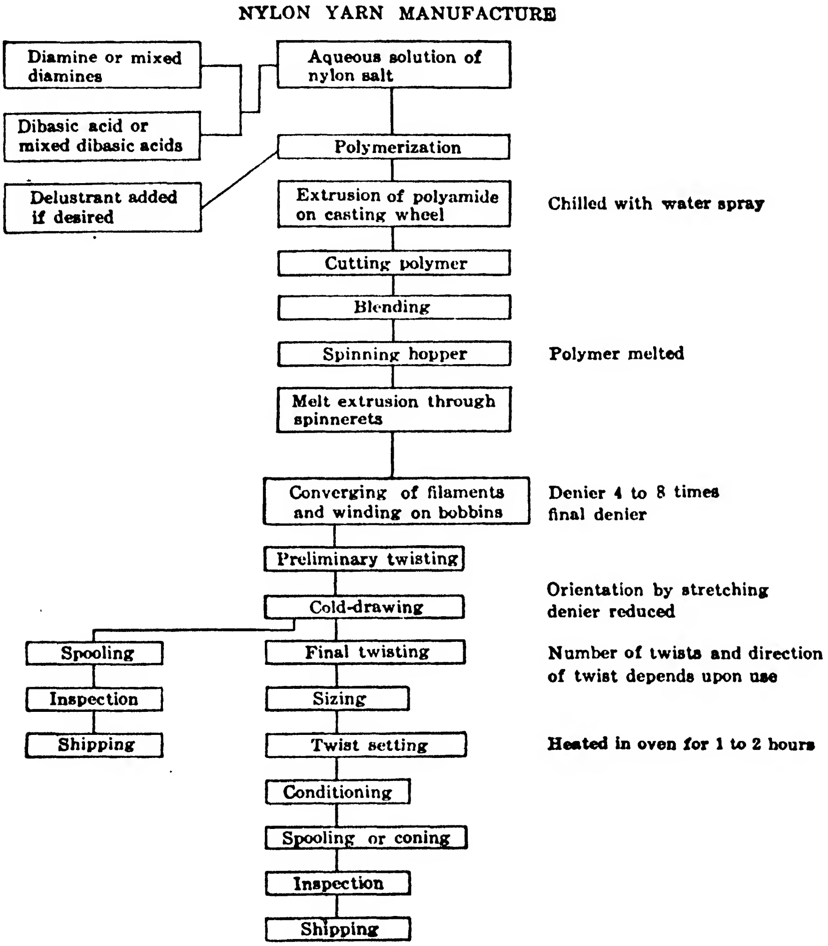


FIG. 7.17 — Flow diagram for nylon filament.

Nylon yarn made from unmodified polymer has high luster, but by adding finely divided pigments, such as titanium oxide, to the molten polymer before spinning, delustering may be accomplished.

Uses. To date, most nylon yarn, because of its high strength, toughness, and excellent elastic properties, has been used in the manufacture of ladies' full-fashioned hosiery. It is also used for ladies' seamless hosiery and men's half hose. The yarn is being successfully used for bait-casting lines, fly lines, sewing thread, bead cords, and braided surgical sutures. Other important uses consist of gloves, knit goods of various

TABLE 63. PHYSICAL PROPERTIES

Comparison of Average Properties of Nylon Yarn, as Determined at 60 per cent R. H. and 70° F., with Several Other Yarns

	Nylon	Silk	Textile Types		High Tenacity Viscose Rayon
			Viscose Rayon	Acetate Rayon	
Dry tenacity (g/d)[*]	4.7–5.5	4.0–5.0	1.6–2.0	1.3–1.5	3.1–3.7
Dry elongation (%)	20–13	15–25	15.0–23.0	22.0–27.0	8.0–13.0
Wet tenacity (g/d)	4.1–4.8	3.6–4.5	0.7–1.0	0.8–1.0	1.8–2.4
Elastic recovery after 4% stretch (%)[†]	100.0	50.0	30.0	50.0	40.0
Moisture absorp. (%)[†]	3.5	11.0[‡]	12.0[‡]	6.5	12.0

[*] Grams per denier.

[†] From Hoff, *Ind. & Eng. Chem.*, **32**, 1562 (1940).

[‡] From Wilson and Fuwa, *Ind. & Eng. Chem.*, **14**, 913 (1922).

TABLE 64. SOME IMPORTANT CHARACTERISTICS OF NYLON (HOSIERY TYPE)

Melting point	(In vacuo) 264° C. (507° F.) (In air) 253° C. (488° F.)
Effect of ultra-violet light	As resistant as silk
Resistance to moths	Not attacked
Resistance to mildew	Not attacked
Resistance to alkalies	Highly resistant even at temperatures around 85° C. (185° F.)
Resistance to mineral acids	Somewhat attacked
Resistance to dry-cleaning fluids	Excellent
Resistance to water	Does not deteriorate
Dyeing properties	Readily dyed with materials used for dyeing cellulose acetate yarns and fabrics and also shows affinity for other classes of dyes
Solubility	Soluble with difficulty in most reagents, at 25°C. (77° F.); xylenol, cresol, phenol, and formic acid are active solvents.
Ironing	No effect on tensile strength for ironing temperatures up to 170° C. (356° F.); melts around 253° C. (488°.)
Refractive index (current manufacture)	1.53–1.57 (in drawn state it is doubly refractive)
Specific gravity	1.14–1.15

kinds, woven dress goods, laces, nets, veilings, bathing suits, underwear, upholstery material, pile fabrics, neckties, ribbons, girdles, and corselets. Woven fabrics, made from various deniers of nylon yarn, are processed by a number of finishing concerns to render them waterproof or water-repellent and are used for raincoats, umbrellas, shower curtains, food covers, and the like.

United States Production. During 1940 it is estimated that about 2,700,000 lb. of nylon yarn were made. When new plant expansion, now well under way, is completed, the annual production will be around 16,000,000 lb. per year.

Yarn Types Available. At present the types of nylon yarn shown in Table 65 are available.

TABLE 65. TYPES OF NYLON YARN

Standard Yarns*

Denier	Filament Count	Turns per Inch	Put-Up
20	7	1	Bobbin
30	10	1	Bobbin
30	10	1	Spool
30	10	8	Cone
30	10	30	Cone
40	13	1	Bobbin
40	13	1	Spool
40	13	8	Cone
40	13	10	Cone
40	13	25	Cone
70	23	1	Bobbin
70	23	3	Cone
70	23	10	Cone
140	46	3	Spool
140	46	3	Cone

High Tenacity Yarns*

37	13	3	Bobbin
56	20	3	Bobbin
65	23	3	Bobbin
74	26	3	Bobbin
93	33	3	Bobbin
111	40	3	Bobbin
131	46	3	Bobbin
167	60	3	Bobbin
195	69	3	Bobbin

* As of June 16, 1941.

Manufacturer: E. I. du Pont de Nemours & Company, Inc., Wilmington, Delaware. *Plants:* Seaford, Delaware and Martinsville, Virginia.

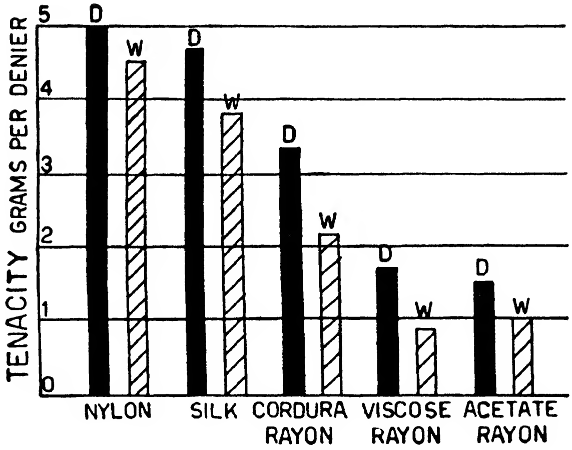


Fig. 7.18 — Tenacity of several fibers.

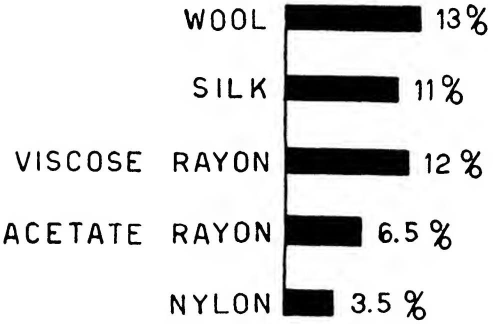


Fig. 7.19 — Water absorption at 60 per cent relative humidity.

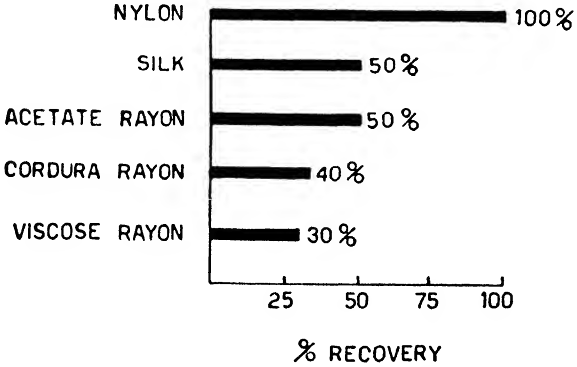
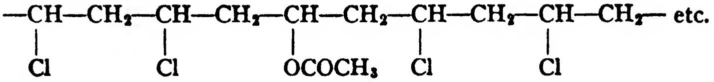


Fig. 7.20 — Comparison of elastic recovery with an imposed load.

Vinyon[12] (Type E)

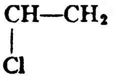
History and General. A new continuous filament yarn, a copolymer of vinyl chloride and vinyl acetate, was introduced in November, 1939. Although vinyl polymer resins, having the vinyl group ($-CH{=}CH_2$) had been known for several years, the copolymer was not made available commercially until after successful completion of research by the Carbide & Carbon Chemicals Corporation. This company manufactures and sells the resin which is manufactured under license and supplied by the American Viscose Corporation. It is known as " Vinyon " synthetic yarn.

Chemistry. For the chemical steps involved in the manufacture of the vinyl chloride-vinyl acetate copolymer see Fig. 13.9, page 493. The copolymer is linear and has the probable formula



$$-\underset{\mathrm{Cl}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH}_2-\underset{\mathrm{Cl}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH}_2-\underset{\mathrm{OCOCH_3}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH}_2-\underset{\mathrm{Cl}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH}_2-\underset{\mathrm{Cl}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH}_2-\text{ etc.}$$

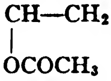
The recurring structural groups which are in random orientation are:



$$\underset{\mathrm{Cl}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH}_2$$

vinyl chloride

and

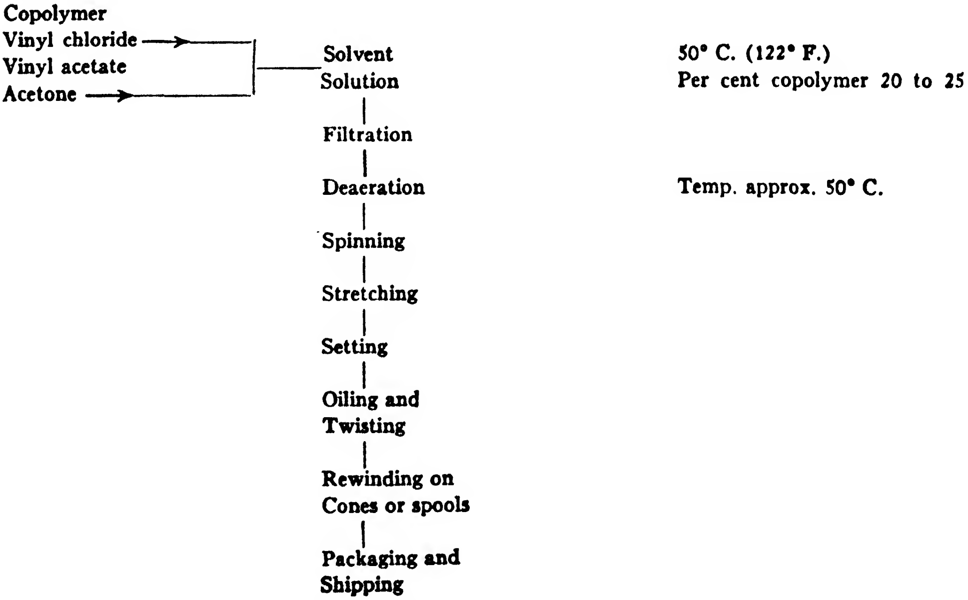


$$\underset{\mathrm{OCOCH_3}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH}_2$$

vinyl acetate

As the formula for the copolymer signifies, the two materials react with themselves and with each other at the double bonds. The type of copolymer used for yarn manufacture consists of 88 to 90 per cent vinyl chloride and 10 to 12 per cent vinyl acetate. The fibers are tough and their strength and elongation can be varied over a considerable range.

Commercial Manufacture. The following flow sheet explains the steps used to convert the copolymer resin into continuous filament yarn.



[12] Registered trade-mark of Carbide & Carbon Chemicals Corporation.

Manufacturing Details. The dry-spinning process explained for cellulose acetate is used in the spinning of " Vinyon " yarn. Acetone is also used as the solvent. The air pressures and temperatures, however, are higher.

During stretching, the molecules are oriented in the direction parallel to the length of the fiber. This drawing operation increases the tensile strength, but in turn reduces elongation. By using degrees of stretching, tensile strength and elongation of the yarn can be varied over a wide range.

Delustered yarns may be prepared by adding certain pigments to the spinning solution. Staple fibers are available.

TABLE 66. PHYSICAL PROPERTIES OF VINYON

Tests at 60 Per Cent Relative Humidity and 70° F.

Denier	40
Filaments	46
Tensile Strength (g./d.)*	3.4 (can be varied from 1–4 g./d.)
Elongation (per cent)	18.6 (can be varied from 12–18 per cent)
Wet tensile strength	Approximately same as dry values, because of the yarn's high resistance to water.

* Grams per denier.

TABLE 67. CHEMICAL AND PHYSICAL CHARACTERISTICS

Average molecular weight	22,000
Density	1.35
Effect of temperature	Above 65° C. (149° F.) shrinkage starts At 75° C. (167° F.) yarn shrinks about 12 per cent. At 80° C. (176° F.) yarn shrinks materially and filaments soften and adhere to each other At 140° C. (284° F.) tackiness develops and adherence to other materials may be realized
Effect of elevated temperatures on yarn strength	Decreases
Flammability	Yarn will not support combustion
Chemical resistance	Acids, excellent Alkalies, excellent Salts, excellent Ketones, dissolved Esters, softened, or partly dissolved Certain ethers, softened, or partly dissolved Certain amines, softened, or partly dissolved Lower aromatic hydrocarbons, softened, or partly dissolved Alcohols, unaffected Glycols, unaffected Aliphatic hydrocarbons, unaffected Resistance to bacteria and fungi Dyeing, requires special procedure which has been worked out over a wide range of colors

TABLE 68. TYPES AND COSTS OF "VINYON" YARN[11]

ST (Medium Strength)

Denier	Filament Count	Price per Pound Spools or Cones
60	46	$1.65
120	92	1.50
180	138	1.40
250	184	1.35

HST (High Strength)

Denier	Filament Count	Price per Pound Spools or Cones
40	46	$1.70
80	92	1.65
120	138	1.55
160	184	1.45
200	230	1 40

Stable Fiber

Fine	$1.15 per lb
Coarse	1.00 per lb

Uses. Vinyon is used for the following: shoes, gloves, fishnet twine, industrial filtering fabrics and twines, composite felts, specialized sewing threads.

VINYLIDENE CHLORIDE POLYMERS (TYPE E)

The chemical steps required in the manufacture of this material are given in Table 71, page 389. Vinylidene chloride polymer has been furnished in monofilament form but has not appeared in the trade in the form of continuous filament yarn. The polymer is manufactured by the Dow Chemical Company under the name "Saran." For the properties of the material refer to section on Monofilaments.

POLYVINYL CHLORIDE (TYPE E)

This polymer, in the plasticized state, has been supplied in the form of transparent films and monofilaments by the B. F. Goodrich Rubber Company under the name "Koroseal." For the chemical steps involved in its manufacture see Table 71, page 389.

Polyvinyl chloride has not been used for commercial manufacture of continuous filament yarn in the United States; however, it has been quite thoroughly investigated and publicized in Germany under the names of "Igelite" and PE-CE fibers.

POLYVINYL ALCOHOL (TYPE E)

For the commercial steps used in the manufacture of polyvinyl alcohol see Fig. 13.14, page 499. This polymer, $(-CH_2-CHOH-)_n$, is a white to creamy-white solid, soluble in water. Although finding application in the manufacture of transparent films,

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[11] As of October 9, 1940.

the polymer has not been used in the United States for commercial manufacture of continuous filament yarn. Its yarns, however, have been investigated experimentally and several patents have been issued on the subject. One patent (U.S. 2,236,061) describes a process using the conventional rayon " bobbin-type " or " bucket-type " spinning machines for collecting filaments from polyvinyl alcohol solution coagulated in a spinning bath comprised of an inorganic salt. Another patent (U.S. 2,239,718) among other things mentions a dry-spinning process similar to that used for cellulose acetate.

Polyvinyl Acetals (Type E)

Several polyvinyl acetals are available commercially. These materials are prepared by reacting polyvinyl alcohol with an aldehyde under the influence of heat and a suitable catalyst (such as sulfuric or hydrochloric acid). One molecule of the aldehyde condenses with two hydroxyls to yield the acetal.

In general, commercial and trade names appear to have been based on the aldehyde use. For example, Alvar = polyvinyl alcohol reacted with acetaldehyde; Butacite and Butvar = polyvinyl alcohol reacted with butyraldehyde; Formvar = polyvinyl alcohol reacted with formaldehyde.

Acetals are not used commercially for manufacturing continuous filament yarns. The materials are water resistant and are finding application in the manufacture of transparent interlayers for safety glass and for other film applications.

Glass Fibers (Type F)

History. Glass fibers, because of their nonflammable properties and resistance to mildew, rot, and acids (excepting hydrofluoric), have received a great deal of consideration from a textile standpoint. The Venetian glass makers of Merano produced exquisite lace glass in the sixteenth century. As early as 1893, special pieces of wearing apparel and glass lamp shades were made in the United States from fibers drawn from a heated rod by means of a drum rotated by a foot pedal.

The modern history of glass fibers actually started during World War I because of a shortage of asbestos, badly needed in Germany, Russia, Austria, and elsewhere for insulation purposes. The old hand process of drawing glass fibers was mechanized by winding onto a drum. In addition, the molten glass was pulled through orifices in place of being drawn from specially prepared glass rods.

Subsequent to this work on the continent during World War I, interest in glass fibers was revived in other countries. In the United States, progress was made in producing both continuous filament fibers and staple fibers which could be handled on textile equipment. On November 1, 1938, Owens-Corning Fiberglas Corporation was formed by Owens-Illinois Glass Company and Corning Glass Works to manufacture industrial products made from glass fiber, thereby utilizing the research carried on by the parent companies.

Manufacturing Processes.[14] Figure 7.21 illustrates the steps in the manufacture of glass fibers.

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[14] Based on information given by James Slayter, director of research, Owens-Corning Fiberglas Corporation.

One strand of the glass fiber continuous filament yarn generally consists of 200 or more individual filaments. The yarn has high luster resembling silk and is very smooth. Photomicrographs show the cross section to be circular.

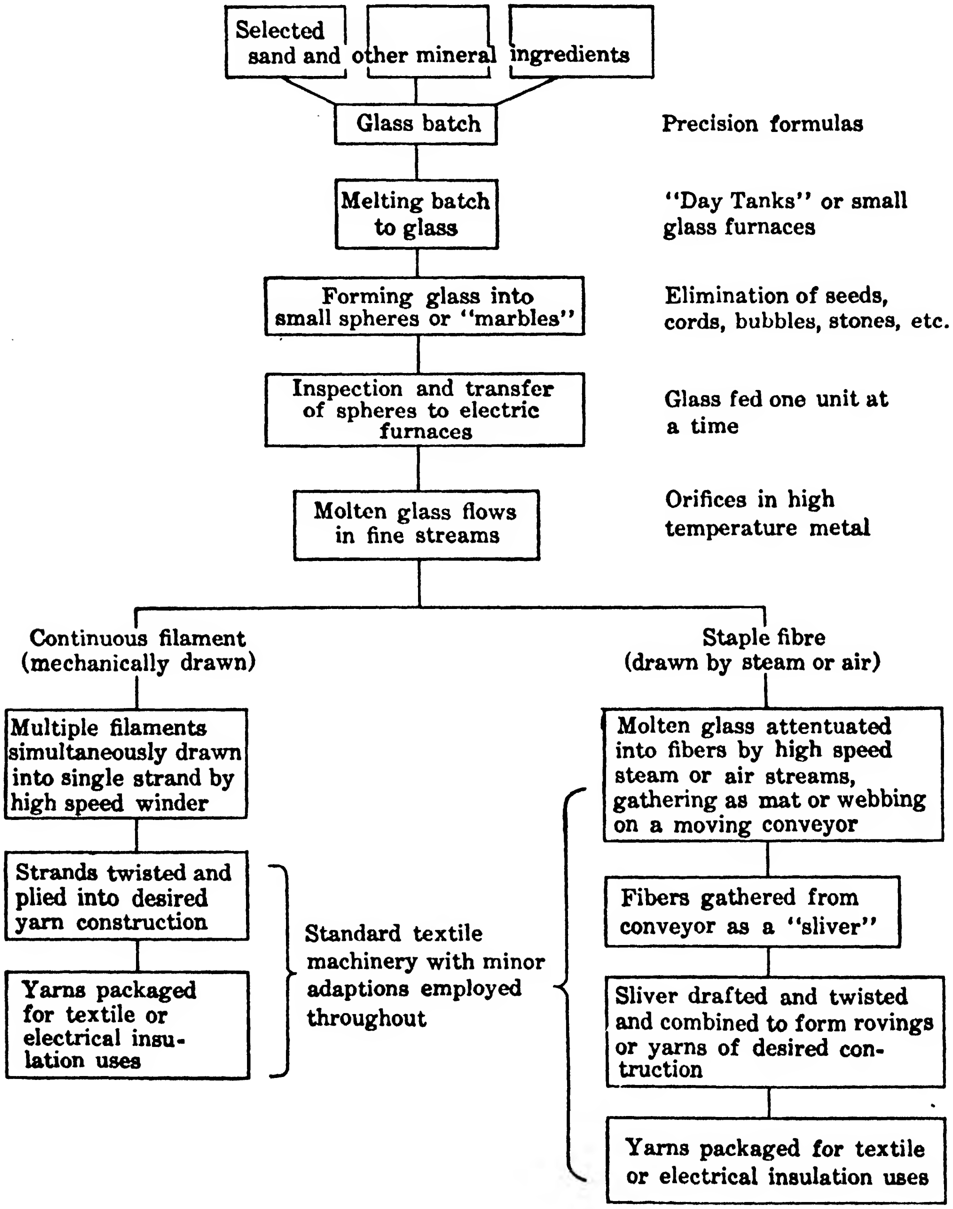

FIG. 7.21 — Manufacturing processes, glass fibers.

The staple fibers have an average fiber length of about 9 in. with the longest around 15 in. The continuous yarn prepared from staple has more of the appearance of cotton than silk due to the shorter fiber length of the glass.

Effect of Glass Composition on Fiber Strength. According to Anderegg: " The effect of the composition of the glass upon the strength of the filaments appears to be only secondary, principally by determining the viscosity range over which satisfactory attenuation takes place." The important factor is to have a thoroughly melted, highly homogenized glass heated to as high a temperature as possible (consistent with good handling).

Flexibility depends upon the thickness of the glass fibers. Fibers ranging up to 0.00025 in. are flexible, can be drafted, twisted, and used on regular textile weaving equipment. Further requirements of the process since publication of Anderegg's article have shown the practicability of using fibers up to 0.0005 in. in diameter for some textile applications.

Physical Properties. *Tensile Strength.* The tensile strength of commercial textile glass fibers has been reported as follows:

Diameter in Inches	*Tensile Strength in Lb. per Sq. In.*
0.0002	300,000–500,000
0.00025	210,000–450,000

Under ordinary testing conditions glass fibers show no evidence of plastic flow.

FILAMENT SIZES

Continuous Filament

	Average Individual Fiber Diameter in Inches		
Designation	*Min.*	*to*	*Max.*
D	0.00021		0.00025
E	0.00026		0.0003
G	0.00036		0.0004

Staple Fiber

	Average Individual Fiber Diameter in Inches		
Designation	*Min.*	*to*	*Max.*
E	0.00026		0.0003
G	0.00036		0.0004
J	0.00046		0.0005

Colored continuous filament yarns are manufactured in a limited range. The coloring matter (excepting gray) is incorporated as an ingredient in the batch formula during the manufacture of the glass.[15] White is the preponderant color of the yarns manufactured.

Prices. *Continuous Filament Yarns.* As of January 15, 1941, the price of yarn prepared from Type D filaments in quantities of 100 lb. or more, ranged from $1.40 to $2.15 per lb., based on the diameter of the yarn. In lots of 200 lb. or more, yarn prepared from Type G glass filaments ranged from $0.73 to $0.98 per lb.

Staple Fiber. Staple fiber prepared from Type E filaments, in quantities of 100 lb. or more, ranged from $0.62 to $1.17 per lb. Staples prepared from Types G and J

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[15] Fiberglas Standards Preliminary Data Sheet G10.2.1-PD, July, 1940.

varied between $0.37 and $0.55 per lb. Prices are subject to change. In general the trend to date has been downward.

Electrical insulation: cords, tapes, braids, sleevings, laminated products, wire covering, cable filling insulation.
Industrial service fabrics: facings for insulating board, sewed blankets for thermal and accoustical insulation.
Battery retainer mats
Awning materials
Neckties
Tablecloths
Draperies
Bedspreads
Heated underwear (deep-sea divers)
Filters, air and laboratory

MONOFILAMENTS

Introduction. With the availability of new synthetic materials possessing low elastic moduli and high tensile strength such as nylon, vinylidene chloride polymers and vinyl chloride polymers, and the development of melt-extrusion and extrusion-molding methods for producing monofils (single filaments) of these materials, there has come a greater demand for synthetic monofils to take the place of natural products, such as gut, hog bristles, horsehair, etc. Outstanding uses of monofils are in the production of numerous types of fabrics, both woven and knitted, and as a substitute for gut in tennis and badminton racquets. A new possibility is in the production of window-screen material to take the place of metallic wire screens. Also, gut and silk fishing leaders are rapidly being displaced by monofils of nylon polymers and vinylidene chloride polymers. Exceedingly sheer full-fashioned stockings knitted from nylon monofils have recently appeared on the American market. With the great variety of synthetic polymers now available it is becoming possible to produce monofils meeting almost any specification as to physical and chemical properties.

Thus far, the synthetic materials which have shown greatest promise in the monofil field are nylon polymers, vinylidene chloride polymers, and the copolymers of vinylidene chloride with vinyl chloride. Other materials that have been used for monofils are plasticized polyvinyl chloride resins, cellulose acetate, and regenerated cellulose. The materials will be discussed in the order mentioned.

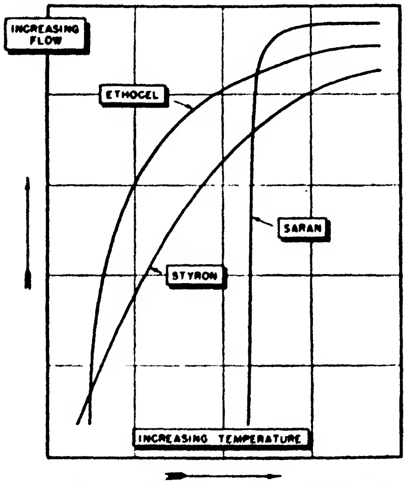


FIG. 7.22 — Plastic flow vs. temperature of several thermoplastics.

NYLON

Types Available. There are numerous types of nylons obtainable, as explained under nylon yarn manufacture. For information on its manufacture, see flow sheet, page 370.

Preparation of Nylon Monofils. Nylon monofils are generally prepared by a melt-extrusion process, which involves melting flakes of the polymer in a melting chamber maintained free from air to prevent oxidation, extruding by gas pressure, or by means of screw pumps or gear pumps through an extrusion orifice, quenching the freshly extruded monofil by means of water in the case of large monofils, and winding on a bobbin or other package. Subsequent treatments of various types may be applied to the monofils to prepare them for specific uses. They are generally oriented to increase their tensile strength by cold-drawing, i.e., by permanently elongating by the application of stress, or by passing through dies, or by cold-rolling. As a general rule, nylons may be cold drawn to from two to seven or more times their original length.

Chemical and Physical Properties of Nylon Monofils. The most common types of nylon monofils are relatively inert to most solvents and chemical reagents. They are dissolved by phenols, formic acid, and cresols. Certain types of nylon monofils are soluble in alcohols and alcohol-water mixtures. Strong acids and alkalies will in time hydrolyze them. Nylon monofils burn only very slowly and tend to fuse before burning.

The following table summarizes some of the outstanding chemical and physical properties of nylon monofils:

Tensile:

Dry Strength*	About 45,000–55,000 lb. per sq. in.
Wet Strength†	About 35,000–45,000 lb. per sq. in.
Dry Elongation*	About 20%–35%. Can be varied widely by drawing to different extents
Wet Elongation†	About 20%–40%
Loop Strength*	Dry 85%–90% of tensile
Elastic Recovery*	100% recovery after 2% stretch 91% recovery after 16% stretch
Modulus of Elasticity (Youngs Modulus)	Dry* — 4.5×10^5 lb. per sq. in. Wet* — 1.7×10^5 lb. per sq. in.
Stress-strain curve (dry)	Linear up to 4% stretch

Thermal:

Specific Heat	0.5 cal. per g. per ° C. (20°–265° C.)
Heat of Fusion	22 cal. per g.

Hygroscopicity (Hosiery Type Nylon):

In equilibrium with 72% relative humidity nylon contains 4.5% moisture.

Optical:

Refractive index	1.53 to 1.57 highly doubly refractive in the drawn state.

Wave Length	*.% Absorption*
2350Å	80
2550Å	10
3300Å	6
3400Å	5
3600Å	0

Electrical (Hosiery Type Nylon):

Volume resistivity	18% R. H., 4×10^{14} ohm-cm.; wet, 5×10^9 ohm-cm.
Dielectric constant	4 at 1000 cycles, 22° C., 18% R. H.
Power factor	5% at 1000 cycles, 22° C., 18% R. H.
Dielectric strength	1300 volts per mil.

* 50 per cent relative humidity.

† After soaking in water for approximately 18 hr.

Sizes. Nylon monofils are available in various sizes from about 10 denier to about 17,000 denier. Prices depend somewhat on size, special treatments for special uses, and other considerations. The following table gives several of the more frequently used nylon monofil sizes and yards per pound of these monofils as well as pounds per 100,000 yd.

TABLE 69. SIZES OF THE COMMON MONOFILS

Diameter in Mils	$(\text{Diameter})^2$	Denier	Yards per Pound	Pounds per 100,000 Yards
7	49	255	17,500	5.7
9	81	422	10,600	9.4
12	144	750	5,970	16.8
14	196	1,020	4,380	22.8
16	256	1,330	3,350	29.8
29	841	4,380	1,020	97.8
51 (16 ga.)	2,601	13,525	331	302.4

Other values for monofils of other sizes may be calculated by means of the following equations in which N = the diameter of the nylon monofil in mils:

Denier	$5.2\ N^2$
Yards per pound	$8.6 \times 10^6/N^2$
Pounds per 100,000 yards	$N^2/8.6$

Uses. Nylon monofils were first used in the form of bristles for brushes, particularly toothbrushes. Subsequently, they were introduced into numerous other types of brushes. Another of the early uses of nylon monofils was in the form of fishing leaders, where the high tensile strength, high elasticity, and water insensitivity gave nylon the advantage over the conventional natural silk and gut leaders. Still another early use was in surgical sutures, which can be readily prepared in sterile form. They are non-capillary and completely non-irritant to the flesh. More recently, nylon monofils have appeared on the market in the form of strings for tennis and badminton racquets. Sheer full-fashioned stockings knitted from 15-denier nylon monofils have been on the market in small quantities. Many other uses have been suggested, and already a number of these are consuming small, but in many cases, increasing quantities. There is little doubt that as production facilities become greater there will be an increasing use of these monofils. The following is a list of uses suggested for nylon monofils, many of which have been tried and found satisfactory, but as yet have not been greatly developed because most of the present nylon production is required for the manufacture of multifilament yarns for hosiery:

Artificial furs
Artificial hair
Artificial straw
Automobile upholstery
Belting
Bow strings
Braided cords
Brush bristles
Carpets
Dental floss
Electrical insulating material
Winding for baseballs
Laboratory aprons
Helmets
Metallized monofil base for fabrics, braids, etc.
Bead and sequin bags and clothing (base for stringing)
Slip covers and seat covers (auto, garden, etc.)
Suitcase and trunk covering material
Furniture and radio decorative fabric
Lampshade material
Roll window screens

- Fabrics for:
  - balloons
  - parachutes
  - sail cloth
- Fishnets
- Fishing leaders
- Full-fashioned hosiery
- Gaskets
- Hats
- Knitted fabrics
- Packing for stuffing boxes
- Seamless hosiery
- Sewing thread
- Shower curtains
- Specialty cloths:
  - camera bellows
  - filter cloths
  - fire hose
  - gear fabrics for molded gears
  - mothproof bags
  - steam hose
  - tapes
  - tracing cloth
  - typewriter ribbons
- Surgical sutures
- Tennis strings
- Tying cord
- Cushion springs (where linen or silk cord, waxed cord or fine wire now used)
- Pull cords for electric lights and bells
- Braided cord, cord belts (for movie machines and other small motors)
- Cord grips
- Decorative cords (for uniforms, etc.)
- Book binding
- Special ropes (for ladders, gymnasium)
- Belt lacing
- Riding whips, lariats
- Violin strings
- Hair nets
- Tire cord
- Suspending wire for galvanometers, etc.
- Rods for weaving chairs, baskets, etc.
- Whalebone substitutes, e.g., stays for women's apparel, parasol ribs (dyed to match), etc.
- Window screens
- Fabrics for paper machine drier canvas
- Reinforcement for cellulose sponges

VINYLIDENE RESINS (" SARAN ")

Types Available. " Saran " is the name coined by the Dow Chemical Company to describe its vinylidene resin polymers. It is available in several forms, notably, polymers of vinylidene chloride (see page 496, Fig. 13.11) and copolymers of vinylidene chloride with vinyl chloride. The compositions, and correspondingly the properties, of the copolymers may be varied over wide ranges from a flexible, moderately soluble resin having a softening point around 70° C. (158° F.) to a hard, tough thermoplastic solid having a softening point of at least 180° C. (356° F.) The latter resins show a greater degree of crystallinity by X-ray diffraction patterns.

" Saran " has appeared on the market in the form of round filaments 10 to 100 mils in diameter; also in oval, triangular, and strip form. It is made in clear transparent, also translucent to opaque, form and in various colored forms. It has been marketed as fishing leaders. " Saran " monofils have also been woven into suspender fabrics and belts.

Preparation of Vinylidene Chloride Polymer Monofils. Vinylidene chloride polymers can be continuously extruded in the form of monofils. As extruded, the monofils are substantially unoriented, the crystals being arranged in a heterogeneous manner. In this form, the tensile strength is low, for example, about 8000 lb. per sq. in. By stretching, the monofils become oriented and the tensile strength may be increased to as high as 40,000 lb. per sq. in. accompanied by a greater flexibility, that is, a decrease in modulus of elasticity. Resistance to flexing fatigue is greatly increased by orientation. Colors may be introduced during the extrusion or at other points in the course of manufacture.

Chemical and Physical Properties of Vinylidene Chloride Polymer Monofils. The vinylidene resins are in general highly resistant to chemical agents. The higher the softening point, the greater the chemical resistance. The intermediate softening-point resins are for the most part unaffected by water, inorganic salts, acids, or alkalies in any concentration at ordinary temperatures. The resins are solvated only by polychlorinated aromatic hydrocarbons such as trichlorobenzene, and more active oxygen-bearing organic solvents, such as ketones, oxides, and ethers; for example, cyclohexanone dioxane, dichlorodiethyl ether (U.S. Patents Nos. 2,349,915–6–7). The oriented resins are more chemically resistant than the unoriented. Vinylidene chloride polymers are odorless, tasteless, nontoxic, nonflammable and have high indices of refraction. They can be plasticized with small amounts of special plasticizers, such as di-(alpha-phenyl-ethyl) ether (U.S. Patent No. 2,232,933).

The following table taken from the published record of October 29, 1940, summarizes some of the important physical properties of Saran.

TABLE 70. THE MORE IMPORTANT PROPERTIES OF SARAN

Injection molding	Temperature, ° F.	275-350°
Injection molding	Pressure, lb. per in.^{2}	5,000 to 40,000
Mold shrinkage	In. per in.	0.013
Specific gravity	—	1.68-1.75
Specific volume	Cu. in. per lb.	16.6-15.8
Refractive index	nD.	1.60-1.63
Tensile strength	Lb. per in.^{2}	Up to 40,000
Elongation	Per cent	10 to 40
Modulus of Elasticity	Lb. per in.^{2} × 10^3	4 × 2.4
Flexural strength	Lb. per in.^{2}	15,000 to 17,000
Impact strength	Ft.-lb. energy to break ½ by ½ in. bar (unnotched)	1-4
Hardness	Rockwell Superficial	65–95
Thermal conductivity	10^{-4} cal. per sec. per sq. cm. per ° C. per cm.	2.2
Thermal expansion, coefficient	10^{-5} per ° C.	15.8
Specific heat	Cal. per ° C. per gm.	0.32
Resistance to heat	° F. (continuous)	150–160°
Softening point	° F.	310–325°
Distortion under heat	° F.	150–200°
Tendency to cold flow	Slight	
Volume resistivity	Ohm.-cm	(50 per cent relative humidity and 25° C.) 6 × 10^{13}
Breakdown voltage	60 cycles volts per mil (instantaneous)	
Dielectric constant	60 cycles	500–2500
Dielectric constant	10^3 cycles	3.0–5.0
Dielectric constant	10^4 cycles	3.0–5.0
Power factor	60 cycles	3.0–5.0
Power factor	10^3 cycles	0.03–0.08
Power factor	10^6 cycles	0.03–0.15
Water absorption	Immersion 168 hr., 25° C.	0.5 per cent

Uses of Vinylidene Chloride Polymer Monofils. In addition to the use as a fishing leader, vinylidene resin monofils are used in the manufacture of fly screens; cord, rope, and rope cores; seats and backs for outdoor furniture, automobiles, subway cars, airplanes, etc.; instrument belting; costume jewelry; whipping and trimming for golf clubs and tennis racquets; dog leashes; and other uses.

Miscellaneous Monofils. Monofils for various uses have also been prepared from a number of other filament-forming plastics, for example, vinyl chloride polymers such as " Koroseal " made by B. F. Goodrich Rubber Company, cellulose acetate, regenerated cellulose, rubber, etc.

These materials may be continuously extruded in some cases, particularly when plasticized; for example, cellulose acetate. Cellulose acetate monofils may also be prepared by coalescing several very small filaments, as in a multifilament yarn, while the filaments are still swollen with solvent. Regenerated cellulose monofils in the form of artificial horsehair and straw have been known for years. These are generally prepared by extruding viscose into a coagulating and regenerating bath, as described for multifilament yarns elsewhere in this handbook. Several patents have been issued on viscose monofils prepared by coalescing several smaller filaments, while still in a gel state or after surface treatments with plasticizing agents.

Chemical and physical properties of monofils of these materials are in general about the same as in the case of the multifilament yarns and films.

Monofils of these materials are used for somewhat the same purposes as in the case of the monofils already discussed, and especially for such uses as wrapping cord, webbing, insect screens, upholstery for furniture, netting, wire covering, and straw hat fabrication.

Conclusion. Thus it is seen that the developments of new plastics materials, new plasticizers for these materials, and new methods of extrusion are rapidly bringing to the forefront in innumerable fields the use of monofils in place of multifilament yarns, both natural and synthetic in type, to supplement animal-type monofils, such as hog bristles, to supplement metallic wires, and for many other purposes where materials heretofore used have had certain shortcomings. With the almost countless possibilities for producing monofils of different properties by varying the reactants and conditions in the preparation of nylons and vinyl type polymers, there are indications that the day is not too far removed when it will be possible to write the specifications for an article and find a synthetic monofil which will meet every requirement.

CHAPTER VIII

SYNTHETIC RUBBERS AND ELASTOMERS

Synthetic rubbers and elastomers are classified as:

Thermoplastic

1. Vinyl chloride-acetate copolymer
2. Polyvinyl chloride
3. Polyvinyl alcohol
4. Polyvinyl butyral

Thermosetting or Curing

1. Rubber (with Styrene)
2. Butyl rubber
3. Modified butadiene polymers (Buna)
4. Polychloroprene (Neoprene)
5. Polyalkylene sulfide (with ZnO) (Thiokol)

It is important that the two different types — thermoplastic and thermosetting, or curing — be considered separately, because their different basic structures and characteristics make them differ in certain practical respects.

From the outline it is noticeable that the only thermoplastic types which have assumed commercial significance are the plasticized vinyl polymers. Each of these four varieties has characteristics which make it particularly suitable in certain applications. Polyvinyl butyral has excellent adhesion to glass and comparatively high tensile strength which fit it admirably for safety glass use. Polyvinyl alcohol has excellent resistance to oil and gasoline which makes it useful for special gaskets and hose linings. Polyvinyl chloride and the copolymer have high tensile strength and elongation, good resilience and abrasion resistance, good fatigue resistance, low creep, low water absorption and good electrical properties — a combination of properties which is responsible for the growing demand for these materials in many fields. The present applications include wire coating and electrical insulation, uppers for shoes, water-repellent film fabrics, upholstery, etc.

The thermoplastic types have an advantage over most of the curing types in aging properties, and resistance to oxidation. In some cases vinyl compounds or other closely related thermoplastics have been combined with the rubber-type materials to improve their oil resistance and other properties. It should be noted that these thermoplastic types are mixtures of a rigid type of resin with a high-boiling solvent or plasticizer and many of their properties are established by the plasticizer selected.

Rubber, the natural product, is the most important member of the thermosetting or curing type of material.

Butyl Rubber. Butyl rubber, although it has less bounce than natural rubber, is less permeable and more resistant to the action of air, oil, and most chemicals. It is essentially saturated in the vulcanized form and is less susceptible to age deterioration than natural rubber. It will depolymerize but this may be retarded by the use of suitable stabilizers in compounding. Chemically it is similar to Ebonite and may be compounded with most ordinary pigments. Carbon black lends abrasion and tear resistance.

At elevated temperatures butyl is attacked by concentrated sulfuric acid and decomposed by concentrated nitric acid and oily products. It will not adhere to natural rubber and therefore is not suited for compounding with natural rubber.

Modified Butadiene Polymers (Buna). The modified butadiene polymers are of two principal varieties — those modified with styrene and those modified with acrylonitrile. The first is known as Buna S and the second as Perbunan or Buna N. The Buna S is noted for superior heat and abrasion resistance while Perbunan has better resistance to swelling in gasoline and oils. Buna S is probably the most reliable synthetic rubber for it has been tested and tried for several years. Perbunan may be compared with natural rubber in resistance to aromatic and aliphatic hydrocarbons. It is unaffected by water, dilute acids and alkalies, and salt solutions.

Polychloroprene (Neoprene). The polychloroprenes have outstanding resistance to solvents, oils and gasolines. They are more expensive than the two materials previously discussed but have excellent performance records. They are unaffected by most organic compounds and resist most organic compounds.

Organic Polysulfide (Thiokol). Organic polysulfide is unaffected by petroleum hydrocarbons and most commercial solvents. It resists alcohol, esters and ketones. Its tensile strength is less than that of natural rubber, but it has a very low permeability rate and is therefore a good conductor for volatile solvents.

All of these natural and synthetic varieties of rubber have good resistance to fatigue flexing. They also have one outstanding property which cannot be matched by the thermoplastic types. Their maintenance of a given degree of flexibility over a wide range of temperature makes them particularly useful in applications where a film or sheeting of moderate flexibility must not stiffen excessively when cooled below 0° F., nor become flabby above 100° F.

The **polyalkylene sulfides** are noted principally for their resistance to organic solvents, but their odor is often objectionable.

Miscellaneous Compounds. Other materials with elastomeric characteristics in a limited degree are known and available, of course. These include plasticized polyvinyl acetates, polyvinyl formals, acetals, polyvinylidene chloride and its copolymers, polystyrenes, polymethacrylates, cellulose esters, polyisobutylenes (Vistanex), etc. However, these are commercially unattractive as synthetics in their own right, or are used merely as modifiers for other synthetic materials.

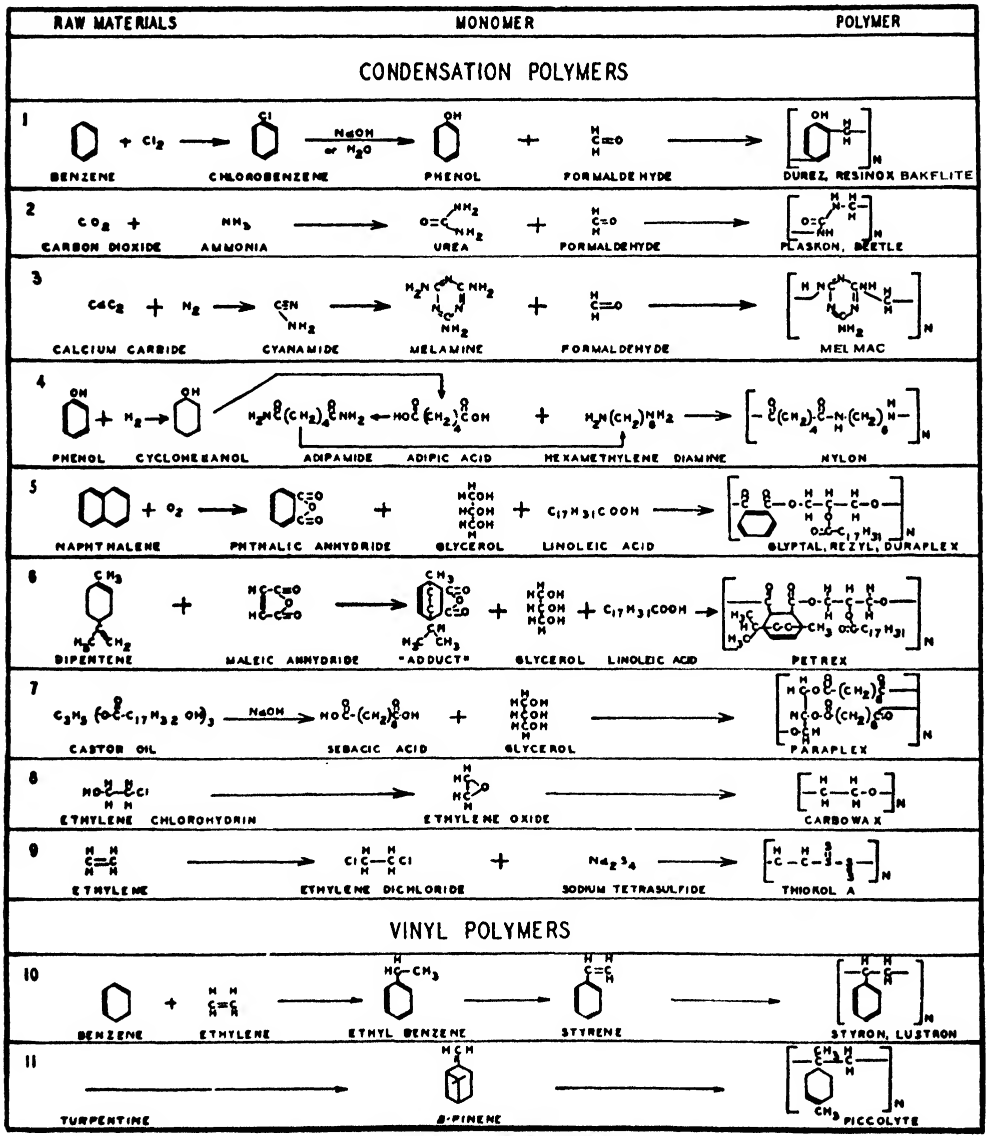
TABLE 71. SYNTHETIC RESINS AND SYNTHETIC RUBBERS[1]

This chart is a revision and extension of the chart published last year [NEWS EDITION (AM. CHEM. SOC.) **19**, 750 (1941)]. Resins from natural products and several new synthetic resins have been added.

Some of the registered trade-marks or trade names designating the resins are listed. For brevity, no attempt has been made to include all of these nor company trade-marks ordinarily associated with more than one type of resin.

The formulas for the resins are necessarily abbreviated and may not always be entirely accurate. In some cases the formulas used have not been previously suggested.

All of the resins and rubbers in this chart are now produced in the United States in commercial quantities.



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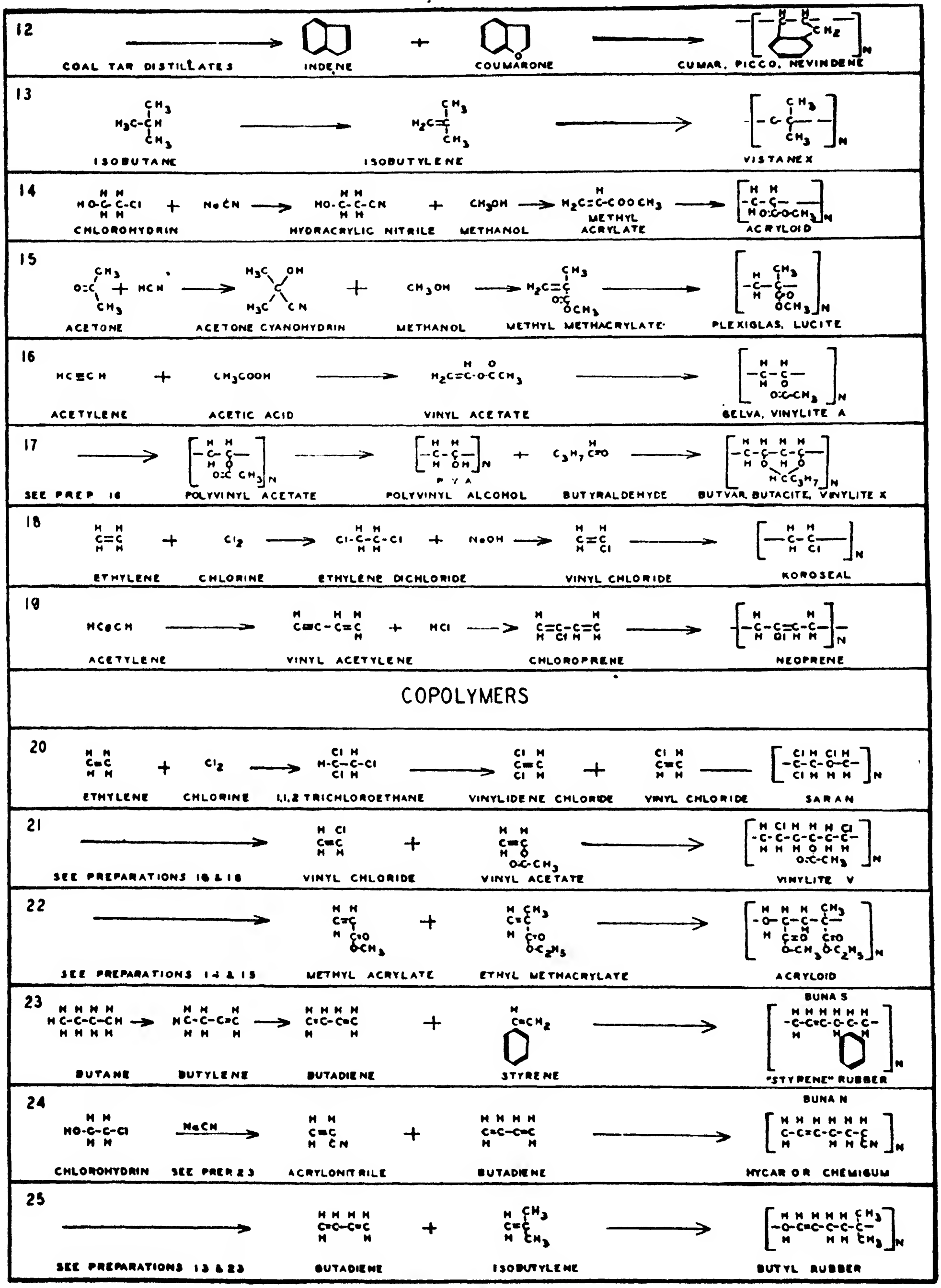
[1] With permission of P. O. Powers, Armstrong Cork Co., Lancaster, Pa.


12
COAL TAR DISTILLATES
INDENE
COUMARONE
CUMAR, PICCO, NEVINDENE
13
ISOBUTANE
ISOBUTYLENE
VISTANEX
14
CHLOROHYDRIN
NaCN
HYDRACRYLIC NITRILE
METHANOL
METHYL ACRYLATE
ACRYLOID
15
ACETONE
HCN
ACETONE CYANOHYDRIN
METHANOL
METHYL METHACRYLATE
PLEXIGLAS, LUCITE
16
ACETYLENE
ACETIC ACID
VINYL ACETATE
GELVA, VINYLITE A
17
SEE PREP 16
POLYVINYL ACETATE
POLYVINYL ALCOHOL
P V A
BUTYRALDEHYDE
BUTVAR, BUTACITE, VINYLITE X
18
ETHYLENE
CHLORINE
ETHYLENE DICHLORIDE
NaOH
VINYL CHLORIDE
KOROSEAL
19
ACETYLENE
VINYL ACETYLENE
HCl
CHLOROPRENE
NEOPRENE
COPOLYMERS
20
ETHYLENE
CHLORINE
1,1,2 TRICHLOROETHANE
VINYLIDENE CHLORIDE
VINYL CHLORIDE
SARAN
21
SEE PREPARATIONS 16 & 18
VINYL CHLORIDE
VINYL ACETATE
VINYLITE V
22
SEE PREPARATIONS 14 & 15
METHYL ACRYLATE
ETHYL METHACRYLATE
ACRYLOID
23
BUTANE
BUTYLENE
BUTADIENE
STYRENE
BUNA S
"STYRENE" RUBBER
24
CHLOROHYDRIN
NaCN
SEE PREP 23
ACRYLONITRILE
BUTADIENE
BUNA N
HYCAR OR CHEMIGUM
25
SEE PREPARATIONS 13 & 23
BUTADIENE
ISOBUTYLENE
BUTYL RUBBER

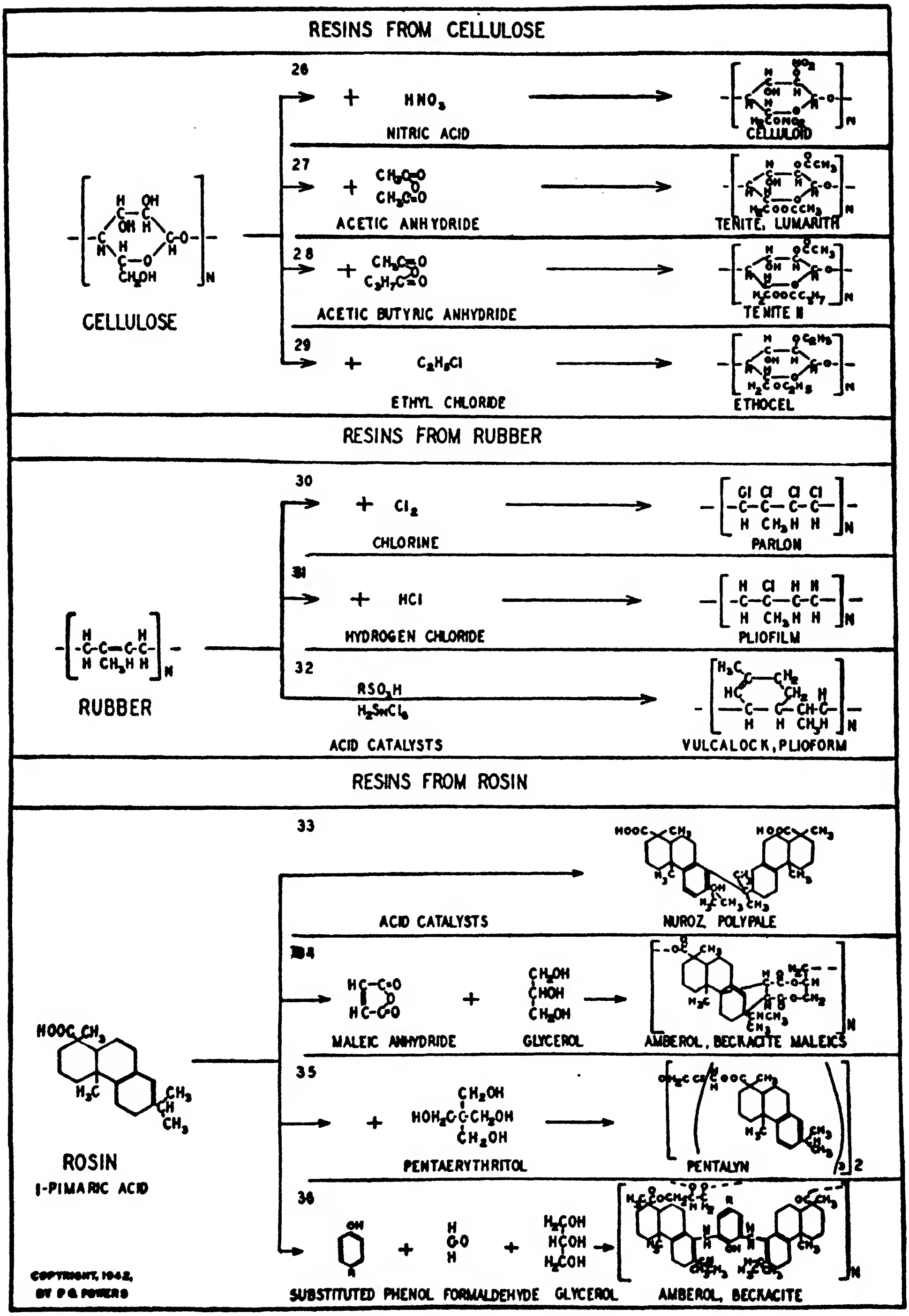


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TABLE 72. CHEMICAL STRUCTURE OF VARIETIES OF SYNTHETIC RUBBER

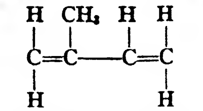
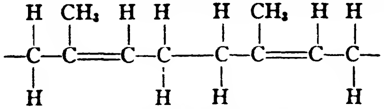
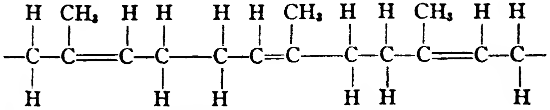
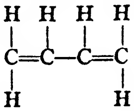
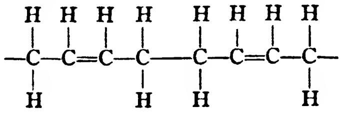
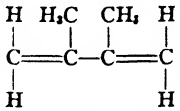
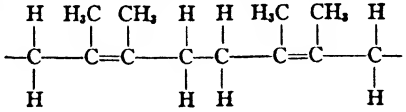
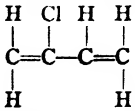
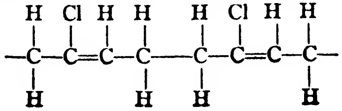
Substance	Starting Materials	Possible of Probable Structure of Polymers	Remarks
Natural rubber	 Isoprene (2 methyl, 1, 3 butadiene)	 (Natural rubber, Isoprene)  (Synthetic isoprene rubbers)	In the natural rubber hydrocarbons the methyl groups occur regularly along the chain. In the synthetic isoprene rubbers, the methyl groups occur more or less irregularly, since, when stretched, they do not give the X-ray results, have groupings somewhat as shown at left, below formula for structure of natural rubber.
Butadiene rubbers	 1, 3 butadiene		The Russian synthetic rubber is a sodium polymerized butadiene. The numbered Buna rubbers (Buna 32, etc.) are also sodium polymers. Buna S consists of mixed polymers of butadiene and styrene polymerized in the form of an emulsion. Buna N similarly consists of mixed polymers of butadiene and acrylonitrile polymerized in the form of an emulsion.
Methyl rubber	 2, 3 dimethyl butadiene		The methyl groups occur regularly along the chain, as shown.
Chloroprene rubbers "Neoprene," "**Sovprene,**" etc.	 (2-chloro-1, 3 butadiene)		In this polymeride the chlorine atoms evidently occur regularly, since when stretched it gives an X-ray fiber diagram.

TABLE 72. CHEMICAL STRUCTURE OF VARIETIES OF SYNTHETIC RUBBER (*Continued*)

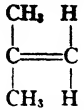
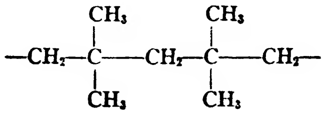
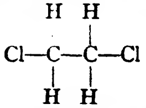
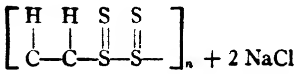
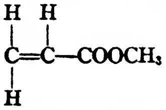
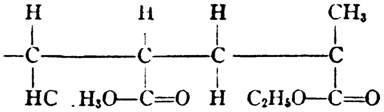
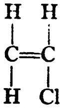
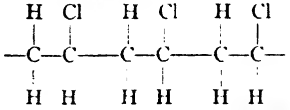
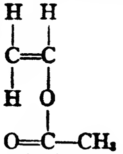
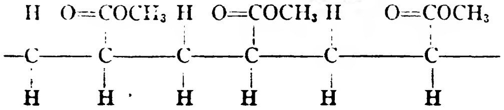
Substance	Starting Materials	Possible or Probable Structure of Polymers	Remarks
Polyisobutylenes " Vistanex," " Oppanol "	 Isobutylene (2-methyl-1 propane)		Polymerization takes place in the presence of borontrifluoride at −40° C. The structure of the product is not definitely known. The unsaturation is very low and probably occurs only in the end molecule. When stretched, the substance gives an X-ray fiber diagram.
Alkyl polysulfide " Thiokol," etc.	 Ethylene dichloride (1, 2 dichloroethane) and  Sodium tetrasulfide		
Methyl acrylate " Acryloid "	 Methyl acrylate		
Polyvinyl chloride Plasticized materials " Koroseal," " Korogel," or " Flamenol "	 Vinyl chloride		
Polyvinyl acetate " Gelva "	 Vinyl acetate		

TABLE 72. CHEMICAL STRUCTURE OF VARIETIES OF SYNTHETIC RUBBER (*Continued*)

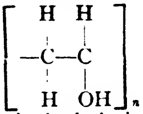
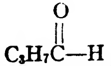
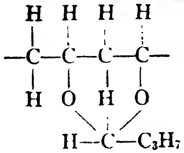
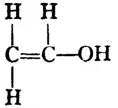
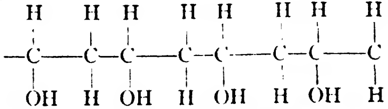
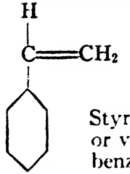
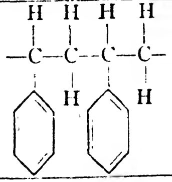
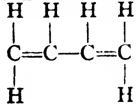
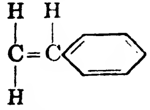
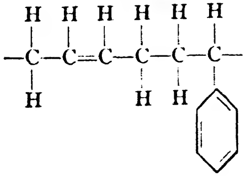
Substance	Starting Materials	Possible or Probable Structure of Polymers	Remarks
Polyvinyl Acetal " Butvar " " Butacite " Vinylite X	 Polyvinyl alcohol and  Butyraldehyde		
Polyvinyl alcohol " PVA" Resin	 Vinyl alcohol	 Polyvinyl alcohol	
Polystyrene " Lustron," " Styron," " Loalin "	 Styrene or vinyl benzene		
Buna S or Buna SS Copolymer of butadiene and styrene	 Butadiene and  Styrene (vinyl benzene)		

TABLE 72. CHEMICAL STRUCTURE OF VARIETIES OF SYNTHETIC RUBBER (*Continued*)

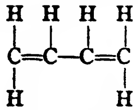
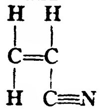
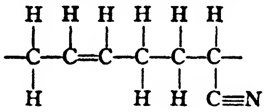
Substance	Starting Materials	Possible or Probable Structure of Polymers	Remarks
Perbunan or Perbunan Extra. Copolymer of butadiene and acrylonitrile (vinyl cyanide) (once called Buna N)	 $H_2C{=}CH{-}CH{=}CH_2$ Butadiene and  $H_2C{=}CH{-}C{\equiv}N$ Acrylonitrile (vinyl cyanide)	 $-CH_2{-}CH{=}CH{-}CH_2{-}CH_2{-}CH(C{\equiv}N){-}$	

TABLE 73. PROPERTIES OF VARIOUS SUBSTANCES OF RUBBERY CHARACTERISTICS: RUBBER DERIVATIVES AND RUBBER SUBSTITUTES;

I. Rubber and its derivatives. Can be vulcanized.

	Chemical composition	Physical characteristics of the unvulcanized material	Vulcanizing characteristics	Typical characteristics of vulcanized material
1. Natural rubber.	1, 4 Linear polymer of isoprene.	Very rubbery. Softens at high temperatures, freezes at low temperatures. Pale color. Slight odor. Chemically resistant.	Vulcanizes with sulfur to become non-thermoplastic.	Very rubbery. High tensile strength, good elongation at break. Rapid recovery after stretching. Resistant to abrasion. Good electrical properties. Not affected by many chemicals or solvents. Excellent rebound elasticity.
2. Reclaimed rubber.	Replasticized vulcanized rubber.	Rubbery. Improves processing of other rubber.	Vulcanizes with sulfur to become non-thermoplastic.	Rubbery. Fair tensile strength, fair elongation at break. Most useful when used in combination with rubber.
3. Thermoprene.	Rubber isomerization product.	Horny, becoming rubbery at higher temperature. Used for stiffening rubber, helping rubber to adhere to metal, or as a paint vehicle.	Vulcanizes with sulfur to give a hard product like Ebonite.	Hard. High strength, low elongation. Useful for stiffening rubber.

II. Rubber substitutes chemically related to natural rubber. Can be vulcanized.

	Chemical composition	Physical characteristics of the unvulcanized material	Vulcanizing characteristics	Typical characteristics of vulcanized material
1. Gutta percha or balata.	Linear polymer of isoprene, isomer of natural rubber.	Tough and horny, becoming rubbery at higher temperatures, and finally melting. Good electrical properties.	Can be toughened by vulcanizing with sulfur, becoming non-thermoplastic.	Tough. Slightly rubbery, good strength. High elasticity.
2. Buna S.	Emulsion copolymer of butadiene and styrene.	Rubbery. Does not soften much with heat.	Vulcanizes with rubber to give a very rubbery, non-thermoplastic material.	Very rubbery. High tensile strength and good elongation at break. Rapid recovery after stretching. Resistant to abrasion. Fairly resistant to heat. Excellent rebound elasticity.
3. Perbunan.	Emulsion copolymer of butadiene and acrylonitrile.	Rubbery. Does not soften much with heat.	Vulcanizes with sulfur to become non-thermoplastic.	Rubbery. High tensile strength. Good elongation at break. Rapid recovery after stretching. Resistant to abrasion. Very slightly swelled by oil. Properties not deteriorated by oil.
4. Neoprene.	Linear polymer of chloroprene.	Stiff and slightly rubbery. Softens greatly with heat.	Vulcanizes with heat to become non-thermoplastic.	Rubbery. High tensile strength, good elongation at break. Fair rebound elasticity. Very resistant to oil. Properties not deteriorated by oil. Resists corona, ozone and light.

TABLE 73. PROPERTIES OF VARIOUS SUBSTANCES OF RUBBERY CHARACTERISTICS: RUBBER DERIVATIVES AND RUBBER SUBSTITUTES (*Continued*)

Cannot be vulcanized.

	Chemical composition	Physical characteristics of the unvulcanized material	Vulcanizing characteristics	Typical characteristics of vulcanized material
1. Vistanex.	Linear polymer of isobutylene.	Rubbery. Softens at high temperature, does not harden at low temperature. Colorless. Odorless. Inert chemically.	Cannot be vulcanized.	—
III. Synthetic resins chemically unrelated to rubber, having rubbery characteristics. Can be vulcanized.				
1. Thiokol.	Condensation product of aliphatic dihalide and soluble polysulfide.	Slightly rubbery. Softens with heat.	Vulcanizes by action of heat and metallic oxides to give somewhat rubbery product still slightly plastic.	Somewhat rubbery. Fair tensile strength, fair elongation at break. Very resistant to oil and aromatic solvents. Resists corona, ozone and light.
2. Alkyd resin.	Glycerol-phthalic acid condensation product.	Oily or plastic resin.	Hardens by heat to give non-thermoplastic resin.	Strong, tough, chemically resistant. Good electrical properties.
Cannot be vulcanized.				
1. Koroseal.	Plasticized gamma polyvinyl chloride.	Great range of rubbery characteristics. Plastic at high temperatures. Colorless. Odorless. Resistant to chemicals and oils.	Not vulcanized.	—
2. Polyacrylates.	Polymers of various acrylates or methacrylates.	Resinous. Softens at high temperatures. Can be molded. Hard, transparent, chemically resistant.	Not vulcanized.	—
IV. Natural materials unrelated to rubber, having rubbery characteristics. Can be vulcanized.				
Factice.	Unsaturated vegetable or fish oils vulcanized with sulfur or sulfur chloride.	—	Already vulcanized in preparation. Non-thermoplastic.	Weak. Crumbly. Used in rubber to improve extrusion characteristics and to maintain form during cure.
Glueglis.	Mixture of glue and glycerol.	Dead and only slightly rubbery. Typical odor of glue. Affected by water, heat, but not by oil.	Insolubilized by chromates or formaldehyde, becoming less thermoplastic.	Slightly rubbery. Used with rubber for deadening it and imparting resistance to oil.

MODIFIED RUBBER

The compounding of natural rubber with some of the synthetic products has produced materials with some new and interesting properties. These materials are called modified rubber as distinct from synthetic rubber, which latter term usually refers to materials having no natural rubber. Modified rubbers for some applications have been found more suitable than either the natural rubber or the synthetic rubbers.

At present attention is being given to the bonding of a natural rubber tread to a synthetic rubber carcass for automobile tires.

The term, " modified rubber," ordinarily does not cover compositions where the proportion of natural rubber is very small. Materials of that character will be found under other headings.

Most mixtures of rubber with synthetic products are still in the experimental stage. Some of the synthetic rubbers (such as chloroprene) that are being most rapidly developed either are not truly compatible with natural rubber or may actually be impaired if rubber is milled into them.

SOME EXAMPLES OF RUBBER–SYNTHETIC MIXTURES

Chloroprene-Rubber Mixtures. A material called Flexible Ebamite can be prepared by mixing rubber and chloroprene and vulcanizing the mixture. Chloroprene alone cannot be vulcanized to the Ebamite stage no matter how much sulfur is present. The mixture of the two has oil- and solvent-resisting properties superior to those of chloroprene and possesses a flexibility not normal in Ebamite.

Chloroprene, like some other artificial rubbers, will blend with rubber on the mill but is not strictly compatible with it. The two are not mutually soluble, and a homogeneous phase is not produced. Lowering the cost of neoprene by the addition of natural rubber has been unsuccessful because of the degrading of such physical properties as the tensile strength, tear resistance, permanent set, and oil resistance.

A small proportion of rubber is often added, however, to chloroprene compositions that are to be subjected to hot oil. Natural rubber softens and counteracts the stiffening effect of neoprene. Almost the only completely successful chloroprene-rubber composition is a mixture of 10 to 25 per cent natural rubber *latex* with chloroprene *latex.* This produces a latex that forms films which possess all the desirable properties of chloroprene and yet do not become stiff and leathery with age or at reduced temperatures, as chloroprene latex films tend to do.

A chloroprene tread can be bonded to a rubber tire carcass by various bonding cements, one of which is a butadiene mixture.

Rubber-Butadiene Mixtures. A mixture of chlorinated drying oils and polymerized chlorobutadiene has been suggested for fireproofing a rubber composition.

Butadiene mixed with natural rubber and vulcanized in the presence of lampblack is used for automobile tires.

Synthetic rubbers like butadiene may be compounded with lampblack, kaolin, scrap rubber, sulfur, zinc oxide, calcium oxide and various accelerators to produce shoe soles.

A solution of a mixture resulting from the polymerization of butadiene or isoprene with balata, gutta percha, or rubber is recommended for bonding rubber to metals.

Another type of modified rubber makes use of a polymerized mixture of butadiene with from 40 to 80 per cent natural rubber, sulfur, and alkali metal as a catalyst.

A modified rubber dielectric composition is made of 80 per cent polymerized styrene or butadiene, with 20 per cent rubber, gutta percha, or balata, or a mixture of these.

Phenol-Aldehyde-Rubber Mixtures. A phenol-aldehyde composition to which is added 20 to 30 per cent rubber and some polymerized vinyl chloride or vinyl acetate forms a molding composition that has both thermosetting and thermoplastic properties.

Phenol-formaldehyde resins are sometimes modified with rubber to prevent hardening and to make them more elastic.

A preparation of viscose, phenol-formaldehyde, rubber, and sulfur may be compounded on rolls and molded and sheeted like rubber. It may then be vulcanized.

Rubber and powdered brittle phenol-formaldehyde resin, when formed by heat and pressure, produce a hard rubber composition.

Rubber-Styrene Mixtures. Rubber dissolved in styrene (monomeric liquid) and heated to 140° C. (284° F.) produces a substance with a nacreous luster, more flexible than polystyrene without rubber.

A dielectric may be prepared from purified rubber compounded with 40 to 80 per cent styrene and up to 20 per cent wax. Rubber compounded with styrene, gutta percha, and small amounts of water-resistant waxes is similarly used.

Rubber, when mixed with phenol-formaldehyde adhesive, attains increased elasticity.

Rubber-Urea Resin. Urea resin in combination with natural rubber is used as a coating material.

A bonding composition can be formed by mixing coagulated rubber with liquid urea-formaldehyde condensation products and heating (below the hardening point of urea resins) until the composition flows. The rubber is dispersed in the heat-hardenable fluid, and the composition serves as a bond for adhesive grains and fillers.

Acrylic Esters-Rubber Mixture. Rubber is compatible with acrylic esters, to which it is added in small amounts as a modifier.

Vinyl Ester Resins. Vinyl resins mixed with dispersions of rubber yield gutta-percha-like compositions.

Rubber and vinyl compounds, heated under pressure in the presence of a hydrocarbon solvent and sulfur and a heavy metal chloride, yield a light-colored solution that may be employed as a lacquer.

A viscous solution of rubber, cellulose derivatives, and polyvinyl chloride has been prepared for use in sticking patches to worn places in clothing.

Chlorinated Naphthalene-Rubber Mixture. Chlorinated naphthalene with about 1 per cent styrene or rubber has been suggested as an insulating composition.

Alkyd Resins. Alkyd resins are used to render rubber adaptable to the formation of plastics compositions that are resistant to hydrocarbons. A latex is thoroughly mixed with a solution of alkyd resin in 5 per cent aqueous ammonia, acetic acid is added, and the precipitate is washed with water, dried, and vulcanized.

An aqueous emulsion of a resin of the alkyd type, and rubber, rubber latex, or a rubber-like artificial material produces a composition often used for impregnating surfaces.

Alkyd resins mixed with natural or artificial rubber before vulcanization have increased strength.

The resin from phenol-glycerol ether and phthalic anhydride may be incorporated with rubber and the mixture vulcanized to yield a rubber mass of increased resistance to chemical and electrical effects.

Cumarone-Indene Resin. A coating material consisting of cumarone resin and 1 to 10 per cent of rubber is prepared.

Cumarone resin is widely used as a modifier of rubber. It has a pronounced softening effect on rubber during milling. The adhesive properties of friction tape are improved by incorporation of cumarone-indene resin.

Ester Gum-Rubber Mixtures. Ester gum is successfully compounded with rubber but so far the material has no special application.

A mixture of rosin, glycerol, and rubber is used to make elastic films.

Lignite-Rubber Mixture. The plasticity and strength of lignite-phenol mixtures are improved by the addition of small amounts of rubber.

CHAPTER IX

NATURAL RESINS

Natural resins are of interest to the manufacturer of plastics or synthetic resins chiefly because of the way the synthetic products have replaced the natural products and even improved upon them. There is scarcely a need for a natural resin that can not be filled if necessary by some kind of synthetic product, which can also be produced in lots having uniform properties.

Acaroid Resin. (Also called gum acaroid, yacca, grass tree gum, or red gum.)

Varieties: Red and yellow.

Source: From trees of the species *Xanthorrhea,* especially *Xanthorrhea australia* and *Xanthorrhea hostilis.* The resin is obtained by beating the stems of these " grass trees " and separating out the powder with a sieve.

Properties: The red resin consists of small red-brown dusty lumps with a lustrous fracture. The yellow is a dark-red friable mass forming a yellow powder. The resin has an odor similar to that of benzoin.

Chemistry: The resin contains 5 to 7.5 per cent or less of benzoic acid. Destructive distillation yields a heavy oil resembling phenol and a light oil resembling benzene. Heating with nitric acid produces picric acid.

Use in association with plastics: Acaroid resins are cheap resins used chiefly as adulterants for other resins, in spirit varnishes for coating metals, and in alkaline solution for sizing paper.

Amber.

Varieties: (1) Succinite — in pale yellow or yellowish-brown brittle lumps, either transparent or opaque. The most important amber. Melts at 250° to 300° C. (482° to 572° F.). (2) Gedanite — or soft amber — of a whitish, yellow color, easily fractured. Melts at 150° to 180° C. (302° to 356° F.). (3) Glessite — of a darker color, usually opaque. Melts at 250° to 300° C. (4) Beckerite — a brown, opaque variety.

Source: A fossil resin derived from *Pinites succinifer.* Amber is collected principally near the Baltic coast.

Properties: Amber is the hardest known resin, but it is brittle and breaks with a conchoidal fracture. It varies in color from pale yellow through dark brown to almost black, and from transparent through cloudy to opaque. Hardness 2.25; specific gravity, 1.09; transparent to translucent.

Chemistry: Distillation of amber (carried out prior to its use for varnish manufacture) yields " oil of amber," a volatile oil of specific gravity 0.95, and optical rotation of + 15° to + 25°. Amber takes a polish well.

Use in association with plastics: " Imitation amber " in the form of cast phenol-formaldehyde resin has taken the place of real amber for such articles as mouthpieces of pipes, and jewelry, at a lower price, while giving a fair imitation of its properties.

Copal. (Also called gum copal.)

Varieties: (1) East African copal (Zanzibar, etc.). (2) West African copal. (3) Manila copal. (4) Kauri copal (from New Zealand and Caledonia). (5) South American copal.

Source: (1) East African copal: Fossil resins found mostly where copal trees have disappeared, but probably a product of species of *Trachylobium.* Gathered in East Africa and shipped from Zanzibar. (2) West African copal: Obtained from coastal regions of West Africa, the finer varieties being fossil or semi-fossil and the poorer varieties coming from living trees. (3) Manila copal: At one time produced only in the Philippines but now gathered in the Dutch East Indies under the name of Macassar, Pontianac, or Singapore copals. (4) Kauri copal: A fossil resin derived from the Kauri pine tree of Australia and New Zealand. (5) South American copal: a product of the *Hymenoca* species, it is gathered from living trees or in the fossil state.

Properties: Copal is a hard brittle resin with a vitreous luster, yellow to red in color and semi-transparent, often with a faceted or indented surface known as goose skin and especially characteristic of Zanzibar copal. When heated strongly, the resin gives off 10 to 25 per cent of its weight as water, gas, and oil or other decomposition products and becomes soluble in linseed oil and turpentine.

Copals	*Acid value*	*Ester value*
Manila	120–130	45–55
Singapore	120–135	50–65
Kauri	65–85	30–40
Angola	50–90	50–80

Copal	*Iodine values*	*Copal*	*Iodine values*
Kauri	74–170	Mozambique	136
Manila	104–148	Madagascar	126
Pontianac	119–142	West African	122–143
Zanzibar	115–123	Sierra Leone	102–105
		Brazilian	122–134

General scale of hardness:

1. Zanzibar copal
2. Mozambique copal
3. Lindi copal
4. Red Angola copal
5. Pebble copal
6. Sierra Leone copal (fossil)
7. Yellow Benguela copal
8. White Benguela copal
9. Comeroon copal
10. Congo copal
11. Manila copal
12. White Angola copal
13. Kauri copal
14. Sierra Leone copal (living trees)
15. South American copals

Chemistry: Copal, like shellac, appears to consist of a mixture of which the principal constituents are free acids and esters. The acid and ester values give useful information concerning the type and purity of the resin examined.

Use in association with plastics: Copal is used chiefly as a varnish resin. Synthetic resin varnishes being superior to the old types in many respects, the natural resin may again be replaced by the synthetic resin.

Dammar.

Varieties: Dammar is obtained from the Dutch East Indies, Sumatra, and the Federated Malay States, the varieties being named according to the places where they are collected.

Source: All dammar resin is obtained from living trees, the principal species being *Hopea, Shore,* and *Balanocarpris.*

Properties: East Indian dammar is sold in the form of stalactitic granules and lumps, almost white to yellowish in color, transparent, covered with dust and having a conchoidal fracture. Dammar is very soluble in alcohol, benzene, turpentine, or carbon disulfide.

The properties of dammar resin are variable, as indicated by the following analysis of some samples of dammar resin of the same type.

Melting Point	*Ash*	*Ester Number*	*Acid Number*
90° C.	0.26%	1.4	45.3
87° C.	0.05%	0	38.5
185° C.	0.03%	0	72.0
200° C.	0.04%	0.2	46.5
97° C.	0.25%	0	38.5

The properties of Burmese Rock dammar are as follows:

Ash	*Saponification No.*	*Acid No.*	*Ester No.*	*Melting Point*	*Specific Gravity*
0.55–0.68%	31 to 37.5	31–31.5	0–5.6	90°–115° C.	0.980–1.013

Rose dammar, in yellowish-white pieces, some with a reddish tinge, has the following characteristics:

Initial Melting Point	*Complete Melting Point*	*Acid Value*	*Saponification Value*	*Alcohol*	*Petrol. Ether*	*Carbon Disulfide*	*Benzene*
130° C.	150° C.	140–151	159–165	82%	30%	45%	25%

Batavian dammar is the finest variety because it forms a very clear solution in turpentine and has fine color.

Chemistry: Most dammars consist very largely of resin acids with a small amount of neutral resenes or of 8 per cent or less of essential oil.

Uses: Used in the manufacture of spirit varnishes for the varnishing of fabrics; in paper and certain cloths for indoor decorative work, in place of phenolic and urea resins.

Dragon's Blood.

Varieties: Palm dragon's blood, from a large rattan palm, *Daemonoropodraco,* growing in the Indian Archipelago; Socotra dragon's blood, from the tree *Dracoenacinnabari,* growing in Socotra, the West Indies, and southeastern Asia.

Properties: The best dragon's blood is marketed as cylindrical rolls 1 in. in diameter and 10 to 12 in. long, wrapped in palm leaves. Socotra dragon's blood is imported in conchoidal lumps. The resin is deep red and opaque, yielding a crimson colored powder soluble in alcohol.

The saponification number of dragon's blood varies from 135 to 145.

Chemistry: Dragon's blood consists of complex resin acids, alcohols, and esters.

Uses: Employed principally as a stain or red spirit varnish.

Elemi.

Varieties and Sources: Manila elemi, from *Canarium luzonicium;* Yucatan elemi, from *Amyris plumieri;* Mexican elemi, from *Amyris elencifera;* Rio elemi from various plants; Brazilian elemi from *Protium heptaphyllum;* African elemi from *Boswellia freriano;* and East Indian elemi from *Canarium zephyrenum.*

Properties: When fresh, elemi resin consists of a mixture of resin with some essential oil, and may be either soft and sticky (soft elemi), or hard and crystalline (if less essential oil is present). The resin is pale in color and has an odor of lemon and turpentine. It has a specific gravity of 0.87 to 0.91 and is dextrorotatory.

Some average figures of other properties:

	Soft Manila Elemi	*Hard Manila Elemi*
Volatile oil	15–20%	8–9%
Ash	0.02–0.2%	0.2–1%
Acid value	17–25	15–28
Ester value	7–25	25–35

Chemistry: The fresh resin contains 20 to 30 per cent of an essential oil which is fragrant, dextrorotatory, and contains various terpenes, chiefly phellandrene and dipentene. The resin itself consists of brein (soluble in cold alcohol) and amyrin (soluble in hot alcohol). Manila elemi also contains a small amount of a crystalline acid, elemic acid, consisting of crystals larger than those of the other crystalline bodies of the resin.

Uses: Elemi has been used chiefly in printing inks and in certain kinds of varnish. It, too, can be largely replaced by synthetic resins.

Guaiacum.

Source: The resin is produced from the wood of certain trees (*Guaiacum officinale* and *Guaiacum sanctum*) which grow in tropical America.

Properties: The greenish black resin is sold in masses and in small fragments or lumps, often admixed with woody material or other foreign matter. It is 87 to 90 per cent soluble in alcohol, and 55 to 75 per cent soluble in ether. The ash rarely exceeds 3.5 per cent; the acid value varies from 40 to 53, the ester value from 121 to 139, and the saponification value from 167 to 192.

Use: Guaiacum resin has little use except in medicine.

Mastic.

Source: Mastic is obtained from trees (*Pisticia lentiscus*) found on the shores of the Mediterranean. Some is also obtained from India.

Properties: The resin is sold as opaque yellowish to yellow-green granules, about one-quarter to three-quarters of an inch long, hard, and with a conchoidal fracture. It has a low melting point and is not brittle when warm, and is consequently waxy when chewed. It softens below 100° C. and melts under 110° C.

Some analytical values for two samples are as follows:

	Acid Value	*Ester Value*	*Saponification Value*	*Ash*	*Moisture*
1.	50	23	73	0.21%	0.97%
2.	56	23.1	79	0.14%	1.40%

It is soluble in alcohol and most other organic solvents except petroleum ether. It is seldom adulterated.

Uses: Mastic is used chiefly in lithographic work and in spirit varnishes.

Rosin or Colophony.

Varieties: American and French rosin are commercial varieties, the French being called galipot, and the American usually being lettered according to grade. (A is nearly black and W. W. almost water-white.)

Source: Various species of pine trees, which when tapped yield an oleoresinous exudation known as crude turpentine. Steam distillation removes the oil of turpentine and leaves the solid rosin.

Properties: Common rosin is usually pale yellow in color, soft, brittle, and practically transparent. It has an aromatic odor resembling turpentine, and is soluble in alcohol, acetic acid, and volatile and fixed oils. The specific gravity is 1.0450 to 1.085. The softening point is about 75° C. (167° F.), and the melting point 120° to 135° C. (248° to 275° F.).

Some analytical figures are:

Specific Gravity	*Acid Value*	*Ester Value*	*Iodine Value*	*Unsaponifiable Matter*
1.0450–1.085	150–175	7–20	118–128	4–9%

Dry distillation yields first rosin spirit (b.p. 80° to 250° C., 176° to 482° F.) and then rosin oil (290° to 310° C., 554° to 590° F.). Rosin spirit is used to some extent as a substitute for turpentine, and rosin oil is used for lubrication alone; also, as axle-grease, with lime and petroleum oils. It is also used in printer's ink.

Chemistry: Rosin consists almost entirely of abietic acid, possibly in the form of an anhydride (or lactone). A very small quantity of esters is present also. Rosin is identified quantitatively by the Storch-Moraroski reaction. A fragment of the resin is dissolved in acetic anhydride and the solution cooled and filtered; and concentrated sulfuric acid added gently to the mixture so as to form a separate layer. A red-violet ring at the juncture of the layers is a positive test.

Uses: Rosin is used as an adulterant for other resins, as an ingredient of very low grade varnishes, and in cheap soaps. It is used for the production of metallic resinate to be employed as rapid-varnish driers, and for the production of rosin spirit and rosin oil. Most driers are prepared by melting the rosin with an oxide of a metal, usually lead or manganese, or by adding a metallic salt to an aqueous solution of the rosin.

Rosin is also used for the production of *ester gums,* produced by combining the acid of the rosin with glycerin and certain other bodies containing hydroxy groups. The ester gums are much better suited for use in varnishes than is rosin. Ester gum varnishes are harder, and wear and weather better.

Sandarac.

Varieties: African sandarac and Australian sandarac.

Source: Most sandarac is obtained from a species of North West African trees (*Callitris quadrivalis*), some (pine gum) being obtained from Australian species of *Callitris.*

Properties: African sandarac is exported as yellowish, dusty lumps, easily pulverized. Some of the Australian varieties yield larger trees and masses. The resin melts at about 160°C. (320° F.) and is soluble in alcohol, ether, acetone, and numerous essential oils. The acid value varies from 90 to 154 and is usually between 140 and 154.

Chemistry: Sandarac contains a large proportion of free acids, especially primaric acid. It also contains a small amount of an essential oil containing dextropimene and a diterpene.

Uses: Sandarac has been used chiefly in the preparation of spirit varnishes.

Shellac.

Source: The resin is secreted by the lac insect, *Tachardia lacca,* one of the coccidae or wax insects, which feed upon the vegetable sap of trees. The lac insects live on the *Butea frandosa* of India, also called the palas tree. The insects swarm twice a year, covering the tree twigs with their larvae, which attach themselves to the tree, suck the sap, and exude the lac resin which soon leaves them completely encrusted. The encrusted twigs are gathered from the forest and broken up in factories by hand or machinery to the form known as " stick lac."

The stick lac is crushed by a mill and the wood and dirt fragments sifted out, leaving the fragments of " seed lac " which are washed and ready to be converted to " leaf lac," or what is usually called shellac, or into cakes known as garnet lac and button lac.

Properties: Shellac is sold in the forms described above as seed lac, button lac or garnet lac. It is a dark-colored thermoplastic material which can be molded easily at 250° to 275° F. Molded articles are glossy, hard and scratch resistant, and also resist carbonization. Shellac is soluble in alcohol and compatible with a number of synthetic resins such as alkyds and phenolics.

Chemistry: (See also under Chemistry of Plastics.) Shellac consists chiefly of a mixture of monobasic-interester-acids, mainly aleuritic acid, shellolic acid, and kerrolic acid, their isomers and similar related compounds. The remainder is made up largely of wax and natural yellow dyestuffs.

Uses: The uses of shellac are similar to those of the newer synthetic resins and shellac is important enough as a plastic to hold its own among them. Shellac is used in solution for impregnating cloth and fabric and for producing laminated compositions suitable for thermal insulation. Shellac has excellent bonding properties and a low dielectric constant, which with its resistance to carbonization makes it valuable for electrical insulators. The principal drawback to its use in this way is its low softening point and ready deformation by heat. When it is modified by a thermosetting synthetic resin such as a phenolic, however, a composition is produced with the electrical properties of the shellac and the heat-resistant properties of the synthetic resin.

Specific gravities of natural resins, arranged in descending order:

Resin	*Specific Gravity*	*Resin*	*Specific Gravity*
Shellac (orange)	1.152	Rosin M	1.069
Shellac (bleached, dry)	1.110	Pontianac	1.068
Rosin ester	1.095	Congo Copal (No. 1, pale)	1.066
Manila ester	1.090	Dammar, No. 1, Singapore	1.062
East India Gum	1.087	Congo (hard, amber)	1.059
Gum sandarac	1.078	Congo (fused to 30% loss in weight)	1.050
Congo ester	1.076	Kauri (Grade 303)	1.043
Manila copal (hard)	1.072	Canada balsam	1.00
Gum mastic	1.070		

Refractive indices of natural resins, arranged in descending order:

Resin	*Refractive Index*	*Resin*	*Refractive Index*
Kauri (Grade 303)	1.565–1.540	Gum mastic	1.536–1.535
Rosin	1.548	Natural rubber	1.535
Amber	1.548–1.538	Shellac (bleached dry)	1.534
Congo (hard, amber)	1.545	Canada balsam	1.530
Congo (fused to 30% loss in weight)	1.545	Copal	1.528
Pontianac	1.545	Rosin M	1.525
Gum sandarac	1.545	Shellac (orange)	1.516
Manila copal (hard)	1.544	Dammar, No. 1, Singapore	1.515
Varnish, dry	1.54–1.51	Congo ester	1.506
Shellac	1.54	Manila ester	1.506
Congo Copal No. 1, pale	1.54	Linseed oil, dry	1.50–1.48
East India Gum	1.537	Rosin ester	1.496

CHAPTER X

FILMS

Self-supporting thin transparent films, in contrast with paint and lacquer films which are formed directly on the surfaces with which they are left in permanent contact, are produced by several techniques. Extrusion, molding blocks and cutting into thin sheets, milling, dipping, and stripping from smooth surfaces are all known and used. The principal commercial processes today are broadly divisible in two categories: those in which the film-forming mass is extruded through a carefully controlled orifice into coagulating, drying, or cooling media; and those in which the film-forming mass is deposited on a perfectly smooth surface, allowed to harden in contact with the surface, and removed therefrom.

In the first group of processes, the accuracy of control of the orifice opening, its smoothness, and materials of construction largely determine the merit of the film made. Numerous patents have been obtained on extrusion hoppers and auxiliaries. Basically, all of them are similar to that shown in B.P. 3929 or U.S. P. 1,049,658 of Jan. 7, 1913. See Fig. 10.1.

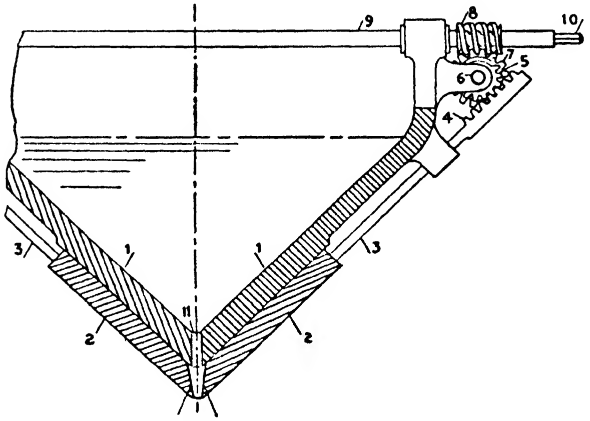


Fig. 10.1 — Section of hopper used for casting viscose.

One or both lips are movable and locally adjustable, and the film-forming mass is forced from them by pressure or gravity into a hardening medium. In the second group of processes, the polished surface on which the film-former is deposited, fulfills most of the functions of the extrusion hopper and it is the nature of this surface which determines many of the characteristics of the film produced on it.

Extrusion hoppers can be used in conjunction with drying surfaces and the polished drying surface is sometimes made to constitute one side of the extrusion orifice. Film-forming solutions can be applied to the drying surface by brush, spray, doctor-knife or doctor-roll, and by dipping as well as by hopper. Surfaces which have been used or tried extensively on a commercial basis vary all the way from metals and glass to coated textiles, paper, and rubber. Copper, nickel, and chromium have been preferred as drying surfaces and find use in the form of wheels or endless bands stretched between large drums.

Most film-formers can be converted to films by either of the general classes of processes. Since the type of process chosen has an important bearing on the appearance, physical characteristics, and cost of the film made, the processes in widest use today have been adopted principally to develop the characteristics wanted by the markets to which it is expected the film will go.

By far the largest volume of thin transparent film now made is regenerated cellulose cast from hoppers into acid coagulating baths. Probably the next largest volume (if considered as inclusive European production) is cast onto metal belts. The use of metal wheels, nickel or chromium plated, takes third place (second place in the United States). Smaller volumes of production are made on coated rubber belts; heavier sheets are still made commercially by slicing molded blocks; and some gelatin sheeting, principally for photographic filters, is made by dipping and stripping from glass plates.

FILM MATERIALS

The number of commercially available film-forming materials has increased markedly in recent years. Over a long period of years there has been built up a list of synthetic materials suitable for film making and based on natural products such as cellulose, rubber, casein, and gelatin. Within the past decade, an equally long list of man-made synthetic materials capable of producing various interesting transparent films has been formed. The inter-reaction products of the newest synthetics are so numerous, and the development of new commercial films from them so rapid, that it is difficult at present to be sure that a classification of films as commercial, semi-commercial, or experimental is correct from one month to the next.

However, the following groupings by classes is substantially complete and correct. Trade names are given of the more widely known representatives of the different types of films listed. Asterisks denote European production. Trade names of some of the many film specialties are listed in the following description of film types. These often represent plastic films loaded with bronzing powder or having pearlescent or other special finishes, or constitute laminations of different materials.

TABLE 74. TYPES OF FILMS

Commercial or Semi-Commercial Films and Trade Names	*Experimental Films (Not Known to Have Become Commercial)*
Cellulose Base	
Cellulose	
From Viscose: " Cellophane " cellulose film	
Sylphrap, Transparit,*	
Heliozell,* Sidac*	
From Cuprammonium Solution:	
Cuprophan*	**From Denitrated Nitrate Film**
Cellulose Acetate	
From Triacetate: Geaphan,*	
Triphanfolie*	
From Secondary Acetate:	
" Cellophane " CA, Kodapak,	
Plastacele, Lumarith-Protectoid,	
Rhodialine*	
Safety Samson	

TABLE 74. TYPES OF FILMS — *Continued*

Commercial or Semi-Commercial Films and Trade Names	*Experimental Films (Not Known to Have Become Commercial)*
Cellulose Base — *Continued*	
Cellulose Acetate Butyrate and/or Propionate: Kodapak	
Cellulose Nitrate: Celluloid, Samson, Kodaloid, " Pyralin " nitrocellulose film	
Cellulose Nitrate Acetate: Triacell*	
	Methyl Cellulose
Ethyl Cellulose: Ethocel	Benzyl Cellulose
	Glycol Cellulose
Starch Base	
	Starch
	From Potatoes
	From Koniaku
Rubber Base	
Rubber	
Rubber Hydrochloride: Pliofilm	Rubber Chloride
Protein Base	
Gelatin: Clarophan,* Transflex	
Casein: Lactophane*	From Algae (Seaweed): Cefoil*
	From Fish
	From Soybeans
	From Peanuts
	From Leather (Scrap): Naturin*
Clay Base	
	From Bentonite: Alsifilm
Super Polyamide Base	
Nylons and Interpolymers	
Synthetic Polymer Base	
Polyvinyl Alcohol: " Cellophane " PA	
Polyvinyl Alcohol Acetate: " Cellophane " PA	Polyvinyl Acetate
Polyvinyl Chloride: Koroseal, Igelite*	
Polyvinyl Chloride Acetate: Vinylite, Elastiglas	Polyvinyl Formal: Formylon
	Polyvinyl Acetal
Polyvinyl Butyral: Butacite	
Polystyrol: Victron, Styroflex*	
Methyl Methacrylate: Lucite Plexiglas	

* European production.

Regenerated Cellulose Film. " Cellophane " cellulose film is the most widely used thin transparent film. It was first produced in France in 1908, and commercial thin sheeting was introduced about 1912. Until 1924, small quantities were imported into the United States principally for the wrapping of candy boxes.

American manufacture was begun in the spring of 1924 at Buffalo, N. Y. A few years later moistureproof " Cellophane " cellulose film was invented by Charch and Prindle, U.S. P. 1,737,197, and the development of this improved product gave considerable impetus to the thin-film industry. At present the moistureproof cellulose sheeting constitutes about three-quarters of the total consumption.

No exact data are available on the production of regenerated cellulose sheeting; however, it has been estimated by *Chemical & Metallurgical Engineering,* Jan., 1941, from glycerol consumption, that 80,000,000 pounds of "Cellophane"-like products such as sheeting, sausage casing, caps and bands, and bottle seals were produced in 1937. Since that year, production has been increased.

The price of transparent regenerated cellulose sheeting in 1924 was $2.65 per pound. Today it is quoted at $0.33 per pound for the normal quality, $0.41 for the moistureproof.

The uses of viscose film have been developed much farther in this country than elsewhere in the world; however, it is also produced in Belgium, Canada, England, Germany, Holland, Japan, and Poland, and manufacture has been reported in Czechoslovakia.

Composition. Normal regenerated cellulose film is essentially about 85 per cent cellulose and 15 per cent softener, which may be glycerol or any other satisfactory cellulose plasticizer. This composition under normal atmospheric conditions (35 to 40 per cent R. H.) carries about 7 per cent moisture. Additions are made to this basic composition for color, moistureproofing, flameproofing, to make film capable of retarding rancidity in wrapped products, and for other special purposes.

The moistureproof variety contains about 10 per cent additional solids consisting of waxes and plasticizers in suitable resin carriers.

Process of Manufacture. Cellulose films can be made from the same viscose used in rayon manufacture. The chemistry of this part of the film-making process is discussed in detail under viscose rayon multifilaments.

Casting. For film manufacture, viscose is forced under pressure to the hopper of the casting machine. It is extruded into a coagulating bath which is a mixture of 10 to 15 per cent sulfuric acid with water and the 15 to 25 per cent salts resulting from the neutralization of the caustic in viscose and the secondary reactions of the various other components of viscose with the coagulating bath. Most of these secondary reaction products are desirable if not necessary to the production of satisfactory film.

There have been many patents claiming beneficial additions to coagulating baths. Most widely recommended have been the metallic salts, principally of zinc, as well as glucose and sodium sulfate.

From the coagulating bath, the film passes in turn to warm wash tanks, desulfuring, washing, bleaching, washing and plasticizing tanks. The fourteen or fifteen tanks involved constitute the wet end of a casting machine. They are essentially as shown by Brandenberger in one of the first American patents in the art, U.S. P. 1,548,864. See Fig. 10.2. Following the acid wash, desulfuring is accomplished with a dilute caustic and sulfide solution at or near its boiling point. This is followed by washing tanks at decreasing temperatures from which the film passes into a sodium hypochlorite, chlorine water, or hydrogen peroxide bleaching solution. A cold wash and glycerination follow.

Cellulose films can be dyed either on the casting machine or by after-treatment of semi-finished, dried mill rolls. Both direct and vat dyes are used according to whether or not extreme fastness of color is required in the finished product.

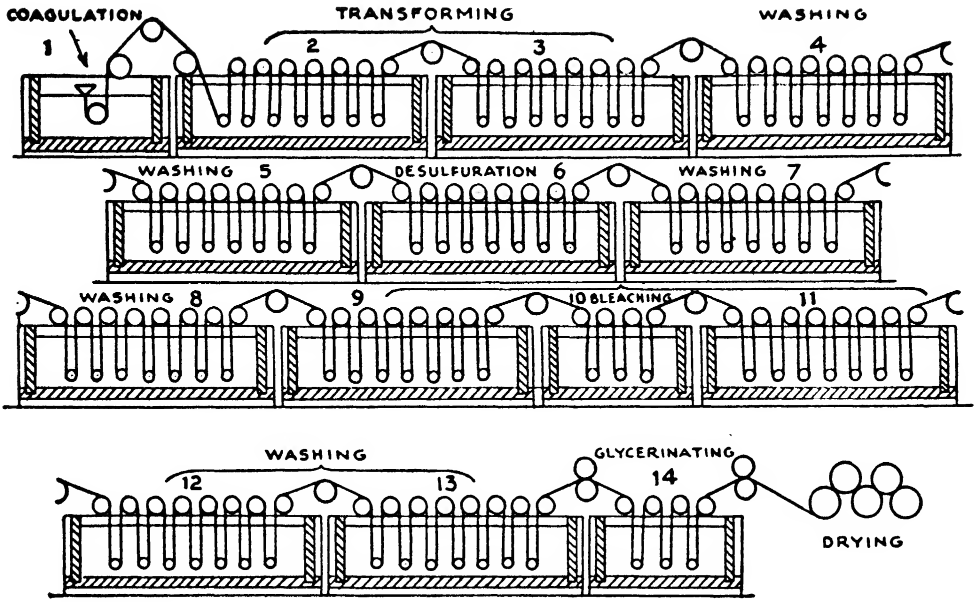


FIG. 10.2 — Schematic diagram of cellophane casting machine.

Dyeing is accomplished by heated rolls on equipment essentially the same as recommended by Brandenberger, U.S. P. 981,368 and 1,548,864.

The manner in which regenerated cellulose film is dried can have great influence on the strength of the film, its appearance, its surface, and its subsequent service. Drying control is automatically effected and recorded.

Finishing. Film is wound up in large mill rolls. These units are sampled, stored in a conditioned area, and eventually forwarded to one or more of the various finishing operations. The possible directions of flow through these are best shown schematically as in Fig. 10.3.

Plain and moistureproof cellulose film may be embossed on standard type equipment using heated, steel engraved rolls. Various designs such as linen, silk, and moire are available.

Moistureproofing. Moistureproofing can be effected by processing transparent sheeting with one of several possible compositions explained by Church and Prindle in U.S. P. 1,826,696 and 1,826,699.

When properly applied and dried, these compositions lay down on the base film coatings of approximately 0.00006 in. thickness which are capable of blocking about 999 of 1000 parts of water vapor normally transmissible through the base film under the same pressure and temperature conditions.

Packaging. Thin films generally are sold in rolls and sheets, with various modifications of each. The greatest volume of product is represented by slit rolls, the price of which is usually considered base price for the film.

In this country, due to the almost universal use of automatic wrapping machinery, the dimensions of the slit roll have become well standardized. Cellulose film is cut to order in any width from about 1.5 to 43 in. in multiples of 1/16 in. Rolls are usually wound to 8 in. O. D., on cores of 3 in. I. D. and ¼ in. thickness. These standardized dimensions permit estimating that a roll will weigh about 2 lb. per in. of width.

Narrower widths from the above minimum downward to 0.01 in. are specially slit and packaged, usually for the millinery and electrical trades. They are wound on small cores, tubes, and spools with single and multiple ends and various rates of traverse.

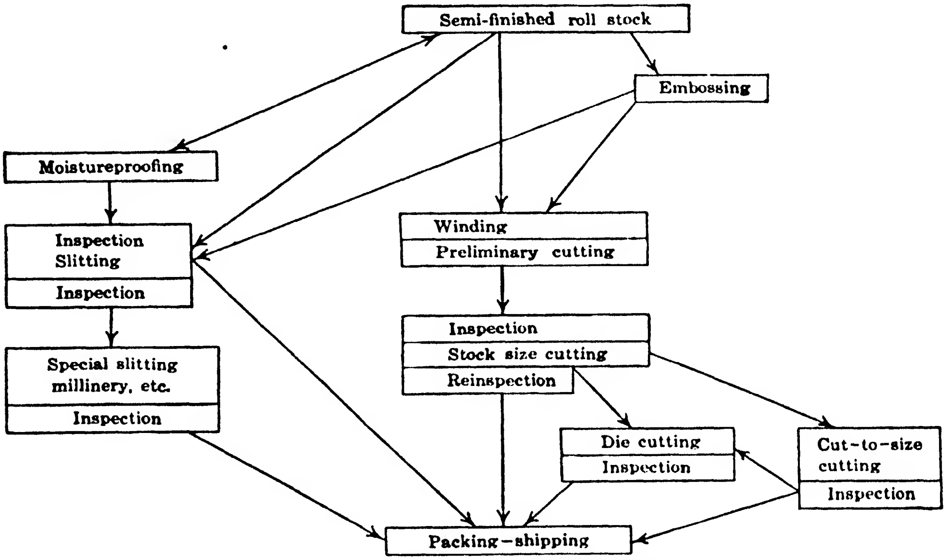


FIG. 10.3 — Flow of stock material through finishing operations.

Mill rolls are unwound to large sheets of film, known as " stock size." After preliminary cutting, the reams are sorted and inspected and a final cut is taken from all edges to produce a finished package. These reams are wrapped and stored, or cut to smaller sizes or die-cut on order.

Specialties. The thin-film industry has encouraged the production by specialized converters of specialties such as narrow slit film, braids, ribbons, string, tubes, straws, bags, and laminated and printed film. Many ingenious products have been made and themselves constitute raw materials for other uses, and numerous patents have been issued in this field.

Gauges. Present thicknesses, weights, and area factors of commercial regenerated films are as follows:

TABLE 75. PROPERTIES OF REGENERATED FILMS

Gauge	Thickness	Weight per Sq. Meter	Sq. In. per Lb.
300	0.0089 in.	32.5 gm.	21,500
450	0.0012 in.	45 gm.	15,500
600	0.0017 in.	60 gm.	11,500
300 moistureproof	0.001 in.	35.8 gm.	19,500

Wrapping machine usage of regenerated cellulose film demands a narrow tolerance in thickness variation. This rarely exceeds + 3 per cent, i.e., + 0.00003 in.

Commercial regenerated cellulose sheetings, both thinner and thicker than the above standards, have been made by the Brandenberger process.

Very heavy sheeting is made by laminating together thin sheets with gelatin or other adhesives. Common gauges of plied material are 1200, 1800, and 2400. These should be considered as multiples of the above cited gauges.

Transparency. The transmission of visible light by thin cellulose sheeting is approximately 92 per cent. It shares this characteristic with a few of the other films such as cellulose acetate, ethyl cellulose and polyvinyl alcohol, polyvinyl acetal and polystyrene.

Unlike glass, it transmits about 70 per cent of the light waves in the ultra-violet curative region of 2900 to 3100 Å. A table comparing viscose sheeting with cellulose acetate and polyvinyl alcohol sheeting in ultra-violet transmission is given under the description of cellulose acetate film.

Strength Characteristics. The following are average characteristic figures for cellulose sheeting of normal production and given softener content. Increases in softener content generally increase the elongation and tearing resistance and decrease the tenacity. All characteristics vary with moisture content and can be varied by orientation and deorientation of the film.

	300	*450*	*600*
Tenacity in Kg. per mm.^{2}	10–13	12–15	16–22
Elongation in %	17–30	22–32	22–40

Many other tests are made on cellulose films, based mostly on those used for paper and textiles. Tests are also conducted in the trade to determine the suitability of films under conditions which they must meet.

Permeability. Ordinary cellulose sheeting transmits water vapor rapidly. Gases readily soluble in water also diffuse through it under moist conditions, although it is impermeable to such gases when dry. Average gas transmission values for regenerated cellulose film and " Cellophane " in grams per square meter per hour with vacuum on one side of the film and one atmosphere pressure on the other are:

TABLE 76. GAS TRANSMISSION VALUES

	Regenerated Cellulose		Plasticized " Cellophane "
	0 Per Cent R. H.	100 Per Cent R. H.	100 Per Cent R. H.
Air	0	2.5×10^{-7}	2.4×10^{-6}
Hydrogen	0	9.7×10^{-8}	3.6×10^{-7}
Oxygen	0	4.1×10^{-7}	—
Nitrogen	0	1.6×10^{-7}	—
Carbon dioxide	0	1.5×10^{-5}	2.0×10^{-4}

Moistureproof " Cellophane " cellulose film is tested by the method of Charch and Scroggie published in the *Paper Trade Journal* on Oct. 3, 1935. A sample of film is sealed over a glass dish containing water and weighed. After exposure in an oven, the moisture loss is determined. The air in the oven is circulated and kept practically dry by contact with concentrated sulfuric acid. Testing temperature is maintained at 39.5° C. (103.1° F.). Average values of normal products are:

Moistureproof " Cellophane "	***Cellulose Acetate***	***Ethyl Cellulose***	***Normal " Cellophane "***
12	7000	5500	8000

The figures represent grams of water lost per 100 square meters of film surface per hour at 39.5° C. and approximately 100 per cent relative humidity differential.

Uses. Although most of the early workers with cellulose derivatives mention the possible utility of thin cellulose film, probably none foresaw the extent to which that usefulness would be developed. Even today it is difficult to estimate how much farther the application of transparent cellulose films may expand beyond the several square yards consumed yearly by every man, woman, and child in the United States. Equally difficult to measure are the possible social effects of the wide use of transparent films. These films certainly produce a quicker turnover of consumer goods and their wide usage may well have an inhibitive effect on the spread of disease.

The principal uses for cellulose films today are in the protection and wrapping of tobacco products, textiles and paper products, candy and chewing gum, bakery and meat products, tea and coffee, and numerous other foods.

It is also used extensively on soaps, perfumes, drugs, rubber goods, and innumerable novelty items. It has industrial as well as wrapping uses, as in the electrical industry.

Regenerated Cellulose Film from Cuprammonium Solution. So far as is generally known, cuprammonium film has been produced commercially only in Germany. At least four trade names have been published: Bembazell, Cuprozell, Cuprophan, and Transphan. The commercial production of cuprammonium sheeting in Germany has never been large and has been confined to the manufacture of film of thinner gauge than standard 300 cellulose films from viscose. It has been produced primarily for the electrical and millinery markets.

Process of Manufacture. Cuprammonium film is substantially the same in composition as cellulose sheeting regenerated from viscose. The chemistry of film manufacture is the same as for fiber manufacture (see page 344), up to the point of plasticizing the film with glycerol. The cuprammonium solution is extruded through a slit which is not immersed in the coagulating bath but maintained a slight distance above it. Coagulation is accomplished in a caustic solution. It can be done in a dilute acid solution.

Thereafter, washing and acidification are necessary to free the film of copper. Bleaching may be omitted. Although casting equipment similar to that used in viscose sheeting manufacture is suitable for making cuprammonium sheeting, certain modifications are introduced in order to capitalize on the characteristics of the cuprammonium process which make it of interest in yarn production.

Tenacity is increased as much as practical by stretching the film during coagulation, while an effort is made at the same time to avoid transverse shrinkage. The process is described in some detail in U.S. P. 2,035,645. The effect of these modifications is to produce a thin film of excellent clarity and sufficient strength to be practical for many purposes.

Finishing, packaging, and converting are the same as with viscose sheeting except that embossed and moistureproofed products are now known to be available. A large part of the production is slit to very narrow widths for special uses.

Gauges. The claims of U.S. P. 2,035,645 relate to cellulose hydrate foils weighing 5 gm., 10 gm., and 15 gm. per sq. meter, respectively. The trade (in Germany) has been offered two gauges, one of about 23 gm. per sq. meter and the other of 15 gm. per sq. meter. Corresponding factors are:

TABLE 77. GAUGE THICKNESS AND WEIGHT

Gauge	Thickness	Weight per Sq. Meter	Sq. In. per Lb.
200	0.00063 in.	23 gm.	30,000
150	0.00041 in.	15 gm.	46,500

The appearance of cuprammonium film shows that the struggle to produce commercial, ultra-thin films with perfectly plane surfaces is difficult. The ultra-thin film is very limp and difficult to handle on the usual type of wrapping machine.

The light transmission characteristics are substantially the same as those of viscose film.

Strength Characteristics.

	230
Tenacity in Kg. per mm.^{2}	8–12.5
Elongation in %	16–30

Uses: Cuprophan, according to the patent cited in the foregoing, is made to fill the "need for an extremely thin, absolutely transparent cellulose hydrate foil." Its principal uses have been "for the binding of bass strips in the manufacture of hat material," as a raw material to make millinery braid, and for electric wire wrapping.

Regenerated Cellulose from Denitrated Nitrocellulose Film. So far as is known, this process, which is old in the art of fiber manufacture, has been applied to film production only in Germany and only in the production of artificial sausage casing. The small samples examined were translucent rather than transparent and seemed very tough.

The producing company, long a manufacturer of nitrocellulose, is reported to have given up the production of denitrated products since the outbreak of war.

The economics of the process are against it in competition with other cellulosic films.

Cellulose Triacetate Film. Cellulose triacetate film has not been offered on the market in this country, although some is made commercially in both France and Germany. The technique of producing it is the same as for cellulose acetate, described in the following. It is more expensive than film produced from the secondary acetate because of the higher cost solvents required. The film is less water-sensitive than normal cellulose acetate film.

As in the case of cellulose films from viscose, early workers with cellulose acetate foresaw in the last century the possible technical importance of films made from this plastic. The large scale development of such film has lagged behind that of viscose for technical and economic reasons.

While cellulose triacetate possesses obvious advantages over viscose regenerated cellulose film in decreased water-sensitivity, over nitrocellulose in burning characteristics, and over both films in electrical properties, it found little commercial success until the so-called secondary acetates were produced.

The better flexibility of products made from the secondary acetates, and ability to dissolve them in commercially available low-cost solvents such as acetone, aroused interest first in the production of photographic film therefrom. Such safety film was offered the public in Europe as early as 1908. However, not until recent years has cellulose acetate established itself firmly as the safety base for amateur film.

Thin films of cellulose acetate followed the development of photographic base films and began to assume commercial importance in Europe in the period between 1920 and 1930. Their use in this country has grown appreciably only since 1930.

Solvent-type, plastics films can be produced with a much smaller total investment than viscose film although the investment per annual pound is usually higher. Consequently, there have appeared in almost every central and western European country a number of acetate films. The list of trade names is indicative of the present extent of the development of foreign cellulose acetate sheeting:

Acetophane
Celastoid
Cellitfilm
Cellofoil
Cellon Klebefolie
Cellosit
Cellstop
Clarifoil
Danofan
Geaphan
Neophan
Neophane
Protexane
Protectoid
Rhodialine
Rhodialite
Rhodiana
Rhodite
Rhodophane
Transparenta
Triphanfolie
Ultraphan
Utex
Vitroloid
Vitreo-Colloid

This list excludes trade names of heavier cellulose acetate films and specialties representing various combinations. Some U.S.A. trade names are:

"Cellophane" CA
Crystalloid
Insuloid
Kodapak
Lumarith-Protectoid
Transolene

Despite the large number of cellulose acetate film producers, the total consumption of thin cellulose acetate film is well below that of viscose cellulose film. Consumption in the United States at present probably does not exceed 4,000,000 pounds per year. The higher costs and generally lower strength of cellulose acetate film direct its usage to special fields, and perhaps this has restricted its consumption as a wrapping material.

Composition. Thin films can be made from any of the cellulose acetates, the chemistry of which is discussed in connection with multifilament yarn production. Generally preferred are the higher viscosity, higher acetyl content flakes from which more durable sheeting is producible.

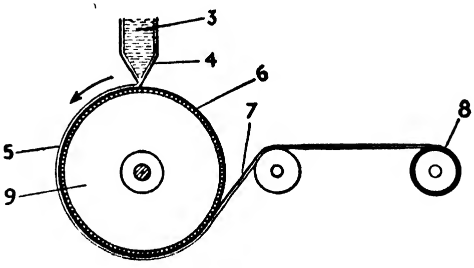
Cellulose acetate films generally consist of 75 to 90 per cent cellulose acetate and 25 to 10 per cent of plasticizer. Numerous plasticizers have been recommended in the patent literature. Most commonly used are phosphates and phthalates such as triphenyl phosphate and dibutyl phthalate. A normal cellulose acetate film will have a moisture content of 1 to 3 per cent under room atmospheric conditions.

Process of Manufacture. Cellulose acetate solutions for film manufacture differ from those used to make yarn in that the desired film plasticizer is contained in the "dope."

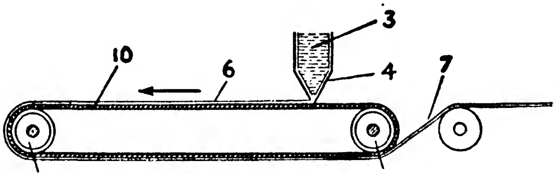
Flake, plasticizer, film waste from finishing operations, and solvents are mixed to a constant viscosity and solids content, filtered, and deaerated. There is no ripening stage as with viscose but the deaerating period is almost equally long due to the high viscosity of the dope it is desirable to use, and the difficulty of removing all air bubbles from it.

Casting and Drying. All commercial, thin cellulose acetate film is cast either onto a wheel or metal band. The distinction is well presented by the sketches of U.S. P. 2,198,621. See Fig. 10.4.

Commercial wheels have been reported varying from 6 to 35 ft. in diameter. They are carefully made of seasoned metal, ground and plated. Usually there is a primary plating of copper which is covered with a final polished plating of nickel, chromium, or silver. The finished surface must be mirror-smooth since minute indentations might not only reproduce themselves in the finished film but also tend to act as foci for bubble formation.



WHEEL TYPE MACHINE



BAND TYPE MACHINE

Fig. 10.4 — Film forming machines.

With a wheel which is perfectly smooth and axially true, it is practical to use a " scraper type " hopper. By micrometer wedge, such a hopper can be held at a fixed distance from the surface of the rotating wheel.

A pool of the casting solution can be maintained behind the scraper which, together with the wheel surface, constitutes the casting orifice. This arrangement has certain advantages but obviously requires a high degree of mechanical precision and operating skill and the present trend is toward independent hoppers and casting surfaces.

Heat is applied as rapidly as is possible without causing a film skin to form prior to the elimination of most of the solvent. If appreciable quantities of solvent vapor are trapped in the film, bubbles result. Temperature is increased as the film progresses around the wheel and a forced circulation of air is maintained. Many theories exist as to the most suitable air flow arrangement and several are practiced.

The temperature of the wheel surface directly beneath the hopper is critical. A differential of one or two degrees Centigrade is maintained between wheel surface and casting solution temperature to prevent the solvent in the solution from flashing too quickly to vapor and forming bubbles.

Also very critical, if the space between hopper and wheel is appreciable, is the control of air flow. The liquid film between hopper and wheel must be protected from air currents by baffles.

Directly substitutible for the casting wheel is the metal band machine. It offers the advantages of greatly increased drying surface at floor operating levels, and decreased investment per annual pound. It lends itself better to the recooling of the casting surface, and replacement of this surface, if damaged, is cheaper than the refinishing of a wheel surface.

The band machine consists of a band, usually of metal, stretched between two drums and properly housed and driven. It is used in conjunction with the same hoppers employed on wheels, and the same conditioners and other auxiliaries. The hopper is located over the head drum which drives the band. The other drum controls the tension on the band and keeps it running in line. Commercial bands of copper, nickel, laminations of copper and nickel, brass, various steels, and rubber have been used. One European manufacturer produces endless bands of copper or nickel, but the majority of users weld the two ends together in place on the machine. Band widths and lengths are limited only by construction and mechanical considerations. Widths up to about 60 in. and lengths to about 300 in. are possible.

The upper half of the band is supported. The lower half cannot be supported in the usual manner since the film returns to the head drum on its outer surface. The film may be reconveyed the length of the machine, if desired, in order to take advantage of the heat and air circulation in the band housing.

Although nickel band surfaces can be polished to as high a finish as wheel surfaces, it has become practice to use the less expensive metals and coat them with materials insensitive to the film solvent. Gelatin and cellulose provide good coating for cellulose acetate, and cellulose acetate in turn a good coating for gelatin film production. Properly applied coatings provide surfaces which are smoother than the polished metal.

The solvents evaporated from the film on either wheels or bands may be recovered by direct condensation, or by carbon absorption or, in the case of acetone, by dissolution in water and subsequent separation and distillation.

At a point about 2 or 3 ft. ahead of the hopper, the film is stripped from the wheel or band after having completed approximately one revolution. From the stripping roll, the sheeting is conveyed into a conditioning compartment where its moisture content is adjusted and usually controlled at about 1 per cent.

If driven rolls are used between the wheel or band and the film wind-up, allowance is made in the drives for shrinkage, in order that no surface scratching of the film occurs from its slippage over hard surfaces. Most of the rolls in a cellulose acetate machine are either highly polished or fabric covered since a principal merit of this type of sheeting is its brilliant, plane surface, and imperfections would rob it of several of its larger markets.

Finishing. Finishing is practically the same as with regenerated cellulose film.

Moistureproofing can be accomplished by surface application of the compositions used to treat " Cellophane," modified only to the extent necessary to avoid too severe attack on the cellulose acetate by the solvents used.

" Semi-moistureproof " film may be made by additions to the casting solution. Dyed and pigmented cellulose acetate films can also be produced similarly; however, since the volume of business for these products is relatively small, they are usually made by suitable after-treatments.

Specialties. Cellulose acetate film lends itself to the production of even more specialties than cellulose film. The ease of laminating it by heat and pressure, the possibility of adding materials such as bronzing powders to the casting solution, together with the inherent visual appeal of cellulose acetate sheeting, have contributed to its wide use for fashion and decorative purposes.

The numerous trade names of special cellulose acetate sheeting indicate its usefulness in such fields:

Arcasol — Mat on one side
Armourbex — Cellulose acetate coated net
Celloglass — Cellulose acetate coated net
Cellon-Drahtglas — Cellulose acetate coated net
Celluwelf — Cellulose acetate with adhesive coating
Celusa — Cellulose acetate coated net
Isoflex — Cellulose acetate with bronzing powder
Lucinite — Cellulose acetate embossed
Nacrolaque — Cellulose acetate with pearl finish
Pearloid — Cellulose acetate with pearl finish
Rhodoid — Cellulose acetate with air bubbles
Ultraphan-Polierfilm — Low softening cellulose acetate for veneer work
Vimlite — Cellulose acetate coated net
Vio-Ray — Cellulose acetate coated net
Viralite — Cellulose acetate coated net
Vito-Mesh — Cellulose acetate coated net
Vitrex — Cellulose acetate coated net

Cellulose acetate sheeting laminated to both sides of metal foil and slit to narrow widths has the appearance of flexible metal ribbon and has greater freedom from tarnish than the metal.

Gauges. Cellulose acetate film thicknesses are expressed as decimal fractions of an inch. The usual gauges and corresponding factors, based on a specific gravity of approximately 1.26, for a film containing about 25 per cent plasticizer and 2 per cent water (sp. gr. Cellulose acetate, 1.33) are:

TABLE 78. WEIGHT FOR CELLULOSE ACETATE

Gauge	Thickness	Weight per Sq. Meter	Sq. In. per Lb.
88	0.00088 in.	28	25,000
100	0.001 in.	31.8	22,000
120	0.0012 in.	38.2	18,300
140	0.0014 in.	44.5	15,700
200	0.002 in.	63.6	11,000
300 and heavier	0.003 in.	95.4	7,300

Thicker sheeting made by extrusion is obtainable up to gauges of about 0.030 in. thickness. Cut sheets from about 0.010 in. to almost any desired thickness can be made by slicing molded blocks of the plastic. Extensive applications are found in transparent semi-rigid containers.

The market price ranges from about $0.60 per pound upwards, according to gauge.

Properties. Cellulose acetate film will soften at about 200° C.–150° C. (392° to 302° F.) or lower, depending upon the nature and quantity of plasticizer used in it. The application of a flame causes it to melt, and the hard, round beads formed on cooling, with the acetic odor of the smoke, constitute a simple means of distinguishing it from regenerated cellulose film.

It can be readily laminated to paper, cloth, and the like, by heat and pressure. It is stable to light indefinitely. While not impermeable to moisture vapor it is relatively insensitive to water.

Transparency. In clarity and transparency, cellulose acetate ranks with the best films available. Its ultra-violet transmission is slightly higher than that of either polyvinyl alcohol or regenerated cellulose:

	Per Cent 2536 Å.	*Per Cent* 3130 Å.	*Per Cent* 3650 Å.
Cellulose acetate	82	84.7	87.7
Polyvinyl alcohol	77.5	72.9	81.1
Regenerated cellulose	75.7	70.3	79.2

Strength Characteristics.

	88	*100*	*120*
Tenacity, kg. per mm.^{2}	6–10	11–14	13–14
Elongation	23–35	33–34	35–36

Tearing resistance is somewhat lower than that of regenerated cellulose.

Permeability. The permeability of cellulose acetate sheeting to moisture is approximately the same as that of ordinary regenerated cellulose, although cellulose acetate is less water-sensitive.

Its permeability to various gases in grams per square meter per hour as measured with a vacuum on one side of the film and one atmosphere pressure on the other is:

	g. per sq. mm. per hr.
Air	2.5×10^{-6}
Oxygen	1.5×10^{-5}
Nitrogen	2.6×10^{-6}
Hydrogen	1.5×10^{-5}
Carbon dioxide	1.4×10^{-4}

Uses: The principal uses for cellulose acetate sheeting capitalize its perfectly plane surface and excellent clarity. It is laminated extensively to paper, board, and cloth, used as window material in boxes and envelopes, and as a wrap.

Excellent multicolor printing is done in reverse on cellulose acetate sheeting and the printed sheet then adhered to a paper or other backing.

Films of Cellulose Acetate Butyrate and /or Propionate. The mixed esters of cellulose represent for some purposes an improved film-former over cellulose acetate. The various steps involved in their manufacture are described on page 508.

In view of the several desirable characteristics of cellulose acetate as a photographic base film, it was logical to seek still further improvements in the higher members of the cellulose ester series. With increase in the number of carbon atoms in organic acids reacted with cellulose, there is a drop in the percentage moisture regain of the cellulose ester. Cellulose propionate takes up about one-half the percentage of moisture regained by the acetate, and the butyrate only about three-quarters of that regained by the propionate.

Other changes of importance to films, which occur as the length of the acid residue in cellulose esters is increased, are:

The density decreases.
The melting point decreases.
The tenacity decreases somewhat.
The elongation and flexibility increase.

Process and Properties. The cellulose mixed ester commercially available may be converted to film form essentially in the same manner as cellulose acetate. In appearance they are the same, but their physical characteristics differ. Representative figures are:

Gauge	*100*
Tenacity kg. per mm.^{2}	9–9.5
Elongation in %	60

Cellulose Nitrate Films. Thin films of cellulose nitrate could offer at best only few minor advantages over cellulose acetate or regular cellulose films and these would be offset by the fire hazard usually associated with cellulose nitrate products.

Such films have not been offered commercially for packaging or related uses in this country or abroad. The heavier films for special purposes, such as Celluloid, Kodaloid, Viscoloid, and Pyralin nitrocellulose sheeting, are of course well known. A specialty — Cilkoid — has been offered as a surgical wrapping material. Triacell has been reported from Holland as a mixed nitroacetyl ester film.

Cellulose Ether Films. Although methyl, benzyl, and glycol cellulose are film-formers, none have been marketed commercially in this country. Methyl cellulose caps known as " Flaka-Kalseln " have been sold in Germany.

In general, the cellulose ether films have lower tenacities and higher elongations than the cellulose ester films. They have, also, the highly desirable characteristic of low temperature flexibility. Comparative data on plate-cast unplasticized sample for approximate 88 gauge are summarized:

	Tenacity Kg. per mm.^{2}	*Elongation %*
Cellulose Acetate 45% Acetyl	6.5	3.7
Cellulose Acetate 56% Acetyl	6.6	2.8
Cellulose Acetate Triacetate	5.9	3.2
Nitrocellulose	5.7	4.7
Ethyl Cellulose 45% Ethoxy	4.4	4.9
Ethyl Cellulose 48% Ethoxy	5.1	4.9
Ethyl Cellulose 49.5% Ethoxy	4.4	5.6
Benzyl Cellulose	4.5	5.2

These values can be changed greatly by plasticizer additions, method of extrusion, choice of solvents used for the casting solutions, as well as physical and chemical characteristics of the raw materials.

Ethyl Cellulose Film. This film has been offered commercially in this country for only three or four years, and present consumption tends to be in the heavier gauges. It is more expensive than cellulose acetate film, selling at present for about $0.80 per pound and upwards, with increasing thickness.

In addition to the Ethocel film made in this country, thin film is produced in Germany under the same " Isophan."

Composition. The commercial thin films are usually produced from medium viscosity, medium ethoxy content ethyl cellulose. The plasticizer content and nature can vary widely due to the good inherent physical characteristics and the excellent compatibility of ethyl cellulose. A plasticizer content of 10 to 15 per cent is normal but films are useful with softener contents ranging from 0 to about 50 per cent.

Process of Manufacture. The general method of casting ethyl cellulose film is the same as that used to make cellulose acetate film. The ethyl cellulose can be readily dissolved in a mixture of toluol and ethanol.

Drying presents no unusual problems, the film giving up residual solvent about as readily as cellulose acetate. Finishing and packaging are on the same basis as " Cellophane."

Gauges. The specific gravity of ethyl cellulose is approximately 1.14 (without plasticizer), and it produces a larger area per pound than other commercial cellulose derivative films.

TABLE 79. WEIGHTS FOR ETHYL CELLULOSE FILM

Gauge	Thickness	Weight per Sq. Meter	Sq. In. per Lb.
88	0.00088 in.	25.4 gm.	27,600
100	0.001 in.	28.8 gm.	24,300
120	0.0012 in.	34.6 gm.	20,200
200	0.002 in.	57.5 gm.	12,150

Properties. The transparency of ethyl cellulose films is comparable to that of the other cellulose derivatives and regular cellulose films.

Physical characteristics of a representative commercial film are as follows:

Gauge	*88*
Tenacity in kg. per mm.^{2}	5.6–6.5
Elongation in %	40–50

Permeability. Ethyl cellulose is not inherently moistureproof. Its compatibility with moistureproofing ingredients permits compounding satisfactory moistureproof films such as described in United States Patents 2,201,747 and 2,205,210.

Uses: The special merits of thin ethyl cellulose film have not yet found any outstanding markets at the prices it must command at present. The medium and heavier gauges have proved useful for containers produced by " drawing."

Some tape is offered for electrical uses, the higher ethoxy content films showing very low moisture content (0.98 per cent) at equilibrium with 35 per cent R.H. at 75° F.

Starch Films. Considerable research and speculation have been devoted to starch as a potential raw material for film manufacture. It could be as cheap as cellulose and, of course, shares with cellulose the same empirical formula $(C_6H_{10}O_5)_x$. The experimental starch films investigated have been, in general, inferior in all physical characteristics to cellulose films.

An exception, perhaps, was film prepared and promoted in France several years ago. The raw material was the Koniaku tuber, a product of Siam and Indo-China, apparently related to the tropical taro or dasheen. The starch extracted from this tuber produced film comparable with regenerated cellulose films except for the disadvantage of greater water sensitivity.

Efforts to raise the vegetable in Europe were unsuccessful. Its price in the Orient, where it is valued as a food product and imported as such into Japan in large quantities, prevents its competition with cellulose.

No starch films are known to have been produced commercially.

Rubber Film. Thin rubber sheeting is usually produced on molds by dipping and hardening *in situ*. Small quantities of continuous flat sheeting are made for surgical bandages, but aside from this use very few demands are known for the flat film. The outstanding characteristic of rubber is its elasticity for which there is little need in films.

Thin rubber membranes can be made from cements, rubber solutions in solvents, or from latex. The curing necessary, before rubber assumes its properties of durability and elasticity, slows down greatly any continuous sheeting operation.

To make rubber sheeting, which is usually of medium and heavier gauges, the rubber industry has evolved a technique peculiarly its own. Broadly outlined, this consists of milling, calendering, and curing, and these processes are beginning to find use in the thin sheeting industry with some of the newer, rubberlike, synthetic plastics. Milling takes the place of the usual mixing operation, and sheet formation can be accomplished at good production rates between calender rolls. In the case of rubber, the sheet is rolled up with a liner material until it can be cured by whatever method is desired in view of the future service of the sheeting.

The physical characteristics of any rubber product are so much a function of the compounding additions made that only the broadest generalizations are possible. Rubber films can be made with elongations at break varying up to about 1000 per cent. Tensile strength of flexible products usually lies between 4000 and 5000 lb. per sq. in.

Rubber Hydrochloride Film. If natural rubber is reacted with hydrochloric acid, rubber hydrochloride is produced as indicated by the equation:

$$(C_5H_8)_x + HCl \longrightarrow (C_5H_9Cl)_x,$$

in which $(C_5H_8)_x$, the isoprene polymer, is assumed to represent natural rubber.

Exposed to light or heat, HCl may split off and accelerate decomposition of the rubber hydrochloride. In 1925, Bradley and McGavack pointed out, U.S. P. 1,519,659, the possible utility of the compound if stabilized. Later, Calvert (U.S. P. 1,989,632), found improved stabilizers, outstandingly hexamethylenetetramine which rendered rubber hydrochloride capable of remaining flexible from three to fifteen times as long as pure rubber hydrochloride.

Rubber hydrochloride is a dry, white, amorphous powder. It can be made in two ways: by the solvent method in which HCl gas is bubbled through a rubber cement in naphtha, benzol, or chlorinated hydrocarbon solution; or by direct synthesis of liquid HCl [at −15° C. to −50° C. (5° to −58° F.)] with crepe rubber (U.S. P. 1,980,396).

To produce a satisfactory film-former, the reaction is not carried to the theoretical end point. It is stopped at 88 per cent of complete hydrochlorination (approximately 30 per cent chlorine content) since the fully reacted product is brittle in nature and the lower addition products are sticky and weak.

The properties and method of production of the flake can have an important influence on the film produced. The type of raw rubber selected and length of time it is milled affect color and strength of the finished products.

Rubber hydrochloride film has been offered in this country under the name " Pliofilm " for about five years and is finding increasingly widespread and interesting uses.

Compositions. Commercial films are available either plasticized or unplasticized. Both types contain low percentages of suitable stabilizing agents. The balance of the unplasticized film is substantially rubber hydrochloride with a small percentage of unreacted rubber.

Plasticized films can be made by the addition of 5 per cent or more of special plasticizers such as butyl stearate (U.S. P. 2,153,954). Metallic oxides (U.S. P. 2,046,986) have a stabilizing effect on rubber hydrochloride, and where pigmented or opaque films are desired, stability can be increased by the addition of bronzing powders — aluminum, for example (U.S. P. 2,136,342).

The moisture content of rubber hydrochloride films is normally below 1 per cent.

Process. Flake made by the solvent process can be precipitated from solution by alcohol, neutralized with alkali such as ammonia or sodium carbonate, washed, and dried. Thereafter, it is redissolved in the casting solvent, filtered, and extruded in a band-type machine.

Where flake and film are made at one location, economy is effected by hydrochlorinating in a solvent which forms no undesirable by-product with HCl and neutralizing, filtering, and extruding this solution after proper mixing in of stabilizers, colors, plasticizers, etc.

The casting solution is extruded onto a rubber belt coated with a water-soluble resin. Just before completing one revolution on the belt, the film is stripped off, returned through the lower drying compartment, and wound up at the foot end of the machine. The extra passage through the dryer is advantageous in removing the last traces of solvent to which rubber products in common with some of the newer plastics tend to cling tenaciously.

Before winding up, the film can be passed through a pair of calendering rolls, U.S. P. 2,161,454, to improve the surface of the " air side " of the film. Finishing and packaging are as described for films discussed in the preceding.

Gauges. Rubber hydrochloride film has a specific gravity of approximately 1.09. The corresponding weight and area factors are:

TABLE 80. WEIGHTS FOR RUBBER HYDROCHLORIDE FILM

Gauge	Thickness	Weight per Sq. Meter	Sq. In. per Lb.
100	0.001 in.	28.0 gm.	25,000
120	0.0012 in.	33.3 gm.	21,000
140	0.0014 in.	39.0 gm.	18,000
170	0.0017 in.	48.0 gm.	14,500
225	0.0025 in.	63.5 gm.	11,000

The base price of Pliofilm is $0.67 per pound for the unplasticized 100-gauge film, and $0.88 per pound for the thinnest plasticized gauge offered commercially, 120 gauge.

Properties. Having high elongation and good tearing resistance, rubber hydrochloride film can be sewed or stapled like cloth or paper. Two other characteristics are relatively unusual in the film. It is inherently moistureproof and it can withstand considerable deformation, after mild heating, to permit so-called " stretch wrapping " of very irregular objects.

It softens at about 110 to 120° C. (230° to 248° F.) and can be welded to itself by the application of heat and pressure.

Transparency. Normal rubber hydrochloride film shows light transmission slightly below that of the cellulose derivative films. Its apparent haze, as measured by the percentage of light dispersed, is higher than that of cellulosic films. A tendency toward yellow coloration in rubber hydrochloride may be offset by tinting it blue.

Strength Characteristics.

	Unplasticized	*Plasticized*
	100	*140*
Tenacity in Kg. per mm.^{2}	. . . .	6.7–7.1
Elongation, %	Greater than 13.9	Greater than 31.0

The tearing resistance of rubber hydrochloride film is relatively high. This and the durability of the film can be greatly changed by the amount and nature of the plasticizer used.

Permeability. The permeability of plasticized and unplasticized rubber hydrochloride to moisture vapor are indicated in U.S. P. 2,153,954 to be: 10 per cent plasticized — 20.9 g. per sq. m. per 24 hr.; unplasticized — 8.57 g. per sq. m. per 24 hr.

Uses: Rubber hydrochloride film has been used extensively as a primary closure material to line bottle caps. Extending this use further, complete packages of film for liquid products, such as pickles, have been made.

Garment covers and bags and similar articles take advantage of the good tearing resistance of rubber hydrochloride, which permits sewing it like cloth. Another use in which this film substitutes for cloth is in the manufacture of raincoats, shower curtains, umbrellas, and make-up capes.

Dried products such as fruits, vegetables, desiccated soups, popcorn, seeds, garlic, and deliquescent salts and tablets are wrapped in rubber hydrochloride successfully.

It is resistant to a number of chemical compounds, and on some antiseptic and cleansing compounds can be applied as a direct wrap. It is used as a coffee-bag material in view of its unusual characteristic of high impermeability to oxygen, coupled with low impermeability to carbon dioxide.

Rubber Chloride. Rubber chloride is produced in a manner similar to that employed in the production of rubber hydrochloride. Chlorine gas is bubbled through a rubber cement solution until approximate saturation is accomplished. The product $(C_5H_8Cl_2)$, analyzes usually about 60 per cent Cl, twice the chlorine content of rubber hydrochloride.

Although it is a fair film-former, and is claimed in the patent literature to be more stable than the hydrochloride, rubber chloride has not been used so far as is known for commercial film manufacture.

Gelatin. The earliest commercial transparent films in this country were probably gelatin, and the once familiar term — isinglass — was applied to them. In Europe, the industry is said to date back to the middle of the last century.

Until the cellulose derivatives brought about the development of continuous film-producing machines such as the wheel and metal band, gelatin films were generally made by dipping glass plate in warm gel solutions and draining, drying, and stripping.

In this country the development of continuous production methods has not increased its use of gelatin films outside of certain special fields. In Europe, however, there are still a half dozen commercial gelatin films.

Clarophan
Hafo
Kleko
Novo-heliophan
Pliaphane
Silva plana
Vitrophan

Transflex is an American trade name for gelatin film.

Composition. Pure gelatin sheeting is weak, brittle, and very sensitive to water. Materials such as Turkey red oil are added to increase strength and flexibility. Water-sensitivity is decreased by treatment with aluminum acetate, formaldehyde [D.R.P. 91,505 (1893)], or surface coating (U.S. P. 1,976,027). Dyes are cast in the gelatin solution and flameproofing agents are incorporated in sheeting for lantern-slide use. Such addition may easily total 25 per cent or more of the film solids.

The base material may vary from edible gelatin to glue gelatin, depending upon the use of the film.

Process of Manufacture. The commercial process for continuous production is essentially the same as that used to make cellulose acetate film by the wheel or band machine technique. Numerous coatings for the band have been recommended, cellulose acetate and nitrocellulose [D.R.P. 209,006 (1908)], rubber solutions in naphtha [D.R.P. 128,035 (1900)], and shellac (D.R.P. 484,546), among others.

Uses. Gelatin film is a preferred material for optical filters. It is also used widely as color slide material for Klieg lights. The use of gelatin sheeting as a top layer in candy boxes and direct wrap for candy where sharp corners could be avoided is almost entirely displaced in this country by regenerated cellulose; however, gelatin film still finds use for drawn forms such as capsules and small tubes and boxes. It is also used as a bottle cap, and inexpensive phonograph records have been made with it.

Casein Film. Casein film has been made on a small scale in this country in the past. For general purposes, it had the same handicaps to overcome as gelatin film, a tendency to be very brittle in the winter and too sticky and soft in the summer. At present, the only commercial film reported is an English product, Lactophane, about which very little is known.

Attempts to commercialize such film are to be expected in Europe in line with totalitarian policies, but the basic characteristics and economics of casein do not hold much promise for it as a film-former.

Other Protein Base Films. The literature has discussed from time to time experimental protein films from newer sources. Aside from isinglass from fish gelatin, only two names are known to have been given protein films in recent years: Cefoil is reported to be an English film made from marma algae; and Naturin, a German sheeting from scrap leather. No samples of Cefoil have been available. Naturin appeared on the market in Germany and was imported into this country as a sausage casing.

It was made up by a group primarily interested in leather production and the principal raw material was leather scrap, to which could be added sinew and muscle material obtained from slaughterhouses. The leather was cleaned and digested with phenol derivatives and worked into doughy masses which could be extruded by the usual means. Ingenious mechanical devices were patented by Freudenberg and Beck which made use of rotary nozzles so arranged that multi-walled tubes, having the longitudinal axes of the respective film tubes crossed over each other, could be produced. Such lamination of the individual tubes is desired to give sufficient strength to the whole casing.

Bentonite Film. The name Alsifilm has been given to a thin film produced from certain clays, which in very small particle size are capable of forming films. Proper fractionation of the slurries can be made by carefully controlled decantation or ultracentrifuging. The suspension can be thickened by heating, deposited on plates, and dried.

The films formed are not transparent, although those made from certain white clays are translucent. For most of the possible uses of clay films, the yellow opaque coloring is satisfactory.

The crude films are water-sensitive and friable. The water-sensitivity can be decreased and the strength increased by heating, which can be carried in the case of this substance to red heat.

Plasticization can be effected by the incorporation of certain metallic salts, and some tearing resistance can be obtained by including cellulose fibers in the mass. The indicated uses for clay films are as substitutes for mica, principally in the electrical industry.

Nylon Film. Synthetic linear polyamides by their very nature are excellent film-formers. The chemistry of these materials is indicated in the Nylon section on multifilament yarns.

Patents which have been issued indicate nylon films varying from rigid to highly elastic sheetings. In general, Nylons are relatively unaffected by water, solvents, and many chemicals. They are tough and stable and clear. Nylon films have to date been made only on an experimental scale.

Polyvinyl Alcohol Film. Polyvinyl alcohol $(CH_2—CHOH)_x$, the commercial development of which got under way in Germany in the twenties, has begun to assume commercial importance in this country only in the last decade. It is outstanding as a water-soluble synthetic for its toughness, stability, and general chemical resistivity. To date, it has been used as a film-former only on an experimental and semi-commercial scale.

Composition. Good self-sustaining films of polyvinyl alcohol can be made with no additions to the casting solution. The water in the air under normal conditions (35 per cent R. H.) is at equilibrium with 2 to 3 per cent water in the film, and this has a plasticizing effect. More flexible films are made with 5 to 20 per cent of polyhydroxy compounds such as glycols and glycerol. Other additions such as dyes, fillers, and agents for special effects can be made readily since polyvinyl alcohol has excellent compatibility characteristics.

Process of Manufacture. Like gelatin and other water-soluble materials, polyvinyl alcohol film can be made by casting aqueous solutions onto wheels or band machines, drying, and stripping.

Band coatings may be of certain water-soluble resins (U.S. P. 1,981,472), or of almost any properly softened cellulose ester or ether.

The sensitivity of the film to water can be decreased by heat, formaldehyde, chromium compounds, certain dyestuffs, dibasic acids, and copper-and-zinc ammonia compounds. It may be surface-sized or coated to effect moistureproofing.

Heavy mixtures of compounded polyvinyl alcohol can also be sheeted and extruded by mills and similar rubber-processing equipment.

Properties. Polyvinyl alcohol film is glass-clear and second only to cellulose acetate film in ultra-violet light transmission. It is unusually tough and resistant to tear and puncture.

The impermeability of polyvinyl alcohol film to oxygen is higher than that known to be the case for any commercial film. The film shows zero transmission at high (70 per cent) and low (19 per cent) relative humidities. Incomplete tests show similar impermeability to carbon dioxide, hydrogen sulfide, and hydrogen.

Polyvinyl alcohol film is unaffected by most of the common organic solvents, as well as fats, oils, and greases. It can be sealed to itself by the application of heat and pressure, if a small quantity of moisture is present either in or on the film.

Uses. Polyvinyl alcohol film can be sewed to make garment covers and bags and related articles not subject to contact with water. It is useful as a cover for shoes during manufacture. It can be stretched and set in its stretched form. When heated after wrapping around an irregular object, it shrinks tightly to the object, conforming to its outline.

Bags strong enough to hold lubricating oil can be made from polyvinyl alcohol, as well as bags suitable to be dissolved together with their contents such as dyestuffs, lye, etc.

Polyvinyl Alcohol-acetate Film. The interpolymer of polyvinyl acetate with polyvinyl alcohol is similar in many of its characteristics to polyvinyl alcohol. The films which have been made experimentally differ in that they have still greater solubility in water than polyvinyl alcohol and are thermoplastic at relatively low temperatures.

A commercial tape for splicing paper rolls in paper mills has been produced (Can. P. 364,627). It has the merit of dissolving when the spliced roll is returned to the heater.

Polyvinyl Chloride Film. This film was first announced from Germany as a non-flammable, highly acid-and-alkali-proof sheeting for special uses such as battery separator plates and wherever unusual resistance to chemicals is required. It has been variously named Vinofol, Vinoflex, and Igelit PCU.

Polyvinyl chloride, $(CH_2—CHCl)_x$, is difficult to dissolve but by after-chlorination becomes soluble in acetone. The stability of the sheeting is thereby also improved and the softening point elevated about 10° C. (50° to 60° C. (122° to 140° F.) dependent upon test).

In Germany, such film is known as Igelite PC. The film tends to be brittle and is difficult to plasticize because of its relative incompatibility.

Astralon is another German film reported to be a copolymer of vinyl chloride and methyl methacrylate. It has been used principally in thick masses as glass substitute. The same material has also been called Igelite MP.

Decelith and Diafon are also foreign films of vinyl polymers. The former has found good acceptance as phonograph record material abroad.

In this country, polyvinyl chloride is heated to improve its film-formability by milling at elevated temperature with a plasticizer such as tricresyl phosphate (U.S. P. 2,050,595). The mass is then applicable by the usual means as a coating to fabrics, or may be sheeted directly. Sheeting 0.003 to 0.004 in. thick may be made by calendering down still heavier milled sheets. It has been given the trade name Koroseal.

Solutions in special solvents such as methyl ethyl ketone can be cast. A sample of thin film 0.00075 in. thick and another 0.004 in. thick showed:

	75	*400*
Tenacity in kg. per mm.[2]	3.7–4.0	2.0–4.3
Elongation, %	25	125–212

Tearing resistance of the film is high. Its softening point is approximately 55° C. (131° F.). It is resistant to ozone, oils, most common solvents and strong acids and alkalies. Acetone attacks the material and it dissolves in pyridine. It shows fair impermeability to moisture vapor, transmitting 169 gm. per sq. meter per hour, and has excellent resistance to dimensional changes.

Uses. Highly plasticized polyvinyl chloride thin film is used principally for cable wrapping. Heavier film would be useful in raincoats and shower curtains. The price should be in the range of $2.50 to $3.00 per pound.

Polyvinyl Chloride-acetate Film. The copolymer of polyvinyl chloride and polyvinyl acetate, as would be expected, is more flexible than the polyvinyl chloride and less tacky than the polyvinyl acetate. The preferred commercial copolymer is about 90 per cent polyvinyl chloride. The trade name " Vinylite " is applied to the sheeting, while heavier gauges used for belts, suspenders, and wristwatch bands have been called Elastiglass.

The copolymer is frequently employed without plasticizer, variation in the polyvinyl acetate content being capable of providing different degrees of flexibility.

Process of Manufacture. The vinyl polymer mass is milled to the desired viscosity and calendered to sheeting. Rough calendered sheeting can be subsequently polished, if desired. Sheeting is commercially available in thicknesses ranging from 0.003 to 0.030 in.

Properties. In its chemical resistivity, the copolymer is very similar to the plasticized polyvinyl chloride. It is completely soluble in pyridine but resists most organic solvents, except acetone. It shows good resistance to concentrated acids and alkali. It is unaffected by oils. Its tearing resistance and general durability are good both at normal and low temperatures.

Sheeting about 0.004 in. thick showed the following:

	400
Tenacity in kg. per mm.[2]	3.7–4.4
Elongation, %	305–375

The softening point is slightly higher than that of the plasticized polyvinyl chloride. It is waterproof. It shows moisture vapor transmission of 500 g. per 100 sq. meter per hour.

Uses. This vinyl sheeting finds electrical applications and is widely used for raincoats, shower curtains, and novelties. In many uses it is directly substitutable for thin rubber sheeting. It is readily laminated to other materials.

The film is being used for primary closures in bottle caps and jar covers. Prices range from $0.85 to about $2.00 per pound.

Polyvinyl Acetal Films. Films made from the condensation products of polyvinyl alcohol with formaldehyde and acetaldehyde have been experimental, although some 0.005-in. thick sheeting of the former type was offered under the name Formylon.

The polyvinyl acetal films generally can be dissolved in a number of solvents and the film's outstanding characteristics are good tearing resistance and good flexibility.

Polyvinyl Butyral Film. This material $[C_3H_7OCHO(CHCH_2)_2]_x$ has become commercially valuable as the interlayer of present-day safety glass. It is clear, stable, and tough at low temperatures as well as under normal atmospheric conditions. The sheeting is known in this country as Saflex, Butacite, and Butvar. The Canadian product has also been called Butvar film.

This sheeting is not known to have been produced commercially in thin gauges below 0.003 in. thickness.

Polystyrene Films. Polystyrene $(CH_2—CHC_6H_5)_x$ has one outstanding characteristic, unusual dielectric quality.

Thin film has been made under the name Styramic for the electrical trade. In Europe, Styroflex and Trolit or Trolitulfolien have also been produced, as well as specialties, Ferrisol and Ferropal, which represent polystyrene-containing metal type powders.

The film is cast from solvent solution by the usual technique. It is claimed that stripping difficulties are eliminated by the use of dioxan with benzol or toluol. Its moisture content even after prolonged submersion remains close to 0 per cent.

Methyl Methacrylate Film. Heavy sheeting of this material $(CH_2CCH_3COOCH_3)_x$ has become well known under the trade names Lucite and Plexiglas. Thin film from solvent solution has only been made experimentally. Unusual clarity is its outstanding characteristic.

CHAPTER XI

PLYWOOD

History. The strength and structural advantages of plywood have been known and utilized since ancient times. The fact that the cross-grain weakness of wood can be overcome by gluing thin sheets of wood — called veneer — with the grain of the adjacent sheets at right angles is not in any sense a recent development. Wood in this type of construction retains its desirable properties, physical strength, ease of working, and natural beauty, and has tremendous strength in all directions due to the alternating cross-grain construction.

In the past, engineers and architects have been restricted in their use of plywood and unable to take full advantage of the outstanding structural and decorative characteristics of this material only because of the fact that there were no adhesives available that would bond veneer permanently under all conditions of exposure. It is obvious that the layers of veneer in plywood must be permanently bonded if the tremendous advantages of this material are to be utilized. The plastics industry has now provided the plywood industry with glues that produce a bond stronger than the wood under any conditions of long-time exposure to water and extremes of temperature or physical stress.

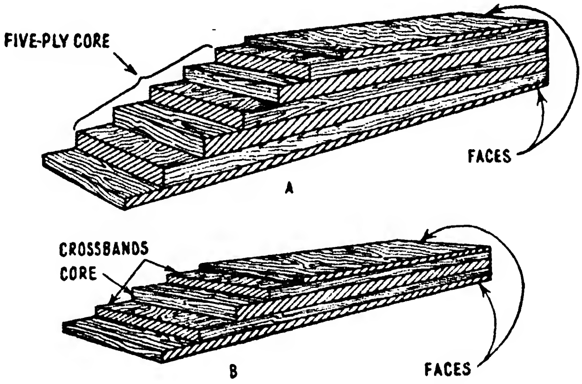


Fig. 11.1 — Plywood terms illustrated.

Construction of Plywood. Before going into further detail on the characteristics of these adhesives, a short discussion of the construction of plywood is necessary. In almost every case plywood is manufactured by gluing thin sheets of wood with the grain of each sheet at right angles to the adjacent one. To prevent warping, a balanced construction is used in which the grain of the two outer plies, known as faces, are parallel, and the core or center ply at right angles. This is the normal three-ply construction. When more than three thicknesses of veneer are used, as in the case of five-ply construction, two crossbands are cross grain to the core and the faces parallel to the core. (See Fig. 11.1.) This method of balanced construction for plywood always consists of the use of an odd number of sheets of veneer. Plywood may be constructed of any number of plies with this balanced construction of each layer of veneer being opposed by a similar layer on the opposite side of the core.

Not only the physical weaknesses of wood — that is, unidirectional strength — are overcome in this method of construction, but also the characteristics of various species of wood may be combined to great advantage. Costly woods, such as mahogany and walnut, that in lumber form have been restricted to exterior paneling and furniture of only the most expensive homes, are now available for all types of architecture in the form of plywood. Very thin veneers of these decorative woods are used as faces on cheap and structurally stronger wood as cores and crossbands which gives a more economical material both from a decorative and structural point of view. Modern adhesives have made this type of plywood permanent in any conditions of high humidity, heat, or cold.

A standard method of construction is to use cheap, softwood core and crossbands and hardwood face veneer. The softwood core provides resiliency and lightness of weight, and the hardwood surface is retained without the brittleness and high cost as is the case with hardwood lumber.

Adhesives. As has been pointed out, the foregoing advantages of plywood have long been known, but applications have been restricted by the glues available.

Until the introduction of synthetic materials, vegetable or starch glues, and animal or hide glues were the only adhesives used in plywood manufacture. The use of these glues confined plywood to applications where resistance to high humidity or bacterial action was not necessary. In effect, plywood was restricted to the cheapest of furniture and was regarded as a cheap substitute for solid lumber.

The first improvement in adhesives that opened up new fields for plywood was the introduction of casein glue. This is a proteinous material made from milk that is water resistant to a degree, but extremely vulnerable to fungus or bacterial action upon exposure. Although it is now rapidly losing ground because of the introduction of synthetic resin cold-set adhesives, casein glue made possible great advances in the plywood field because of its improved water resistance over the old vegetable and animal glues. From a manufacturing standpoint, casein has very desirable qualities in ease of working. No heat or special treatment of the wood is necessary to set the glue, and under conditions where high water resistance or exposure are not necessary, it produces a fairly satisfactory bond.

Most of the early work in wooden aircraft was done with casein glue although it has now almost completely been replaced in this field by cold-setting urea-formaldehyde adhesives that are permanently resistant to water and bacterial action.

Since the rise of the plastics industry, several synthetic resins have been developed that, used as adhesives for plywood, produce a bond stronger than the wood itself, under any conditions of submersion in water or for months' exposure to the elements. These synthetic materials have no protein ingredients and in contrast to casein and other protein adhesives are unaffected by fungus action. It is the introduction of these adhesives that made available the structural advantages of plywood to engineers in all branches of industry.

Thermosetting plastics — that is, resins that soften up and flow, and then set hard under heat and pressure — have found the widest application in the adhesive field. Once a thermosetting resin has set between the layers of veneer of plywood, the bond is insoluble and permanently infusible.

Two types of thermosetting adhesives are used — phenol-formaldehyde and urea-formaldehyde. Phenolics require a temperature of 300° F. to fuse and set the resin, and are used almost exclusively in what is known as hot-press operations. Either an alcohol solution of the resin is spread on alternate plies of veneer, or thin sheets of tissue paper saturated with the resin are placed between the layers of veneer and the plywood bonded under heat and pressure between platens of large hydraulic presses held at 300° F. The panels are formed in these hot presses under pressures ranging from 100 to 300 lb. per sq. in. The phenolic glue fuses and flows between the fibers of the veneer and under continued heat and pressure sets hard.

Urea-formaldehyde resins being water soluble before setting are applied in a water solution to alternate layers of veneer and set up either cold or accelerated by hot-press operations. Large rubber roll spreaders are used to apply the liquid resin on the veneer. The low temperatures at which urea resins flow and set makes them more practical for use with wood than the high temperature phenolics.

Urea-formaldehyde adhesives are available in both hot- and cold-setting forms. For many operations, such as the manufacture of plywood from thick layers of veneer where, because of the high insulating characteristics of wood, it is impractical to heat the glue line, or assembly work in the aircraft field, cold-setting urea-formaldehyde resins that form an inert, insoluble bond merely by a chemical reaction of the glue and an accelerator have made possible tremendous advances in the plywood and wooden aircraft field.

Urea-formaldehyde, thermosetting resins are also used, like the phenolic resins described, in hot-press operations. The outstanding difference between the two is that the urea resins are pressed at temperatures of only 220° F., while the phenolic requires a temperature of 300° F.

Wherever the type of plywood permits it, hot pressing offers quite a few advantages to the manufacturer over cold pressing, although there is no difference between a urea-formaldehyde bond that sets in the cold or is accelerated by heat in hot-press operations.

As in the case with phenolics, urea resins soften up and flow between the wood fibers under heat and pressure where they set hard due to chemical reaction accelerated by the continued heat. This permits the manufacturer to spread his veneer and allow the glue to dry out before pressing. In cold-press operations the layers of veneer must be put under pressure before the glue film has dried out as the glue solution must be liquid enough to flow under pressure and penetrate the wood surface before the glue film dries. When no heat is applied, the water solution of the unset glue must penetrate the wood, while in hot-press operations the glue, having dried out before pressing, will in the elevated temperature soften and flow itself before setting. Thus hot-press operations permit the manufacturer to use much longer assembly periods — in some cases up to 48 hours — while pressure must be applied to cold-pressed panels within a half hour of the time of spreading.

At 220° F., hot-press panels are completely bonded in from 3 to 10 minutes' cure in a hot press — about half the time necessary for similar panels bonded with phenolic resin at 300° F. Cold-press panels must be kept under pressure for at least 4 hours at room temperature before pressure may be removed. Obviously, increased production will soon more than offset the costly equipment necessary for hot-press operations.

One of the main objections to manufacturing plywood using phenolic resin and high temperatures is that very exact control of moisture content of veneer is necessary to cause flow of the resin and prevent blisters. At press temperatures of 220° F. this is not necessary with urea hot-press glues which are applied in water solution. There is also no danger of injury to the wood at these relatively low temperatures as is the case using 300° F.

Where the highest quality of bond is not essential, as in the highly competitive furniture industry, urea glues may be cheapened by the addition of wheat flour or rye flour. The water resistance of the bond is of course reduced in proportion to the amount of flour added.

Some work has been done with thermoplastic resins, such as butyrate and Vinylite as adhesives for plywood. The high cost and difficulty of using these materials, while offering no material advantages over the thermosetting glues, have limited their application to experimental work and a few specialized fields.

Thermoplastic resins soften and flow under heat and must be cooled to set. When used with a material with such high insulating qualities as wood, the panels would have to be hot pressed and then cooled under continuous pressure which would necessitate extremely long and costly cures. The bonds of plywood made with these materials tend to creep under stress at higher temperatures and become brittle at low temperatures.

Forming Plywood. In the discussion of the construction of plywood, its structural advantages, and adhesives used, only flat plywood has been mentioned. Although the largest volume of plywood is manufactured by either hot- or cold-pressing methods in the form of flat plywood, the material is by no means restricted to this form. Recent engineering developments utilizing older methods of manufacture have been made with which plywood may be manufactured in curved shapes. Formed plywood has tremendous possibilities in the aircraft field because of its unequalled strength with little weight and smooth surface.

At the very start of the aircraft industry, the first manufacturers tried to make use of plywood because of its great strength and light weight. The continuous smooth surface of plywood has many advantages over metal with rivets, both in reduced wind resistance and mass production possibilities. They were forced to turn to metal, however, because the plywood at that time came apart upon exposure when bonded with the vegetable and proteinous adhesives of that time.

A little work in elementary planes has been continued using wood. Very thin flat plywood bent around wooden spars and ribs has for some time been a standard method of construction of certain small planes and gliders. Urea or phenolic resin bonded plywood is used for the skins while urea-formaldehyde cold-press glue has almost completely replaced casein for the assembly of the structural spars and ribs.

The greatest possibilities for plywood in aircraft and many other fields, such as automotive or marine, have been opened up by the development of engineering processes for the manufacture of formed plywood. These processes make possible the cementing together of the layers of veneer in a mold by hydraulic pressure instead of steam, and the bending of flat plywood around curves, which had been the earlier method. Manufacture of plywood with compound curves is possible with this procedure, thus giving a strain-free form immensely strong for its weight.

Actual flight tests of planes have shown that greater speed per horsepower is obtainable with this type of structure than with the most modern metal types. The working properties of wood, and limits of the curves around which it can be formed, make it a natural material for streamlined structures. This permits the use of the skin-stress principle of construction already proved in the metal planes. That is, the main loads of the wings and fuselage of the plane are carried by the skin of molded plywood, and not by complicated spars and ribs.

The much publicized " plastic " airplane is no more than formed plywood bonded with a plastics adhesive. Flight and strength tests to date show this type of aircraft has greater speed per horsepower and much greater possibilities for mass production than the most modern metal type.

It is essential for aircraft construction that only the most durable adhesives be used for the plywood, i.e., thermosetting resins.

Because of the complications of laying of veneer in curved molds, a long assembly period is necessary and, therefore, hot pressing is essential. Either phenolic glues or urea resins, developed to permit a lapse of a week between spreading and pressing, may be used.

To manufacture formed plywood with compound curves using hot-setting resin adhesives, two outstanding processes have been developed: (1) the Vidal process, and (2) the Duramold process.

The *Vidal* process consists of laying the sheets of veneer spread with the resin adhesive on a male mold. The veneer is laid up cross grain with the mold and veneer completely enclosed in a rubber bag. Hermetically sealed, the veneer is pressed and glued in the shape of the mold with hydraulic pressure of hot water or steam in large pressure tanks or autoclaves. (See Fig. 11.2.)

Because the high temperature necessary to set phenolic resins destroys rubber bags and injures the wood, low-temperature urea glues are the most practical for this operation. With the use of hot water around 212° F. and compressed air, urea resin glues give permanent bonds under conditions of mass production where bag life and mold life are significant factors.

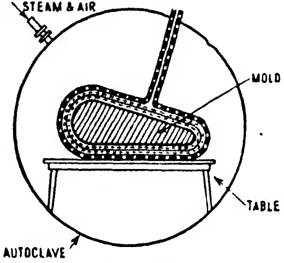
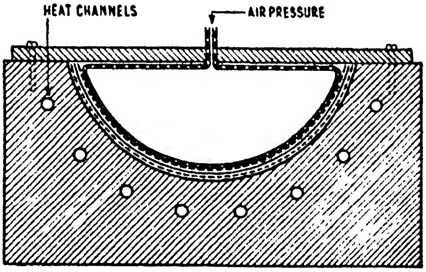


FIG. 11.2



FIGS. 11.2 and 11.3 — Different methods of forming and curing plywood.

In the *Duramold* process, the veneer is laid in a female mold and pressed with a rubber bag inflated with steam. (See Figs. 11.3 and 11.4.) Low temperatures are also desirable for this operation to preserve the bag and prevent injury to the wood.

In both the Duramold and Vidal processes, pressures of from 30 to 100 lb. per sq. in. are used, as with fluid pressure the pressure is always normal to the surface and, therefore, the excessive pressures of flat-press operations are not necessary.

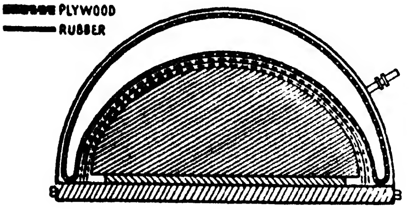


FIG. 11.4 — Duramold process.

Experimental work has been done on variations of these two processes to supply heat and set the resin, such as using molds heated by steam coils or high-frequency electric current similar to a diathermy machine. However, they all utilize the same principle of pressing the veneer in curved shapes with fluid pressure to produce a strain-free structure.

Reinforcing ribs of parallel grain plywood may be made and glued to the surface with these processes.

Probably the most spectacular development of plastics-bonded plywood will be in the manufacture of formed bodies for not only aircraft and parts but also automobiles. Already, leading automotive manufacturers are experimenting with some plywood.

CHAPTER XII

SYNTHETIC COATINGS[1]

The utilization of synthetic materials in present-day industrial coatings has progressed to such an extent that the replacement of oils and old type oleoresinous vehicles in some industries has been nearly 100 per cent.

The following classification will serve to outline various types of present-day synthetic coating materials:

Alkyds

Unmodified alkyds
Resin modified alkyds
Oil- or acid-modified alkyds
Phenolic modified alkyds

Phenolics

Straight phenolics
Modified phenolics

Cellulose Esters and Ethers

Nitrocellulose
Ethyl cellulose
Cellulose acetate
Mixed esters

Polymeric Resins

Urea-formaldehyde
Melamine-formaldehyde
Vinyl compounds
Acrylic ester polymers
Polystyrene resins

Esterified Resins

Glycerol abietate (Ester-gum)
Esterified copals
Mixed esters of abietic and maleic acids
Pentaerythrityl abietate

Rubber-base Resins

Chlorinated rubber
Depolymerized rubber

In some instances, these resin synthetics may serve as the sole non-volatile constituent of the vehicle. This is more particularly true of certain alkyd and phenolic resins of the modified types. However, in most cases, they are cross blended with each other, or cooked and otherwise processed with drying or non-drying oils, waxes, or natural resins to produce the finished product. In this manner, qualities of finish — either transparent or opaque — are attained not heretofore possible without these man-made materials. For more adequate description, each group is separately treated, and product types selected, based upon current commercial practice. In certain cases, typical formulations better illustrate the applications of these synthetics.

ALKYDS

Alkyd resins are one of the most important and widely used types shown in the foregoing chart. They may serve as major ingredients of both air-drying and baking finishes, suitable for inside or outside exposure. These resins are formed from the heat reaction of polyhydric alcohols and polybasic acids. The most common example of such a reaction is that of glycerol with phthalic anhydride. Other polyhydric alcohols such as ethylene and diethylene glycols, pentaerythritol, and the like may be cross-blended with glycerol, or used alone. Likewise, other dibasic acids, such as adipic, succinic, maleic, citric, and sebacic, can replace phthalic anhydride as a constituent.

Probably the most commonly used resin of this entire field is the economical glycerol phthalate. Glycerol is available as a by-product from the soap industry in large quan-

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[1] **Prepared in co-operation with O. P. Clipper, Plaskon Co.**

TABLE 81. OUTSTANDING PROPERTIES AND USES OF SYNTHETIC COATINGS

Type of Coating	Main Method of Film Formation	Type of Dry			Outstanding Properties	Most Typical Commercial Application
		Air	Force	Bake		
Unmodified Alkyd	Condensation	—	—	X	Thermoplasticity and dielectric strength with mica, etc.	Laminated paper, cloth, or mica sheets for electrical insulation
Resin-Modified Alkyd	Evaporation	X	—	—	Hardness, clear-rubbing, print-resistance	Furniture lacquers
Oil- or Acid-Modified Alkyd	Condensation and oxidation	X	X	X	Exterior durability, toughness, adhesion	Motor-car, truck, and refrigerator finishes
Phenolic Modified Alkyd	Oxidation and condensation	X	—	X	Improved water- and alkali-resistance	Washing-machine finish
Straight Phenolic	Condensation and polymerization	X	—	X	Water-vapor and chemical resistance	Automobile primers and surfacers
Modified Phenolic	Condensation and polymerization	X	—	—	Abrasion and water-resistance with wood oil	Marine finishes
Nitrocellulose	Evaporation	X	X	—	Speed of dry	Leather finishes
Ethyl Cellulose	Evaporation	X	X	—	Heat resistance and low-temperature flexibility	Cable lacquer coatings
Cellulose Acetate	Evaporation	X	X	—	Low flammability	Interior trim aircraft lacquers
Mixed Cellulose Esters	Evaporation	X	—	—	Exterior durability of clear coatings	Protection of bronze statues
Urea-Formaldehyde	Condensation	—	—	X	Chemical and abrasion resistance, color	Refrigerator finishes
Melamine	Condensation	—	—	X	Heat resistance	Stove-parts finishes
Vinyl	Evaporation	X	—	—	Resistance to continuous water immersion	Swimming-pool coatings
Acrylic Ester	Evaporation	—	—	X	Resistance to abrasion and flexing	Textile and rubber cloth coatings
Polystyrene	Evaporation	X	—	—	High dielectric strength	Hardwood coatings for electrical line insulator
Ester Gum	Inter-esterification with compounded oils and resins	X	—	—	Low cost — general miscibility	Four-hour dry wood oil varnishes
Esterized Copals		X	—	—	Exterior durability in long oil varnish	Long oil spar varnishes
Mixed Abietic-Maleic Esters		X	—	—	Quick solvent release	Nitrocellulose sanding sealers
Pentaerythrityl Abietate		X	—	—	Pale color, quick dry	Linseed or dehydrated castor oil varnishes
Chlorinated Rubber	Evaporation	X	X	—	Removal of surface tack. Increase chemical resistance	Fortification of air-drying alkyds
Depolymerized Rubber	Evaporation	X	—	—	Resistance to strong alkali	Inside lining for caustic soda storage tanks and tank cars

TABLE 82. SOME TYPES OF FINISH AND MATERIALS FROM WHICH COATINGS MAY BE PRODUCED

KEY

No.	*Resin or cellulose compound*	*No.*	*Resin or cellulose compound*
1.	Unmodified alkyds	12.	Urea-formaldehyde
2.	Resin modified alkyds	13.	Melamine
3.	Saturated oil- or acid-modified alkyds	14.	Vinyl polymers
4.	Unsaturated oil- or acid-modified alkyds	15.	Acrylic ester polymers
5.	Phenolic modified alkyds	16.	Polystyrene polymers
6.	100 per cent phenolic	17.	Ester gum
7.	Modified phenolic	18.	Esterified copals
8.	Nitrocellulose	19.	Abietic-maleic esters
9.	Ethyl cellulose	20.	Pentaerythrityl abietate
10.	Cellulose acetate	21.	Chlorinated rubber
11.	Cellulose acetate propionate	22.	De-polymerized rubber

NOTE. This method, using key figures, serves to simplify the table and assists in the speedy identification of the vehicles used. The resins or cellulose compounds as indicated by the key figures generally show only the principal ingredients present. This is particularly true of Nos. 17–20 inclusive, as these resins are, in nearly every instance, reacted with oils, fatty acids, and other materials to form the finished coating.

Accessory (motor car) finishes (5–12) (8–4)
Adhesive cements (8) (21)
Agricultural implement enamels (5–21)
Aircraft (fabric) dopes (8–3) (9–3)
Aircraft (exterior, metal) primers (4) (6) (7)
Aircraft (exterior, metal) finishes (5–21) (4–21)
Aircraft (interior) finishes (10)
Armature (electric) insulations (1)
Artistic (paintings) protective coatings (15)
Ball and toy (rubber) lacquers (8–3)
Beverage dispensing cabinet enamels (4–12)
Bicycle enamels (5–12)
Bobbin (spinning) finishes (14)
Bridge (and structural steel) aluminum vehicles (4)
Button (wood) lacquers (8–19)
Cabinet (radio, wood) lacquers (8–2) (8–19)
Cabinet (bathroom, metal) enamels (4–12)
Cable (rubber coated) insulation coatings (9–3)
Can (food container) coatings (4–12) (5–12)
Can (beer) coatings (14)
Clock (metal) lacquers (8–3)
Clock (wood) lacquers (8–2)
Coil (electric motor) coatings (16)
Decalcomania lacquers (8–3)
Doll finishes (8–17)
Drum (metal) coatings (6)
Electroplating ("Stop-off") lacquers (14) (21)
Electric light bulb (colored) lacquers (10)
Floor (concrete) paints (21) (22)
Floor (wood) coatings (7) (17) (19)
Furniture (metal, exterior) (4–12)
Furniture (metal, office) (5) (6) (7) (8–3)
Furniture (wood) finishes (8–7) (7)
Furniture (wood) sealers (8–2) (8–19)
Gasoline station enamels (4)
Gunstock lacquers (8–19–3)
Handle (broom, etc.) finishes (8–17)
Hardware (metal) coatings (4) (5) (8–2) (8–17)
Hospital equipment enamels (3–12) (4–12)
Laboratory table-top enamels (21) (22)
Lampshade (parchment) coatings (15)
Machinery enamels (5) (6) (7) (8–2) (8–5)
Map (paper) coatings (8–1) (10–1)
Marine paints (6) (7) (20)
Musical (plated metal) instrument lacquers (11–7) (11–3)
Paper bag (heat sealing) coatings (22)
Paper container (glassine) coatings (22)
Paper label coatings (8–19) (21)
Piano lacquers (8–7–3)
Plastic molded article finishes (5–12)
Refrigerator enamels (3–12)
Rubber cloth finishes (15) (15–8)
Sign (exterior, metal) coatings (4)
Sign (interior, silk-screen) lacquers (8–17)
Spar varnishes (17) (18) (20)
Statuary (exterior, bronze) coatings (11)
Stove-parts enamels (3–13)
Swimming pool paints (14) (21) (22)
Talon (zipper) finishes (14–8)
Tank lining (interior, metal) coatings (22)
Theatrical scenery lacquers (10)
Toy (metal) enamels (6) (7) (4–2–12)
Toy (wood) enamels (8–17)
Utility (four hour) enamels (19) (2)
Venetian blind enamels (4)
Wallboard (imitation tile) lacquers (8–3) (8–9–3)
Washing machine enamels (4–12) (5–12)
Wire (insulating) enamels (6) (15) (16)
Wrinkle (typewriter, etc.) finishes (2) (4) (7)
Zone marking paints (8–19) (8–2)

tities. Phthalic anhydride is economically produced from coal. If coal is distilled, various products result, starting with aromatic benzol, toluol and xylol, and ending with hard pitch as a still residue. One of the intermediate products in the distillation is naphthalene ($C_{10}H_8$). When naphthalene is oxidized in the presence of a suitable catalyst, and with carefully controlled conditions, it will yield a usable grade of phthalic anhydride.

Unmodified Alkyds. If a good grade of dynamite glycerol and phthalic anhydride are charged into an aluminum still, bubbling CO_2 gas throughout the mixture while heating to reaction temperatures with good agitation, and held at suitable temperatures for a sufficient period, water is formed and boiled away from the resulting resin. If this liquid mass is cooled somewhat to permit the addition of alcoholic or alcohol-ether type solvents (such as butanol, ethanol, Cellosolve, methyl Cellosolve, Cellosolve acetate, or mixtures) before the solidification of the resin occurs, a very light colored, more-or-less viscous, filterable solution of glycerol phthalate results. This unmodified resin is insoluble in straight aromatic and aliphatic hydrocarbon solvents, and is incompatible with many other types of synthetic resins and oils used in the coating industries. For that reason, the commercial prominence of such condensates is limited. They are more commonly used as resinous binders for flake mica (or other forms) to produce laminated sheets suitable for molded or pressed insulation work. This type of insulation material has dielectric strength and heat resistance and is used in commutator construction and other vital electric motor parts. In other coatings, their compatibility with cellulose acetate makes them suitable for use as the resinous component of such finishes. Their paleness of color and partial compatibility with nitrocellulose has caused them to be used in some specialty lacquers.

However, if such modifying agents as fatty acids, oils, or resins are introduced in the reaction still before solvent thinning occurs, then much more universally compatible and useful modified resins are formed. These are the commonly used alkyds of today.

Modified Alkyd Resins. These may be further classified into four main groups: (1) Modifications with natural resin acids, (2) modifications with saturated fatty acids and oils, (3) modifications with unsaturated fatty acids and oils, and (4) modifications with phenol-formaldehyde resins. Resins from each group vary considerably from those in other groups, and each class will be separately treated.

Modifications with Natural Resin Acids. When abietic acid (rosin) is reacted in the still with glycerol phthalate, an extremely hard and brittle resin is formed that is characterized by relatively high melting point and quick solvent release. Properly formulated and controlled, low viscosity and satisfactory color characteristics may be obtained. Such resins find wide application in lacquer-sanding sealers (fast schedule) and inside-furniture lacquers, as well as interior varnish applications. Their properties of quickly acquired print-resistance and insolubility in rubbing oils are of particular advantage. They are highly compatible with cellulose esters and soluble in many vegetable oils and relatively low cost solvents. This kind of alkyd of course lacks the toughness and durability of the fatty acid and oil modified types, as its characteristics are considerably affected by the rosin modifying agent. For that reason, these resins are limited to interior applications; even so, they find considerable usage in economical coatings.

There is another resin series of this general type made from terpene derived resin acids. Soft flexible alkyds can be produced from these terpene derivatives, useful in nitrocellulose lacquers as well as adhesives. On the other hand, by varying the polyhydric alcohol and the ratio of ingredients, hard durable alkyds may be obtained that find application in high-gloss baking enamels, heat-sealing lacquers, high quality furniture coatings, etc. They are much tougher and more durable than their abietic acid homologues, but not so universally compatible with other resins and oils, nor so economically produced.

Modifications with Saturated Fatty Acids and Oils. This type of resin, which began to acquire increasing prominence after 1925–26, exhibits but little tendency toward oxidation. Polymerization, if any occurs, is almost negligible, and transpires over a period of months rather than hours, in contrast to the unsaturated modified alkyds.

In composition, they branch in many cases from a phthalic glyceride base, the modifying agent being such materials as castor, cocoanut, cottonseed, stearic, and similar acids and oils. Usually 25 to 40 per cent of the fatty acid or oil is present, the balance being glycerol phthalate, maleate, sebacate, etc. In most instances, these resins are limited in their petroleum solvency — requiring aromatic hydrocarbons (such as toluol) for stable solution. Their viscosity is considerably affected, as are most alkyds, by the presence of alcoholic or ester solvents. Such solvents in small amounts produce very thin solutions of resin characterized by excellent stability.

These non-drying alkyds have made possible the tremendous improvement in quality of nitrocellulose lacquers so evident during the past decade, or longer. In quality lacquers, especially for outdoor use, they have largely replaced the older type dammar and ester gum resins. They offer better original color and color retention, superior adhesion and toughness, and — particularly in the automotive and similar fields — considerably improve chalk resistance with attendant increase in durability. This is in some measure the result of higher possible ratio of resin to nitrocellulose. To illustrate, we will show two typical formulations in motor-car vehicle, one utilizing the old type conventional dammar resin and the other containing the type of alkyd in question:

Conventional Vehicle	
Nitrocellulose	100 parts
Dammar Resin	40–45 parts
Oil	15–20 parts
Plasticizer	35–30 parts

Improved Vehicle	
Nitrocellulose	100 parts
Alkyd (Non-drying)	75–150 parts
Plasticizer	25–15 parts

These various ratios of ingredients in either type may vary somewhat from the above, depending upon the color of the finished enamel and whether hard or soft types of pigments are used. Further, if an iridescent finish is desired, the percentage pigment is usually much lower than those finishes not containing dispersed aluminum — this necessitating somewhat different formulations. In the alkyd type vehicle, it is sometimes advantageous to use an even higher resin to nitro-cotton ratio, such as 2 to 1.

There are many other adaptations of this versatile series with nitrocellulose and also ethylcellulose. Resulting formulations include such a wide variation in products as flexible quick-drying linoleum coatings (with unusual abrasion resistance) copper and other metal lacquers, leather and fabric finishes, easy-polishing interior molding lacquers (possessing depth of luster with little buffing) and other industrial specialties.

Certain well-known commercial resins of this general type also find another outlet. Their solutions are often cross-blended with the modified unsaturated alkyd (group 3). They are generally used with short oil oxidizing alkyds (or combinations of short and medium length) upon such articles as automotive accessories and heater shells. Relatively rich solvent combinations are best present in such coatings. They bake with high speed and offer excellent adhesion with unusual filling properties directly over bare metal. This particular kind of non-drying alkyd acts in the manner of a plasticizing agent for the oxidizing variety, although it does not impart any appreciable stickiness or softness of film unless used in exorbitant amounts. A much higher percentage of this type plasticizing resin can be incorporated into enamels than the softer chemical and oil plasticizers such as dibutyl phthalate and bodied oils, thereby obtaining superior filling on rough and pitted metal in addition to greater film toughness.

Modifications with Unsaturated Fatty Acids and Oils. This is the type of resin that is more commonly used, and probably in greater quantity, than any of the other alkyds today. The various homologues may serve alone, or be cross-blended with each other, as the sole vehicle in an unending number of applications, both air-drying or baking, suitable for indoor exposure. These resins are characterized by remarkable adhesion to surfaces offering difficulty in this respect with other finishes. They have excellent weathering properties when correctly pigmented (including retention of luster and elasticity), easy adaptation to feasible baking schedules, desirable coverage and spraying properties, and, in many instances, permit economical reduction with low-cost aliphatic thinners. Their films are high in tensile strength and distensibility; they are not particularly water-resistant when partially cured, as in recently applied air-dried finishes. But this resistance is greatly increased as curing develops by exposure to sunshine and natural aging — or if the film is baked. Complete curing of these alkyds produces high molecular weight insoluble compounds that are very water- and weather-resistant. Even though adversely affected by overlong periods of immersion in water or exposure to highly humid atmospheric conditions, as soon as these drying-oil phthalate resin films have an opportunity to again dry out, they appear little the worse for the exposure. Excellent elongation recovery is once more attained. When applied upon motor cars, bicycles, lawn furniture, and toys, several coats can be cured with one baking. Their films have decidedly superior color-retention properties when compared against oleoresinous varnishes.

These general properties, of course, depend to a large extent upon the particular formulation ratios and kinds of drying oils or acids used. Generally speaking, the best outdoor durability is found when using the long oil modified type for such finishes as truck and automotive enamels, or maintenance paints for filling stations. The short and medium oil length variations are commonly used upon articles for indoor use, although medium oil lengths are sometimes utilized for exterior applications when baked. The following ratios of resin base (such as glycerol phthalate, etc.) to drying-oil or unsaturated fatty acid (such as linseed acids) will serve to illustrate what is usually designated as the three oil lengths:

	Per Cent Glycerol Phthalate	*Per Cent Oil-Acid*
Short oil	60–70	30–40
Medium oil	50–60	40–50
Long oil	33–50	50–66

The various oils and oil-acids with which these resins are modified are partially listed in the following: China wood, dehydrated castor, perilla, oiticica, linseed, soya, sunflower, safflower, and hempseed. The base resin may be glycerol phthalate, maleate, sebacate, and others. In some cases more desirable alkyds may be produced by utilizing ethylene and diethylene glycols in place of glycerin. Certain recent developments have substituted pentaerythritol in whole, or in part, for the trihydric alcohol. Many possibilities exist here.

This general type of synthetic, in all its variations, has proved so versatile that it appears in architectural and inside wall finishes, coatings for transportation equipment, and enamels for general household and office metal fixtures.

Modifications with Phenol-formaldehyde Resins. Phenolic Modified Alkyds. This variation of alkyd is distinguished from the others in that greater water resistance in its coatings is obtained. An increase in ultimate hardness and chemical resistance is also made possible — this in spite of some delay in initial set of these modified films. There is usually a light but noticeable tackiness during the first few minutes (baking), or hours (air-dry) of film formation. Some sacrifice of color and color retention is also evident, particularly over long aging periods.

However, these defects are of little consequence in auto-body primers and surfacing undercoats, in addition to many colored air-dry and baking enamels. It is in these fields that the utilization of the good properties of this type alkyd appears to best advantage. Increase in alcohol, perspiration, and oil resistance in coatings containing phenolic modifications has popularized their usage upon metal chairs, desks, filing cabinets, and like applications.

PHENOLICS

Phenolic resin is a general term commonly applied to condensation products of phenol, cresol, xylenol, or mixtures of the various homologues and substituted phenols, with aldehydes such as acetaldehyde, formaldehyde, paraformaldehyde, benzaldehyde, or mixtures of the various homologues. Near-molecular proportions of the phenolic body and aldehyde are heat reacted in suitable stills with arrangements for removal of water, gas, or other undesirable products formed in the reaction. Basic or acidic catalysts may be present.

There are, in general, two types of phenolic resins: the straight or unmodified phenolic, and the modified type of resin. The first type (especially the heat reactive products) could really be classified under the subject of Polymeric Resins, including it with the urea-formaldehyde and vinyl groups. However, it would be more difficult to include the modified phenolic type (particularly those extended with drying oils and acids) under such a grouping. Therefore, it was decided to include them together under their own general title of Phenolic Resins — particularly because they are so well known throughout the coating industries as such.

The resin derivatives of simple phenol and cresol and formaldehyde are quite useless in varnish making, as they are non-reactive with and insoluble in drying oils and aliphatic solvents. However, oil solubility can be attained if the aryl and alkyl phenols are substituted in place of simple phenol. Investigation in this field was greatly accelerated with the commercial availability of such compounds as butyl, amyl, octyl, and phenyl phenols. Further, simple phenolic and cresylic acid-formaldehyde resins can be made reactive with drying oils if dispersed in natural resin acids such as rosin or copal and their esters. Chemical combination and modification with oil fatty acids likewise induces oil solubility.

Unmodified (Straight) Varnish Phenolics. There are two distinct groups of 100 per cent phenolic resins, one characterized by condensation within the resinous body when reacted in the varnish kettle, the other by the absence of this self condensation, remaining permanently fusible and reacting as phenols having active double bonds. The first group is formed by the reaction of phenol and formaldehyde in the presence of alkaline catalysts such as hydroxides or sulfites of sodium and potassium, ammonia, and the like. The second group may be produced using acid catalysts (hydrochloric, sulfuric and other mineral acids).

Straight Heat-reactive Phenolics. Pure phenolic resins of this class correspond to those identified with the first group of the preceding paragraph. Their reaction with oils and resins in the varnish kettle is relatively rapid and sometimes violent, accompanied by formation of free water and turbulent foaming. Kettle procedures are therefore more complicated and somewhat uncertain, because of the rapid condensation within the resin molecule. Temperatures and time of reaction have to be very carefully controlled to avoid solidification of the varnish or formation of unstable vehicles.

These resins are used to improve the durability of rosin, copals, and other soluble gums, as well as oils. They appreciably raise the melting point, increase water resistance and speed the drying of properly formulated coating vehicles. They are particularly desirable in industrial baking undercoats and enamels, and in chemical resistant coatings, as they dry by polymerization as opposed to oxidation when subjected to heat.

Straight Complex Phenolics. These 100 per cent phenolic resins fall within the classification of the second group, viz.: permanently fusible and non-heat-hardening. Reaction with oils and other resins is distinctly different from that of the first group. There is no violent foaming and liberation of gas in the reaction kettle. The phenolic hydroxyl group often delays the gelatinization of highly unsaturated oils when heated. Slower reaction times and higher temperatures are possible, resulting in more uniform varnishes of greater stability. These complex resinoids definitely show some reaction at the double bonds with those conjugated double bonds of the unsaturated oil molecule. This formation of ring compounds contributes toward more stable molecular arrangement, resistant to breakdown.

These flexible complex phenolics are utilized in the fortification of ester gum varnishes, for gas-proofing or oxidizing finishes, for improvement of adhesion in cellulose acetate coatings, and for increasing the chemical resistance of nitrocellulose lacquers. (Some elastic non-oxidizing variations are used as plasticizers in lacquer formulation.) In general varnish formulation, they may be used to increase speed of drying, chemical and water resistance, and exterior durability.

Modified Phenolics. Phenol-aldehyde condensation resins, modified by dispersion in abietic acid or natural copals — or reacted with fatty resin acids — are the most widely used type of commercial phenolics. The substituted butyl, amyl, octyl, and phenyl phenols are here utilized. The ortho and meta products, originally used, produced resins of very poor heat resistance that discolored badly with light. For that reason, today's improved modifications are made from the various para substitutions. These para phenols produce a marked improvement in this important property (discoloration).

In general, such condensates improve the properties of varnishes in a manner similar to the straight phenolics, but to a lesser degree. The two main exceptions to this conclusion are improved gloss and greater hardness. The modified types are superior in these respects.

Certain oil- and resin-acid modified phenolics are advantageously incorporated into nitrocellulose lacquers. Such combinations can be made to rub just as quickly as dammar, but to a clearer and brighter film that has much less tendency to bloom after long aging periods. In addition, an appreciable increase in film strength (as demonstrated by hot-and-cold check tests) is obtained.

Modified phenolics are present in many interior decorating finishes (such as the 4-hr.-drying type), architectural coatings, quick-drying primers and baking enamels for metal, rubbing varnishes for wooden furniture, long oil exterior varnishes, perspiration-resistant wrinkle finishes for office equipment, and many other applications.

Cellulose Esters and Ethers

From these cellulosic base materials have sprung the quickest drying coatings the industrial world has ever used. All four types enumerated in the general classification (nitrocellulose, ethyl cellulose, cellulose acetate, and mixed esters), provide films that dry solely by evaporation. Any polymerization or oxidation progresses so slowly that it is negligible for many practical purposes. Accordingly, the speed of drying can be readily controlled by means of the evaporating rates of solvents used for solution. It is possible to formulate metal lacquer enamels with such fast-drying characteristics at room temperatures that they may be buffed and polished lightly with a high-speed polishing wheel within 1½ min. after one-coat spray application. Such products have been successfully used in coating chrome-plated automotive accessory parts subject to exterior exposure. Even after a 1- to 2-min. air-drying period, single coats may be so tough and hard that entry into the film with the fingernail is impossible. Yet their integrity of film after exposure periods upon plated metal is excellent. In the other extremity, such slow-drying lacquers may be produced that they are entirely suitable for silk-screen work, overprint lacquers applied on decalcomania coatings, and other applications where slowness of dry is an essential requisite. Finishes utilizing any of these four basic cellulose complexes (or compatible mixtures) will be termed as " lacquers " in the following pages.

Nitrocellulose Lacquers. Nitrocellulose is formed as a reaction product of purified cellulose (obtained from either cotton linters or wood pulp) and mixtures of nitric and sulfuric acid. It is subjected to carefully controlled conditions of time, temperature, and pressure to produce an ester having a nitrogen content varying between 10½ and 13 per cent (approximate). Celluloid plastics are made from nitrocellulose having the lower nitrogen content, whereas the higher range provides explosive cottons. It is those esters having a nitrogen content of 11½ to 12 per cent that serve to produce soluble and stable solutions for pyroxylin lacquers. These latter finishes are much more commercially utilized than those lacquers produced from the other three common cellulose esters and ethers.

Synthetic coatings from cellulose nitrate may be either clear or pigmented, undercoats or finish-coats, air-dried or baked, glossy or dull, hard or elastic — depending upon the selection and ratio of the several ingredients. They are comprised of four main components: cellulose nitrate, synthetic or natural resins, chemical plasticizers, and either oxidizing or non-drying oils. In opaque coatings, pigments are an additional component. They are usually dispersed by means of pebble or steel-ball mills, steel-roll grinding equipment, or heavy duty special type mixers whose shearing action breaks down agglomerates to unusually fine particle size, in the presence of a heavy surrounding media and a suitable dispersing agent. The vehicle into which the pigment is to be ground may be any one, or mixtures, of the four main components. This selection depends largely upon which vehicle is most suitable for easily wetting that particular pigment (or pigment combination) to be dispersed. In general, pebble or steel-ball mill grinding is the most economical method; whereas processing in heavy duty special mixers (using nitrocellulose solution as the vehicle) provides the finest dispersions offering the most latitude in formulation. Roller mills are best used to produce stable, thick pigment pastes which do not materially deteriorate (by gelation, evaporation, or skinning) over long storage periods. In this manner, each individual pigment ground into chemical plasticizer, non-drying oil, stable resin, or intermixtures of each, may be prepared in advance. This method facilitates quick manufacture of colored products, as the pre-ground pigment pastes of different colors may be cross-blended with each other, if properly selected, to produce the particular shade desired. This cross-blending is accomplished in power-driven closed mixers, at which time nitrocellulose solutions, additional resin and/or plasticizer, and thinning solvents are incorporated.

There is not sufficient space in this outline adequately to describe in detail and compare such fundamentals as the methods of grinding, mixing, and other processing, the manufacture and proper uses of the various nitrocellulose grades, the methods of raw material selection and formulation of products, and other basic information. Such a description and comparison would in itself require an entire volume. The reader has available several voluminous publications on the subject of nitrocellulose and pyroxylin lacquers to which he is referred, if detailed information is desired. However, a general presentation of some important types of pyroxylin lacquers (with attendant typical formulas shown in subsequent paragraphs) will assist in a broader understanding of these coatings.

Wood-finishing Lacquers. This description will be limited to transparent pyroxylin sealers and finishing coats, both gloss and flat sheens. Opaque pigmented lacquers are generally similar in composition to the transparent formulations except that they may have a higher plasticizer content, to counterbalance the usual embrittling effect of most film pigmentations. They may also have a higher viscosity, in order to suspend better the pigment particles during wet storage.

The lowest viscosity types of nitrocellulose ordinarily are used in these transparent wood lacquers, as ability to deposit a film of sufficient depth to fill smoothly over the pores is essential. It must be borne in mind that part of this film is removed in subsequent sanding, rubbing, polishing, and clean-up operations. After these, there must be sufficient remaining film to present a uniform, lustrous appearance. For that reason, these sealers, and clear or flat lacquers, have a solid content of approximately 21 per cent (or more) at suitable spraying viscosities. Three heavy spray applications at this solid content usually suffice to produce satisfactory thicknesses of film upon filled casegoods and cabinet work.

It is possible to increase the percentage solids of wood lacquers (at spraying consistency) to a point bordering somewhat under 30 per cent, and still retain desirable properties such as toughness, easy rubbing, bright films, and cold-check resistance. Both of these non-volatile percentages shown are confined to the lacquers sprayed at room temperatures. This is mentioned because there has been some movement in the past five years to utilize commercially these lacquers in concentrated form, their volatile solvents so diminished in amount and adjusted in composition that they may be satisfactorily sprayed in a closed pressure-system while hot. Heating at 135° to 150° F. lowers their viscosity to an extent permitting satisfactory atomization at solid contents ranging from 35 to 45 per cent. There are some basic advantages in this method of application; however, most of today's commercial wood lacquer applications are made at normal temperatures.

Resins most commonly used in these pyroxylin undercoats and finishes are of five main types: (1) Ester gum, (2) natural resins, (3) resin-modified phenolics, (4) resin-modified alkyds, and (5) saturated-acid modified alkyds.

Ester gum is the most economical of this group, but finds limited use in higher quality lacquer finishes because of its solubility in rubbing oils, and " after-blooming " or hazing of finishes containing it. However, it does find some application in higher quality sanding sealers and is usually compounded with some harder resin having less solvent retention. In respect to its utilization in the medium and lower quality wood lacquers, it is more universally employed than any other resin.

Dewaxed dammar has been used in commercial pyroxylin coatings since the early 1920's and is probably the most commonly used natural resin. It imparts low viscosity, easy rubbing and polishing, and reasonably good check-resisting characteristics to lacquer finishes.. It is not so frequently used in sealers. Natural resins such as elemi, dewaxed shellac, and others are in some cases incorporated for special properties, but their usage is not so wide as dammar.

Resin-modified phenolics have replaced dammar to some appreciable degree because they are lower in cost and improve the general quality. For instance, resistance to cold-check, abrasion, and solvents, can be increased. Lacquers high in dammar content are poor in resistance to fats and waxes, and extremely low in alcohol resistance. If dammar is replaced with the proper modified phenolic in this same lacquer, high resistance to fats, alcohols, and waxes is observed. These same improvements (only to a lesser degree) are of course evident when comparing lacquers of lower resin content. The selection of a higher resin lacquer was made only to illustrate better the advantages.

Resin-modified alkyds have supplanted ester gum and natural resins to a large extent in sanding sealers. Rapid sanding undercoaters have been developed and used on production schedules that require no more than 15 to 30 min. air-drying in order to permit satisfactory sanding. Such speed is largely attributable to the rapid solvent release and higher melting point of this type resin, and its inherently good compatibility with nitrocellulose, especially in the higher resin ratios.

These alkyds also find wide application as the partial or sole resin constituent of clear and flat lacquer finishing coats. In clear lacquers, their use is often in conjunction with dammar. They are insoluble in rubbing oils, have higher melting points than the older type lacquer resins, and provide excellent alcohol resistance.

In respect to the fifth, or last, group of lacquer resins, alkyds modified with saturated acids are incorporated into wood lacquers probably in smaller amounts than any of the other four resin groups shown. Their main use with nitrocellulose lies in the metal lacquer field. However, in wood finishes, their ability to impart greater cold-check resistance is appreciable. This is particularly true in those high-solid finishes which do not have exceptionally good resistance to checking. Further, certain resins of this group, having excellent color characteristics, are sometimes incorporated into both sealer and finish coats to obtain (and maintain) paleness of color. It might here be worthy of note that these resins have the ability to maintain their color in lacquers when stored over reasonable time periods. The same cannot be said of dammar lacquers, as they soon darken materially in storage, eventually turning to a dark amber cast.

There are two kinds of plasticizers commonly used in wood lacquers: the first type commonly known as the chemical plasticizers; the second type, as oil plasticizers. There is such a large number of them available for softening pyroxylin wood lacquers (particularly the chemical type) that an attempt at description and comparison of the individual products cannot be made here. Instead, a simple enumeration of those finding common commercial application in the past follows:

Chemical Plasticizers

Dibutyl phthalate
Diamyl phthalate
Tricresyl phosphate
Triphenyl phosphate
Tributyl phosphate
Triacetin
Butyl stearate
Butyl tartrate
Triethyl citrate

Oil Plasticizers

Raw castor oil
Treated linseed oil
Treated tung oil
Blown soya oil
Blown rapeseed oil
Blown wood oil
Blown castor oil

The chemical plasticizers are true solvents for cellulose nitrate, and impart good flow and luster to the film. However, they are partially volatilized by prolonged heating or aging, which leads to eventual film embrittlement. Non-drying oils, such as raw and blown castor, are useful in overcoming this defect when mixed with the chemical plasticizers. When used alone, however, they have the definite disadvantage of spewing or sweating from the film, particularly if subjected to heat. The best results are obtained by intermixing plasticizers of the two groups. For example, an equal part mixture of blown castor oil and dibutyl phthalate is successfully employed; also, two parts tricresyl phosphate and one part raw refined castor oil give excellent results. This latter oil is outstanding in its ability to retain flexibility at low temperatures.

Solvents and other thinning agents are of three types: active solvents (usually esters, ketones, and alcohol-ethers); latent solvents (alcohols); and diluents (coal-tar aromatics and aliphatic petroleum fractions). The active solvents are characterized by their ability to produce low solution viscosity and deposition of the film in such a manner that freedom from waviness, orange-peel effect, pinholing (formation of small gas blisters), and other surface defects are minimized. Latent solvents are those alcohols which are activated by the presence of true solvents in such a manner that they assist in solution and lowering of viscosity. When mixed alone with nitrocellulose, they are incapable of solution. Diluents are present in practically all commercial formulations as cheapening agents or extenders. Lacquer costs would be unnecessarily high without them. A partial listing of individual constituents from these three types follows:

Active Solvents

Methyl acetate
Methyl acetone
Acetone
Ethyl acetate
Ethyl methyl ketone
Isopropyl acetate
Isobutyl acetate
Butyl acetate
Amyl acetate
Secondary amylacetate
Isobutyl ketone
Butyl propionate
Ethylene glycol monomethyl ether
Ethylene glycol monomethyl ethyl ether
Ethylene glycol monomethyl ethyl ether acetate
Ethylene glycol monomethyl butyl ether
Ethyl lactate
Butyl lactate
Cyclohexanol
Diacetone alcohol

Latent Solvents

Ethyl alcohol
Isopropyl alcohol
Isobutyl alcohol
Butyl alcohol
Amyl alcohol

Diluents

Benzol
Toluol
Xylol
Aromatic solvent naphtha
Aliphatic petroleum fractions
Hydrogenated petroleum fractions

It is obvious from the large number of possible combinations that an almost endless variety in formulation is possible. The solvents and diluents shown have a very wide range in evaporation rate. Some volatilize almost instantly upon application of the coating; others may maintain the film in liquid or plastic form for 30 to 60 min. (or longer) after application at usual room temperatures and humidities. Three relatively simple and practical thinner combinations that may be used in wood lacquers are shown:

Quick-drying	*Per Cent (vol.)*
Methyl ethyl ketone	10
Isopropyl acetate	5
Ethyl alcohol	15
Isobutyl acetate	15
Secondary amyl acetate	5
Toluol	50
	100

Medium-drying	*Per Cent (vol.)*
Butyl acetate	30
Butyl alcohol	10
Toluol	60
	100

Slow-drying	*Per Cent (vol.)*
Butyl propionate	20
Butyl alcohol	15
Amyl alcohol	10
Xylol	30
Petroleum Naphtha (240°–290° F. range)	20
Ethyl lactate	5
	100

Pigments incorporated into sanding-lacquer sealers and undercoats (to assist in quick and easy sanding) and flat lacquers (to produce desired sheens) are most suitably dispersed in pebble- or porcelain-ball mills. Past experience has shown that the metallic soaps, such as calcium and zinc stearate, and zinc palmitate, are satisfactory for use in sealers and undercoats. Flat lacquers may be produced from gloss clear lacquers by means of the incorporation of finely dispersed aluminum stearate, special hard waxes, diatomaceous silica, and a recent " fluffy " variation of silica, in addition to the soaps suitable for use in sealers.

It is also possible to produce sheens of velvet flatness by substituting flat gum resins (such as fossilized East India copals) for a part of the gloss resin. By careful manipulation of solvent balance and selection of resin and plasticizer, this latter method is made commercially feasible. It is limited somewhat because such products show sensitivity to temperature changes and offer difficulty in producing and maintaining uniform sheen. Stability in wet storage has long been a problem of flat lacquer finishes.

Three type formulas are given in order to clarify the general formulation of this important type of furniture finish — the wood lacquers:

Quick Sanding Wood Sealer
(Non-volatile 21%)

	Per Cent (by wt.)
½ sec. nitrocellulose (dry)	7
Ester gum	3
Resin modified alkyd	7
Glycol sebacic alkyd	2
Dibutyl phthalate	1
Zinc palmitate	1
Ethyl alcohol	5
Butyl alcohol	7
Isopropyl acetate	10
Isobutyl acetate	12
Amyl acetate	5
Toluol	40
	100

Clear Gloss Rubbing Lacquer
(Non-volatile 21%)

	Per Cent (by wt.)
½ sec. nitrocellulose (dry)	9
Modified alkyd (non-drying acid type)	2
Resin modified phenolic	7
Tricresyl phosphate	2
Castor oil	1
Ethyl acetate	10
Butyl acetate	15
Butyl alcohol	6
Amyl alcohol	3
Toluol	25
Xylol	15
Ethylene glycol monobutyl ether	5
	100

Rubbed Effect Flat Furniture Lacquer

	Per Cent (by wt.)
½ sec. nitrocellulose (dry)	8
Dammar (dry and dewaxed)	3
Resin modified alkyd	5
Blown castor oil	1.5
Glycol sebacate	2.5
Aluminum stearate	1
Butyl acetate	18
Ethyl alcohol	10
Butyl alcohol	7
Amyl alcohol	3
Methyl butyl ketone	3
Butyl lactate	3
Xylol	20
(Petroleum hydrocarbon — boiling range, 210°–280° F.)	15
	100.0

Metal-finishing Lacquers. This outline is limited in its scope to the extent that not all of the multitudinous variety of forms can be described. As in the case of wood lacquers, confinement will be made to transparent coatings. Opaque coatings are modifications with the preselected pigments dispersed throughout clear vehicles similar in composition to the transparent lacquers. To produce such opaque finishes, some changes in ratio of solid components to each other, or the elimination of some ingredients (with subsequent introduction of new constituents) are often necessary. Further, vehicles for opaque pyroxylins are usually much more concentrated and viscous in order to provide satisfactory pigment suspension.

The four basic ingredients of transparent metal pyroxylin coatings are similar to those used in transparent wood finishes. However, because these metal finishes find many more applications in exterior coatings, the resin content is generally lower and of a more durable type — and the percentage plasticizing agent is usually higher.

The cellulose nitrates used in these metal lacquers cover a much wider viscosity range than those in formulations for wood. Whereas these latter finishes utilize the lower viscosity types such as 10-centipoise, ¼-, ½-, and 5- to 6-second varieties — the metal formulations also include the much more viscous 20- to 30-second cottons, bronzing type (40- to 70-second) and even 1000-second variety. Metal surfaces are relatively non-porous, and not so absorptive as wooden ones. It is not necessary to apply metal lacquers at such a high solid concentration. In fact, it may be desirable to formulate with the higher viscosity pyroxylins to produce more economical thin films of greater strength and resistance to deterioration, abrasion, and weathering. The high-viscosity cottons are more durable than the low.

Resins incorporated into interior exposure metal formulations correspond with those five classified types as enumerated under wood lacquers.

The resins best utilized in exterior applications are of two kinds: (1) the saturated, and (2) the unsaturated fatty acid or oil modified alkyd. The first kind (non-drying phthalic resins) impart to a valuable degree outstanding weathering properties, toughness, chalk resistance, and color retention. The second kind (oxidizing phthalic resins) offers the formulator the opportunity of approaching the high-building characteristics obtainable in the past only with slower drying oil and varnish films. Lacquers of exceptionally high solid content are possible because of the high ratio of resin to pyroxylin. Only small amounts of the latter are necessary to harden initially these drying alkyds, which, in themselves, would dry to a tough film in a relatively few hours, even without the aid of cellulose nitrate. Such synthetic lacquers have additional outstanding properties, such as high resistance to abrasion, heat, alcohol, grease and oils, and greater extensibility than the more usual types.

To conclude and assist in the description of these coatings, several formulations are shown:

Clear Bronzing Lacquer	*Per Cent (by wt.)*
30–40 sec. nitrocellulose (dry basis)	16
Elemi gum	3
Ester gum	3
Castor oil	4
Ethyl acetate	10
Butyl acetate	20
Toluol	26
Ethyl alcohol	10
Butyl alcohol	8
	100

Gloss Brass Polishing Lacquer	*Per Cent (by wt.)*
15–20 sec. nitrocellulose (dry basis)	8
Maleic modified alkyd (hard type)	6.5
Dibutylphthalate	3.5
Ethyl acetate	20
Butyl acetate	12
Butyl alcohol	12
Toluol	38
	100

Gloss Synthetic Sign Finish	*Per Cent (by wt.)*
½ sec. nitrocellulose (dry basis)	10
Unsaturated oil modified alkyd	30
Saturated acid modified alkyd	10
Dibutyl phthalate	2
Ethyl alcohol	7
Butyl alcohol	7
Butyl acetate	14
Butyl propionate	5
Amyl alcohol	5
Toluol	5
Xylol	5
	100

Clear Dipping Metal Molding Lacquer	*Per Cent (by wt.)*
5–6 sec. nitrocellulose (dry)	11
Saturated acid modified alkyd	22
Pale maleic alkyd (hard type)	5
Tricresyl phosphate	2
Xylol	18
Mineral spirits (aliphatic)	12
Amyl acetate	15
Amyl alcohol	5
Butyl lactate	3
Methyl ethyl ketone	6
Pine oil	1
	100

Flexible Nitrocellulose Coatings. These pyroxylin lacquers for use on non-rigid bodies (as opposed to metal and wood) such as paper, leather, rubber, textiles, and fabrics, must obviously withstand much flexing and bending, to which those lacquers heretofore described are not subjected. They therefore are characterized by much higher plasticizer content and partial or complete absence of resin. The absence of resin is permissible in such coatings because adhesion to these porous surfaces is usually not difficult to attain. The applications first applied strike well into the surface by penetration and absorption, thus securing a good bond. Inasmuch as succeeding coats are bound to each other by cohesion, rather than adhesion, little difficulty is encountered here. However, to ensure satisfactory films of long life, special emphasis must be placed upon the quality of plasticizing agent, and a careful balance maintained between it and the other ingredients. Pigmentation of colored products should be kept as low as possible, consistent with workability. The type of plasticizers giving excellent results are the long oil (non-drying) extended alkyds. Selection of raw materials in the manufacture of these plasticizers must be made with care. Their flexibility is in general increased the greater the distance between the reactive bonds in the acid used. For instance, sebacic acid will produce a more flexible resin than succinic. In some instances, such as pale paper coatings, the selection of plasticizer is sometimes governed by their paleness of color. Specially prepared alkyds, or their mixtures with colorless chemical plasticizers and castor oil, are often useful in such nearly colorless paper coatings.

Ethyl Cellulose. This cellulose ether is a reaction product of alkali cellulose and ethyl chloride, and has assumed industrial prominence because of a diversification of outstanding properties which are described in the following paragraphs. It is more flexible than nitrocellulose, particularly at low temperatures, and does not require the relatively expensive ester and ketonic solvents to produce solution. A number of types, ranging from the low viscosity variety (7-centipoise) to the thick viscous kind (300-centipoise) are commercially available.

One of its additional prominent characteristics is stability to heat and light. In the case of nitrocellulose lacquers, breakdown is accompanied by acid decomposition products which promote further decomposition. Not so with ethyl cellulose, as it is an ether rather than an ester. Heat resistance is notably superior to nitrocellulose, as exhibited in the greatly improved type of cable-coating lacquers utilizing this ether with permanently flexible types of plasticizers (such as various glycol-sebacic acid condensations) which are mutually miscible with each other in all proportions. Then, too, the low-temperature flexibility of ethyl cellulose is highly advantageous for automotive, marine, aircraft, neon sign, and other cable applications subjected to tremendous changes in temperature. Such cable lacquers have excellent dielectric properties and resistance to oils and greases. They can be formulated with high flame resistance.

Economical solution of ethyl cellulose is accomplished quickly and easily by stirring it into a mixture of 80 to 85 parts (by weight) toluol and 15 to 20 parts ethyl alcohol. Benzol, xylol, solvent naphtha, and turpentine may be substituted in place of toluol; other alcohols and esters may replace the ethanol. When using esters such as butyl acetate, it is possible to incorporate low-cost petroleum diluents having evaporation rates comparable to toluol. This cellulose ether is so compatible with a variety of resins, oils, and plasticizers that little difficulty is experienced from the standpoint of solution. It is used as a base for high-grade fabric, leather, paper, and rubber lacquers.

Ethyl cellulose is compatible with nitrocellulose in all proportions. This is utilized to augment a variety of pyroxylin coatings. For instance, in the case of motor-car lacquers, the replacement of 15 per cent of the cellulose nitrate by this ether will greatly improve the extrusion characteristics of the dried film. The same or similar substitution in aircraft dopes greatly improves their film flexibility and resistance to "ring-worming." Likewise, the cold-check and alkali resistance of furniture lacquer coatings may be improved.

There are three additional "specialty" applications of ethyl cellulose that will be briefly described.

1. This cellulose derivative is compatible with vegetable drying oils if incorporated into some varnishes by cooking with the oils and resins. There is an appreciable increase in the speed of drying; tackiness so prevalent in varnishes is largely removed. Films of improved toughness may also be obtained by this method. Ethyl cellulose invariably imparts higher solution viscosities.

2. Its compatibility with various waxes, both vegetable and synthetic, has provided a different type of paper and cardboard coating. Ethyl cellulose may be dissolved directly into the molten wax by means of heating, or solvent solutions of each can be intermixed. The melting point of the wax can thus be raised, and greater film toughness and solution stability are obtained.

3. Ethyl cellulose provides a plastic, safe, quick-grinding vehicle for dispersing water-paste pigments on the two-roll colloid mill. Water is easily evaporated, as the operating temperatures are above its boiling point. Dry pigment dispersions characterized by extraordinary gloss are quickly obtained. They are of commercial value for pigmenting high-gloss, quick-drying printing inks, as well as high-grade leather and fabric coatings.

Cellulose Acetate Lacquers. Finishes made from the acetyl ester of cellulose are not so widely used as those based upon nitro or ethyl cellulose. In fact, they are frequently specialty products, higher in cost than most commercial coatings. However, they may possess definite properties peculiar only to them. For instance, strong, light-weight yet durable lacquers of pleasing sheen and appearance for interior decoration of commercial aircraft are produced from this base ingredient. They dry very quickly and have no peer in the organic finish field in resistance to ignition and burning.

Noteworthy properties of this stable ester other than its low flammability include great toughness or resilience, stability to light and heat, water-white solution, and resistance to weak acid, alcohol, oils, and gasoline. It is difficult to obtain solution as it is soluble in relatively few commercial solvents. Once in solution, further difficulty is encountered in obtaining resins with which it is compatible. Even such materials are compatible to a limited extent in most cases. High solids, in the sense of some other lacquer types, are unknown.

Solvents and latent solvents that may be used to provide workable solutions of cellulose acetate are listed:

Solvents	*Latent Solvents*
Acetone	Methyl ethyl ketone
Methyl acetate	Ethyl acetate
Nitromethane	Ethyl alcohol
Methyl Cellosolve acetate	Ethylene dichloride
Ethyl lactate	Methyl Cellosolve
Dioxan	Nitropropane
Diacetone alcohol	

It is advisable to have some ethyl alcohol present in formulations, even with the more active solvents, as it exerts a definite tendency in solvent combinations toward true solution. Toluol and such aromatics may be used as a diluent, but not to the same large extent as in cellulose nitrate lacquers.

Plasticizers are compounded with acetate finishes to increase elasticity, to further decrease the low rate of flammability, and to lower the sensitivity to moisture. Either tricresyl or triphenyl phosphate is effective in retarding the burning rate to a degree insufficient to support combustion. The water sensitivity can be appreciably lessened by careful selection of plasticizers. For instance, alkyl phthalates (or their mixtures with phthalyl glycolate and aryl phosphate) greatly assist in this respect, particularly when used with acetate higher in degree of acetylation. Moisture resistance is also increased if a cellulose ester high in acetic content is used.

A tabulation showing some of the more important commercial plasticizers follows:

Dimethyl phthalate
Diethyl phthalate
Diphenyl phthalate
Dimethyl Cellosolve phthalate
Methyl phthalyl ethyl glycolate
Ethyl *p*-toluene sulfonamide
Triphenyl phosphate
Tributyl phosphate
Dibutyl tartrate
Diamyl tartrate
Camphor
Acetyl triethyl citrate
Triacetin
Tripropionin

Resins used with this relatively incompatible ester are few, and no large listing is available for this reason. There are certain kinds of complex straight phenolics and very special alkyd resins modified with saturated acid that are compatible. Formaldehyde-toluene sulfonamide condensations (Santolites) and methyl methacrylates are useful for special purposes, in small amounts. Adhesion to surfaces, water resistance, gloss, and ultimate hardness can be improved with their addition.

Some of the first clear and pigmented dopes applied upon fabric aircraft were formulated from cellulose acetate bases plasticized with triphenyl phosphate, and dissolved in solvent mixtures of acetone, benzol, diacetone alcohol, and ethyl lactate. Nevertheless, it is a well-known fact that such large areas coated with these dopes exhibited loss of tautening properties and allowed entire wing sections and fuselages to become " flabby " in wet or humid atmospheres. For this and economic reasons, their commercial utilization was limited. Replacement with nitrate dopes (or ethyl cellulose-nitrate mixtures) was inevitable. However, today's commercial metal airliners have certain smaller sections such as fins, rudders, stabilizers, and " flippers " of fabric construction. Acetate dopes are used here because of their superior flame resistance, thus contributing a safety feature when used for interior decorations in modern air transport. Their pleasing decorative properties are utilized in finishing theatrical scenery because of this same feature. Other applications include coated fabrics (card table covers), imitation leather, wire insulations, wood and paper sealers (in crystallizing lacquer finishes), and coloring of electric light bulbs.

Mixed Esters. There are two main types — cellulose acetate-butyrate and cellulose acetate-propionate. Generally speaking, they have properties somewhat similar to cellulose acetate, with the added advantages of a much wider range of solubility and compatibility, and they are more water and alkali resistant. Durable, non-yellowing, weather-resisting, clear metal lacquers offering excellent protection to brass, bronze, aluminum, magnesium, copper, and steel can be formulated from either mixed ester. This treatise, however, will deal only with the acetate-propionate ester, inasmuch as it has more general miscibility and solubility characteristics. From it, very high-grade flexible coatings for both metal and fabric aircraft, bronze statue work, store and building fronts, sizing of fabrics, and rubber-coated ignition cables may be produced.

Nearly all types of chemical plasticizers are suitable for softening this ester. For instance, tributyl, triphenyl, and tricresyl phosphates, chlorinated diphenyls, various citrates and phthalates, and many others are satisfactory. Usually, relatively small amounts of plasticizer are added.

Resins suitable for incorporation into cellulose acetate-propionate may be either natural or synthetic. More economical formulations can be made by incorporating ester gum, gum elemi, or dammar. For outside durability, the saturated fatty-acid modified alkyds and complex 100 per cent phenolics are preferable. In pigmented lacquer coatings, this mixed cellulose ester is superior to any of the other esters or ethers in maintenance of color and resistance to chalking.

The solubility of the acetate-propionate compound in some of the cheaper and more common solvents assists in producing finishes having costs somewhat competitive to other of the more expensive commercial finishes. An equal-part mixture of toluol and alcohol is a simple solvent combination suitable in many instances. Such a mixture may be varied at will by the addition of other individual solvents, such as acetone, methyl ethyl ketone, ethyl and butyl acetate, the various alcohol ethers (Cellosolves), ethyl lactate, dichlorides of methylene, ethylene, and propylene. As time progresses, the unusual light-fastness and durability of quick-drying lacquers made from these relatively expensive mixed esters will be more generally recognized. They will probably be more commonly used, with resultant economy in cost, in special air-drying applications best utilizing their stable features.

Polymeric Resins

Urea-Formaldehyde Resins. Formaldehyde and urea, under carefully controlled conditions, will react together to form resins that are colorless, thermosetting condensates. Commercial products are available as solutions in organic solvents. They harden quickly by polymerization rather than oxidation, thus tending to equalize the hardness throughout the coating, in contrast to those films formed solely by oxidation and/or evaporation, as in the case of alkyds. This helps to eliminate or minimize internal and interfacial stresses, as well as the casehardened type of drying so prevalent in oxidizing finishes. Hardness combined with toughness is thus made available to produce films highly resistant to marring and scratching.

The original color of these resin concentrates is water-white; the solution is bright and sharply clear. They also have excellent color retention when baked in industrial finishes, and the ability to impart much of this property to alkyd resin coatings. Further, they reduce or, in most formulations, entirely eliminate the tendency of certain vehicles to gas-check, and assist in the elimination of wrinkling on fatty edges or other heavily coated areas. They differ somewhat in their compatibility with other resins, oils, and varnishes, but in general exhibit this property to a degree sufficient for use in most industrial finishes. Those resins lower in true viscosity and degree of condensation have a surprisingly great tolerance for varnishes and oils offering difficulty in this respect.

Urea-formaldehyde resins are probably best plasticized by the alkyd resins, and have found wide industrial application with all of the three main types of modified alkyd: those modified with saturated fatty acids and oils, the unsaturated oil and acid variations, and the phenolic alkyds. The selection of plasticizing varnish of course depends upon the type of finish desired.

The following urea-alkyd resin combinations will serve as prototypes:

1. Urea resin and alkyds modified with saturated oils or acids produce baking finishes highly resistant to discoloration over long aging periods, and provide resistance to fats, oils, solvents, waxes, soaps, and other chemicals; industrial applications include such finishes as those used upon refrigerators, kitchen-bathroom-hospital fixtures, and a variety of other objects.
2. Urea resin and alkyds modified with unsaturated fatty acids and oils furnish excellent vehicles for today's auto-body, motor-car accessories and parts, truck, toy, and bicycle enamels. Such finishes have been found most suitable for objects subjected to rough usage and outdoor exposure.
3. Urea resin and phenol-modified alkyds serve well as vehicles for washing-machine and laundry-equipment enamels, as well as water-resistant undercoaters for truck and automotive finishes; the phenolic modifications provide more resistance to water vapor and moisture conditions, at the same time increasing final hardness of film with no sacrifice in toughness.

There are other fields of usefulness wherein urea-formaldehyde resins have application in specific formulations. For instance, the oleo-resinous type of baking varnish may be materially fortified in toughness, hardness, and chemical resistance by the incorporation of as little as 5 to 10 per cent of urea resin. Not all of such mixtures are compatible, and selection must be made with care. Maleic ester varnishes are best suited for this fortification. Likewise, as some urea resins are more widely compatible than others, the selection here again must be made by trial with the specific varnish. Those condensates prepared in capryl or octyl alcohol are particularly desirable for this purpose.

Some unique properties are obtainable only with urea condensates in particular formulations with ethyl cellulose and nitrocellulose lacquers. Total solids can be increased without appreciable gain in viscosity, and short schedules utilizing higher heat may be employed inasmuch as the urea constituent seems to protect especially the nitrocellulose, which in normal formulations shows some decomposition over 225° F. Resistance to many organic solvents, usually foreign to finishes of this kind, is thus made possible. In addition, by this method, colorless solid of great hardness is added, allowing the further modification with pale flexible alkyds, if desired.

Special urea resins are available as solutions in the lower alcohols, which can be utilized as primary ingredients for cloth-printing inks. Likewise, other specialties have been used as crease-resistant and anti-wrinkling applications for cloth, and as the important hardening agent for high-speed litho printing inks.

It is somewhat difficult to classify urea-formaldehyde resins as a group because of their diversification. Aside from those products condensed in the presence of low alcohols (such as methyl, ethyl, and others) and high alcohols (such as octyl and others), there are those resins condensed and reacted with intermediate alcohols present. Butanol is most frequently used in these latter type condensates. They, as a group, probably typify those resins of most commercial value, and may be classified relative to degree of condensation. The viscosity of these resins is directly controlled by the degree of condensation, the higher viscosities resulting from higher condensations. For convenience, they are here arranged in three classifications: low viscosity, medium viscosity, and high viscosity resins.

Low Viscosity Urea Resins. These resins are usually manufactured with butyl alcohol and xylol as the solvent constituents. Their solutions are very thin, at 50 per cent resin concentrations having a Gardner Holdt bubble tube viscosity in the lower range of the alphabet, dependent of course upon the ratio of butyl alcohol to xylol. To illustrate further, commercial solutions may have a viscosity in the general range of " N." A slight increase in percentage butyl alcohol in place of xylol very materially lowers this value.

Solutions of this class of resin have the highest degree of compatibility. This allows them to be used with the widest variety of varnishes, resins, and solvents. If properly controlled in manufacture, these solutions permit thinning with the lower cost petroleum solvents, and have exceptionally low water contents. Contents of 0.4 to 0.6 per cent are not unusual; certain formulations are consistently supplied with water present to the extent of 0.1 to 0.3 per cent (maximum). These low water contents make possible the use of such solutions in the presence of those pigments which are critical to water.

Synthetic baking enamels utilizing these resins can be formulated having abnormally high solids at spraying viscosity, thus better enabling them to fill sand scratches or other imperfections in either undercoat or metal. Fewer coats may be applied to obtain a specific film thickness. Such enamels will sheet-out in the oven to a smooth surface with little tendency toward upheaval or drawing together of the film.

These low viscosity resins are suitable for general formulation and they find their use in diverse fields. They are particularly suitable for high solid refrigerator and laundry equipment coatings, beverage dispensing cabinet enamels, motor-car formulations, bathroom and kitchen fixture finishes, and the like.

Medium Viscosity Urea Resins. Solutions of these resins, compared with those of the low viscosity (approximate body N) class, have viscosities in the general range of "V"–"X" (Gardner Holdt tubes). This increase in viscosity is accompanied by some decrease in compatibility, which however is sufficient to allow general usage with many alkyd and other type vehicles.

These solutions, upon evaporation of the solvent, leave a more viscous and less tacky film than the solutions of the low viscosity class. Their field of usefulness covers the finishing of general metal articles whose baking schedules sometimes do not allow full cure of film. They are also used in some refrigerator formulations, washing-machine enamels, lawn furniture and similar coatings.

The urea resins of medium viscosity are the type of condensate that offers so many possibilities when mixed with specially constructed alkyd modifications in the finishing of fine wood furniture. Blended with natural resin, tough, easy-sanding, high solid sealers can be produced which force-dry in 1 hr. at 125° to 140° F. Sealers of this nature hold out finishing coats exceptionally well, and allow good bonding if the proper type of alkyd is selected for use in the top coat.

Clear rubbing furniture coatings containing this type urea solution and alkyd resin (modified with unsaturated fatty acids), properly accelerated, provide high solid films that force-dry to tough mar-resistant finishes of excellent rubbing and polishing characteristics. Schedules of 1½ to 2 hr. at 125° to 140° F. suffice. Surfaces may be rubbed with pumice and oil as soon as cooled to room temperature. Clarity and depth of film, paleness of color, solvent resistance, economy and speed of application, and resistance to hot-and-cold check tests are some of its outstanding properties. Only one application each of sealer and varnish is necessary to provide a finish of outstanding appearance and durability over stained and filled veneer.

High Viscosity Urea Resins. These are the resins condensed to the highest degree. Their solutions have markedly higher viscosity than those of lower condensation products (Gardner Holdt Z-2, Z-3 at 50 per cent concentration in butyl alcohol and xylol). The increased viscosity of these special condensates is accomplished by a decrease in compatibility. However, this latter is sufficient for some purposes. The solvent evaporation of their solutions deposits an even more viscous and less tacky film than the medium viscosity urea solutions.

The high viscosity resins are suitable for use whenever very thick films must be applied (especially upon upright surfaces), with little attendant danger of sagging or "curtaining." They are especially useful in finishes containing pigments which are difficult to keep in proper suspension, such as the aluminum powders used in iridescent finishes.

General. The development and perfection of these usable forms of urea-formaldehyde condensates soluble in organic solvents has been of high value to the paint, varnish, lacquer, ink, and textile industries. Their commercial availability has enabled the formulators of these industries to produce vehicles that are major improvements over prior practice. Some changes in formulation from established practice are of course necessary when using these resins. For instance, their use in some cases alleviates the necessity for the presence of metallic driers; also, caution must be exercised when using highly basic pigments, such as zinc oxide, as they cause slower conversion of the urea base resin.

With proper formulations, curing times of organic coatings may be markedly shortened, even at decreased temperatures. Physical properties as well as chemical resistance can be improved. In short, these resins provide a new tool for the technical worker in the synthetic coating field, increasing his versatility as well as broadening the industrial applications of coatings.

Melamine Resins. The recent commercial availability of the organic amine, melamine (chemically — 2, 3, 6 tri-amino; 1, 3, 5 triazine) has led to a new series of resins commonly called " melamines." They are the water-white resinoids resulting from the condensation of melamine and its iso form with formaldehyde. As in the case of urea-formaldehyde reactions, the condensation is accomplished in the presence of monohydric alcohols and acidic catalysts.

Melamine resins have two outstanding characteristics: first, high retention of color and luster at abnormally high temperatures; second, fast curing rates, even at the lower commercial temperatures. These properties are desirable in special applications. For instance, baking schedules, from the standpoint of either temperature or time, are in some cases insufficient to cure some coatings properly. The incorporation of melamine resins greatly assists in eliminating soft films, even though hot from the baking ovens, thus facilitating quick handling of the coated objects with less danger of surface injury. Further, melamine modified coatings are useful when coated upon stove parts, electrical accessories, and similar objects adjacent to a source of heat. They are especially utilized in those white and pastel shades, or colors having clean hues. In addition to excellent color retention, melamines are able to impart maintenance of film gloss at the higher temperatures. Therefore, such industrial applications wherein this feature is important provide another outlet for this type of resin.

Melamine resin films are harder and more brittle than urea resin films. The chemical resistance of coatings containing melamines appears to be approximately equal to similar urea coatings. However, the former is more brittle and more liable to crack. By lowering the melamine resin content, in order to correct for the hardness factor and to equal the durability of the urea coating, part of this (melamine) chemical resistance is lost. Accordingly, when comparing films of equal hardness and durability, melamine coatings actually have less chemical resistance than the urea type.

There is some question concerning the ability of melamine coatings to withstand exterior exposure to a degree equal to similar urea-formaldehyde coatings. Some exposure tests have shown them to be somewhat less durable in this feature. Also, testing by immersion in warm aerated water (panels primed and surfaced with auto-production baking undercoats) has indicated a higher tendency of melamine coatings to " blister " or " pimple." Usually, melamine films have less adhesion than urea films to some surfaces, especially those offering difficulty in this respect, such as molded plastics radio cabinets, clock casings, etc.

Because of the relatively high cost of melamine itself, the commercial utilization of its condensates is somewhat limited. However, recent trends have been toward co-condensation with urea. These products show promise, as they have nearly as much retention of color and luster at high temperatures as do the pure melamine products. This can be demonstrated by mixing together individual solutions of straight melamine and straight urea resins in various proportions, and uniformly casting their films upon glass panels. If such panels are baked for comparable times at 350° to 400° F., it will be noted that those films containing relatively small amounts of melamine resin are nearly as resistant to darkening as the films containing much larger proportions of melamine product. In brief, the incorporation of melamine resin in small amounts with urea helps to maintain color at elevated temperatures all out of proportion to the relatively small amounts added. This important fact has been utilized in the production of co-condensation products to the fullest degree, as such products are obtainable economically lower in cost. The same beneficial effect may be accomplished by blending individual solutions of each resin.

Vinyl Compounds. Polymers of vinyl chloride and acetate have been commercially produced for some years both in this country and abroad, for use as thermoplastic molding compounds of crystal clarity. More recent developments in the manufacture of copolymerized acetate-chloride esters have provided products suitable for use in the coating fields which are odorless, tasteless, colorless, and nonflammable. They produce stable films unaffected by water, alkali, alcohol, petroleum solvents, and many acids. These resins are manufactured in various degrees of polymerization; this affects their physical properties, varying them over a wide range. The higher the degree of polymerization, the more viscous the product and the lower its compatibility with other resins and nitrocellulose. Such variations are also affected by the selection of raw materials. The polyvinyl alcohol and acetal and the divinyl acetylene homologues enlarge the series of resins of this type.

Vinyl vehicles provide pigmented coatings representative of the true shade of pigment used. There is no discoloration from the vehicle. Bright colors retain their original cleanliness, and white tones of extraordinary cleanliness are possible. Pigments are best incorporated by dispersion directly into the dry thermoplastic resin, using a two-roll colloid mill. This concentrated pigment mixture is taken from the rolls in sheet form and dissolved in a heavy-duty mixer by adding such solvents as used in nitrocellulose lacquers to produce a heavy paste. The paste is later diluted with desired solvents and additional vinyl resin solution (and other resins or plasticizers if desired) to produce the finished product. In addition to the ester and lacquer solvents, the ketones are very essential in these coatings. There is a series of such products commercially available, typified by methyl ethyl ketone, isobutyl ketone, methyl amyl ketone, and others. Toluol and xylol serve well as extending solvents or diluents; alcohols and aliphatic hydrocarbons are highly undesirable. Vinyl films, even though applied under very humid conditions and in the presence of such water-miscible quick evaporating solvents as methyl ethyl ketone, are cloudless and free from blush when dry. This is in contrast to nitrocellulose films applied under similar circumstances.

Such pigmented coatings as described above have provided excellent swimming-pool paints, and similar finishes for other difficult applications. Vinyl coatings are outstanding in their ability to resist chalking, if properly formulated.

Their use for industrial specialties such as bobbin coatings (in the textile industry) is illustrative of many other adaptations for both wood and metal objects. In this industry, bobbins are subjected to extreme wear and abrasion during the swift and continuous passage of thread over their surface. The expense of periodically refinishing the huge number used in each textile factory is enormous. The ability of vinyl coatings to withstand the wear as well as the constant expansion and contraction of both wooden and aluminum bobbins under severe humidity changes is phenomenal.

Vinyl resins are compatible with nitrocellulose, and they are used with this type of lacquer to increase the water, alcohol, and chalk resistance. Exterior white sign pyroxylin finishes of the highest type may thus be formulated. Vinyl acetate-chloride copolymers are utilized in coating sheet metal for subsequent fabrication into beer cans. These diverse industrial applications demonstrate to some degree the remarkable chemical properties of this series of polymers.

Acrylic Ester Polymers. Catalytic polymerization of methacrylic esters proceeds to completion under carefully controlled conditions of temperature, time, and percentage oxygen available, with the resultant formation of resins high in softening point, tensile strength, brilliant in clarity, with excellent dielectric constants, and having good molding properties. In fact, the various acrylic polymers have found greater outlet in the molding field than in the coating industry to date. They are relatively expensive as raw materials for coatings, and their commercial utilization for such purposes has started slowly.

These polymers vary from hard resins to soft elastic variations, and even exist as viscous liquids. Methyl methacrylate polymer is representative of the hard high-melting type; at the other end of the series is liquid lauryl methacrylate polymer. By means of copolymerizing definite ratios of the various monomers, any degree of hardness and elasticity between these two extremes may be produced. n-Propyl, n-butyl or isobutyl methacrylate polymers are commercially more adaptable types. Interpolymerization among themselves or with methyl methacrylic resin permits a large number of possible resins having physical characteristics suitable for use in the coating field.

These polymeric resins are soluble in aromatic or chlorinated hydrocarbons, esters, and ketones — producing brilliant solutions of water-white color. Their adhesion to metal and other surfaces, while in some cases good, is usually greatly improved by baking. Dry films of these polymers are practically impervious to water, mineral oils, and fats. By the selection of specific monomer, a resin having high solvency in aliphatic petroleum thinner may be obtained. This type lends itself more readily to spray application (the other resins not breaking up well in the spray gun), but may be dipped, roll-coated, or brushed in the same manner as all other resins of this general type. Proper selection of solvent for each method of application (except spray) is not a difficult problem.

Acrylic ester polymers have already been used in insulating wire baking enamels having unusually high dielectric properties. Coil-impregnating enamels have been produced which should be baked after dipping the wound rotor or armature parts.

Compatibility of these polymeric resins with nitrocellulose, and to a lesser degree with cellulose acetate, permits formulations for rubber cloth and imitation leather that have highly desirable resistance to scrub-tests, abrasion, and flexing.

In the case of rubber coatings, proper formulations can be applied to the uncured stock, and both baked in one operation.

Polystyrene Resins. These light-colored synthetic resins are synthesized under heat and pressure from two basic raw materials, benzene and ethylene. There are three types produced, dependent upon the conditions and temperatures to which the vinyl benzene monomer is subjected, and the presence or absence of catalyzer. If vinyl benzene is polymerized without catalyst at temperatures under 175° C. (347° F.), alpha-metastyrol is formed. Beta-metastyrol results in a similar manner if the temperatures exceed 175° C. Low-temperature polymerization (in the presence of hydrogen peroxide or other catalysts, and in the absence of air) can be made to form a polymer lighter in color than the beta homologue, but having analogous properties.

These resins are highly thermoplastic and practically all those produced have been used in the molding industry. However, these polymers are mentioned, as potentially some can be utilized in synthetic coatings. They are readily soluble in cheap and available solvents, have excellent color and water-resistant characteristics, unusually good dielectric properties and tensile strength. Newer developments in these resins should include a harder type.

ESTERIFIED RESINS

Ester Gum. This inexpensive reaction product of rosin (abietic acid) and glycerol is manufactured in large permanent stills (stainless steel preferred) with condensers to remove water and by-products formed in the reaction. Careful selection of raw material, good temperature control, uniform heating, and complete removal of free glycerin are necessary to obtain the highest grade of product. It is far superior to both natural and limed rosin from the standpoint of better color and color retention, improved water resistance, and durability in oleoresinous coatings. It can also be used in grinding varnishes that are satisfactorily neutral in their action with basic pigments, such as zinc oxide. The usual acid number ranges from 4 to 6, although some grades are purposely supplied with acid numbers of 12 to 16. The latter have improved solvent and wetting properties, and better retard the gelation of some 100 per cent phenolics and wood oil. This glycerol abietate resin is advantageously used in nitrocellulose and other lacquers. It is much more compatible here than rosin, and offers less tacky films having greater toughness and print resistance. It is generally used in modifying various alkyd and phenolic varnishes.

Esterified Copals. There are certain of these natural resin copals (Congo) that lend themselves well toward esterification with polyhydric alcohols. The resulting advantages over the natural gums are roughly of the same magnitude and of similar nature to those of ester gum over rosin. In the varnish kettle, better chemical reaction and inter-esterification takes place between the oil and esterified copal than occurs in the usual oil-copal reaction.

Mixed Esters of Abietic and Maleic Acids. These resins are easily formed by the esterification reaction of glycerin and abietic-maleic acids. Reactions are carefully controlled and carried out in the same equipment used to make ester gum. By careful selection of raw materials, and introduction of a bleaching agent, these glycerides of abietic-maleic acid may be produced in exceptionally pale form. Some darker variations may be produced from abietic acid, copal mixtures instead of abietic-maleic combinations.

These products are used to a large degree in furniture finishes. They impart such properties as hardness, alcohol resistance, gloss, pale color, good flow, and fast dry. In nitrocellulose sanding sealers, their low solvent retention permits quick and easy sanding. In oleoresinous varnishes they especially impart fast dry, good initial color (wet), and color retention (dry film). There are some castor-maleic mixed esters that are outstanding in color properties, and which impart a hard " waxy " feel to the varnish film.

Pentaerythrityl Abietate. Whereas glycerol abietate is superior to rosin in many of its chemical and physical aspects, there was still need for a further improvement in durability and stability. It was well known that an increase in the molecular weight of esters usually produces increased hardness and water resistance. Investigation of polyhydric alcohols higher than glycerin in molecular weight led to pentaerythritol. This alcohol was found to react with rosin to produce an ester of much higher melting point, with attendant increase in hardness. It could be made desirably pale in color and was readily soluble in all the drying oils; reducing with low solvency petroleum thinners was permissible.

Pentaerythrityl abietate resin, when cooked into drying oils, exhibits high-temperature stability. Prolonged cooking does not darken or decompose this ester. This is not true of ester gum or any other commercial esterified resins. Glyceryl esters decompose when temperatures approach 600° F., and show appreciable loss by volatilization. This higher polyhydric alcohol ester does not show these defects. Paler, quicker drying coatings of much greater alkali resistance are made possible.

RUBBER–BASE COATINGS

These coatings are prominent in their ability to combine outstanding chemical and flame resistance, hardness, and quick solubility in low-cost solvents with high speed of drying at room temperatures. The film is firm and non-tacky as soon as solvent evaporation is nearly complete. There are two types of base resins: chlorinated rubber and depolymerized rubber. They differ somewhat in their solubility, flexibility, and other less important characteristics, but as a whole, produce coatings that have generally similar properties.

Chlorinated Rubber. Natural rubber can be reacted with chlorine to form hard brittle resins containing approximately 66 per cent chlorine. They are commercially produced in a wide range of viscosity characteristics — varying from the thin 5-centipoise type to the very viscous 1000-centipoise variety. The lower viscosity resins are more brittle and deposit weaker films; the higher viscosity products form noticeably tougher films. All are soluble in a wide variety of readily available solvents, such as aromatic coal tars, hydrogenated petroleum products, esters, and chlorinated hydrocarbons. They are insoluble in alcohol, turpentine, and the low-solvency aliphatics.

It is not difficult to find suitable resins and plasticizers with which these hard films may be modified. Selections of certain resins from any of the four types of modified alkyds can be made. Likewise with the modified and straight phenolics. Resins such as dammar, ester gum, and chlorinated diphenyls are useful. There is a long list of plasticizers, both chemical and natural, that may be utilized; to mention a few, methyl abietate butyl stearate, diamyl phthalate, triphenyl phosphate, thermolized tung oil, bodied linseed oil, dehydrated castor, fish oil and soya oil.

Modified with plasticizer and resin, and properly formulated, chlorinated rubber coatings of exceptional resistance to strong alkalies and acids, abrasion, water, and mildew formation, may be obtained. Clear films have poor light resistance, but when pigmented, this is overcome. Durable colored enamels for exterior masonry work exhibit excellent film conditions after long aging. Freshly laid concrete floors and plastered interior walls are other surfaces upon which such coatings provide excellent protection and decoration. Special formulations for paper coating provide outstanding resistance to the passage of water vapor. Adhesives, utilizing the extremely high viscosity resins, properly plasticized, will adhere tightly to impervious surfaces with which few other materials will bond at all.

Chlorinated rubber resins are widely used in fortifying alkyd air-drying or low-bake enamels. Here it greatly accelerates the initial dry, quickly removing surface tack, and imparts alkali and acid resistance. These properties are particularly suitable for adoption in coatings for laundry equipment, metal-aircraft finishes, truck enamels, farm machinery and the like.

Depolymerized Rubber. This form of modified isomerized rubber is produced by means of dissolving the selected stock in a suitable aliphatic petroleum fraction in the presence of tin chloride (or other catalyst), and subjecting to heat and pressure. Subsequent precipitation with suitable organic non-solvent and removal from the volatile matter provide a resin that, when milled and thoroughly masticated on large two-roll colloid mills, will readily dissolve in high-test gasoline and other cheap aliphatic solvents with very low resultant viscosity (compared with that of natural rubbers). It is peculiar to this type of resin that its solution viscosity in certain aliphatic fractions is lower than when dissolved in aromatics such as benzol.

This resin, when dissolved in high-test naphtha (up to concentrations of 20 per cent non-volatile) can readily be atomized in a spray gun, or may be brushed (up to 25 per cent resin concentration). Other methods of application, such as dipping or roll-coating are easily possible, principally because of the solvent selection available. Most aromatic or aliphatic petroleum fractions will dissolve this uncyclized rubber — in addition to coal-tar thinners, turpentine, chlorinated solvents, and others — with large variations in drying time and viscosity.

Films of such solutions are characterized by their chemical inertness and resistance to strong alkali, moisture, acids, salts, and many other chemicals. Practically unaffected by alkali, and having outstanding impermeability to moisture and water vapor, coatings of this resin are especially useful for application upon newly laid basement floors, damp walls, or other masonry. Excellent chemical resistance has likewise popularized their use upon such surfaces as metal storage-tank and tank-car interiors (used in storage and transportation of sodium hydroxide), huge water-sealed gas holders (such as storage tanks for unscrubbed city gas), paper labels and paper bags, laboratory table tops.

Pigmentation of this resin is best and most economically accomplished by combining the dispersing of the pigment and the milling of the rubber resin into one operation. There are commercially available many colors of concentrated pigment-resin powders which may be dissolved, with additional clear (or transparent) powdered resin in the selected solvents to form the opaque finished product.

Future Trends in Synthetic Coatings

Synthetic resins and materials are used, in one way or another, in nearly all types of protective coatings. One by one, synthetic resins have been found capable of replacing natural products, and of imparting to the finished coatings not only the desired properties of the product they replaced but other superior properties which make such replacement highly desirable.

To utilize many of these new coatings, it has been necessary to subject the coated object to elevated temperatures, thus producing a film of improved durability. Notable advances are being made in baking equipment for these synthetic coatings; further improvements will be forthcoming. One of the outstanding advantages which these finishes possess is speed of cure, and the future will provide finishes which are still faster. This may be accomplished by three methods: (1) modifications of existing resins; (2) utilization of resins not currently used; and (3) development of more active catalysts. In this connection, the future may bring air-drying applications in types of coatings that at present are usable only by heat conversion. Future development of new synthetic drying oils (perhaps such as that currently being carried on with dehydrated castor oil) will provide additional tools with which the chemist may work.

By means of synthetics, applications at higher solid content will be utilized. This will allow closer approximation to the ultimate goal of the perfect single-coat finish.

The utilization of all the potential developments will provide the protective coating industry with materials which possess greater ease of application and wider fields of usage. Further, these coatings will be more resistant to solvents, chemicals, water, weather, and other factors which cause premature failure of present-day protective coatings.

ADHESIVES

Commercial Adhesives (Other than those for plywood manufacture). There are available a variety of adhesives composed of synthetic rubber or rubber hydrochlorides, or cellulose esters. These are available in several forms:

1. Air-drying solvent — rubber compounds
2. Air-drying solvent — rubber
3. Air-drying solvent — latex
4. Chloroprene
5. Chloroprene and rubber hydrochloride
6. Cyclized rubber and chloroprene
7. Cellulose esters
8. Vinyl compounds

Type 1. These are available from thin liquids to putty-like consistency. Strong adhesion coupled with non-staining, waterproofness, and permanent resilience make them suitable for certain uses as: adhesion to metals, plastics, rubber, brickwork, glass, leather, and fabrics. Actual uses consist of: attaching running board compositions, waterproofing, windshield installations.

Type 2. Air-drying solvent rubber adhesives are employed extensively in such uses as: cements for the shoe industry, photo-mounting, bookbinding, waterproof seams for raincoats.

Type 3. Latex adhesives have a wide variety of uses including: the manufacture of shoes, laminated paper, the bonding of cork liners, fabrics, bristles.

Type 4. Chloroprene adhesives are resistant to oils, gasoline, and other solvents. This indicates its use for oil-resisting bonds such as gaskets.

Type 5. This class of chlorinated rubber compounds requires heat for curing and does not rely on the loss of solvent for bonding. Temperatures of 130° to 140° C.

(265° to 284° F.) are required. This type of adhesive is widely used in the formation of cable covers.

Type 6. Cyclized rubber-chloroprene adhesives are heat-curing adhesives and are chiefly used for bonding rubber linings to steel tanks.

Type 7. Cellulose ester adhesives contain an air-drying solvent and do not require heating for bonding. They are widely used for a variety of cementing jobs.

A summary of the applications of these several types of adhesives follows:

TABLE 83. INDUSTRIAL ADHESIVES AND APPLICATIONS

Type	Nature of Cement	Adheres to:	Typical Industrial Applications
Rubber Type A	Air-drying compounded rubber base solvent cement	Metals Rubber Wood Glass Plastics Stone Fabrics Cork Asbestos sheets	Plastic, metal, and linoleum covered tables Metal letters to glass, wood, etc. Clock construction Typewriter sound deadening Bonding anti-drumming materials Bonding mirrors in vanity cases Attaching handles to cardboard cartons Furniture construction Aircraft and auto sound insulation Foil-lacquered labels to cellophane
Rubber Type B	Air-drying rubber solvent cement	Rubber Leather Rubberized fabrics Wood Cloth Paper	Sports goods Felt insulation to metal, wood, etc. Cardboard box construction Automobile and aircraft Upholstering adhesive Blueprint adhesive General household adhesive Photo-mounting Attaching protective coatings to highly polished metal surfaces
Rubber Type C	Air-drying aqueous suspension of rubber	Leather Rubber Fabrics Paper Wood	Label adhesive Airplane and automobile upholstery Suit case construction Cardboard containers Rubber sheeting to wood and plaster board
Chloroprene self-vulcanizing	Air-drying rubberlike synthetic cement	Leather Rubber Rubberlike synthetic materials Cloth	Seaming coated fabrics Cable sheaths insulation Gasoline-proofing riveted metal seams Butt-jointing rubber and rubberlike synthetic materials Bonding oil-and-gasoline-resistant linings to outer sheaths, or to frictioned fabric Seaming garments and aprons for oil-field use Seaming fabrics for gas-bag
Thermosetting chlorinated rubber-chloroprene combination	Air-drying rubberlike synthetic cements	Rubber Metal Synthetic rubberlike materials Fabrics Braid	Bonding synthetic rubberlike materials to metal cable-armor Rubber-covered steel roll Bonding metal inserts to rubber and rubberlike synthetic materials Bonding resilient covering to steel keg and other containers Bonding steel and aluminum nipples and couplings to hose without mechanical attachment

TABLE 83. INDUSTRIAL ADHESIVES AND APPLICATIONS—*Continued*

Type	Nature of Cement	Adheres to:	Typical Industrial Applications
Thermosetting cyclized rubber chloroprene combination	Air-drying rubberlike synthetic cements	Rubber Metal Synthetic rubberlike materials Fabrics Braid	Bonding rubber to metal Bonding synthetic rubberlike material to fabric or braid Bonding rubber to synthetic rubberlike materials Bonding certain synthetic rubberlike oil-resisting materials to the same material
Cellulose Ester	Air-drying solvent nitrocellulose cement	Leather Metals Cloth Wood Rubber	General office adhesives Toy and novelty construction Furniture construction

Adhesives for Plastic Plywood. Plywood has become a new and better building material since the advent of the new resin adhesives. No longer is plywood just bonded wood lamination which comes apart and deteriorates in the presence of dampness or water. Plywood is a member of the plastics family because it can now be formed into permanent shapes of rather intricate curvature.

Plywood is extensively used because of its durability, practicability, and mechanical strength. Plastic plywood is durable because the use of the new waterproof adhesives overcomes the natural tendency for wood to swell or shrink, which invariably results in warping. Checking and splitting common to solid lumber is absent in plywood.

Plywood, its use, and manufacture, are not new because history indicates the use of the material by the ancient Egyptians. What is new is the application of synthetic resins in the formation of plywood, which is made in several ways:

A. Flat Press
    Hot-setting glues
    Cold-setting glues

B. Formed
    Vidal process
    Timm
    Duramold

There are several classes of resin adhesives which compete with or have displaced the older adhesives such as animal glue, vegetable glue, blood albumin, and casein. The most important are derived from either phenol- or urea-formaldehyde resins, which two classes are used exclusively for manufacturing plywood for aeronautical, marine, and building purposes. Such resins give exceedingly strong bonds, are water-resistant, and resist the action of fungi and vermin.

Not only are these newer resins for bonding wood plies, but they are now used for impregnating wood, yielding a new type of building material having unusual strength and permanent characteristics.

Classes of Resin Glue

Urea-Formaldehyde — Dry Powder or Liquid
    Hot-setting
    Cold-setting
    Special types

Phenol-Formaldehyde
    Dry Glue Film
    Alcohol Solutions

Vinyl

TABLE 84. GENERAL APPLICATIONS

	Urea Cold Press	Urea Hot Press	Phenolic-Film	Phenolic-Liquid	Vinyl
Flat Press	√	√	√	√	√
Formed Plywood	—	√	—	√	—
Aviation					
Skin	—	√	√	√	—
Assembly	√	—	—	—	—
Spar	√	√	—	—	—
Skis	√	√	√	—	—
Marine					
Plywood	—	√	√	—	—
Spar	√	√	√	—	—
Rafts	√	√	—	√	—
Dinghies	√	√	√	√	—
Automotive					
Paneling	—	√	—	—	—
Plywood	√	√	√	—	—
Frames	√	—	—	—	—
Miscellaneous					
Bottle Cap Liners	√	—	—	—	√
Sun Helmets	√	√	—	√	—
Fiber Cartons	√	√	—	—	—
Beer Barrel Staves	√	√	—	—	—

UREA RESIN ADHESIVES

Two types of urea resin adhesives are available — hot and cold setting. The hot- and cold-press types, supplied in powder form, are stable over a long period of time. They are used with a hardener, usually sold separately, and require mixing with water prior to use. Urea adhesives are available in 100-lb. bags in ready-mixed dry powder form requiring only the addition of water, in which they dissolve readily. Wet or liquid type also sold commercially.

Cold-press Types. The normal proportions for cold-press glue are 100 lb. of dry glue, 65 lb. of water, 2 lb. of appropriate hardener. At normal room temperature the solution of glue has a working life of approximately 4 hr. At higher temperatures this period is reduced. As the glue solution without hardener is stable, it is sometimes desirable to mix up a batch sufficient for several shifts, adding the hardener to small lots drawn off as needed. The wood requires no special preliminary treatment and the glue may be applied with a modern glue spreader preferably equipped with grooved rubber rolls. A spread of 30 to 40 lb. per 1000 sq. ft. of single line is sufficient. Pressure must be applied while the glue line is wet. The assembly period must not be longer than 15 min. Pressures should range from 150 to 300 lb. per sq. in., depending upon the type of wood. With simple laminations and tight-fitting joints the pressure may be released before the glue has completely set. At average temperatures this period is between 3 and 6 hr.

For maximum waterproofness and strength, glues should be used as supplied without additions. Where low cost is essential, extenders may be added; usually wheat flour is used. It is not recommended to use over 50 lb. of extender per 100 lb. of dry glue.

Hot-press Urea Glues. One hundred pounds of dry glue, 60 lb. of water and 2 lb. of appropriate hardener form the usual mix. At room temperature the liquid life of hot-press glue is 24 hr. Normally the assembly period is ½ hr. or less. Pressure from 150 to 300 lb. per sq. in., at temperatures of 220° to 240° F., should be applied as soon as panels are laid up. When employing unextended resin, for panels with core up to and including ⅛ in., the minimum pressing time is 2 min. plus 1 min. for every 1/20 from the platen to the deepest glue line.

Special copolymer glues include one having a long assembly period (several days) for use in the autoclave system for forming plywood. In using this glue the plies are spread with a thin film of resin glue (15 to 20 lb. per 100 sq. ft.) and allowed to dry for an hour or more to facilitate easy handling. After this period the plies are relatively free from tackiness and may be laid together over the desired form and held in place by staples or tape. The assembly is enclosed in a rubber bag which is then evacuated and placed in an autoclave; hot water (200° to 212° F.) is introduced and the desired pressure obtained by applying air under pressure. The glue line is cured under these conditions for a period of time depending upon the thickness of the piece being glued.

The resulting bond is waterproof and is exceedingly strong. This type of glue is particularly recommended for aviation use, also for the formation of ribs for station wagons, and similar purposes.

PHENOL–FORMALDEHYDE GLUE FILM

This type of adhesive consists of a film of paper impregnated with an alcoholic solution of phenolic resin and subsequently dried and sold commercially in rolls of continuous sheet. When heated, the resin melts and sets into a hard waterproof bond, but its use is limited to instances where heat and pressure are available. The finished bond is strong, waterproof, and fungus-resistant.

In employing film glue it is essential that certain precautions be observed:

1. There must be sufficient pressure to bring the plywood surface into intimate contact. For this reason film glue presents some problems in formed plywood manipulation.
2. The moisture content of the veneers must be carefully controlled, and should never exceed 12 per cent. From 6 to 10 per cent is the optimum range.
3. The temperature must be controlled. Because film glues cure at 285° to 300° F., deterioration of rubber bags and wooden forms will occur if they are used for making formed plywoods.

Liquid Phenolic Resin. Liquid phenolic resins, which are solutions of phenolic resins in alcohol, are available. Stock may be prepared and kept in storage for two or three weeks before gluing. The precautions for film gluing must be observed when using the liquid glues.

PART IV

Manufacture of Plastics

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CHAPTER XIII

MANUFACTURING PROCESSES

The articles and flow sheets have been arranged according to this general plan:

- I. Thermosetting plastics
    - A. Condensation products
- II. Thermoplastic materials
    - A. Polymerization products
    - B. Cellulose derivatives
- III. Plastics derived from natural products.

Introduction. The following series of articles on the manufacture of some of the more important plastics includes one or more flow sheets accompanying each article.

These flow sheets are meant to give a composite picture of the steps which may be followed in the manufacture of a given plastic. They do not necessarily follow the procedure of any one manufacturer, nor are all the steps shown necessarily embodied in the commercial processes. For example, as far as is practical the ultimate raw materials have been indicated on the flow sheets, whereas in practice it is customary for the plastics manufacturer to use compounds already prepared (such as formaldehyde, acids) rather than raw materials such as water gas, limestone, coke, and others mentioned in the flow sheets.

Also, products as different as coating materials and molding-powders are often produced in entirely separate processes instead of in branches of the same process as shown in the flow sheets — because the type of resin used in one must often be different in composition, degree of polymerization, or other characteristics from the type used in the other. All the products have here been shown together on one chart so that by following any one path the major steps in the manufacture of the principal products of one plastic can be traced at a glance.

The articles accompanying each flow sheet mention alternate procedures, conditions of the reaction, difficulties encountered, and sometimes describe equipment used. In general they follow the flow sheets but go more into detail.

FLOW SHEETS ACCOMPANYING ARTICLES[1]

Thermosetting Plastics
- Phenol-formaldehyde molding compositions
- Cast phenolic resins
- Soybean-phenolic molding powder
- Urea plastics
- Melamine-formaldehyde plastics
- Two polybasic acids and two polyhydric alcohols most used in the production of alkyd resins
- Alkyd resins

Cellulose Derivatives
- Cellulose acetate plastics
- Cellulose nitrate for plastics
- Plastics from cellulose nitrate
- Ethyl cellulose plastics

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[1] **Key with flow sheet for phenol-formaldehyde.**

Cellulose Derivatives
- Lignin plastics
- Casein plastics — dry process
- Zein plastics

Thermoplastic Materials
- Vinyl ester resins
- Vinyl chloride-acetate copolymer
- Typical vinyl-aldehyde resin plastic
- Vinylidene chloride plastics
- Polyvinyl alcohol plastics
- Acrylic resins
- Polystyrene
- Cumarone-indene resin, used as a binder

Natural Products
- Cold-molded bituminous plastics

MANUFACTURE OF PHENOL–FORMALDEHYDE PLASTICS AND MOLDING COMPOSITIONS

Comparable resins are formed by combinations of many cresols, xylenols or related compounds with various aldehydes, but the most generally useful type is that made from phenol and formaldehyde.

Phenol is prepared by the distillation of coal tar by which means the related compounds cresol and xylol are also produced. In fact, phenol obtained in this way is contaminated with these other compounds. Synthetic phenol is prepared at moderate cost by the catalytic oxidation of benzene at high temperatures. Another method for preparing phenol is to treat benzene in the vapor phase, with or without a catalyst, with not more than one molecular equivalent of oxygen, under at least ten atmospheres pressure. The reaction is carried out in an autoclave at temperatures of 300° to 400° F. Formerly, benzene was chlorinated to chlorobenzene and treated with sodium hydroxide under pressure to yield phenol. See under Phenol, Raschig process.

The formaldehyde may be prepared by the oxidation of methanol, or directly from carbon monoxide and hydrogen.

In preparing the resins, phenol and formaldehyde are allowed to condense in a steam-jacketed chromium-lined or nickel reaction kettle under nonrefluxing conditions.

Either acid catalysts (usually sulfuric acid) or alkaline catalysts (usually ammonia or hexamethylenetetramine) may be used, but condensation will take place even in the absence of a catalyst. After the reaction has started, the heat of the reaction becomes so great that cold water is substituted for the steam in the kettle jacket to control the reaction.

The molecular ratio of 1:1, phenol to formaldehyde, is used to produce a thermosetting molding compound. If a greater proportion of phenol is employed, a permanently soluble and fusible, though hard, resin may be obtained. This is suitable for use as varnishes and lacquers.

In the presence of an acid catalyst the reaction tends to go to completion rapidly. With such a catalyst a low percentage of formaldehyde will form permanently fusible or nonpolymerizing resins which may be dehydrated easily by heating. These resins may be converted to the infusible type by reheating with more formaldehyde or by adding a formaldehyde derivative such as paraformaldehyde or hexamethylenetetramine.

The formaldehyde employed in the reaction may be either the 37 per cent aqueous solution known as formalin or the dry form, paraformaldehyde.

When equal proportions of formaldehyde solution and phenol are used the mixture forms two layers after a few hours' heating. The lower layer consists of the sirupy condensation product and the upper one of water. The water may be removed by

KEY TO FLOW SHEETS

Boxes indicate operations or apparatus used during a particular stage of the process.

Circles indicate basic materials used.

Dotted circles indicate materials which may be used at the discretion of the manufacturer, or to produce special effects.

Arrows indicate the direction of flow.

Dotted connecting lines indicate optional paths to be followed, or supplementary processes. Dotted lines have not been used where either of processes of equal merit may be used.

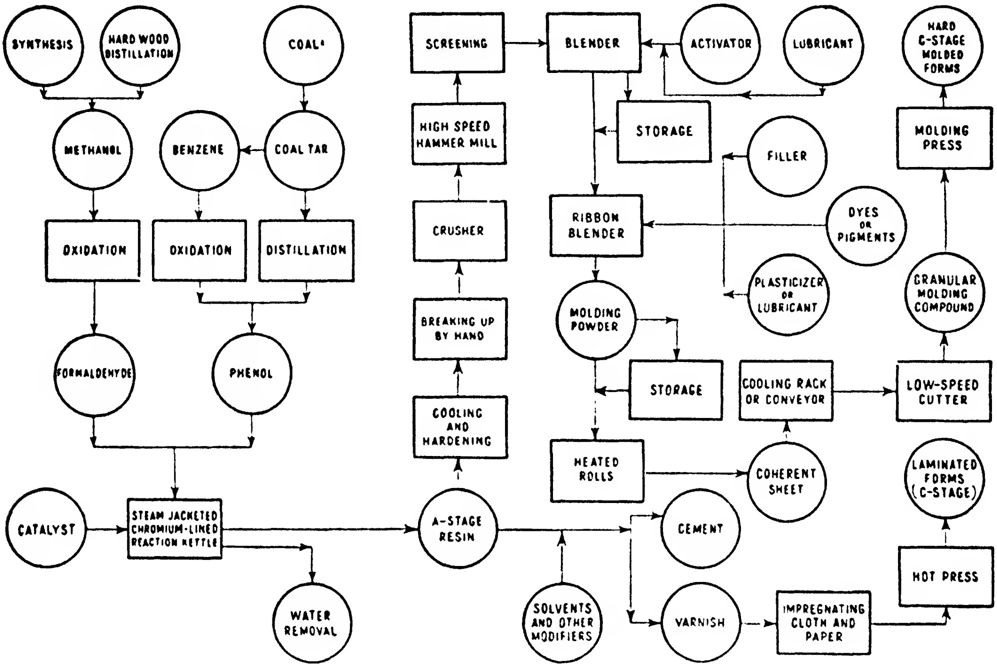

FIG. 13.1 — Manufacture of phenol-formaldehyde molding compositions.

decantation and the lower layer heated (usually in vacuum) to eliminate as much of the remaining water as possible. The condensation sirup is then run quickly into pans to cool to solid resin. Thorough elimination of the water results in the formation of a clear transparent product.

While the resin is still in the reaction kettle, care should be taken to keep the walls and surface of the container free from a crust of hardened resin which will tend to insulate the rest of the contents, and may interfere with the handling of the liquid portion.

Tests to determine whether the reaction is complete consist in determining the viscosity of samples of the resin at frequent intervals. The hardened resin is tested for solubility and for polymerization time at various temperatures.

In the manufacture of molding powders, the hardened resin is taken from the pans and broken up into large lumps and placed in a crusher, where the size of the pieces is reduced. These pieces are further ground in a high-speed hammer mill until they pass a 200-mesh screen. The powder is then blended with a small amount of lubricant (calcium stearate) in a ribbon blender and, if an acid catalyst was used, with a small percentage of hexamethylenetetramine to act as an activator. The soluble, fusible, hard resin in the cooling pans often is called the A-stage resin, and the final molded and infusible product less frequently is called the C-stage resin.

To produce different grades of molding powder, the basic powder is placed in a ribbon blender and mixed with plasticizers, additional lubricant, pigments if desired, and filler, usually wood flour. Mineral fillers such as asbestos, mica, and talc are also frequently used. The blended material may be molded as such, or may be prepared in various size granulations or in pellet form. It may be passed between heated rolls to reduce it to a plastic sheet which then cools on a rack or conveyor to a rigid sheet. This can be fed into a low-speed cutting machine and cut to the desired granulation, screened, and the oversize particles passed through the cutter again. A final blending is often made with other batches of the material or any other modifying substance.

Phenol-formaldehyde molding compounds are available in a great variety of modification, some being designated as follows:

Acid resistant
Alkali resistant
Arc resistant
Buffing type
Closure type
Extrusion type
Friction resistant
General purpose
Heat resistant
High dielectric
High impact
Moisture resistant
Non-bleeding
Sanding type

Because of the natural tendency towards an amber color in phenolics, they are seldom made in light colors. Dark red, brown, black, or a dark mottle are most frequently used. The general purpose material has a wood flour filler and is usually black or brown.

A formula for a typical molding compound:

	Pounds
Phenol	42
Formaldehyde	27
Wood flour	52
Hexamethylenetetramine	3.7
Sulfuric acid	0.1
Black nigrosin dye	1.3
Calcium stearate	0.7

MANUFACTURE OF CAST PHENOLIC RESINS[2]

Cast phenol-formaldehyde resins were introduced in this country early in 1928. By 1933, the total sales volume had jumped to 2,800,000 lb. Production for 1941 was well over 6,000,000 lb.

Chemistry of Cast Phenolic Resins. Before the advent of cast phenolic resins in 1928, it was customary to prepare liquid phenolic condensation products by reacting boiling phenol and formaldehyde, usually in equimolecular proportions, in the presence of a catalyst, e.g., ammonia, fixed alkalies or acids, until the clear mixture clouded to a water-insoluble product. On cooling, the liquid resin settled because of its higher

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[2] Prepared by the Catalin Corporation.

gravity, leaving a supernatant water layer. Since such resins have little affinity for water, the modern colloid chemist classifies them as *hydrophobic systems.*

By varying the conditions of the initial condensation reaction between phenol and formaldehyde, it is possible to prevent the separation of the resin phase even after acidification and cooling. To accomplish this, the manufacturer uses first relatively high mol ratios of formaldehyde. In practice it is usually two parts by weight of 37 per cent formaldehyde to one part of synthetic U.S.P. phenol. Secondly, and of no less importance, is the amount of fixed alkali used as a catalyst to cause the actual resinification between the phenol and the formaldehyde. This varies between 15 and 30 gm. per 1000 gm. of phenol, depending upon the properties desired in the final product. The third prerequisite is an optimum time period for the chemical reaction. The proper balance between amount of catalyst and time of reaction will secure a resin which when acidified will not precipitate from its water solution when it is cooled to 10° F.

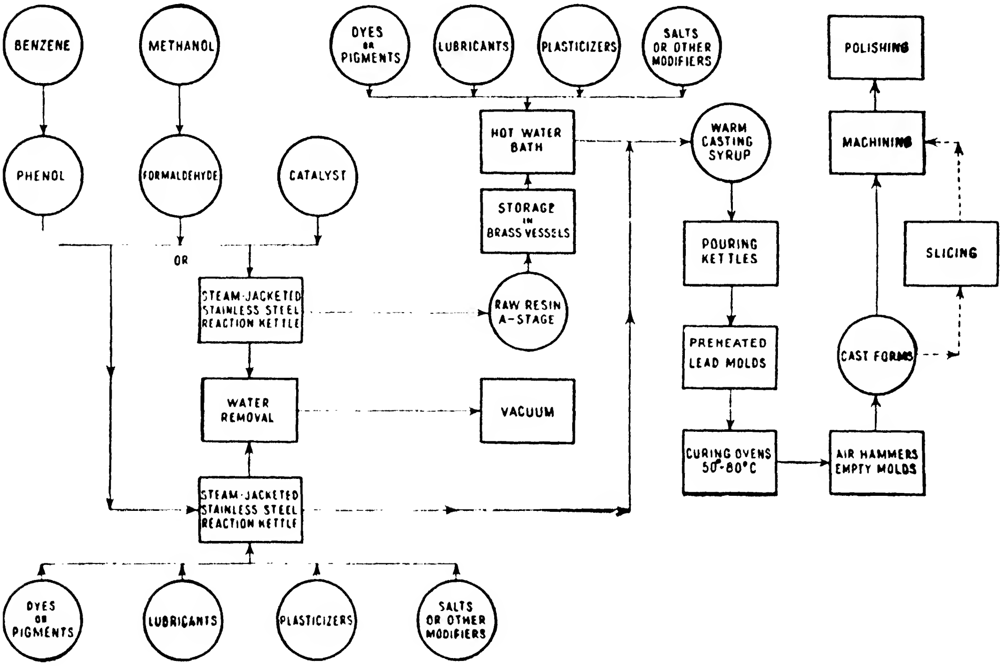


FIG. 13.2 — Manufacture of cast phenolic resins. (Key on page 475.)

The fourth feature of the process is the use of lactic and/or phthalic acid added at the end of the condensation to neutralize the free alkali. No acid has been found to equal lactic acid. The chemical structure — asymmetric carbon atom, hydroxy and carboxylic groupings — is intimately associated with the classification of the resin on acidification. Other acids that are too expensive but seem to follow such reasoning are alpha hydroxy isobutyric and salicylic. Lactic acid has the further advantage that its sodium salts are exceedingly soluble in the small amount of water that is finally allowed to remain in the resin. This prevents the formation of minute crystals in suspension, which might act as cleavage points to lower the tensile strength of the finished product.

If the four conditions are followed carefully, a light-colored, wholly water-soluble resin is obtained. In contrast to the water-insoluble *hydrophobic* resin these newer water-soluble phenolics are known as *hydrophilic* products. A combination of all four features must be used to give the ideal hydrophilic resin.

In actual practice it is customary to bring about the initial chemical reaction or condensation at a lower temperature of approximately 70° F. for 2½ to 3 hr. The principal reason for the low-temperature process is better control over the strong exothermic reaction. This heat of reaction for a phenol-formaldehyde ratio of 1 to 2.35 using 3 per cent of the phenol as caustic soda is 158.9 B.t.u. per lb. of reactants. Dissipating the heat through the water-cooled jacket of the reaction vessel makes it comparatively easy to obtain precise temperature control for large kettle batches and also provides a more economical use of kettle space. On high-temperature reactions careful supervision is required to prevent "super-condensation" at 104° or even 106° F. which may seriously affect the hydrophilic character of the resin.

Vacuum Dehydration. At this stage the resin is chemically a mixture of several phenyl alcohols, as such or in chemical combination with one another as a result of the elimination of a molecule of water. Yet the average molecular size cannot be large since the initial resinous condensation product contains upward of 40 per cent of water, which is removed by heating the resinous mass in a jacketed kettle to a final temperature of 75° to 85° C. (167° to 185° F.) under vacuum at a pressure of 30 to 50 mm. of mercury. For 1600-lb. batches the time cycle may be from 10 to 15 hr. The rise in viscosity during dehydration under heat is not only attributable to the elimination of the solvent water but is paralleled to a marked degree by the increase in molecular dimensions.

Accurate control on the viscosity and indirectly on the water content at the end point of the dehydration may be determined theoretically by any one of a number of standard viscosity measurements, although a falling ball or hardness determination of the chilled resin at 10° C. (50° F.) is preferred.

The properly dehydrated product is a light-colored or water-clear resin having a moisture content, depending upon formulation, from 5 to 12 per cent. It is fusible and soluble, and has a honeylike consistency. In this condition it is poured hot into open lead molds, split molds, glass molds, etc., preparatory to an oven cure at 70° to 80° F. for 3 to 7 days.

Naturally, the rate of heat hardening or polymerization to produce the final infusible, insoluble resin is primarily determined by formulation and operating procedure. The addition of plasticizers increases the cycle. In general, excess formaldehyde, low pH, low water content, and high condensation tend to lower the time of oven operation.

The curing rate, however, cannot be too fast or the air bubbles that are admixed with the resin at the time of pouring will not have sufficient time to rise before the initial gelation or heat hardening.

The steam-heated ovens for curing are 12 by 20 by 9 ft. in height and are capable of curing up to 8000 lb. of resin during one operating cycle. Positive circulation of hot air in all parts of the oven is accomplished by using adjustable louvres in the sides of the units through which the hot air is uniformly circulated from a thermostatically controlled heating unit.

The end point of the polymerization or oven-curing cycle is carefully controlled by removing samples periodically from each run and testing for hardness on a Rockwell machine. Fortunately, the tensile strength goes hand in hand with hardness. Maintaining accurate hardness specifications assures a product having adequate tensile strength for fabricating operations.

Photomicrographic studies have thrown light on the colloidal structure of cast phenolic resins. The continued accumulation of technical data has assisted greatly in improving manufacturing operations.

Colorability. One of the most important phases of operations in the manufacture of cast resins is the wide use of dyestuffs and pigments to obtain pleasing color effects. These range from the most vivid reds, greens, and blues to the softer and more subtle shades of brown, beige, or gray. The importance of color may explain in part the tremendous growth of plastics in our daily lives, because there is no medium better adapted to portray color.

In coloring cast resins both dyestuff and pigment must be chosen for their stability to chemical action, heat, and light. Since the color must be incorporated with the unfinished reactive liquid resin, it must wholly resist the severe action of the phenyl alcohols, free formaldehyde, and lactic acid. For many coloring agents this is rough treatment, not to mention the heat hardening of the plastics at 78° to 80° C. (172° to 196° F.) for 3 to 7 days.

Important, of course, is the resistance of all phenolic resins to sunlight conditions. An accelerated test can be made by exposing the finished product to the ultraviolet light of the carbon arc. Several hundred dyestuffs and pigments have been tested in this manner during the last 8 years. The investigation covered many classes of coloring materials, i.e., basic dyes, acidic dyes, triphenylmethane, sulfur colors, vat dyestuffs, and inorganic pigments. Of all the colors tested, only twenty qualify as satisfactory, and they do not represent a particular type of dyestuff but cover many groups of colors.

Physical Properties. The importance has been stressed of the hydrophilic character of cast resins and the separation of the minute water droplets during the heat hardening. Cast resins owe their exceptional machinability and remarkable physical properties to this structure.

Just as fillers in the older phenolic molding powders relieve internal stresses and strains, so the presence of the aqueous phase in cast resins gives a more stable and balanced system. A comparison of the physical data shows remarkable similarity with little preference for either material.

The specific gravity of cast resins varies from 1.31 to 1.33. They are nonflammable and possess little or no odor and are tasteless.

For special applications where it is necessary to obtain an extremely inert surface, a short heat treatment at 75° to 80° C. is recommended for 24 to 48 hr. after the cast resin is fabricated. This casehardening operation removes the volatiles, principally uncombined formaldehyde and a small amount of water, and further improves the stability.

Application of Cast Resins. The trend in cast resins has been to approach as nearly as possible the finished fabricated article. This practice applies not only to small items such as knife handles, brush backs, pipe stems, and the like, but also to large panels and pilasters used for facing cigarette vending machines and automatic phonographs.

Such practice demands skill and ingenuity in the design and construction of the " master pattern " or arbor used to prepare the open lead molds. For the manufacture of simple round rod castings used in the fabrication of buttons, the arbor has the same dimensions of length and diameter. When the cold pattern is dipped vertically into molten lead and immediately withdrawn, it is enveloped with a thin continuous coating of crystallized lead. Sufficient taper is allowed in the arbor construction so that the lead mold can be removed with only slight jarring. This simple procedure is in contrast with the complex dipping arbor for the preparation of radio housing molds which must be provided with an intricate grill, dial, and control openings. Many complications are involved in tool design. All arbors must have vertical or slightly tapered sides. Naturally, no undercuts are permissible.

Since there are definite limitations to the so-called profile castings made by the ordinary dipping arbor, supplying castings made in three-dimensional split molds is important. This new molding procedure permits more complicated designs and other features formerly obtainable only through expensive engraving and high fabricating costs.

Technical Cast Resins. Not long ago Dr. Raschig announced the commercial production of cast technical resins in Germany. A similar product is now available for specific industrial applications. In addition to the physical and chemical properties of standard cast resins, including high tensile, compressive, and flexural strengths, cast technical resins are inert to a large number of organic solvents including alcohols.

They will withstand organic and many inorganic acids, either alone or in aqueous solution, even at elevated temperatures. One application in particular showed the product unattacked when subjected to a 50 per cent sulfuric acid solution at 120° F. for 5 hr.

Among the suggested industrial uses are linings for chemical tanks, noncorrosive pipe lines, production of noiseless gears, etc.

Although the basic color is a translucent ivory, it can also be offered in a limited number of attractive colors.

Manufacture of Soybean–Phenolic Molding Powder

No soybean protein plastic comparable to casein has been made commercially but much progress is being made with soybean-phenolic materials.

One type is made up of about equal parts of phenolic resin, wood flour and soybean meal from which the oil has been extracted with solvents. (The soybean meal may be hardened with formaldehyde.) This gives a moldable plastic with a water absorption (about 3.0 per cent) lower than that of casein (12 to 20 per cent) but higher than that of straight phenolic material (0.5 per cent). These modified soybean plastics have nearly as great impact strength and flexural strength as the straight phenolic plastics and are more easily dyed light colors.

A typical formula for soybean-phenolic molding powder is as follows:

	Pounds		*Pounds*
Formaldehyde	250	**Soybean meal (extracted)**	330
Ammonia	26.3	**Wood flour**	396.6
Phenol	250	**Lime**	26.3
Alcohol	33	**Water**	12.4
Pigments	75	**Stearic acid**	4.1
Hexa	26.3	**Zinc stearate**	4.1

The phenolic resin is first prepared by reacting the phenol and formaldehyde in a large stainless-steel, steam-jacketed reaction kettle, usually in the presence of an alkaline catalyst (ammonia). The other ingredients are added and the batch is then mixed, first in a steam-jacketed mixing vessel, then in a banbury mixer until thoroughly homogeneous.

After this it is dried and ground in the usual way, and screened. The molding powder which emerges from the screening operation is finally blended with lubricants such as stearic acid, zinc stearate, or calcium stearate. Hexamethylenetetramine is usually added as an activator for the phenolic material.

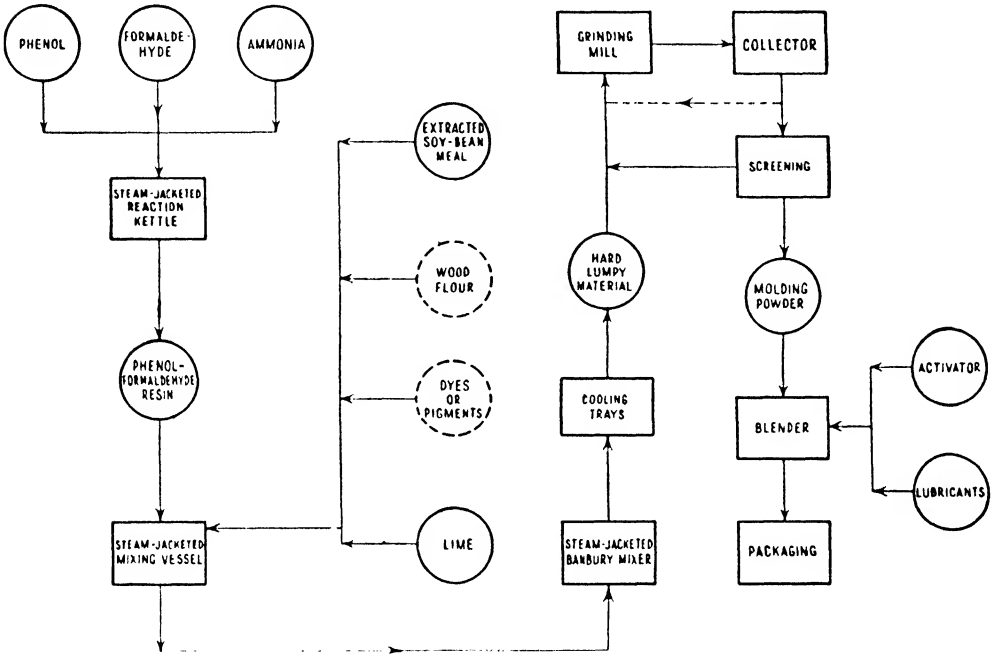


FIG. 13.3 — Manufacture of soybean phenolic molding powder. (Key on page 475.)

Molding powders of this general type have been produced for phonograph records and bottle caps.

Laminated materials can be produced by impregnating heavy paper such as kraft paper with a water dispersion of the soybean protein, drying to about 12 per cent moisture content, and curing in a hot press. The resultant lamination compares favorably with phenolic laminated in strength and rigidity, but is of course inferior in water resistance.

MANUFACTURE OF UREA PLASTICS

It can truly be said that urea plastics can be made from coal, air, and water, and the urea plastics industry probably owes its development to this fact. It was necessary to find processes by which the raw materials for urea plastics could be prepared synthetically from readily available materials at low cost, before these plastics could reach industrial importance.

Urea (NH_2CONH_2), the essential ingredient in this plastic, is now prepared cheaply by heating together carbon dioxide and ammonia at a pressure of 50 to 100 atmospheres. Ammonia (NH_3), which is often used as an addition to the reaction mixture as well as a raw material for urea, is also prepared synthetically from nitrogen and hydrogen. Thiourea ($NH_2S{\cdot}NH_2$), which is often used as a partial substitute for urea in these plastics to improve their properties, is made by reacting calcium cyanamide and ammonium sulfide.

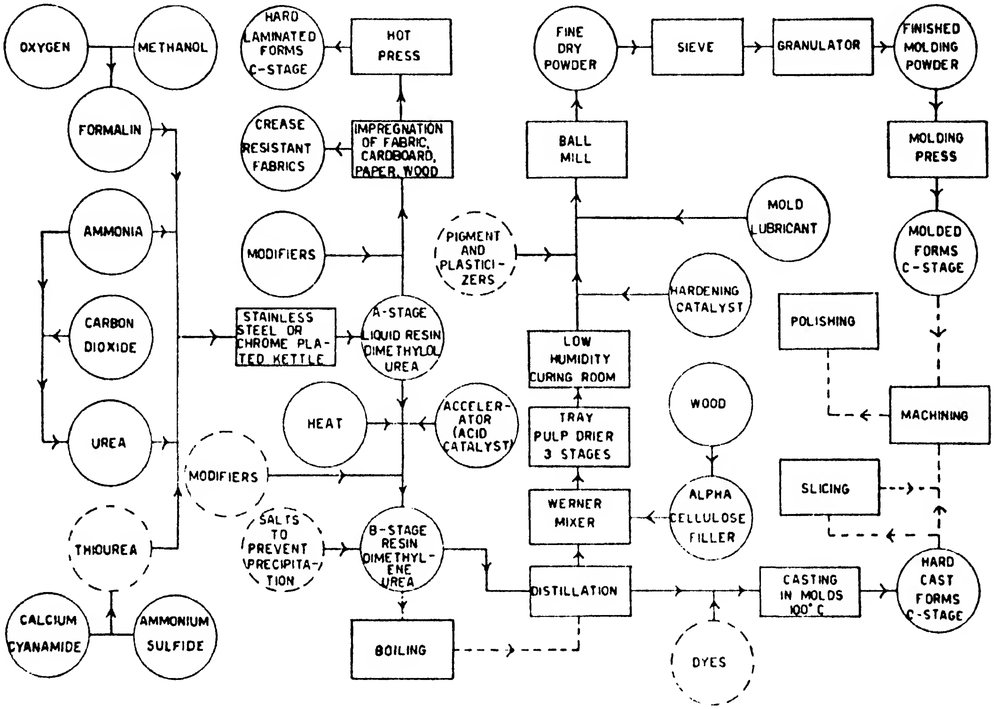


Fig. 13.4 — Manufacture of urea plastics. (Key on page 475.)

$$CaNCN + (NH_4)_2S \longrightarrow NH_2S{\cdot}NH_2 + NH_4 + CaCN$$

The formaldehyde used in the reaction may be prepared from methyl alcohol, which in turn is prepared from hydrogen and carbon monoxide.

$$\underset{\text{water vapor over red hot coke}}{H_2O + C} \longrightarrow \underset{\text{water gas}}{H_2 + CO}$$

$$CO + 2H_2 \xrightarrow[\text{catalyst, high pressure}]{} \underset{\text{methyl alcohol}}{CH_3OH}$$

$$2CH_3OH + O_2 \xrightarrow[\text{metallic silver or copper}]{300^\circ C} 2HCHO + 2H_2O$$

The formation of urea resins takes place in three stages. First, a quantity of neutralized formalin, urea, thiourea if desired, and a small amount of ammonia are allowed to stand in the cold for about 2 hr. to react, forming a transparent, liquid, A-stage resin which contains about 60 per cent condensation product. The character of the reaction product depends on whether an acid, a neutral, or an alkaline condensation medium is used. In the presence of ammonia or other alkaline condensing agents, mono- and dimethylolurea, both crystalline compounds, are formed. A stainless-steel reaction kettle is used with chromium plating as alternative if the mixture contains thiourea. Theoretically, one molecular proportion of urea to two of formaldehyde should be used, but practically the formaldehyde ratio must be reduced to 1.5:1 to reduce the tendency to form gas bubbles during molding.

$$\mathrm{CO}\!\left\langle\begin{array}{l}\mathrm{NH_2}\\ \mathrm{NH_2}\end{array}\right. + \quad 2\mathrm{HCHO} \longrightarrow \mathrm{CO}\!\left\langle\begin{array}{l}\mathrm{NHCH_2OH}\\ \mathrm{NHCH_2OH}\end{array}\right.$$

1 molecule urea + 2 molecules formaldehyde → 1 molecule dimethylolurea

If the reaction is carried out carefully in cold alkaline solution an almost quantitative yield of dimethylolurea is obtained.

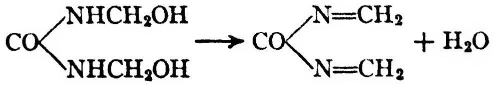
The A-stage resin may be used for the impregnation of paper, cardboard and fabrics, and may then be hardened by heat. Impregnated sheets may be laminated and hardened under heat and pressure to form decorative, strong, resistant boards and panels. Liquids for impregnating and laminating are frequently modified with other materials such as phthalic anhydride and glycerol, the latter helping to fix excess formaldehyde.

A preparation suitable for impregnating may be prepared from urea, formalin, and 1.5 per cent phthalic anhydride, refluxing the mixture at 90° F. and evaporating in vacuum until a sirup is formed. Phthalic anhydride glycerol esters make good plasticizers for these materials.

Fabrics may also be impregnated with the A-stage resin and squeezed almost dry before being subjected to conditions which convert the resin to the C stage, to produce modified, crease-resistant materials.

A convenient solution for treating fabrics contains 20 parts of 40 per cent formaldehyde solution, 10 parts of urea, 5 parts of boric acid, and 60 parts of water by weight. The fabric is immersed at room temperature, removed, squeezed, dried at 130° F. and held at room temperature for 3 min. Excess uncondensed reagents are removed in boiling soap solution. Acid catalysts should be used for the final condensation, to give a non-crush effect more resistant to washing. Adding a catalyst to the urea formaldehyde mixture, boiling for 5 min , and cooling rapidly converts the mixture to the A-stage resin, making possible repeated impregnations with more dilute solutions. A-stage urea resins are widely used as adhesives in solution.

If it is desired to make plastics from the resin, dimethylolurea must be converted or made to form a gel. This is done with the elimination of water, and is characterized by a gradual change through a viscous liquid to a gel, as polymerization of the resin proceeds. With an acid catalyst and elevated temperature, the dimethylolurea later polymerizes.



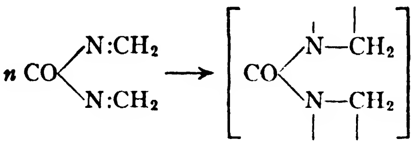
$$\mathrm{CO}\!\left\langle\begin{array}{l}\mathrm{NHCH_2OH}\\ \mathrm{NHCH_2OH}\end{array}\right. \longrightarrow \mathrm{CO}\!\left\langle\begin{array}{l}\mathrm{N{=}CH_2}\\ \mathrm{N{=}CH_2}\end{array}\right. + \mathrm{H_2O}$$

B stage

The uncombined water is not eliminated at this stage.

Gelatinization is spontaneous and is accelerated by heat and by the addition of 1 to 5 per cent of a neutral salt. It may be delayed or prevented by salts of the alkali metals with weak organic or inorganic acids, such as sodium acetate. Ammonium salts and acid salts may cause immediate gelatinization. In the presence of thiourea no acceleration is needed.

The final polymerization or heat hardening is brought about by the polymerization of dimethylene urea.



If cast resins such as Pollopas or " organic glass " are to be produced, the pH of the condensation liquid is adjusted, and various modifiers added. Glycerol is added to facilitate removal of the water, as well as neutral salts to prevent turbidity during the hardening. The partially polymerized liquid is distilled to a thick sirup, dyes being added if desired, and is cast into molds. Large pieces may be cast in this way, but there is some tendency to crack because of unequal evaporation from the top and sides of the mold. A mold of porous material impregnated with a semipermeable membrane which allows passage of the solvent may be used, but has certain disadvantages. Polymerization with the elimination of water to form the C-stage resin is effected with heat. Cast blocks of the resin may be sliced or machined and polished.

If molding powder is to be produced, the intermediate resin is boiled to increase its viscosity and start the polymerization. The most stable material, used in molding powders, is produced by polymerizing one molecule of monomethylolurea with one of dimethylolurea. Thiourea is sometimes used in molding powders, though progress has been made in improving the straight urea plastics to eliminate the thiourea. Thiourea-formaldehyde resin is distinctly different from urea-formaldehyde, and it is believed that urea-thiourea resin is also a definite compound and not a mixture of the two resins.

The viscous condensation liquor may be mixed with salts to prevent precipitation before it is vacuum distilled to form a partly polymerized thick sirup. Passage of a stream of dry air or inert gas through the liquid during distillation helps remove volatile impurities. The sirup is then poured out and mixed with about one third its weight of alpha-cellulose filler (sulfite wood pulp or wood flour) in a Werner mixer, and mixed at about 45° C. (113° F.). The wet pulp so obtained is spread in trays to dry, at a temperature not above 90° C. (194° F.). Drying is usually carried out in three stages, followed by storage in a low-humidity curing room. After thorough drying, the material is ball milled until it has been ground to an impalpable powder. Pigments, a small amount of mold lubricant such as zinc stearate, about 1 per cent of a solid acid substance as hardening catalyst, and various other modifying agents are added during the milling operation. Hexamethylenetetramine or its salts may be added to prevent loss of flow properties after storage; triphenyl phosphate may be added as a plasticizer, and sucrose may be added to prevent cracking during heat hardening.

After milling, the powder is sifted through fine muslin and densified or put through a granulator to form granules of the desired size. The finished molding compound, powder or granule, emerges.

During the application of heat and pressure in molding, the polymerization is completed. Two molecules of water are lost and the resultant product is believed to have the composition $C_5N_4H_{10}O_3$. The resins are molded at 285° to 315° F. and pressures of 3000 to 6000 lb. per sq. in. The rate of setting depends on the temperature applied, the form of the part, and the curing agents present. The finished part will not soften under heat and is insoluble.

A typical recipe for preparing 100 lb. of molding compound:

	Pounds
Urea	42
Formaldehyde (37.5 per cent sol.)	42
Cellulosic filler	40
Curing agent and lubricant and dye	1.8

Urea resins are too brittle to be worked up easily into satisfactory coatings but the urea- and thiourea-formaldehyde resins can be vulcanized by means of polysulfides either before or after condensation and the products worked up into lacquers containing oil, spirit, or Cellosolve. Glycerol-phthalic anhydride plasticizers may be used with urea resins to produce varnish coatings, and attempts have been made to produce varnish solutions by performing the condensation in solution in high boiling solvents such as Cellosolve or other substituted glycols.

MANUFACTURE OF MELAMINE–FORMALDEHYDE PLASTICS

Melamine, or 1, 2, 5 triamino, 2, 4, 6 triazine, is the most promising of the azines that can be condensed with formaldehyde to form resinous products. Melamine plastics are being developed rapidly because of recently discovered methods of producing the source material from dicyanodiamide.

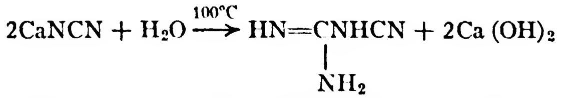
Dicyanodiamide is produced from calcium cyanamide, in turn produced from nitrogen and calcium carbide, which can be made from coke and lime.

$$5C + 2CaO \longrightarrow 2CaC_2 + CO_2$$

coke and lime = calcium carbide and carbon dioxide

$$CaC_2 + N_2 \xrightarrow{\Delta} CaNCN + C$$

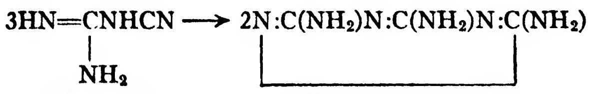
calcium carbide and nitrogen, heated in electric furnace, yield calcium cyanamide and carbon



$$2CaNCN + H_2O \xrightarrow{100°C} HN{=}\underset{\underset{NH_2}{|}}{C}NHCN + 2Ca(OH)_2$$

calcium cyanamide and water yield dicyanodiamide and calcium hydroxide

When dicyanodiamide is heated to high temperature in an autoclave, usually with liquid ammonia and often in the presence of another organic solvent, melamine is produced.



$$3HN{=}\underset{\underset{NH_2}{|}}{C}NHCN \longrightarrow 2N{:}C(NH_2)N{:}C(NH_2)N{:}C(NH_2)$$

dicyanodiamide melamine or cyanurotriamide

Melamine can also be produced using $CNNH_2$, NH_4SCN, methyl sulfocyanurate, or cyanuric chloride as a starting material. Although the conversion of dicyanodiamide to melamine used to be accomplished by heating the dicyanodiamide with a large amount of ammonia, it has been found that the yields are higher if less ammonia is used, and it is possible to omit the ammonia. Often the dicyanodiamide is dissolved in some solvent such as methanol or monoethanolamine, or various other alcoholic or ketonic solvents, but liquid ammonia alone may be used. Pressures up to 3 atmospheres may be employed, and a temperature of 100° to 150° C. (212° to 302° F.). The product of the reaction is blown out into a cooled receiver. A variation is to pass the dicyanodiamide, dissolved in liquid ammonia, continuously through a heated reaction tube, the liquid product being withdrawn through an outlet valve or a suitable nozzle. The melamine produced in this way may be filtered and washed if necessary, though certain patented processes claim to give a product in an almost completely pure state.

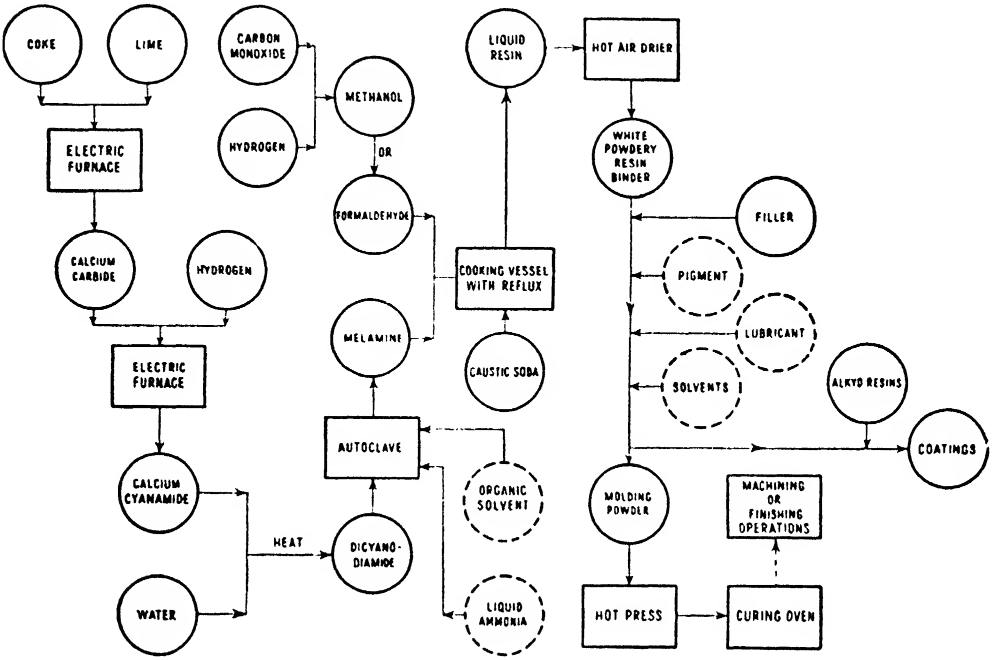


Fig. 13.5 — Manufacture of melamine formaldehyde plastics. (Key on page 475.)

Melamine as well as other azines can be condensed with aldehydes, alcohols, and carbohydrates to form resinous products. The melamine-formaldehyde resins can be used to produce molding powders and molded articles and with alkyd resins to produce light-colored coatings and baking finishes. They are somewhat similar to urea-formaldehyde resins and are thermosetting. So far, their chief commercial use has been as a binder, especially in insulating and in abrasive compositions.

For example, melamine aldehyde resins used in place of ceramic binders in resistors for lightning rods or other electrical uses are prepared as follows:

A mixture of 126 parts of melamine to 162 parts of 37 per cent aqueous formaldehyde is adjusted to a pH of from 7.2 to 9.0 by the addition of caustic soda. This sirupy mixture is refluxed for 10 min. and then sprayed at a rate of about 10 lb. per min. into a hot-air drier, the interior of which is kept under a 2-in. vacuum. The white resin powder that condenses may be discharged continuously from the container.

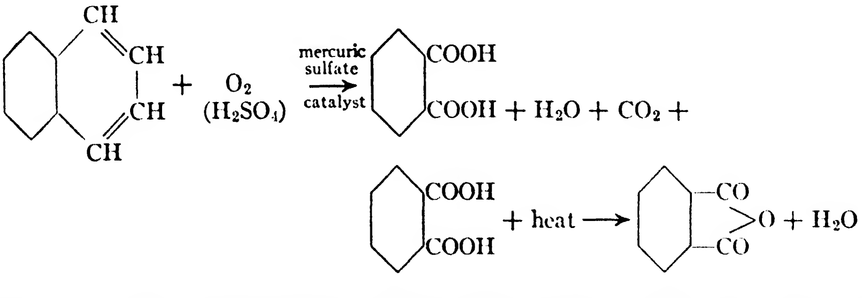
One part of this resin mixed with four parts of silicon carbide and a small percentage of flake graphite makes a suitable molding composition, the molded parts being superior to ceramics in that they do not crack when baked and are never weakened and may be strengthened by the high temperatures engendered by heavy electrical loads.

In making melamine-resin binder for abrasive wheels, a resin is first prepared from one part of melamine to two or more of formaldehyde. It is desirable to wet the grit particles with a partial ester of a polyhydric alcohol before adding the resin. About 1000 parts of aluminum oxide 40-mesh abrasive grit may be wetted with 50 to 250 parts of ethylene glycol monoformate in a mixer and 100 to 150 parts of spray-dried melamine-formaldehyde resin and 0.5 to 1 part of phosphoric acid slowly mixed in. When an apparently homogeneous, substantially free-flowing dry powder is formed, it may be molded under pressure and cured in an oven at about 80° C. (176° F.) for several hours and finally at 100° to 150° C. for a further period.

Manufacture of Alkyd Resins

Alkyd resins result from the condensation of polybasic acids with polyhydric alcohols. The polybasic acid most frequently used in the manufacture of alkyd resins is phthalic anhydride, and the most frequently used polyhydric alcohol is glycerin. The resin resulting from the condensation of these two compounds is also known as a glyptal. It has excellent electrical properties and is a good coating material, but is expensive.

Phthalic acid is prepared by the oxidation of naphthalene. Formerly this was accomplished by using fuming sulfuric acid as the oxidizing agent and mercuric sulfate as the catalyst, the sulfur dioxide so produced being reoxidized by air in a contact sulfuric acid plant to form sulfur trioxide again. From this sulfur trioxide more fuming sulfuric acid could be prepared. Phthalic anhydride is prepared by heating phthalic acid slightly above its melting point.



The more modern method, known as the Gibbs process, makes use of the catalytic action of the oxides of certain of the rare metals to combine naphthalene with the oxygen of the air. Since phthalic acid readily loses water, phthalic anhydride is produced. The reaction is carried on at a temperature of about 250° C. (482° F.), and if the conditions of the reaction are not carefully controlled, either the naphthalene will remain unchanged or combustion will take place.

Another polybasic acid frequently used in the production of alkyd resins is maleic acid. This is prepared in a manner similar to that used for the preparation of phthalic anhydride. The catalytic oxidation of benzene, a coal tar product, in the presence of air and a metallic oxide catalyst at 400° to 500° C. (752° to 932° F.) results in the production of maleic acid, which readily loses water to yield maleic anhydride as a final product.

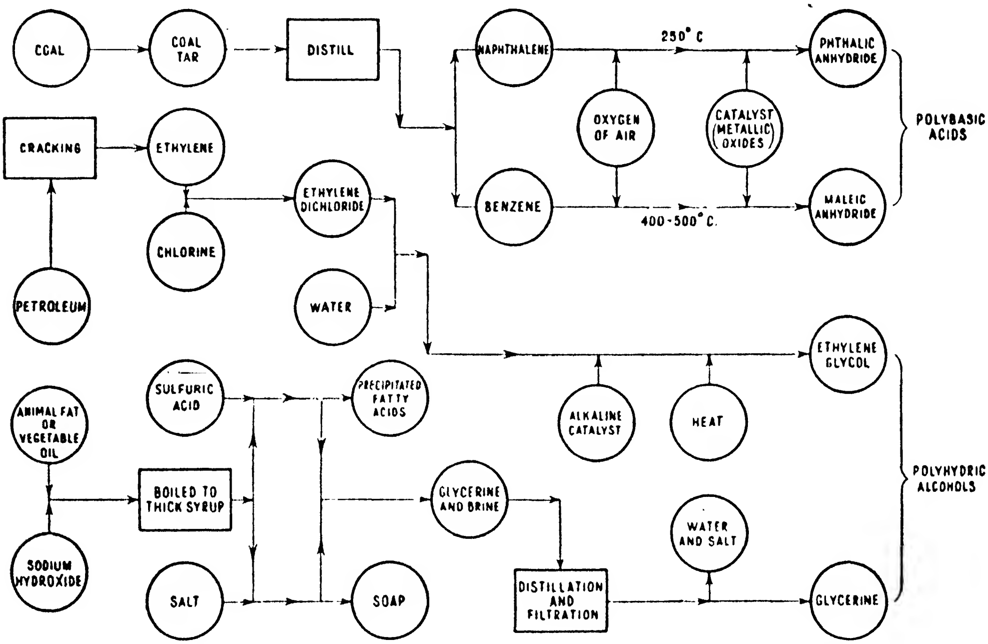
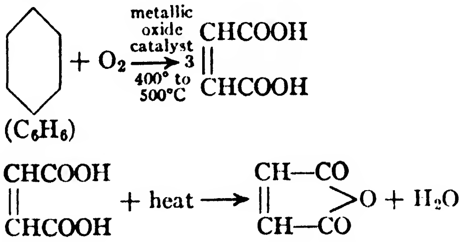


FIG. 13.6 — Manufacture of two polybasic acids and two polyhydric alcohols, most used in the production of alkyd resins. (Key on page 475.)



$$(C_6H_6) + O_2 \xrightarrow[400^\circ \text{ to } 500^\circ C]{\text{metallic oxide catalyst}} 3 \begin{array}{l} CHCOOH \\ \| \\ CHCOOH \end{array}$$

$$\begin{array}{l} CHCOOH \\ \| \\ CHCOOH \end{array} + \text{heat} \longrightarrow \begin{array}{l} CH—CO \\ \| \qquad\quad >O \\ CH—CO \end{array} + H_2O$$

Other polybasic acids used in the production of alkyd resins are as follows:

- Malic
- Citric
- Glycollic
- Tartaric
- Fumaric
- Oxalic
- Malonic
- Succinic
- Adipic
- Pimelic
- Suberic
- Azelaic

The two most frequently used polyhydric alcohols are glycerol and ethylene glycol.

Glycerol is prepared by boiling an animal fat with sodium hydroxide, adding sulfuric acid to precipitate the insoluble fatty acids, and distilling off the separated water solution to leave the glycerol which can be purified by further distillation. Glycerol is a by-product of the manufacture of soaps.

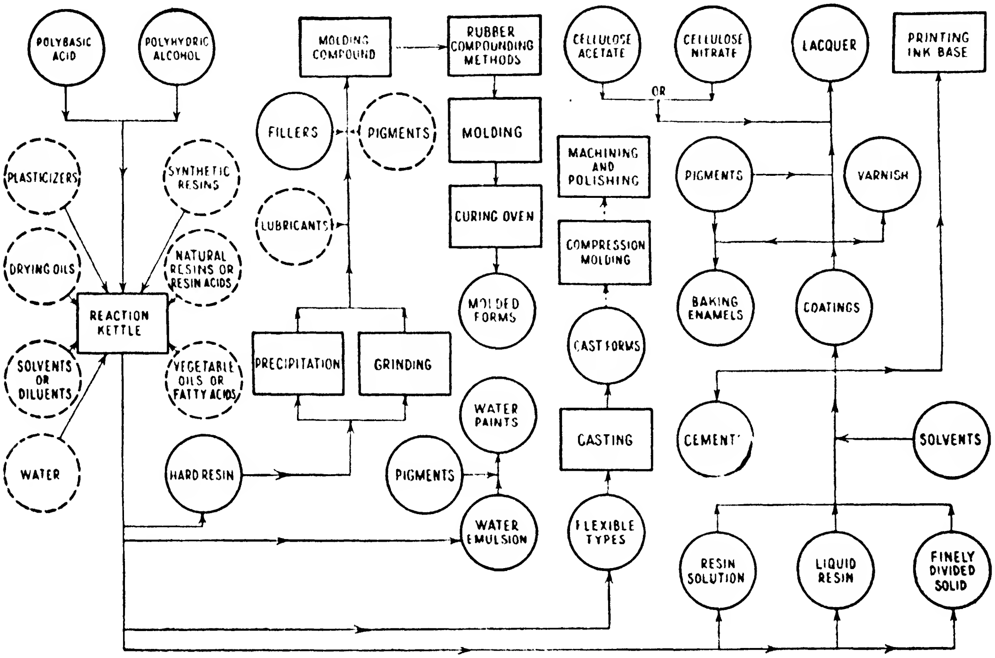


FIG. 13.7 — Manufacture of alkyd resins. (Key on page 475.)

Ethylene glycol is prepared industrially from ethylene by various methods. One method is to treat the unsaturated hydrocarbon ethylene with hypochlorous acid, forming ethylene chlorohydrin, which is both a primary alcohol and an alkyl halide. By treating ethylene dichloride with dilute alkali or heating it under pressure with water, ethylene glycol is formed.

$$\begin{array}{l} CH_2Cl \\ | \\ CH_2Cl \end{array} + H_2O \longrightarrow \begin{array}{l} CH_2OH \\ | \\ CH_2OH \end{array} + HCl$$

Another industrial method is to convert the chlorohydrin to ethylene oxide, a cyclic ether, by means of sodium hydroxide. Heating the oxide with water in the presence of an acid catalyst causes the formation of ethylene glycol.

$$\begin{array}{l} CH_2Cl \\ | \\ CH_2OH \end{array} + NaOH \longrightarrow \begin{array}{l} CH_2 \\ |\!>O \\ CH_2 \end{array} + NaCl + H_2O$$

$$\begin{array}{l} CH_2 \\ |\!>O \\ CH_2 \end{array} + H_2O \xrightarrow[\text{acid catalyst}]{\Delta} \begin{array}{l} CH_2OH \\ | \\ CH_2OH \end{array}$$

In the preparation of alkyd resins, the polybasic acid and polyhydric alcohol are cooked in a reaction kettle with various modifying agents. Other synthetic resins may be added to improve certain properties; drying oils and natural resins or resin acids may be added for the production of coating materials; plasticizers and vegetable oils or fatty acids may be used to produce softer or more flexible products; solvents and diluents have various purposes in addition to that of forming a resin solution for casting cements or coatings; and water may be used in the production of water emulsions.

When the resin is obtained in the form of a water emulsion, it may be used, with the addition of pigments, as a water paint. The particles coalesce on drying to form a smooth waterproof coating.

The A-stage liquid resin, the resin solution, or the finely divided solid resin (the latter usually with the addition of solvents) may be used to produce cements and coating materials. Alkyd resins find use also as a printing-ink base, and an ingredient of lacquers, in conjunction with cellulose acetate or nitrate. Other types of coatings produced are varnishes and baking enamels.

A flexible type of alkyd resin of special composition, containing plasticizers, can be used for casting shapes and even for compression molding, especially for compression forming of sheets, etc. The finished articles may be machined and polished.

The resin drawn off from the reaction kettle may be prepared for a molding compound either by precipitation of the dissolved resin in a finely divided state or by grinding the solidified resin in a mill. To the resulting powder or granulation are added lubricants and any desired fillers or pigments. As the resin is thermosetting, compression molding is usually employed. The prepared molding composition is worked by rubber compounding methods, then molded in a press and placed in the curing oven.

MANUFACTURE OF VINYL ESTER RESINS

Vinyl ester resins have as their raw materials coal, limestones, water, and acid. Coke and lime under high heat yield calcium carbide which, with water, yields acetylene.

$$2CaO + 5C \longrightarrow 2CaC_2 + CO_2$$

$$CaC_2 + 2H_2O \longrightarrow HC{\equiv}CH + Ca(OH)_2$$

The acetylene may then be used for the manufacture of vinyl acetate, vinyl chloride, vinyl aldehydes, or various vinyl copolymers.

For vinyl acetate the acetylene is combined with acetic acid in the presence of a catalyst. When acetyl sulfuric acid is the catalyst, vinyl acetate is formed with little ethylidene diacetate, which latter interferes with the desired reaction when acetylene is passed into acetic acid, cutting down the yield of vinyl acetate.

$$CH{\equiv}CH + CH_3COOH \longrightarrow \underset{\text{vinyl acetate}}{CH_2{=}CH{-}OCOCH_3}$$

$$CH{\equiv}CH + 2CH_3COOH \longrightarrow CH_3CH(OCOCH_3)_2$$

Vinyl acetate, a liquid at room temperatures, polymerizes slowly to form a gel. At high temperatures this change occurs more rapidly and is further accelerated by the action of light and by various catalysts such as benzoyl peroxide, oxygen, silica, and bauxite. Perborates and percarbonates may be used but are less efficient catalysts.

High temperatures yield a hard, brittle solid; lower temperatures, a tough resin of a higher degree of polymerization.

The action usually takes place in an autoclave, in the presence of a suitable solvent or diluent. By varying conditions, it is possible within fairly wide limits to produce polyvinyl acetate of predetermined characteristics. The resin is precipitated out, dried, ground and compounded as a molding powder, not commonly used for ordinary molding because of an objectionable tendency to cold flow. It is however used with various fillers in the manufacture of plastic floor tile, artificial leather, pressed wood composition, and surfacing for outdoor signs and panels.

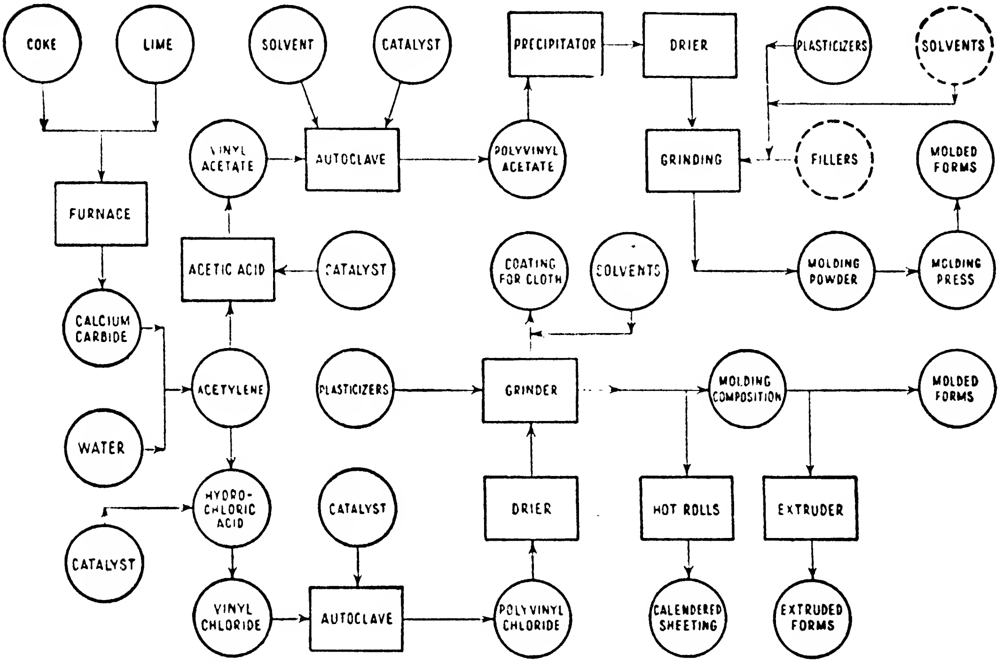


FIG. 13.8 — Manufacture of vinyl ester resins. (Key on page 475.)

In solution it is used as an adhesive and for coatings.

In the preparation of vinyl chloride acetylene is passed into a hydrochloric acid bath in the presence of catalysts such as ammonium chloride and cuprous chloride. As in the case of the preparation of vinyl acetate, ethylidene dichloride is produced, but its formation can be cut down by the use of silica gel or highly active carbon as a carrier for the catalyst. The reaction is carried on at a temperature of about 180° to 240° C. (356° to 464° F.).

The vinyl chloride produced is a gas at room temperature, liquefiable in a freezing mixture. It is polymerized in an autoclave to a tough linear polymer suitable for the production of plastics. The polymerization is accelerated by benzoyl peroxide or soluble lead salts. Varying the conditions of polymerization produces resins with a wide range of solubilities.

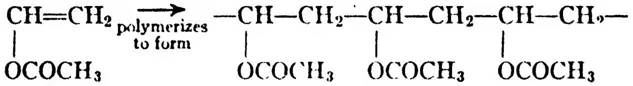
When plasticized, the resin (after compounding) is suitable for the production of molded products, transparent sheeting, and extruded forms. Some good plasticizers for vinyl chloride are tricresyl phosphate, dibutyl phthalate, dibutoxyethyl phthalate, and triglycol dihexoate.

The plasticized material is flexible and somewhat elastic and can be used for the production of flexible tubing and extruded wire insulation. Its excellent electrical insulating properties make it useful in the electrical field. Pigments may be added if desired, and fillers for molding compounds.

Vinyl chloride resin is incompatible with most other synthetic resins, and is inferior in many respects to the vinyl chloride-vinyl acetate copolymer.

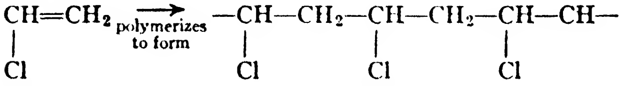
MANUFACTURE OF VINYL CHLORIDE–ACETATE COPOLYMER

If vinyl chloride and vinyl acetate are mixed and the mixture polymerized, a resinous product results which is different from and surperior to polyvinyl chloride, polyvinyl acetate, or a mixture of the two.



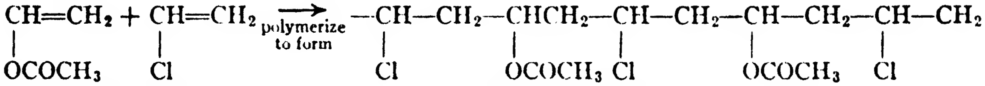
$$\underset{\displaystyle OCOCH_3}{\underset{|}{CH}}{=}CH_2 \xrightarrow[\substack{\text{polymerizes}\\ \text{to form}}]{} -\underset{\displaystyle OCOCH_3}{\underset{|}{CH}}-CH_2-\underset{\displaystyle OCOCH_3}{\underset{|}{CH}}-CH_2-\underset{\displaystyle OCOCH_3}{\underset{|}{CH}}-CH_2-$$

vinyl acetate polyvinyl acetate



$$\underset{\displaystyle Cl}{\underset{|}{CH}}{=}CH_2 \xrightarrow[\substack{\text{polymerizes}\\ \text{to form}}]{} -\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH-$$

vinyl chloride polyvinyl chloride



$$\underset{\displaystyle OCOCH_3}{\underset{|}{CH}}{=}CH_2 + \underset{\displaystyle Cl}{\underset{|}{CH}}{=}CH_2 \xrightarrow[\substack{\text{polymerize}\\ \text{to form}}]{} -\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle OCOCH_3}{\underset{|}{CH}}CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2-\underset{\displaystyle OCOCH_3}{\underset{|}{CH}}-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_2$$

vinyl acetate and vinyl chloride a vinyl chloride-acetate copolymer

This copolymer is formed by combining vinyl chloride and vinyl acetate in an autoclave in the presence of benzoyl peroxide. Its properties may be varied by changing: (1) the proportions of vinyl chloride to vinyl acetate in the reaction mixture; (2) the amount and nature of the solvents or plasticizers added; and (3) the conditions and extent of polymerization of the resin. Most commercial products are made with about 90 to 95 per cent of vinyl chloride and usually are polymerized while mixed with a solvent. The polymer is usually precipitated with the aid of a nonsolvent such as water and is then dried with mild heat in a large continuous rotary drier. It is then worked in a masticator, and modifying substances are incorporated.

Plasticizers such as tricresyl or other phosphate, ethyl or dibutyl phthalate and various glycollates, abietates or ethyl hexoates are almost invariably added, since they increase the toughness of molded forms and give flexibility and elasticity to the highly plasticized forms used as rubber substitutes. The polyvinyl acetate appears to plasticize the polyvinyl chloride internally.

Solvents, of which ketonic solvents are the most satisfactory, may also be added. Coal-tar solvents, which cause the polymer to swell, may be used as diluents.

The finished resin is clear, colorless, and transparent to visible and to ultra-violet light but has a tendency to decompose or darken on exposure to light or to heat. Lead and metal stearates such as those of cadmium or calcium that retard this discoloration are worked into the resin. Other types of compound are being investigated to improve the heat stability of the compound.

Dyes or pigments may be added to give almost any desired color, and filler may be used to produce molding powders giving a series of molded materials ranging from transparent to completely opaque.

The rubberlike solid may be worked on standard rubber milling machines.

After all the desired modifying substances have been added and the mixture thoroughly kneaded under gentle heat, the material may be fed directly into an extruder to produce transparent flexible tubing, hose, tape, and the like, or it may be passed out between hot rollers onto a moving belt to form calendered sheets. The surface may be pressed to give a grained, leatherlike effect or other design. Usually, transparent sheeting is produced either colorless or dyed, highly plasticized or without filler or pigment. Latest improvements have made possible the manufacture of perfectly clear and transparent sheeting, with a smooth, glassy surface in which the solvents, plasticizers, or other modifiers do not cause any haze. The material is fed warm from the rollers onto the surface of a liquid such as mercury, upon which it floats until cool set. The copolymer of vinyl chloride and vinyl acetate has a tendency to corrode metals with which it comes in contact, possibly by the liberation of chlorine from slow decomposition of the resin. Stabilizers help to prevent this, and incorporation of alkali compounds of organic acids serves to remove the chlorine.

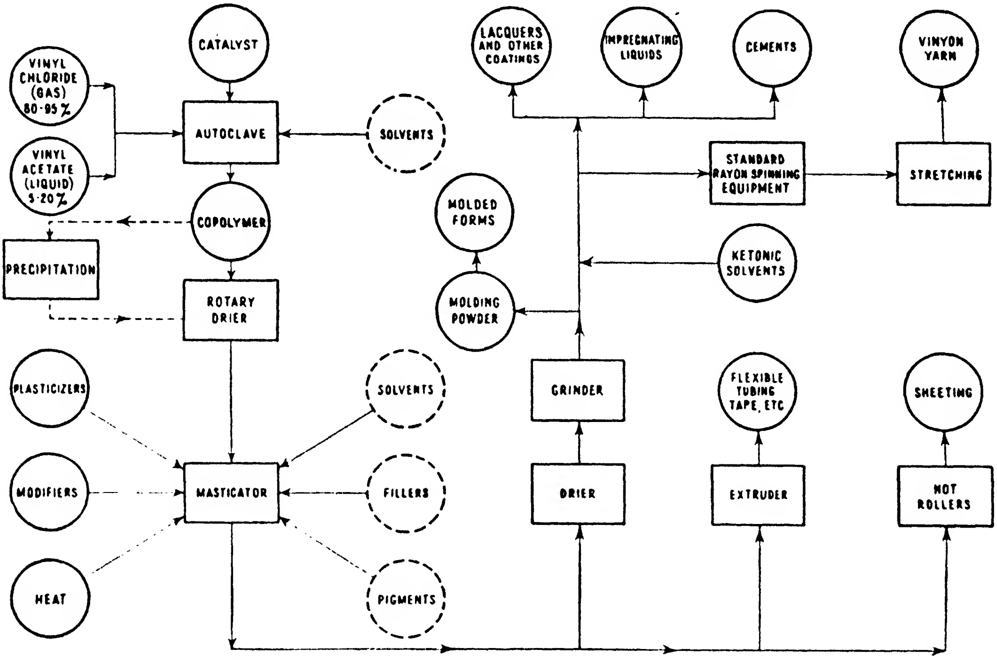


FIG. 13.9 — Manufacture of vinyl chloride-acetate copolymer. (Key on page 475.)

If molding powders are to be prepared, the mixture from the masticator must be dried and ground to a powder. Large moldings such as doors may be made from filled vinyl ester copolymers, since they show little mold shrinkage or warping.

In active practice, the same batch of resin is not used for all applications, since resins of different molecular weight are suited to different applications. Usually copolymers of about 10,000 molecular weight are used for injection molding and about 12,500 molecular weight for compression molding. Extruded material and plasticized sheeting are usually made from material of an average molecular weight of about 21,000, whereas stiff sheet stock has a molecular weight of 15,000 to 16,000.

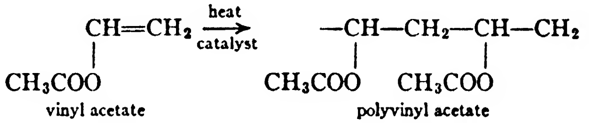
The dried and ground modified resin (a modification of about 9000 molecular weight), when dissolved in ketonic solvents and used as a coating material, makes a good chemical-resistant lacquer and has many uses as a coating, as for phonograph records. Sheets of material impregnated with the liquid may be pressed to a hard, durable, smooth, resistant finish. The dissolved copolymer is also useful as a cement.

One of the newest developments is the production of synthetic textile fiber from this copolymer. The material, of about 22,000 molecular weight, is dissolved in a ketonic solvent, usually acetone, and is spun in standard rayon-spinning equipment to form fine filaments. Stretching these, while still more or less plastic, aligns the linear chain molecules lengthwise in the filaments, thus increasing tensile strength and elasticity. The resulting yarn may be woven into a variety of useful articles, the applications of which have not as yet been fully explored. Vinyon filter cloth is now in use.

Manufacture of Polyvinyl-Aldehyde (Acetal) Plastics

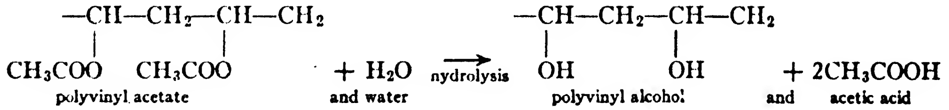
Vinyl aldehyde resins are prepared by reacting a suitable aldehyde with polyvinyl alcohol, which is obtained by the hydrolysis of polyvinyl acetate.

Vinyl acetate is first polymerized with the aid of heat and a catalyst such as benzoylperoxide.



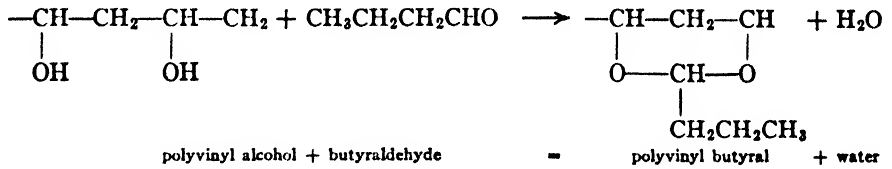
$$\underset{\text{vinyl acetate}}{\underset{\mathrm{CH_3COO}}{\underset{|}{\mathrm{CH}}}{=}\mathrm{CH_2}} \xrightarrow[\text{catalyst}]{\text{heat}} \underset{\text{polyvinyl acetate}}{-\underset{\mathrm{CH_3COO}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH_2}-\underset{\mathrm{CH_3COO}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH_2}}$$

The resulting polyvinyl acetate, dissolved in a liquid vehicle, is then caused to hydrolyze in the presence of an acid, or more usually, an alkaline catalyst. During hydrolysis the splitting off of the acetyl groups, leaving hydroxyl groups in their place, results in the formation of polyvinyl alcohol.



$$\underset{\text{polyvinyl acetate}}{-\underset{\mathrm{CH_3COO}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH_2}-\underset{\mathrm{CH_3COO}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH_2}} + \underset{\text{and water}}{\mathrm{H_2O}} \xrightarrow{\text{hydrolysis}} \underset{\text{polyvinyl alcohol}}{-\underset{\mathrm{OH}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH_2}-\underset{\mathrm{OH}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH_2}} + \underset{\text{and}\quad\text{acetic acid}}{2\mathrm{CH_3COOH}}$$

The polyvinyl alcohol is caused to react with an aldehyde, yielding as a condensation product a polyvinyl acetal compound. In the preparation of vinyl butyraldehyde, polyvinyl alcohol is reacted with butyraldehyde under the influence of heat and a suitable catalyst.



$$\underset{\text{polyvinyl alcohol}}{-\underset{\mathrm{OH}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH_2}-\underset{\mathrm{OH}}{\underset{|}{\mathrm{CH}}}-\mathrm{CH_2}} + \underset{\text{butyraldehyde}}{\mathrm{CH_3CH_2CH_2CHO}} \longrightarrow \underset{\text{polyvinyl butyral}}{\begin{array}{c}-\mathrm{CH}-\mathrm{CH_2}-\mathrm{CH}\\ |\qquad\qquad\quad |\\ \mathrm{O}-\!\!-\mathrm{CH}-\!\!-\mathrm{O}\\ |\\ \mathrm{CH_2CH_2CH_3}\end{array}} + \underset{\text{water}}{\mathrm{H_2O}}$$

$$\text{polyvinyl alcohol} + \text{butyraldehyde} = \text{polyvinyl butyral} + \text{water}$$

The process of hydrolysis and condensation may be carried on either separately or as one operation, but neither is carried entirely to completion. The commercial vinyl acetals contain small percentages of leftover polyvinyl alcohol and polyvinyl acetate, the presence of these substances apparently serving to improve the properties of the finished plastics, which properties also are affected by the amount of polyvinyl alcohol and polyvinyl acetate remaining (extent of the hydrolysis and condensation), by the type of aldehyde employed in the condensation and by the size of the molecules. The molecular size in turn is determined by the extent of polymerization of the polyvinyl acetate from which the acetal resin is prepared, and also by the treatment of the material during the other stages of its manufacture.

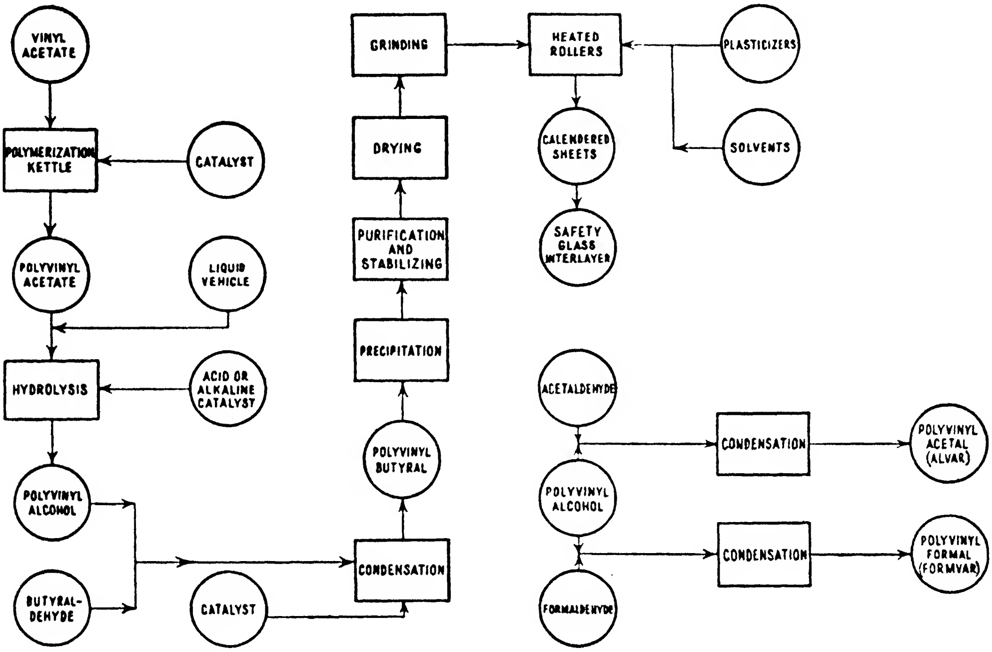
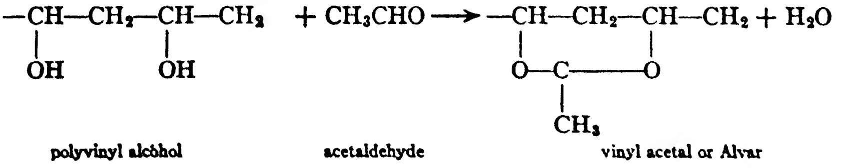


FIG. 13.10 — Manufacture of a typical vinyl aldehyde resin plastic. (Key on page 475.)

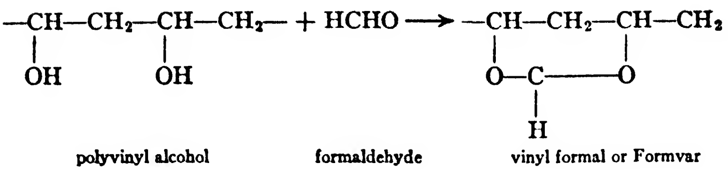
After the vinyl-butyraldehyde resin has been formed it is precipitated by a nonsolvent such as water and may then be purified and stabilized before being dried in heated air currents. The dry material is ground, softened on heated rollers, and compounded with plasticizers, fillers, and coloring materials. Volatile solvents are often worked into it at this stage.

After compounding, it is pressed into thin sheets which are spread out and seasoned to expel volatile solvents. Later they are used for interlamination of safety glass.

When polyvinyl-acetaldehyde or polyvinyl-formaldehyde resins are to be prepared, the appropriate aldehyde is condensed with polyvinyl alcohol in a manner similar to that described above.



$$\underset{\text{polyvinyl alcohol}}{-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_2-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_2} + \underset{\text{acetaldehyde}}{CH_3CHO} \longrightarrow \underset{\text{vinyl acetal or Alvar}}{\begin{array}{l}-CH-CH_2-CH-CH_2\\ \;\;|\qquad\qquad\;\;\; |\\ \;\;O-\underset{\displaystyle CH_3}{\underset{|}{C}}-O\end{array}} + H_2O$$



$$-\underset{\text{OH}}{\text{CH}}-\text{CH}_2-\underset{\text{OH}}{\text{CH}}-\text{CH}_2- + \text{HCHO} \longrightarrow -\text{CH}-\text{CH}_2-\text{CH}-\text{CH}_2 \quad (\text{O}-\underset{\text{H}}{\text{C}}-\text{O})$$

Polyvinyl-acetaldehyde resins after compounding with plasticizers, fillers, and pigments are suitable for molding. Some vinyl-formaldehyde resins can be molded by compression but are not suitable for injection molding.

MANUFACTURE OF VINYLIDENE CHLORIDE PLASTICS

Vinylidene chloride, or 1-dichloroethylene, may be prepared from chlorine and acetylene. Chlorine is produced by the electrolysis of brine, and acetylene by the reaction between calcium carbide and water.

$$2NaCl + 2H_2O \longrightarrow Cl_2 + H_2 + 2NaOH$$

$$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$$

Acetylene reacts so rapidly and violently with chlorine to form acetylene tetrachloride that a large quantity of inert solid material must be present. A reaction will take place when liquid acetylene tetrachloride is treated in the presence of a catalyst (ferric chloride) and at a temperature of about 135° C., with acetylene and with chlorine, the former being in excess. The vapors from the reaction vessel may then be

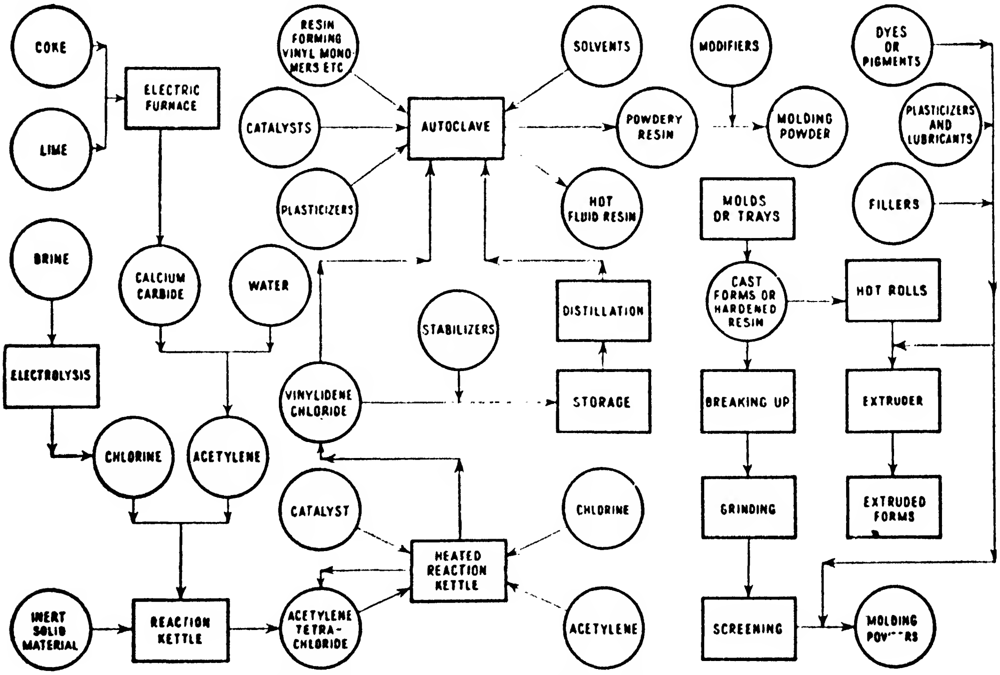


FIG. 13.11 — Manufacture of vinylidene chloride plastics. (Key on page 475.)

condensed to recover acetylene tetrachloride and to yield vinylidene chloride.

$$HC{\equiv}CH + Cl_2 \longrightarrow CHCl_2CHCl_2$$

$$CHCl_2CHCl_2 + HC{\equiv}CH + Cl_2 \xrightarrow[135°C.]{FeCl_3} C_2H_2Cl_2 + C_2H_2Cl_4$$

The vinylidene chloride so obtained is polymerized in a steam-jacketed autoclave by the action of light, heat, and usually with the aid of catalysts. These may be phosphorus pentachloride or oxidizing agents such as ozone, benzoyl, or acetyl peroxide, hydrogen or barium peroxide. Polymerization may take 24 to 48 hr. or even longer, and research is being done to find materials to accelerate the reaction. Work on tetraethyl lead and copper compounds looks promising.

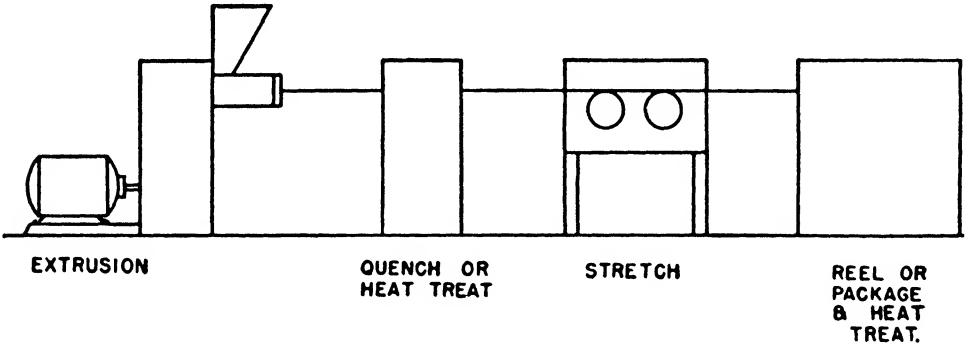


FIG. 13.12 — Orientation process for vinylidene chloride.

The polymerized material, if allowed to harden, becomes a tough, hard mass. This may be worked above its softening point to a plastic state, when plasticizers, fillers, lubricants, and pigments may be thoroughly incorporated in the plastic. Hard material may be broken up, ground, screened, and mixed with other ingredients for use as a molding powder.

A granular product can be produced more easily by polymerizing the resin in the presence of a small amount of nonpolymerizable inert liquid, immiscible with water, but miscible with monomeric vinylidene chloride.

Acetylene tetrachloride, monochlorobenzene, ortho-dichlorobenzene, or trichlorobenzene may be used for this purpose.

A plasticizer such as phenoxy-propylene oxide may be mixed with the vinylidene chloride before polymerization. If desired, the whole reaction mixture may be covered with a layer of water, which may be decanted after the reaction is complete. Polymerization is faster at a high temperature, though the product is inferior. The solvent can be removed by evaporation by warm air, and recovered.

These resins can be molded at substantially lower temperatures if polymerized in the presence of a solvent.

Monomeric vinylidene chloride may be stabilized against polymerization by the addition of a variety of substances which can be removed by fractional distillation before polymerizing the material. Typical stabilizing agents are nitrobenzene, pyridine, ammonia, monoethanolamine, and diethanolamine.

Copolymers of vinylidene chloride and various other substances such as vinyl chloride, vinyl acetate, divinyl ether, styrene, and alkyl acrylates and alkyl esters of substituted acrylic acid compounds are known. Some of these, when plasticized with phenoxy-propylene oxide, yield rubbery materials which may be transparent or nearly so.

The extruded and the molded or cast forms can both be much improved in tensile strength if the long-chain molecules making up the resin are suitably oriented in the extruded forms by stretching while the material is still in a semiplastic condition, and in the cast or molded forms by rolling at temperatures well below the softening point but at pressures sufficient to reduce the thickness of rolled sheets.

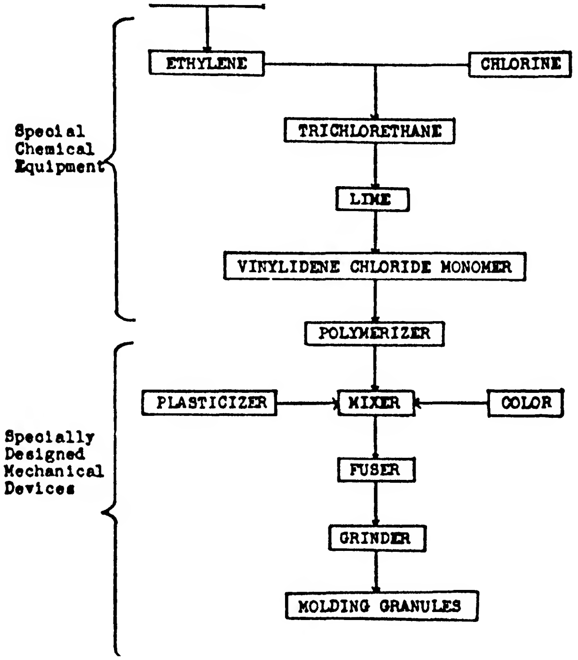


FIG. 13.13 — Vinylidene chloride flow sheet. (Key on page 475.)

Applications. The chief industrial applications of vinylidene chloride resins make use of extruded forms such as extruded tapes woven into chair seats and subway car seats, extruded thread for fish leaders and plastic window screens; but other uses for molding materials are being developed, as the material is being better adapted for molding. A new application is for molded abrasive wheels.

MANUFACTURE OF POLYVINYL-ALCOHOL PLASTICS

Polyvinyl alcohol, prepared by the hydrolysis of polyvinyl acetate, is also used as a basis for plastics materials. When plasticized, it has rubbery characteristics, and has been reported to be the most satisfactory rubber substitute in use in Germany where much investigation of rubber substitutes has been done.

The polyvinyl alcohol is precipitated by a nonsolvent, purified, dried, and pulverized. Plastics are then prepared from it in the following manner:

A small amount of a solvent, such as water, is thoroughly mixed with the powder to form a pasty mass. This is worked on hot rolls, where it is compounded with plasticizers. In general, the plasticizers used for vinyl chloride-acetate copolymers are suitable. Fillers and coloring materials are not commonly added, since they detract from some of the desirable properties of the unfilled plasticized material. The polyvinyl alcohol emerges from between the heated rolls as a thin strip or sheet. The rolls are kept at a temperature of about 100° C. or less to expel the solvent. The product may be ground and the powder used for extrusion or molding. An important extrusion product is flexible tubing.

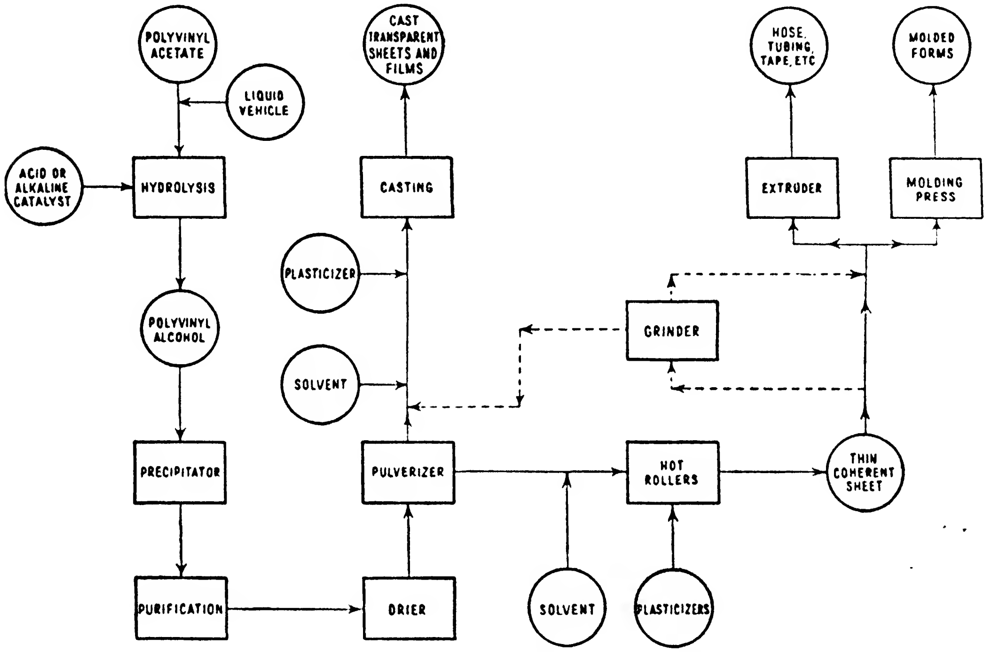


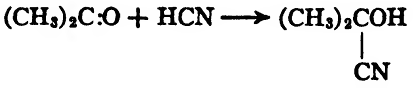
Fig. 13.14 — Manufacture of polyvinyl alcohol plastics. (Key on page 475.)

Dissolving the pulverized material and adding a plasticizer such as stearylamine or octadecylamine gives a casting solution suitable for the production of transparent films.

MANUFACTURE OF ACRYLIC RESINS

Two general types of acrylic resins are used in the production of plastics: polymerization products of esters of acrylic acid ($CH_2:CHCOOH$); polymerization products of esters of methacrylic acid ($CH_2:C(CH_3)COOH$). Methyl methacrylate is the best known and most commonly used in this country.

Methacrylates are prepared from acetone, which is either obtained directly by fermentation or is prepared from propylene, in turn obtained from petroleum or natural gas. The acetone is first converted to acetone cyanohydrin by the addition of hydrocyanic acid.



$$(CH_3)_2C{:}O + HCN \longrightarrow (CH_3)_2\underset{\substack{|\\ CN}}{C}OH$$

The acetone cyanohydrin is then converted to alpha-hydroxyisobutyric acid ester by sulfuric acid and an alcohol containing the alkyl group which it is desired to introduce.

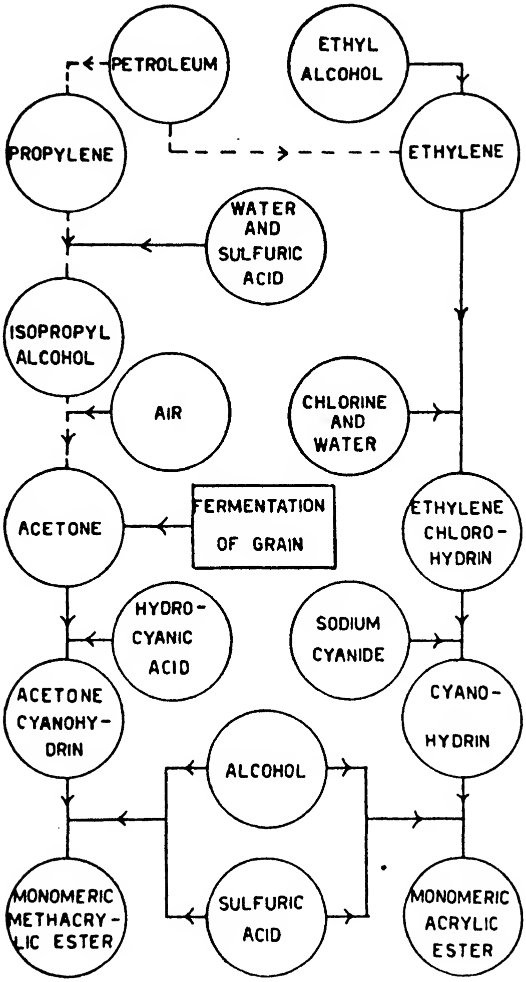
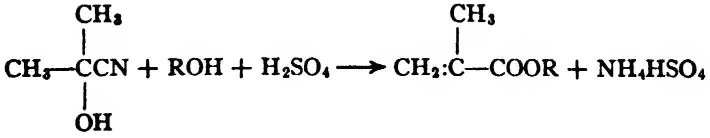


Fig. 13.15 — Manufacture of acrylic monomers. (Key on page 475.)

Dehydration removes the OH group.



$$CH_3{-}\overset{\substack{CH_3\\ |}}{\underset{\substack{|\\ OH}}{C}}CN + ROH + H_2SO_4 \longrightarrow CH_2{:}\overset{\substack{CH_3\\ |}}{C}{-}COOR + NH_4HSO_4$$

The monomeric ester of methacrylic acid is purified by fractionation and subsequently polymerized to the solid resin.

Acrylates are prepared from ethylene chlorohydrin, which is produced by the treatment of ethylene with HOCl (chlorine water). The ethylene is obtained from petroleum or natural gas, or is prepared by passing ethyl alcohol over Al_2O_3 at 360° C. The ethylene chlorohydrin is converted to the cyanohydrin by sodium cyanide.

$$CH_2{:}CH_2 + HOCl \longrightarrow CH_2ClCH_2OH$$

$$CH_2ClCH_2OH + NaCN \longrightarrow CH_2CNCH_2OH + NaCl$$

The ethylene cyanohydrin is then treated with alcohol and sulfuric acid to yield the monomeric acrylic ester, which also is distilled before polymerization.

$$CH_2OH{\cdot}CH_2CN + ROH + H_2SO_4 \longrightarrow CH_2{=}CH{\cdot}COOR + NH_4HSO_4$$

Both kinds of acrylic resins are polymerized by the action of heat, light, and air or oxygen-producing substances which are used as catalysts: hydrogen peroxide, sodium peroxide, and benzoyl peroxide. Difficulties are encountered in the control of polymerization, which is easily started and may proceed more rapidly and more completely than is desired. Slower polymerization gives longer chain molecules, and a stronger product. The polymerization process largely controls the properties of the finished product. Between variations in purity and composition of the monomer, and alterations in the polymerization conditions with so many different end points available, a wide range of properties may result.

Cast resin is more highly polymerized than that prepared for molding compounds, which are further modified by additional substances.

Dyes may be added before the polymerization, if they are stable.

The monomer may be cast in molds and polymerized to its final shape as sheets, rods, blocks, and various forms, or it may be produced in the form of granules. If it is allowed to polymerize while suspended in water in the form of large droplets, a granular product results. An aqueous emulsion of the monomer may be formed by using an emulsifying agent such as ammonium oleate. If polymerization is carried out on the emulsified monomer, a product results which may be used as a coating. The individual particles of the polymer will be found to coalesce on evaporation of the water, leaving a clear, resistant tough film. If the substance is polymerized while in solution, a satisfactory dope results. These dopes are usually produced by dissolving the monomer in a suitable solvent and heating, generally under reflux, in the presence of a catalyst.

Molding powders for injection and for compression molding may be produced in a variety of ways. Use may be made of the production of the granular form of the polymer resulting when the monomer is polymerized suspended in water; or the polymer produced in a finely divided state in aqueous emulsion, or in solution in organic solvents may be precipitated by an agent such as methyl alcohol or acetone, and washed and dried. If the polymerization is effected with the monomer dissolved in a liquid in which the polymer is insoluble, a finely divided precipitate of the polymer will result. The largely polymerized substance may be thoroughly mixed with a quantity of the monomer and then precipitated by means of a differential solvent as mentioned above, or a mixture of the substantial amount of the monomer with the polymer containing various suitable plasticizers may be prepared, having a composition such that granulation will occur at a specified temperature such as 100° C. This mixture is then kneaded at about 100° C. in a closed mixer provided with a reflux condenser, the kneading being continued until a granular product suitable for molding is obtained.

In addition to the above-described ways of producing granular or powdery forms of the polymer, cast sheets may be pulverized for the preparation of molding powders, or

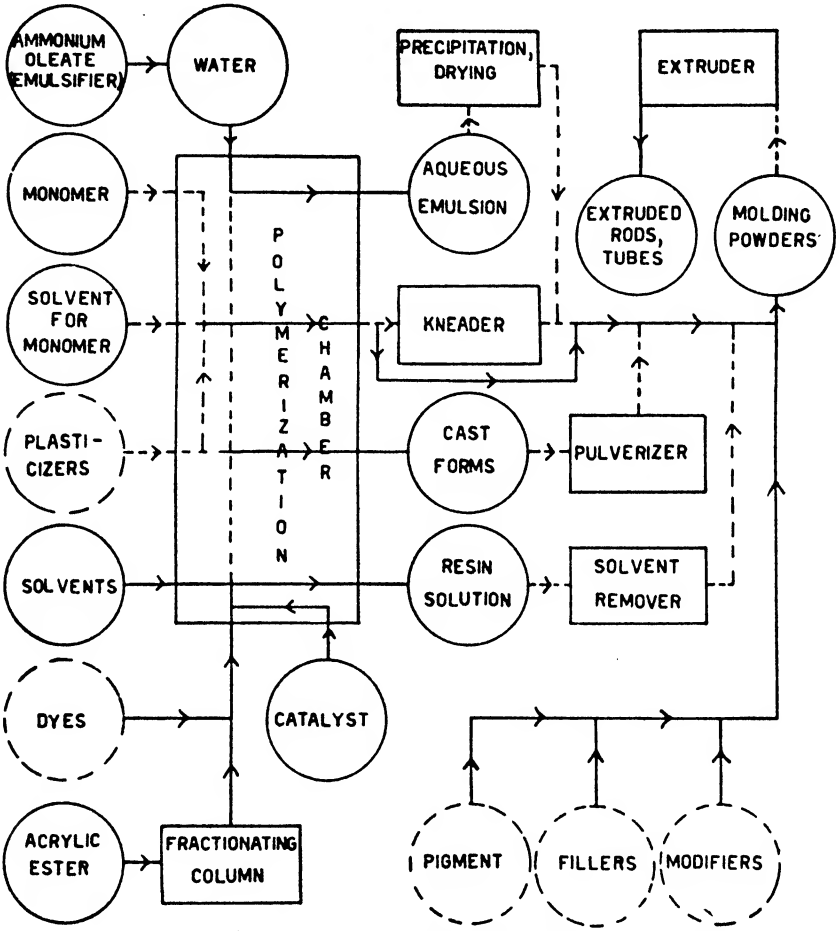


FIG. 13.16 — Manufacture of acrylic resins. (Key on page 475.)

the solvent may be removed from resin solution such as the dopes, and the remaining solid disintegrated.

Powders produced by any of these methods may then be mixed with various additional substances such as fillers, organic or inorganic pigments, and plasticizers. Because of its beautiful crystal clarity, dyes rather than pigments are usually used in methyl methacrylate articles, and fillers and pigments are omitted. The articles may be dyed after they are finished, but the thermoplastic nature of the material makes it more practical and convenient to add the dyes before polymerization. Plasticizers or softening agents such as ethyl phthalate or tricresyl phosphate may be used, and the resin may be modified by the addition of cellulose esters or ethers, rubber or gutta percha, or various other substances. Substances such as clay, soot, talc, or sulfur have been used as fillers.

If the molds or casting surfaces are highly polished, no further polishing or finishing is required on the finished pieces.

Casting sirups may be prepared by dissolving the prepared polymeric acrylic or methacrylic acid ester in a portion of a monomer of a like ester, the proportion of 5 to 10 per cent of the polymer in the solution being suitable.

Being thermoplastic, acrylic resins may be satisfactorily extruded. A modified granular form is appropriate for this method of forming.

Various alternative methods for the preparation of methacrylic acid and acrylic acid have been developed, but they are not yet of commercial importance.

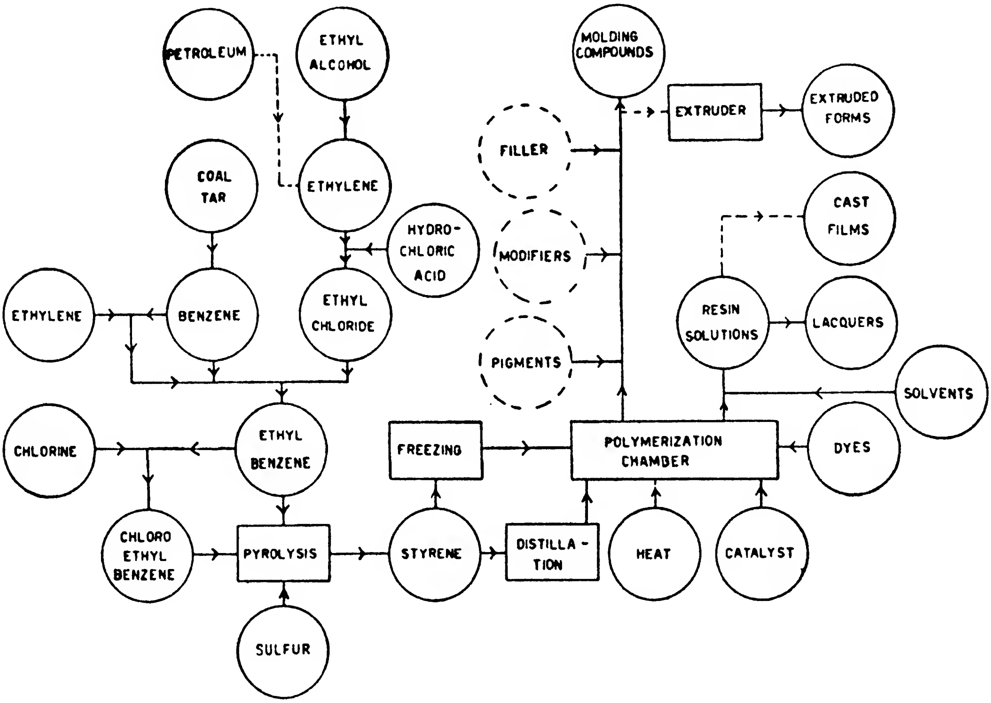


Fig. 13.17 — Manufacture of polystyrene. (Key on page 475.)

Manufacture of Polystyrene

Polystyrene is prepared by the polymerization of styrene, or vinyl benzene, obtained by splitting hydrogen from ethyl benzene, which is prepared from ethyl chloride and benzene or from benzene and ethylene in the presence of a catalyst such as aluminum chloride.

$$C_2H_5Cl + C_6H_6 \longrightarrow C_2H_5C_6H_5 + HCl$$

$$CH_2{:}CH_2 + C_6H_6 \xrightarrow{AlCl_3} C_6H_5CH{:}CH_2 + H_2$$

$$CH_3CH_2C_6H_5 \longrightarrow C_6H_5CH{:}CH_2 + H_2$$

The preparation of styrene or styrol from ethyl benzene may be effected in various ways, perhaps the most important being the heating of the ethyl benzene to a temperature of 500° to 800° C. (932° to 1472° F.) in the presence of an inert gas, with a catalyst such as an oxide of calcium, strontium, manganese, or zirconium. The splitting up in this way of a benzene compound with an aliphatic side chain to give styrol and hydrogen is reversible, hence the hydrogen must be removed. To this end, a dehydrogenating agent such as sulfur is usually added to the ethyl benzene.

$$C_2H_5C_6H_5 + S \xrightarrow[\text{catalyst}]{\text{heat}} C_6H_5CH{:}CH_2 + H_2S$$

Another method is to chlorinate ethyl benzene and obtain styrol from the resulting alpha and beta chloroethyl benzenes by passing the mixture through a hot tube at 500° to 700° C. (932° to 1292° F.) or by treatment with mercurous chloride, eliminating hydrochloric acid in both cases.

$$CH_2ClCH_2C_6H_5 \xrightarrow{500^\circ \text{ to } 700^\circ\text{C.}} CH_2{:}CHC_6H_5 + HCl$$

It is almost impossible to obtain complete conversion of ethyl benzene to styrol, so it is therefore necessary to purify the product of the remaining raw materials and accumulated decomposition products. This may be done by careful distillation, although a good method consists of cooling the solution to between −30° and −60° C. (−22° to −76° F.) below the melting point of the monomeric styrene, which crystallizes out in pure condition.

The liquid monomer is then polymerized by heat, usually in the presence of some catalyst. Great difficulties are encountered in control of the polymerization, which is catalyzed by light, heat, and foreign matter of all kinds. The difficulty and expense of this control, and the cost of manufacturing styrene itself, have kept the price of polystyrene high enough to prevent its wide use in spite of its excellent properties. The extent of polymerization determines the properties to some extent though the rate of polymerization is important too. Slow polymerization gives fewer and longer chains in each macromolecule, faster polymerization giving shorter and more numerous chains. The resulting resins, though similar in all other respects, will differ in strength and flowing properties. Commercial resins may range from 40,000 to 200,000 in molecular weight depending on the time and temperature of the polymerization process and the choice of catalysts. Low-temperature polymers have higher softening points and higher molecular weights.

Polymerization consists of long heating at low temperatures or short heating at high temperatures.

Another method is to treat a solution of the resin in ethyl benzene with ozone for 15 minutes, or with benzoyl peroxide. If liquid styrene is first treated with a slow stream of air and emulsified in very dilute solution with ammonium oleate, it may be polymerized by keeping it at 45° C. (113° F.) for 12 hr. A popular method is to heat styrol in ethyl benzene solution under a reflux condenser at 200° C. (392° F.) for about 3 days in the presence of an organic or inorganic basic catalyst. Hydrogen fluoride is considered a good catalyst and is very active at low temperatures, even as low as 0° C. Catalysts such as benzoyl peroxide, oxygen, and stannic chloride increase the reaction rate at a given temperature, giving polymers of lower chain length. The presence of high boiling esters and ketones during polymerization yields permanently tough products. The presence of short-chain molecules of low molecular weight is believed to cause surface crazing or blushing in molded articles.

Metastyrols have been classed as alpha, beta, gamma, and complex, the alpha variety being most satisfactory for plastics. On heating to very high temperatures, it decomposes to form the monomer. Solutions of the resin are used as lacquers and adhesives, and films made from them have excellent dielectric properties.

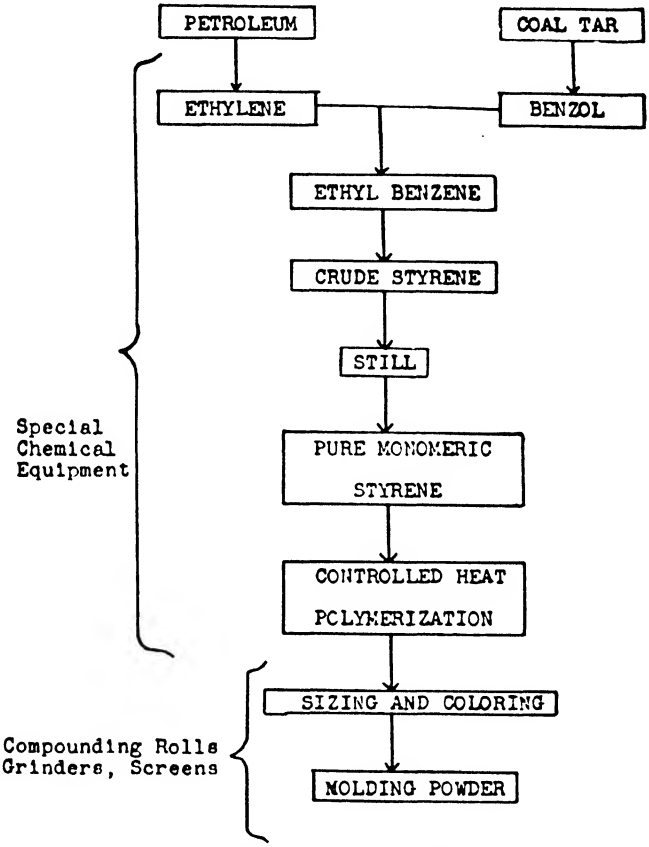


FIG 13.18 — Polystyrene flow sheet. (Key on page 475.)

Chlorination of polystyrene improves some of its properties. A similar resin is produced from divinyl benzene and from styrene polymerized with maleic anhydride. Styrene, divinyl benzene, or methyl styrene may be condensed with butadiene to form resins, and vinyl naphthalene forms polymers similar in some respects to polystyrene.

In preparing molding powders from polystyrene, plasticizers such as tricresyl phosphate may be added to reduce brittleness, though the introduction of plasticizers sometimes impairs the electrical properties, lowers the softening point, or reduces the resistance to chemicals.

MANUFACTURE OF CUMARONE–INDENE RESINS

Cumarone-indene resins are prepared by the catalytic polymerization of cumarone and indene, both obtained from the solvent naphtha, a coal tar fraction. The coal tar light oils are recovered from by-product coking operations, the principal resin-producing substances occurring in the fraction boiling between 150° and 200° C. (302° to 392° F.). This fraction contains cumarone and indene and their methyl derivatives and certain other resin-forming substances. A fractionation of the naphtha boiling between 150° and 200° C. would yield something like the following results (modified from Morrell):

Fraction distilling at °C.	*Material*
160° or below	Styrenes, cyclopentadiene
168–175°	Cumarone (b.p. 172°)
176–182°	Indene (b.p. 182°)
185–200°	Methyl cumarone
200–210°	Methyl indene
215–225°	Dimethyl cumarone

The only method of separating the cumarone and indene out of the mixture is by fractionation.

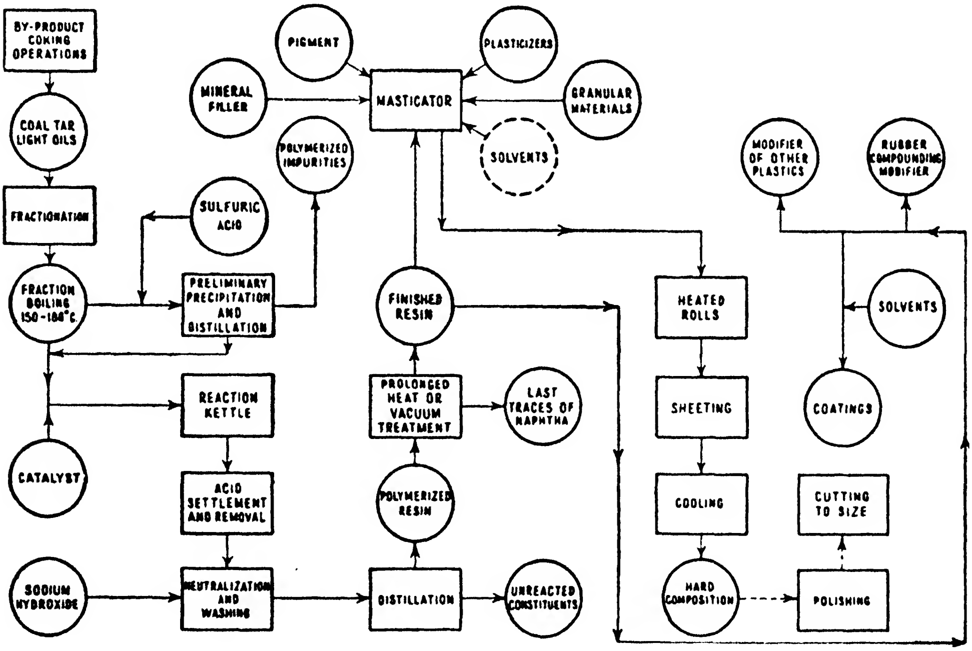


Fig. 13.19 — Manufacture of cumarone-indene resin used as binder. (Key on page 475.)

The selection and preparation of the naphtha is of the utmost importance. A naphtha boiling between 160° and 183° C. (320° to 362° F.), containing about 30 per cent cumarone and indene and free from acid or basic substances such as phenol and pyridines is best. The styrols and pentadiene can be eliminated by adding sulfuric acid in small quantity, causing them to polymerize so that they can be separated out by distillation. Other objectionable substances such as tar bases which give the resin a darkened color are also eliminated in this way. Care must be taken not to polymerize the cumarone and indene at the same time.

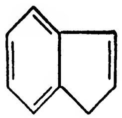
Sulfuric acid is the most important catalyst in the production of a resin by polymerization of cumarone and indene, but aluminum chloride is also effective, as are ferric and stannic chlorides and phosphoric acid. Mild oxidizing agents accelerate the reaction, but violent oxidizing agents react with cumarone.

Usually the naphtha, after refining, is treated with concentrated sulfuric acid in small quantities. The acid is thoroughly mixed in at temperatures of −20° to +80° C. (−4° to +176° F.). The reaction time is greatly decreased by passing the mixture of naphtha and acid between two rapidly moving surfaces which are very close together. The reaction may take only a few seconds under these conditions.

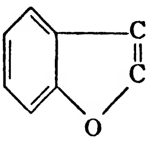
When the reaction has been completed, the acid is settled and removed, and any remaining is neutralized. The unreacted naphthas are then distilled off, leaving the resinified components. Sometimes the formation of emulsions in the mixture complicates the removal of the acid. If a naphtha containing above 40 per cent of resinifiable substance is used, the trouble with emulsion formation is acute. Using a 30 per cent cumarone-indene naphtha or diluting the heavy naphtha with lighter naphtha and stopping the reaction by leading in ammonia gas, may prevent the formation of emulsion, and saline solutions may sometimes be used to break them. The resin should be washed before distillation.

The last traces of naphtha are removed after distillation by holding the resin at high temperature for some time or by placing it in a vacuum. The latter procedure may cause the formation of air bubbles, producing a cloudy product. Insufficient washing of the resin before distillation may result in a whitish cloudy resin because of the incomplete removal of the sodium sulfate formed by the neutralization of the remaining acid.

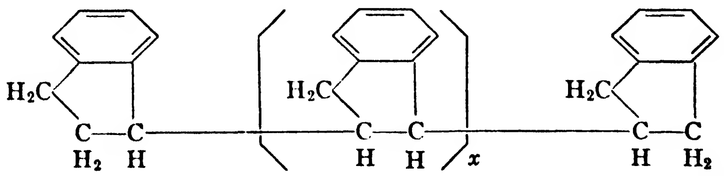
The structure of indene is



and of cumarone



polymerization presumably resulting in a chain molecular structure like this:



By carefully controlling the conditions of the reaction, resins of different degrees of polymerization can be prepared, varying in physical properties from thick sirupy liquids to hard brittle solids. Colors range from pale amber to dark brown.

Cumarone-indene resin is not itself molded as a plastic but is used as a modifier in other plastics and as a binder for floor tile. It is used to improve the flowing qualities and dimensional stability in vinyl resins to be used for transcription records.

Cumarone-indene resin to be used as a base for mastic floor tile is plasticized with oils or pitches to yield a binder of the desired color and physical properties. The binder is then blended in standard masticating equipment with mineral fillers, pigment, and a small amount of granular material. Some fibrous filler such as asbestos is included. The finished binder flows smoothly when heated above the melting point, hence wetting the filler thoroughly and producing a coherent, dense plastic. The plastic is sheeted by being pressed between rolls and is then polished and cut to size.

The resin is also used in rubber compounding as a plasticizing agent. To render the rubber more tacky, the softer grades of the resin are used. The harder grades of resin are combined with solvents and other modifiers, notably plasticizers, to form varnishes, printing-ink varnishes, cellulose lacquers, and other coatings.

MANUFACTURE OF CELLULOSE ACETATE PLASTICS

Cellulose acetate for use in the manufacture of plastics is made by the acetylation of cotton linters to form cellulose triacetate, followed by deacetylating to the desired degree, then precipitating and treating to give the characteristics desired.

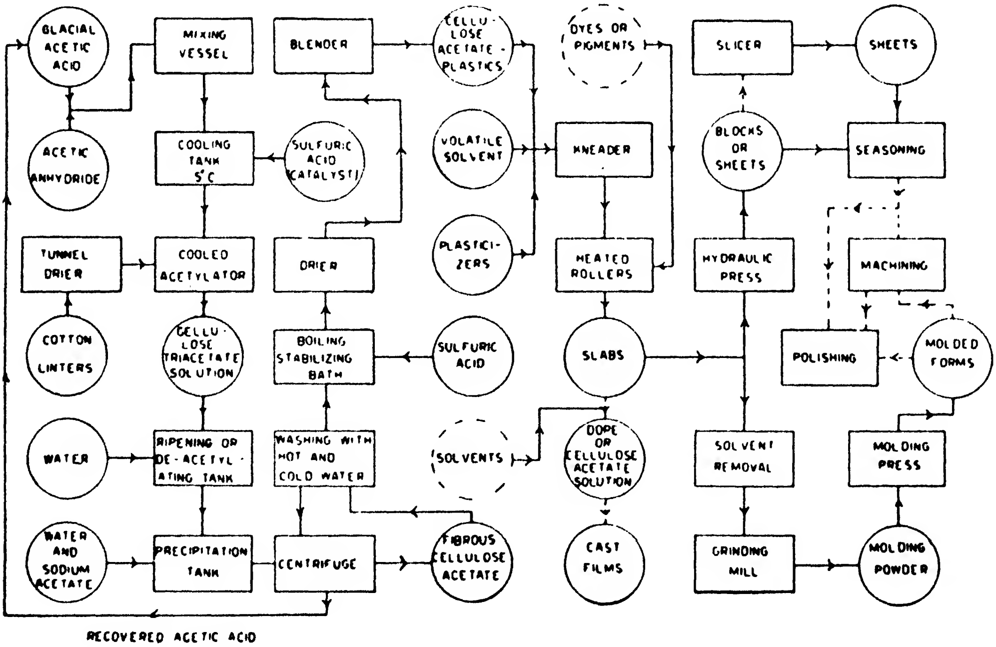


FIG. 13.20 — Manufacture of cellulose acetate plastics. (Key on page 475.)

For the acetylation, glacial acetic acid and acetic anhydride, proportions 5 to 3, are mixed in a suitable mixing vessel and cooled to 5° C. (41° F.) in a cooling tank before the catalyst, sulfuric acid, is added. One part of sulfuric acid to about 52 parts of the mixture should be used, and stirred well, since it will rise in temperature. Sulfuric acid is believed to promote acetylation by combining with the acetic anhydride to form a compound which can dehydrate and combine with cellulose or other organic compounds. Whatever the exact mechanism of the process, it is fairly certain, according to A. G. Lipscomb, that there is actual combination between the sulfuric acid and the cellulose, with or without the intervention of acetic anhydride, and this intermediate compound reacts with acetic anhydride, the sulfuric acid content of the cellulose acetate decreasing as the acetyl content increases. Instead of sulfuric acid, one of its derivatives, such as aromatic sulfonic acid, may be used. Other catalysts have been tried successfully, but none are so satisfactory for commercial purposes.

The cellulose for the acetylation is provided in the form of cotton linters, which may be rendered more amenable to acetylation, if desired, by pre-treatment with a suitable reagent such as formic or acetic acid containing some sulfuric or lactic acid, phenol, halogen or halides. The material may be dried in a tunnel drier, where its moisture content is regulated to 2 to 3 per cent. A higher moisture content wastes acetic anhydride, besides making the temperature more difficult to control and producing a lower viscosity acetate. Too dry a cotton is relatively unreactive.

After the acetylation mixture has been transferred to the acetylating tank and cooled down to about 5° C. (where crystallization commences) the cotton linters may be added (requiring from 30 to 45 min.), with constant stirring. During the addition of the cotton, the temperature rises about 2° C. and from here on should be carefully watched, since it greatly affects the resulting product.

In the next stage of acetylation (from 1 to 2 hr.), the acetylation mixture becomes a fairly homogeneous liquid and the temperature continues to rise at the rate of about one degree every quarter of an hour.

The third stage of acetylation is characterized by a change from a liquid to a stiffer, dough-like consistency, and requires about ½ hr. The temperature continues to rise a few degrees.

The reaction now proceeds rapidly, and cooling must be employed to keep the temperature from rising too high. A brine-filled jacket around the acetylator may be used, care being taken not to overcool the mixture, and to keep it thoroughly stirred. The maximum temperature (not more than about 35° C. (95° F.)) is reached at this time, and the temperature soon begins to fall. After the temperature has continued to fall for an hour or so, samples of the liquid are taken and examined for unacetylated fibers and anhydride. When hardly any trace of unacetylated fibers remains in the clear solution any excess anhydride is removed by a suitable addition of water and the resulting cellulose triacetate solution is poured into the ripening or de-acetylating tank.

The acetylating of cellulose is continued to the triacetate stage only.

$$C_6H_{10}O_5 + 3(CH_3CO)_2O \longrightarrow C_6H_7O_2(OCOCH_3)_3 + 3CH_3COOH$$

This cellulose triacetate, however, is not suited for use in plastics. The cellulose triacetate of about 63 per cent acetic acid content is partially hydrolyzed or de-acetylated by the addition of water. The time and temperature of the ripening and the amount of water added determine end characteristics. About 20 to 25 per cent of water (soft) is used based on the original weight of cellulose. The ripening room is kept at about 21° C. (70° F.) and the ripening period takes about 65 to 75 hr. After 54 hr., tests are begun on small precipitated samples of the product washed free of acid, dried, and ground. The behavior of the ground product in dried chloroform (both hot and cold) is noted. As de-acetylation continues, the product changes first to a powder soluble in chloroform then to one forming a soft plastic, and finally to one forming a hard plastic. Other tests also are carried out, notably the acetone test. The ripening product should dissolve to form a clear solution.

After ripening, the cellulose acetate is transferred to the precipitation tank, where it is mixed with sodium acetate to neutralize the sulfuric acid, and precipitated slowly by the addition of water during thorough stirring. The mixture first becomes cloudy and then forms a fibrous precipitate, which should be free from troublesome colloidal gels. The precipitated fiber is drained free of acetic acid, centrifuged, washed, then centrifuged further. The acetic acid is recovered, and after proper treatment it is used to provide acetic acid for another batch of cellulose acetate.

The washed fiber (which has continued slowly to ripen further) is boiled with dilute sulfuric acid to stabilize it. This is done for the purpose of removing any remaining combined sulfuric acid (which would lower the charring temperature of the finished product). Stabilizing also partly depolymerizes or reduces the particle size of the mixture, and reduces the acetyl content slightly. Samples are drawn off and tested at intervals during the stabilizing until a plastic with the desired properties has been obtained. The precipitated fiber is then removed from the vat, freed of as much water as possible by the hydro-extractor, and transferred to the drier.

The drying temperature is 100° C. or a little higher. Final moisture content is about 1.5 per cent. After drying, the batch is often blended with finished cellulose acetate from other batches, which may modify its properties.

Plasticizers are usually only liquids of high boiling point and low vapor pressure. Some plasticizers which have a solvent or gelling action on cellulose acetate are dimethyl phthalate, dibutyl tartrate, triacetin, methyl phthalyl ethyl glycollate and paratoluene ethyl sulfonamide. Triphenyl phosphate also adds fire-retarding properties.

The doughy colloid produced in a kneader is worked on heated rolls, with the addition of pigments if desired, and the slabs issuing from between the malaxating rolls are variously treated depending upon the form of the product desired. If a molding powder is to be prepared, the slabs are heated to remove and recover the volatile solvents. After drying, the hard masses are ground to powder or granules and emerge as a molding powder for injection or compression molding, depending upon the original formulation of the mixture.

On the other hand, if sheets or blocks of the plastic are to be produced, the plastic material from the rolls is pressed to shape in a heated hydraulic press. It then goes to a slicer where the blocks are sliced into sheets or thick sheets sliced into small blocks used as preforms. Mottled and variegated designs are often produced in sheets by slicing from blocks.

Films are made by casting a heavy dope on a polished, moving surface. After evaporation of the volatile solvents, the film is stripped off, dried, and wound into rolls. Films from 0.0005 to 0.010 in. in thickness are made in this way.

Rigid transparent packaging materials of cellulose acetate may be cast, and their corners and edges welded to form continuous, seamless, transparent containers.

Butyric acid added to the glacial acetic acid and acetic anhydride results in the formation of cellulose acetate butyrate, and other mixed esters are produced in a similar way.

MANUFACTURE OF CELLULOSE NITRATE PLASTICS

Cellulose nitrate plastics as typified by celluloid are made from the substance formed by nitration of cotton linters or fuzz remaining on cotton seeds after the long staple cotton boll is removed.

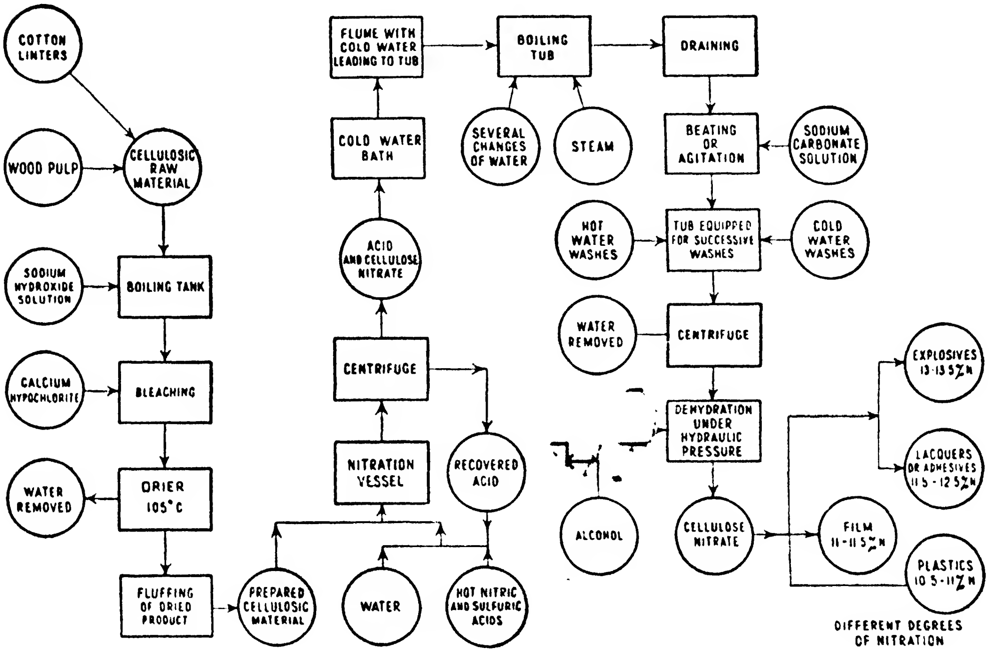


FIG. 13.21 — Manufacture of cellulose nitrate for plastics. (Key on page 475.)

The cellulosic material is purified by boiling w[illegible]ong sodium hydroxide solution. This is followed by a bleaching operation employing calcium hypochlorite, and then by drying in a drier at about 105° C. to the desired moisture content (about 1 per cent). The dry product is fluffed or shaken up. Drying prevents excessive heating during nitration. Cellulose nitrate (nitrocellulose) for military purposes is prepared from wood pulp or cotton linters, but the finer types of material are better for the production of plastics.

The conditions of nitration determine the type of product which will result. Nitration takes place in a nitrator provided with a mechanical stirring device and a means of allowing fumes to escape. The cellulose is treated with a hot mixture (about 30° C.) of nitric and sulfuric acids with water. Usual proportions are 60 per cent sulfuric acid, 20 per cent nitric acid, and 20 per cent water. This bath is twenty to thirty times the weight of the cellulose to be nitrated, though very little of it is used up in the reaction. The acids are of course recovered and used again and again. The use of smaller amounts would mean difficulty in mixing the acids thoroughly with the cellulose, and difficulties in controlling the reaction. The acid and cellulose are stirred for about 20 min. For a product to be used in plastics it is desirable to produce a cellulose nitrate of about 11 per cent nitration, as against 13 per cent for use in explosives.

From the nitrator, the nitrocellulose and acid bath are dropped down into a centrifuge which concentrates the solid and allows the acid to be drawn off. The more or less solid mass of cellulose nitrate, containing considerable acid, is dropped from the centrifuge into a bath of cold water.

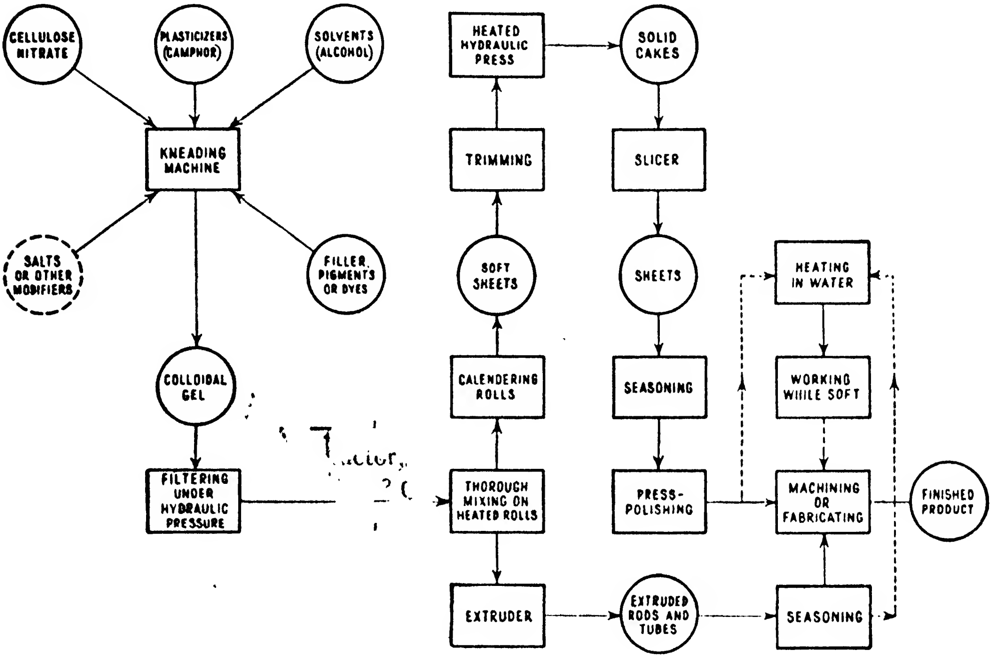


FIG. 13.22 — Manufacture of plastics from cellulose nitrate. (Key on page 475.)

The acid is removed in a boiling tub by boiling in several changes of water. If the acid is not removed, the life o[illegible] plastics made from the material will be shorter. Removal of the acid and unstable cellulose esters may be doubly ensured by treating the boiled cellulose nitrate with a sodium carbonate or washing soda solution, which serves to neutralize any remaining acid. This solution should be added to the cellulose nitrate in a vessel supplied with means for agitating the mixture thoroughly. The solution is then drained off and the cellulose nitrate again washed with hot water at about 100° C. (212° F.) followed by several washes of cold water. There may be as many as twenty final washings.

After the cellulose nitrate has been thoroughly washed, most of the water is removed by a centrifuge, usually of the perforated basket type. Further drying is of alcohol displacement, usually under hydraulic pressure. The alcohol remaining in the cellulose nitrate should be at least 85 per cent by volume.

The finished alcohol-wet cellulose nitrate is converted into a plastic mass by the addition of solvents and of camphor, the standard cellulose nitrate plasticizer. These materials are worked into the cellulose nitrate in a kneader, and a colloidal transparent gel results. About 1 gal. of alcohol to each 10 lb. of cellulose nitrate is used to each kneader, about 200 lb. of cellulose nitrate-camphor mixture being kneaded in a batch. Kneading for 20 min. is enough to effect complete gelatinization. After that the plastics material is strained or filtered under hydraulic pressure while it is still soft. If transparent colors are desired in the finished product, alcohol-soluble dyes must be added during the kneading operation, while pigments are added to give opaque colors.

Further rolling of the mass on heated rolls makes the texture and coloring more uniform and tends to remove some of the volatile solvent (alcohol), thus causing the material to harden. Sheets of the plastic are then prepared by sheeting the material on calendering rolls like those used for rubber. The sheets are trimmed to size and pressed to 3- to 5-in. thickness by hydraulic presses. Sheets may be baked, while under hydraulic pressure, into cakes somewhat larger than the standard 20 by 50 in. sheets. The hydraulic presses used have jackets through which hot or cold water may be run, as desired. Pressures of 250 to 500 lb. per sq. in. are usually employed.

The blocks formed in this way are sliced by machine to almost any required thickness. The thinnest sheet produced commercially is about 0.005 in. thick.

Seasoning of the sheets to remove most of the remaining solvent is carried on in ovens at about 50° C. (122° F.). A sheet emerging from such an oven may weigh 10 to 20 per cent less than it did when it entered. Press-polishing in hydraulic presses is a finishing operation intended to produce a per[illegible]lat, smooth sheet. Uneven drying out in the ovens causes warping. If extr[illegible] such as rods and tubes are to be prepared, the warm plastic mass from t[illegible]ders is led directly into an extrusion press from which continuous rods, tubes, [illegible]heets can be delivered.

The high flammability of cellulose nitrate plastics can be reduced by incorporating fire-retarding plasticizers such as tricresyl phosphate into the mass during the kneading operation.

Cellulose nitrate of slightly higher nitration (about 12 per cent nitrogen) is used to make lacquers, giving toughness and durability with quick drying at room temperature. It is also used in the production of adhesives, artificial leather compositions, and emulsions for coating paper.

The finished cellulose nitrate plastics, both mo[illegible]nd extruded, can be machined, though if they are to be cut on high-speed tools, a cooling jet of water is played on the point of the cut. Cellulose nitrate plastic is softened by warming in water and may then be worked by hand, or molded, or pressed. It softens sufficiently at 70° to 90° C. A good cellulose nitrate plastic should not take fire below 160° C. at the least. Incorporation of a variety of fillers and especially of salts or pigments into cellulose nitrate will produce a great variety of novel color effects — mottled, marbled, pearly.

Manufacture of Cellulose Ether Plastics

The principal cellulose ether used in plastics is ethyl cellulose. Benzyl cellulose is also of interest, but methyl cellulose, which is water soluble, is limited to use as an adhesive or coating material.

Ethyl cellulose is prepared in two steps. Alkali cellulose is first prepared by treating cellulose in the form of wood pulp or cotton linters with a concentrated sodium hydroxide solution. The cellulose swells considerably during the reaction. Excess alkali is drained and pressed out, and the sodium cellulose is dried. Ethyl cellulose is then prepared by heating the sodium cellulose under pressure for about 8 hr. with gaseous ethyl chloride. Temperatures of 180° to 200° C. (356° to 392° F.) are employed. Any excess of ethyl chloride may be distilled off and any soluble impurities extracted with water. After being dried again, the ethyl cellulose is dissolved in alcohol, filtered, and reprecipitated with water.

Ethyl cellulose is thermoplastic and is suitable for injection molding and extrusion. It can be precipitated as a powder which is unsuitable for molding but which can be made moldable by working it on hot rolls with modifying agents and solvents. The product is ground and then may be molded without seasoning.

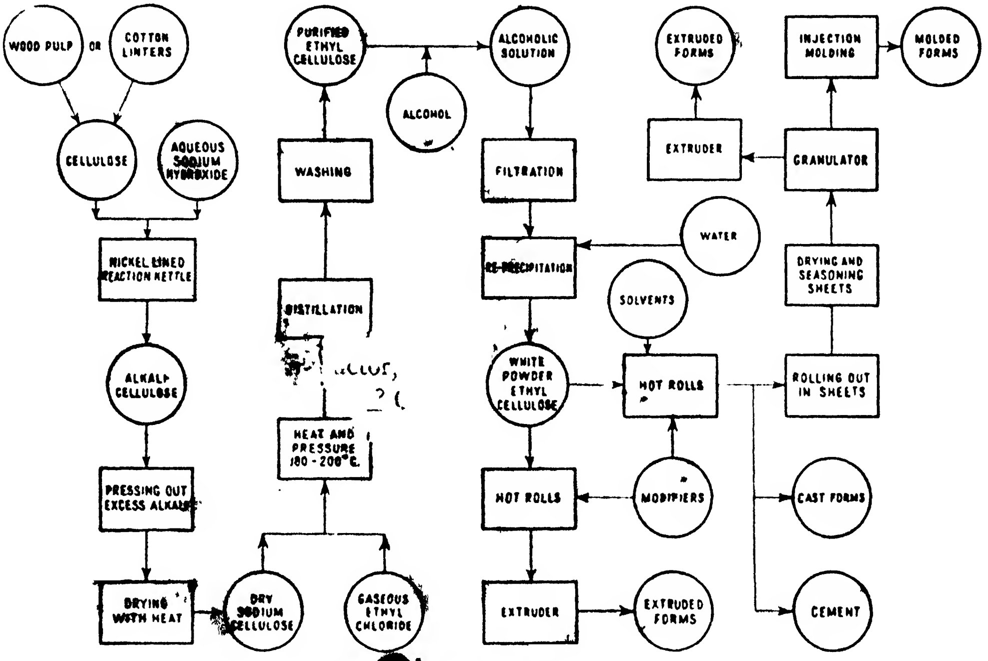


FIG. 13.23 — Manufa[illegible]thyl cellulose plastics. (Key on page 475.)

Plasticizing agents for ethyl cellulose include chlorinated diphenyl and its derivatives, fatty acids, high-boiling esters, and raw or air-blown oils. It is soluble in practically all solvents except straight chain petroleum hydrocarbons and is compatible with many resins, oils, waxes, and plasticizers.

Ethyl cellulose plastics can be fabricated with a minimum of volatile solvents and plasticizers and may be modified by non-volatile resins to form a product of great dimensional stability. It is widely used for the extrusion of wire coatings as insulation.

Sheets of ethyl cellulose may be cast from solution. Hot melt mixtures of ethyl cellulose and hot resins, oils, waxes, plasticizers, and mixtures of these, in the absence of volatile solvents, may be used as paper and cloth coatings to form a base for adhesives.

Benzyl cellulose is also prepared by the intermediate preparation of alkali cellulose. A caustic soda solution of about 18 per cent is employed, but the percentage may vary with the grade of material desired. The excess sodium hydroxide is pressed out, and benzyl chloride is added to the sodium cellulose. The mass is heated for several hours until benzylation of the cellulose has occurred. The product can be used to prepare molding compositions and various lacquers, enamels, and dopes.

Methyl cellulose may be prepared by a process similar to that used for ethyl cellulose, or by direct methylation of cellulose with dimethyl sulfate. With increasing methylation, methyl cellulose becomes horny and harder.

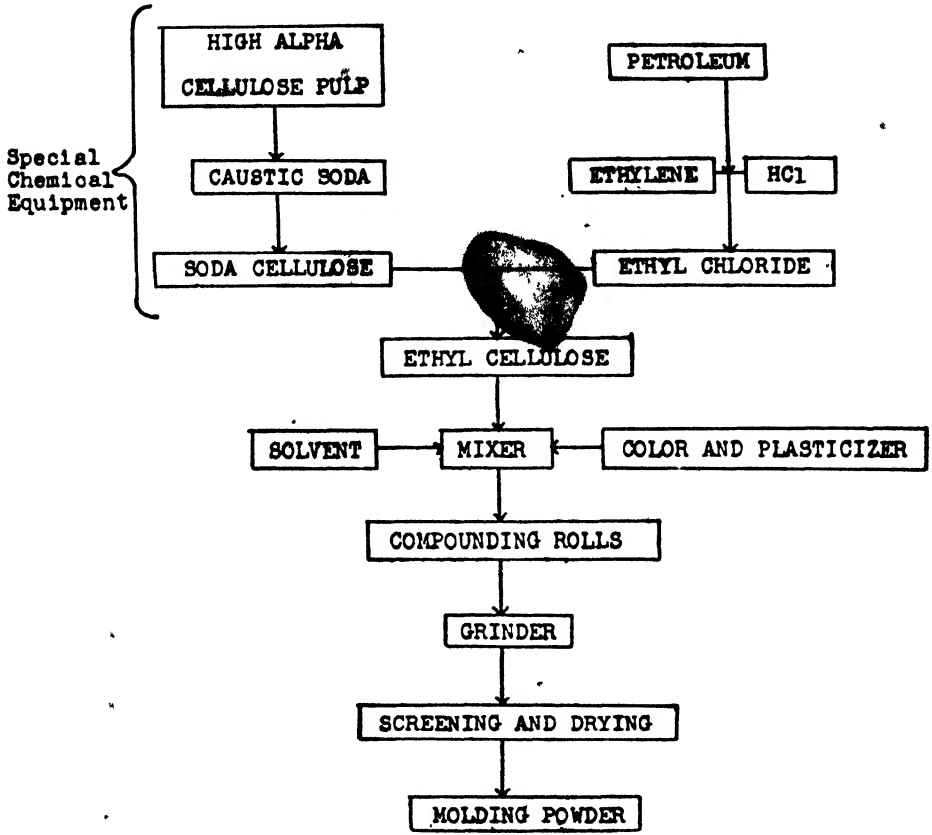


FIG. 13.24 — Ethyl cellulose flow sheet. (Key on page 475.)

Cellulose xanthate may be produced by dissolving dry wood pulp in alkali to form sodium cellulose. The dry sodium cellulose is shredded and treated with carbon disulfide to produce cellulose xanthate which in turn is dissolved to dilute caustic soda to form viscose. The viscose is filtered and ripened in tanks kept at an even temperature of 18° C. Several times during a 4 to 7 days' period, it is passed through filter presses from which the air has been excluded. The viscose is made waterproof when dry by heating it with rubber latex or some other colloidal dispersion and 2 per cent of a wetting agent such as triethanolamine oleate. Plasticizers or other softening agents are added. The viscose sirup may be used to impregnate paper or fabrics for laminating — also for making phonograph records.

MANUFACTURE OF LIGNIN PLASTICS

Lignin, present in wood to about 25 per cent, is the binder of certain promising low-cost plastic materials.

Wood chips, sawdust, corn stalks, straw or cane bagasse may be used as the lignocellulosic source material. Usually this is treated to hydrolyze it to some extent by soaking it in dilute acid or treating it with hot water or steam, in the presence of acid. The softening point of the lignin is lowered with plasticizers such as aniline, but a full separation of the lignin from the cellulosic material is not necessary.

The altered material is reduced to a finely divided state, either by grinding in a rod mill, or (more commonly) by treatment in an exploding chamber or gun. The woody materials are exploded under steam pressure of 800 to 1200 lb. per sq. in. and at a temperature of about 260° C. (500° F.), separating the woody fibers from their lignin bond.

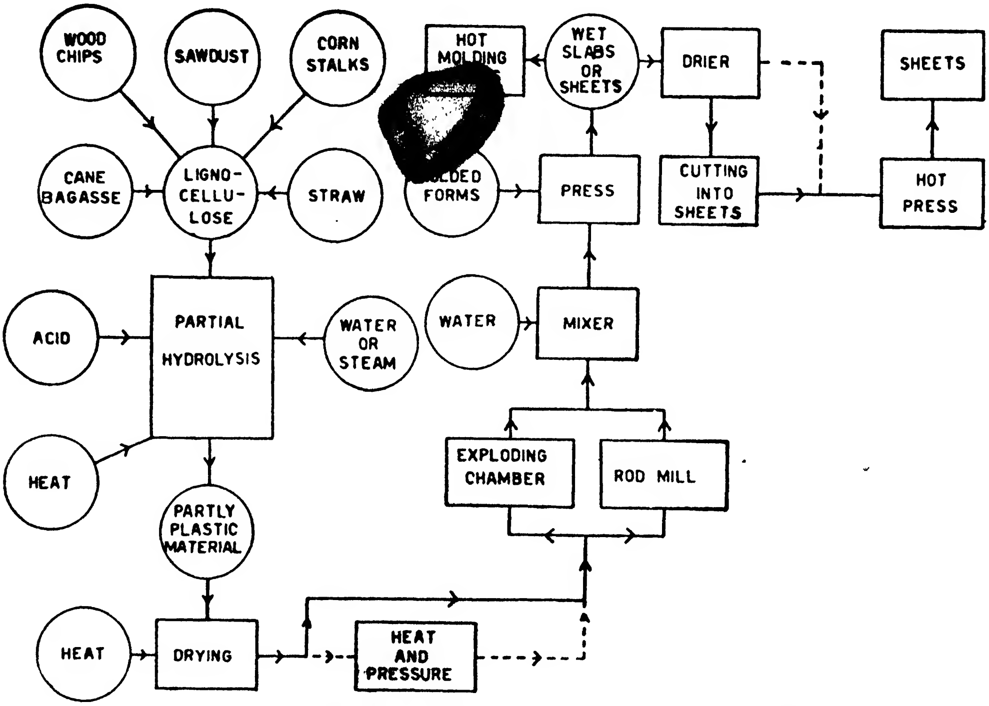


Fig. 13.25 — Manufacture of lignin plastics. (Key on page 475.)

The product is screened and then mixed with water to a pasty condition. Resins, lubricants, and fillers may be added if necessary. Rubber, furfural, aniline, phenol-formaldehyde, benzyl cellulose, or other cellulose plastics are a few of the substances used. For the most part the woody material present serves as a good natural filler and the natural dark glossy finish of the plastic does away with the need for pigments. Petrolatum or paraffin in small quantity also may be added.

The wet plastic mass from the mixer is loosely rolled into wet slabs or sheets which are then pressed into rods, tubes, or other molded forms, or may be dried and cut into mats which are later hot-pressed to form finished, polished sheets. Alternatively, the material from the mixer may be loosely pressed and directly cut into sheets and transferred to the hot-press.

During the pressing, the lignin bond becomes set so that the finished product cannot again be disintegrated and rebonded. The process is similar to the thermosetting of phenolic resins. Mats of the fiber are pressed by one company into panels which trim 4 by 12 ft., and in thicknesses from 0.1 to 1.00 in. Pressures up to 2500 lb. per sq. in. and temperatures up to 280° C. may be used.

The product is cured normally at a temperature of 175° C. and a pressure of about 1500 lb. per sq. in. If desired, the finished sheets may be surfaced with phenolics or ureas in a variety of colors.

In the manufacturing process during which the fibers are exploded, more complete use is made of the lignin bonding material than in the other or " paper type " method. The exploding treatment at once releases the lignin bond and at the same time activates the lignin. An automatic self-hydrolysis of the woody particles takes place, for the hot steam causes the formation of acetic and formic acids.

For further information on manufacture of lignin plastics, see page 312.

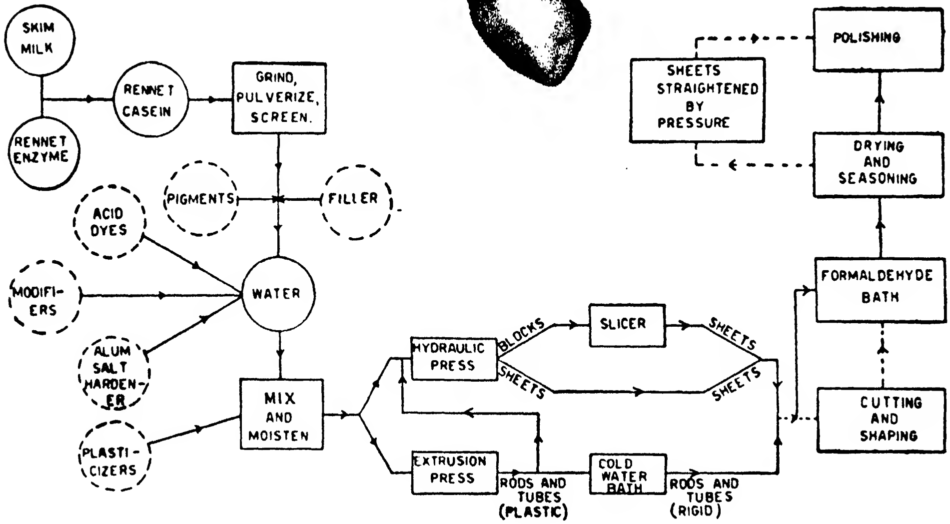


FIG. 13.26 — Manufacture of casein plastics by the dry process. (Key on page 475.)

MANUFACTURE OF CASEIN PLASTICS

Casein plastics are produced by two different processes, both based upon the general method of plasticizing the casein with water and heat, shaping it and then rendering it insoluble by the use of certain reagents, most commonly formaldehyde.

The wet process makes use of acid casein, which is dispersed in an aqueous alkaline medium and later coagulated by acid. The dry process uses rennet casein and is a newer and improved method.

The wet process is the earlier process and is no longer important commercially. It makes use of " acid casein " (actually pure casein) which is dispersed in an aqueous alkaline solution, treated with dyes, fillers, etc., as desired, and coagulated with acid or an acid salt. The curd is pressed at moderate pressures to remove most of the water. It is subsequently pressed at a pressure of approximately 100 lb. per sq. in. to convert the curd to a rubbery plastic which is translucent if no fillers have been added. The pressing requires 1 to 24 hr., depending on the thickness of the sheet desired and the temperature of the press. The soft, plastic sheet is then placed in a bath of aqueous formaldehyde to harden for 3 weeks to 3 months, depending on the thickness of the sheet. After it is thoroughly hardened, the material is allowed to dry or season and is then ready for use in the fabrication of buttons, beads, etc.

Two modifications of this process have been developed which eliminate the long hardening treatment in formaldehyde, the pressed coagulum requiring seasoning only. In one modification the casein is dispersed in aqueous ammonia and the formaldehyde solution is used as a coagulant. In the other, a suspension of casein in water is treated with acetaldehyde and an organic acid, and is then coagulated with alkali.

In general, material produced by the wet process is more brittle than that produced by the dry process.

The dry process makes use of rennet casein almost exclusively, and it is important that the casein selected should have been produced from pure, sweet, fat-free skim milk and should have a pH close to 7.0[illegible]ure content between 7 and 10 per cent, an ash content of about 8 per cent.

Rennet casein, unless ground a[illegible]factory, is supplied in the granular form in which it comes from the drier. It should not be stored for long periods and should be kept in a dry, well-ventilated storeroom until ready for grinding.

Grinding. Before mixing, the casein must be ground to pass a 40-mesh sieve, with a very small percentage passing through a 100-mesh sieve. The grinding may be carried out in a mill with corrugated rolls, such as are used in flour mills, or in an impact pulverizer. Porcelain-lined ball or pebble mills cannot be recommended because of the probable contamination of the ground material with a small proportion of grit. Grit in casein plastics prevents the attainment of a satisfactory polish on finished articles. Any particles of wood, brick, or stone which become mixed with the plastic must be carefully removed before grinding.

If an opaque material is desired, a white pigment such as lithopone, titanium dioxide, titanium-barium pigment, etc., is first mixed dry with the casein, the color being provided by dyes added later with the water. Colored pigments may be added dry, but are somewhat more expensive. Other fillers may also be thoroughly mixed with the dry casein.

Mixing and Moistening. The next step is the thorough kneading and mixing of the plastic in a dough mixer, with the addition of up to 45 per cent of water and various other substances. The percentage of water added varies, depending on how the plastic is to be worked. The greater the proportion of water added, the softer the plastic and the greater the shrinkage on finishing. The water used must be free of iron salts and should be either freshly distilled or softened. If the material is to be colored, acid dyes should first be added to the water.

Alum salts are often added at this point to produce a casein material hard enough to be machined before being immersed in formaldehyde.

The water is usually added in the form of a spray, either continuous or intermittent, though a process has been patented for using water vapor. The use of alcohol, glycerol, sugar sirup, and water of crystallization has been suggested for the gradual introduction of water to the mix.

The following modifiers are also often added to the water before mixing: (1) Talc, lead acid phosphate, or benzanilide to produce a pearly effect: (2) glycerin to the extent of 2 per cent of the weight of the casein, tricresyl phosphate, and methyldiphenylamine to render the plastic translucent to transparent; (3) carbonates, bisulfides, etc., to render the material porous; (4) neutral phosphate esters or reducing agents; and (5) volatile organic substances such as alcohol, acetone, or ethyl lactate.

During the mixing, various plasticizers may be added, usually with the purpose of making the material less brittle. The value of these plasticizers is doubtful because water alone plasticizes the material sufficiently, and the long soaking in the hardening solution tends to remove any soluble substance. Some of the proposed plasticizers are glycerin, aniline oil or acetanilide, sulfonated castor oils, ethereal alcohols with at least two groups substituted with oxyalkyl groups, higher alcohols from dodecyl to octadecyl alcohol, acetic acid, 20 per cent ammonia, the oleic ester of hydroxyethane sulfonic acid, triethanolamine, other ethanol amines or ethylene diamines, amines of the fatty or of the aromatic series, methylolethylurethane, cyclohexylethanolamine.

The mixing may be carried out satisfactorily in any kind of mixing machine that thoroughly turns the powder over and over on itself, has no dead spaces where the plastic can be undisturbed, and does not heat the mixture and form excessive dust from the dry or nearly dry powder.

The " Artofex " mixer is employed extensively by casein plastics manufacturers in the United States and Europe because it is simple to operate, easy to keep clean, efficient, and economical.

After mixing with water, the casein is still quite powdery if thoroughly mixed. The addition of water is accompanied by the liberation of heat known as " heat of absorption." If the soft lumps formed by the first contact of water and casein are not promptly broken up by the mixer, the water and heat cause plasticization of the lumps of casein, which become tough and must be removed and reduced to powder again.

After the addition of water the casein must be used promptly or putrefaction will set in.

Extrusion. The plastic casein is then fed into a heated cylinder press fitted with a rotating screw and a nozzle with a bore of the desired size for producing rods and tubes. The mechanical strength of the finished plastic depends largely upon the mechanical working and macromolecular orientation accomplished during this process. The use of a hydraulic stuffer such as is used in the production of Celluloid is therefore not so satisfactory.

In front of each extrusion machine is a table covered by a belt traveling at a slightly higher speed than that at which the rod is being extruded. The slight tension maintained in this way keeps the rods straight.

The rods and tubes issue from the extrusion nozzle as hot, soft, plastic forms. They may then be placed in cold water until thoroughly cold and transferred to the hardening tank. Excessively hot plastic may produce irregularly surfaced or bumpy rods, or oversized rods or rods with countless tiny bubbles or pinholes.

On the other hand, if sheets are desired, they may be made by placing freshly extruded rods in frames of the desired size (usually thickness 10 by 20 in.), and pressing them in heated hydraulic presses. The rods may be cut into short lengths, piled together and wrapped in a clean cloth until ready to be laid out for introduction into the hydraulic press.

Sheets may also be produced by pressing the soft plastic or the powder in hydraulic presses until it fills frames of the desired size, or by slicing sheets of the required thickness from solid blocks which have been pressed to size.

The frames used for the first method are 10 per cent larger in all dimensions than the size called for by the finished sheet, to allow for shrinkage in drying. They are also heavy enough to withstand the pressure of the press. The charge of plastic (rods from extruders, strips from rolls, or pieces from kneading machines) is weighed to fill the frame exactly and to leave a slight excess to form fins. It is pressed between two thin metal sheets (such as polished zinc) between two heated platens in a hydraulic press capable of exerting a pressure of approximately 1 ton per square inch of material.

Standard large multiple-platen presses, having from six to twenty openings and platens constructed to permit heating with steam and cooling with water, are satisfactory. After cooling the press, the sheets are removed, the metal sheets stripped off, and the sheets of plastic knocked out of the frames.

The slicing of sheets from a solid block of soft plastic is not practicable for large-scale production, though it has the advantage of yielding sheets of absolutely uniform thickness.

Mottled effects are obtained by adding a small quantity of colored material (in the form of soft plastic) to the powder and pressing a sheet directly from the powder, cutting the sheet into ⅛-in. cubes, drying, and extruding. They may also be made by using a double-screw type of extruder with a single nozzle and feeding two separate mixings into each screw.

The material in the form of rods, tubes, or sheets may be cut or shaped before being hardened if desired. This is usually done in the production of buttons from rods of alum casein.

Hardening. The casein plastic is hardened and converted into a substance no longer subject to putrefaction by immersion in a 4 to 6 per cent concentration of formaldehyde — weaker for thin sheets and stronger for thick sheets and rods. They are left in the solution for from 1 to 6 months, depending on their thickness. The formalin treatment tanks are of brickwork and lined with cement, and through these the solution is kept in circulation by pumps, the temperature maintained at about 65° F., and the strength of the solution maintained by suitable addition to the solution from day to day. The formaldehyde must penetrate the mass completely, and the material should be examined occasionally for penetration of formaldehyde. A rough test may be made by placing the piece to be tested in boiling water for a few minutes. Lack of homogeneity in a partially hardened piece is quite apparent. A much more accurate test is the examination of a section with polarized light under a microscope.

The rods, sheets, and tubes are set in frames designed to allow free circulation of the solution, which should frequently be analyzed, tested for pH, and carefully controlled thermostatically.

The hardening is the most disagreeable and expensive part of the process, and attempts are being made to shorten it. A ¾-in. rod takes 241 days to cure, with the time required for drying, and a 1-in. rod requires a year. Hence whole rods in excess of ¾-in. diameter are no longer produced. It has been suggested that hardening accelerators such as alkali or ammonium salts or alkaline or alkaline earth thiocyanates be mixed with the powder before extrusion. It has also been suggested to substitute other hardening agents for the formaldehyde bath, such as formaldehyde vapor, tannic acid, chromium salts, hydrogen peroxide, alum, and the polymerization product of formaldehyde with sulfuric or formic acid. None of these but alum is commercially important. Alum, tannic acid, and picric acid form insoluble salts with the casein, whereas formaldehyde, trioxymethylene and hexamethylenetetramine are believed to denature the casein molecule. After the formaldehyde treatment the pieces are removed from the bath and washed with water.

Drying and After-treatment. Excess moisture and formaldehyde must be removed from the plastic slowly during the seasoning and drying process to minimize the formation of strains in the material, with consequent cracking. Seasoning may be safely speeded up by drying at a moderately elevated temperature in a carefully controlled humidifier, keeping the surface layer soft so that the moisture in the center can diffuse out readily. Elevated temperatures without humidification cannot be recommended. The moisture content is usually reduced to 10 or 13 per cent.

The drying is usually accompanied by warping, especially noticeable in the sheets. Sheets are straightened in low-pressure hydraulic presses where the sheets are pressed between platens heated by steam until the sheets are flexible, and cooling under pressure. Rods seldom require straightening, but may be softened in hot water, and then forced into grooved straightening boards where they cool under pressure, or they may be ground or " trapped " through a suitable machine. Sheets are sometimes sanded to the required uniform thickness. All rods are ground to the required diameter. Special straightening of rods is done under hot plates, but regular commercial straightening is not.

Sheets are seldom sanded, but sold as they come from the molds. The only sanding usually done is to roughen the surface for gluing.

Occasionally casein rods, sheets, or tubes may be polished if the customer orders it and pays more for it, but it is not the rule.

Finished casein pieces are given a dip polish by immersion in a bath of sodium hypochlorite or some other glaze-producing solution.

The method of shaping or molding before hardening, widely used in the button industry, greatly reduces the time required for the process, and recent trends towards incorporating hardening agents in the plastic may finally eliminate the formaldehyde bath. Some substances which have been incorporated in the mixture as slow-acting hardening agents or hardening agents requiring the heat of molding to set them are as follows: trioxymethylene, hexamethylenetetramine, aldehydo-amine polymerization products, diphenol propane and formaldehyde, phenol-formaldehyde, methylol derivatives or urethane, ureas, and methylol dicyandiamide and formaldehyde, formaldehyde in mixture with a hydroaromatic alcohol or ketone, furfural, mixed aluminates of casein and fatty acids, mixture of casein with alkyl substituted acrolein, and a mixture of casein or soybean protein with formamide and formaldehyde. Leading in the same direction have been attempts to produce a molding compound of casein with ammonia, pressing thin plaques of the casein, the benzylation of protein or of casein, and the treatment of casein with a tanning agent such as quebracho. None of these efforts, however, has so far been successful enough to reach commercial importance.

Manufacture of Zein Plastics

Plastics having certain advantages over other protein plastics, such as those made from casein or soybean protein, can be prepared from corn protein or zein. The zein is a by-product of corn processing and becomes concentrated in the gluten fraction during the preparation of corn starch. At present the potential yield of zein is about 1 lb. per bu. of corn.

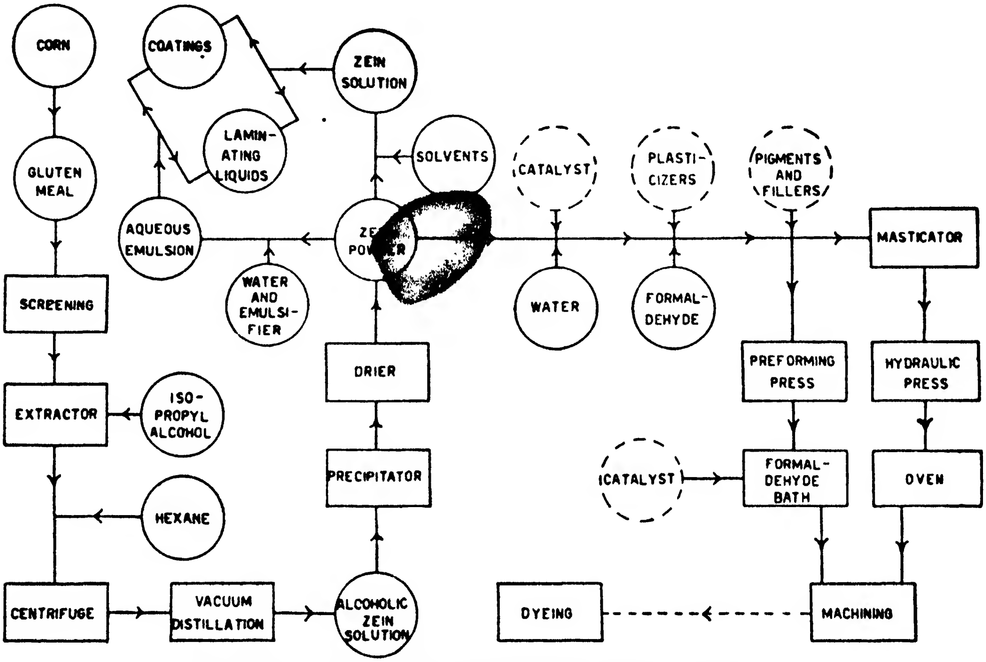


Fig. 13.27 — Production of zein plastics. (Key on page 475.)

The zein is extracted from the gluten meal with isopropyl alcohol, after the meal has been screened to remove particles finer than 40-mesh. The extraction is usually carried on in a seven-stage countercurrent extractor, with 85 per cent isopropyl alcohol at 55° to 60° C. (131° to 140° F.), the contact time being 1½ to 2½ hr.

The isopropyl alcohol extract is cooled and filtered to remove undissolved particles, and the clear extract is mixed with 80 to 120 per cent of hexane by volume. The result is a mixture which separates into two layers, the upper consisting of most of the hexane, a large part of the isopropyl alcohol, and almost all of the oils and pigments which it is desirable to remove. This layer is removed by centrifuging, leaving a 15 to 20 per cent solution of zein in isopropyl alcohol, with only a small percentage of hexane and impurities. The remaining hexane may be removed by vacuum distillation.

The zein is then precipitated from viscous solution by spraying it into a moving body of very cold water, where it rises to the top in fibrous form and is swept away by paddles, pressed into a cake, ground, and dried quickly in a stream of hot air.

The zein powder thus obtained has as its outstanding use the coating of paper, to which it gives a pleasing and scuff-resistant surface without high gloss. The zein may be applied either in alcoholic solution or in aqueous dispersion. Zein is readily dispersed in water by a variety of soaplike compounds. Solutions for coating paper are improved by the addition of rosin and may be plasticized with fatty acid, preferably one that is highly unsaturated such as soybean fatty acid. Paper coated with zein is resistant to the penetration of grease or oils and is useful in the manufacture of food wrappings. It may be waxed without the penetration of wax into the paper.

Zein-impregnated paper may be pressed dry at 100° C. with a pressure of 500 to 200 lb. per sq. in., depending on the plasticizers used, to produce a laminated board. Absorbent paper is used for the lamination, the zein being applied in concentrated solution at an elevated temperature. Rosin, ester gum, shellac, or a resin of similar material may be added up to 50 per cent of the zein content to increase the flow in the laminating process. This may reduce the cost without impairing the mechanical properties.

Because of its cost, zein is employed as an adhesive only for specialized uses such as the application of high-grade film veneers.

The manufacture of plastics from zein was first attempted using it as a substitute for casein in casein-type plastics. Zein has advantages over casein in that it is slower curing and allows the incorporation of formaldehyde into the plastic before forming, thus eliminating the lengthy formaldehyde bath required for casein plastic.

In the production of plastics from zein, the raw material or zein is mixed with 20 per cent by weight of water, and 5 per cent of formaldehyde and pigments, plasticizers, or other materials. The mixture is then plasticized on rolls and can be formed, as by pressing into sheets in a hydraulic press. A partial cure may be effected by pressing for a short time at 100° C. Preliminary forming or machining such as cutting button blanks, punching, stamping, and cutting can be carried out on the partially cured material, and the cure then completed by baking for a rather long period at 60° to 100° C. (140° to 212° F.), the time depending on the oven temperature and the size of the pieces. The completely cured material is suited for machine-finishing, being easily machined and producing little wear on the cutting tools. A circumstance of value in the manufacture of buttons and other novelties is the fact that they can be dyed in a dye bath after all the forming has been completed.

For the production of certain types of articles, the raw zein powder may be cold-pressed, with or without various modifying agents, into any desired shape by using a pill machine with dies of the proper form. Curing may then be effected by immersing the piece in formaldehyde containing a curing catalyst. With a vacuum pressure system, thin pieces can be cured throughout. A considerable saving in cost is effected by this method.

Zein plastics are tough and strong, with a transverse strength of about 15,000 lb. per sq. in. Their water resistance is better than that of casein plastics. They are expected to show outstanding developments in films and fibers when more satisfactory curing methods have been developed.

Zein cures slowly with formaldehyde, compared with the curing of casein, unless a curing catalyst is used. The reaction with formaldehyde is catalyzed by acids, strong mineral acids such as hydrochloric being most effective, though organic acids such as acetic or lactic may be used. Small amounts of ammonia or primary amines act as promoters for reaction but only in the presence of acid. The slow cure with formaldehyde allows the compounding of the curing agent into the molding compounds, or the use of formaldehyde in solutions or dispersions of zein for coating or impregnating.

Zein may also be cured with formamide, though bodies cured with this tend to become brittle on aging. The formamide should be added to the zein solution to be used for coating or other purposes, at least 30 per cent by weight (based on zein) being added if the zein film is to be heated, and at least 40 per cent if it is not to be heated.

The perfect plasticizer for zein plastics has not yet been found, but at present fatty acids of high molecular weight are preferred. Esters of hydroxy acids or dibutyl tartrate may be used, or, where water resistance is not required, high molecular weight glycol esters such as glycol phthalates, high boiling glycol derivatives such as diethylene glycol or Carbitol, or substituted sulfonamides may be used.

Zein is compatible with acid resins such as rosin, Manila ester, or shellac, and with some relatively neutral resins such as alcohol-soluble ester gum. These modifiers give gloss and body to the films and decrease the cost of the dry solids.

MANUFACTURE OF COLD–MOLDED PRODUCTS[3]

Non-refractory (Bituminous) Products. Cold-molded bituminous compositions consist of a mixture of various gummy, pitchlike, viscous substances having adhesive properties and capable of being altered by heat and pressure to form a solid binder for various fillers, notably asbestos.

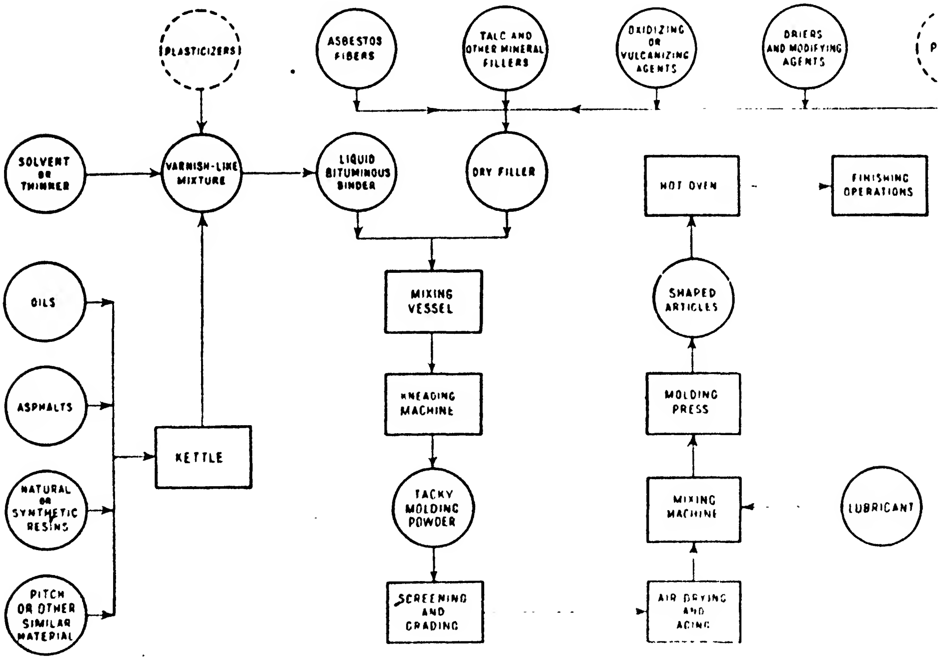


FIG. 13.28 — Manufacture of cold-molded bituminous plastics. (Key on page 475.)

The binder is prepared by mixing various bitumens or asphalts such as gilsonite, steam-reduced or blown petroleum with various oils such as tung oil, castor oil, linseed oil, fish oil, or oiticica oil, adding a small percentage of stearine pitch, vegetable pitch

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[3] Prepared in co-operation with W. R. Heineman, General Electric Co., and Helen Frey.

or other similar material, and also adding some natural and synthetic resins, depending upon the properties desired.

This mixture is cooked in a kettle, then thinned to the desired consistency with a solvent such as petroleum ether, kerosene, gasoline, benzene, high-flash naphtha, or coal tar naphtha, or a mixture of two or more of these or similar solvents. Plasticizers such as butyl or dibutyl stearate, tricresyl phosphate or chlorinated diphenyl may be added to make the mixture more plastic and improve the heat resistance of the final product. The resulting liquid mixture constitutes the binder (15 to 30 per cent of total mix).

The filler usually contains a considerable quantity of short asbestos fibers, mixed with other mineral fillers such as talc, kaolin, silica, and various oxidizing vulcanizing agents such as selenium, sulfur, and litharge. Driers, such as naphthenate, rosin, or litharge; coloring matter, such as carbon black or red iron oxide; and modifying agents may be added depending on the characteristics desired.

The dry filler is placed in a steam-jacketed mixing machine of the Werner-Pfleiderer type and the liquid binder is poured over it. Mixing is continued until the filler is thoroughly coated with binder and the desired granulation is reached. The product may be further milled until a nontacky molding powder has resulted. This is screened and graded according to particle size, plasticity, bulk factor, etc., and is then stored or aged for a week or more. During this aging period, the powder is spread out and air-dried. Loss of the solvent leaves a nontacky powder suitable for immediate molding.

Just before molding, the powder is usually mixed with a small percentage (0.5 to 1) of a lubricant such as a metallic stearate or neutral soap. The molded articles produced must then be baked for about 24 hr. (though the time varies with the size of the pieces) in an oven in which the temperature is gradually increased (20° F. per hr.) from 200° to 400° F. Baking causes evaporation of volatile materials, polymerization of certain of the constituents, and oxidation and hardening of the oils. A hard, stable compound results. Air in the ovens must be kept in circulation during baking.

The articles removed from the oven may be subjected to further finishing operations if necessary. Burrs and fins are removed in tumbling barrels when pieces are sufficiently small, and with wire brushes on larger pieces. Grinding for close tolerances is with a disk or belt grinder. A polish may be applied by tumbling pieces in wax-coated sawdust.

A formula for a typical cold-molding composition is as follows:

(U.S. Patent 1,671,230)

	Binder
Stearine pitch	40 parts
Asphalt	60 parts
Castor oil	10 parts
Benzol	25–100 parts

Filler

(To be used with 286 parts of binder described above)

Asbestos	1100 parts
Sulfur	66 parts
Iron oxide	22 parts

All parts are determined on a weight basis.

Refractory Products. The inorganic or refractory type of compound consists of asbestos filler and cement-water binder.

The formulation usually comprises about 50 per cent cement and 50 per cent asbestos wet down with water in a mixer and mixed until the proper molding properties are attained. The molded parts are hardened by being subjected to water until most of the reaction has been carried on and are then baked in an oven to remove the excess water.

The water absorption of the baked parts is usually around 10 to 12 per cent. In order to reduce this water absorption, parts are sometimes impregnated in waxes, coal tar pitches, and the like.

The organic type parts have a heat resistance of about 500° F., while the inorganic parts can be heated up to about 1500° F.

Following is a comparative list of properties of refractory and non-refractory compounds:

	Refractory (Inorganic)	*Non-refractory (Organic)*
Molding pressure per sq. in., lb.	4000–12,000	4000–12,000
Specific gravity	1.80 to 1.90	1.87 to 2.15
Compressive strength per sq. in., lb.	15,000	6000 to 15,000
Flexural strength per sq. in., lb.	2000 to 5000	3700 to 9300
Impact Izod (½ by ½ in. bar), ft.-lb.	0.4	0.4
Resistance to heat, ° F.	1300	500
Water absorption (24 hr.)	0.5 to 2.6	0.6 to 7.5
Arc resistance	Good	Fair

Applications.

Non-refractory: Flat-iron connectors, handles, etc.

Refractory: Electrical parts where high heat resistance and arc resistance are essential factors, such as: rheostat bases, arc chutes, heating bases, insulators, etc.

CHAPTER XIV

PLASTICS PLANT EQUIPMENT

In producing resins, molding compounds, laminates, surface finishes and adhesives, manufacturers use certain equipment generally available in conjunction with especially designed apparatus of their own. For obvious reasons, specifications of especially designed equipment are not often available.

The equipment used for processing cellulose derivative plastics such as cellulose acetate and cellulose nitrate includes:

Kneaders or mixers
Hydraulic filter presses
Converting rolls
Hydraulic caking or block presses
Sheeting planers
Seasoning chambers or vaults
Hydraulic plate polishing presses
Stuffers or extruding machines for rods and tubes, etc.
Grinders for molding powders

FOR SHEETS, RODS, AND TUBES OF CELLULOSE NITRATE AND OF CELLULOSE ACETATE

For the production of sheets, rods, and tubes of cellulose nitrates and acetates, the following equipment is required for the operation specified:

Preliminary Mixing: Covered dough-mixer of W. & P. (Werner & Pfleiderer) type; parts in contact with the charge are of stainless steel or other non-rusting metal; special stuffing boxes to prevent entry of grease.

Filtering: Special hydraulic press (macaroni press) with two cylinders movable between low-pressure and high-pressure stations, at the former of which the dough is loaded into a cylinder and at the latter forced through fine cloth, suitably supported.

Final Mixing: Mixer as above, airtight and connected to vacuum line leading to condenser for recovery of solvent.

Rolling: Milling rolls like those of the rubber industry, and preferably non-rusting; cored for heating and chilling.

Caking (for sheets and cut rods): Cored and corrugated base plate, upon which the block is formed; chase to confine the block; hydraulic press; circulation of hot water (for nitrate), or steam (for acetate) and of cold water.

Sheeting: Special planer with reciprocating carriage (to support the base plate which carries the block of plastic), and stationary knife adjusted vertically to cut sheets of desired thickness.

Cutting Rods: Similar planer provided with annular knives.

Extrusion of Rods and Tubes: Hydraulic stuffers equipped for baking under pressure to consolidate the plastic prior to its extrusion through dies; screw stuffers fed with unbaked plastic from rolls.

Seasoning: Boxes or vaults with racks for hanging sheets, etc., and with circulation of hot air.

Straightening and Polishing of Sheets: Multi-platen hydraulic press, each platen cored for heating and chilling; polishing plates and equalizing cushions.

Straightening of Rods and Tubes: Hot-water bath, straightening table, and cold-water bath.

Grinding of Rods and Tubes to Size: Centerless grinder.

FOR CELLULOSE ACETATE MOLDING POWDER

The production of cellulose acetate molding powder requires the following types of equipment for the operation specified:

Grinding of Cellulose Acetate Flake: Grinder and screens.

Mixing, Filtering, Rolling, or Extruding: Mixer (either a W. & P. or Banbury mixer), filter (optional), and rolls as above or extruders.

Grinding: Grinder and screens.

FOR METHYL METHACRYLATE SHEETS, SLABS, RODS AND TUBES

Equipment used in casting methyl methacrylate sheets and slabs:

Sirup-Making: Kettle with agitator.

Casting (polymerization): Casting in glass cells for sheets and slabs, and in special molds for rods and tubes.

METHYL METHACRYLATE MOLDING POWDER

Equipment for manufacturing methyl methacrylate molding powders:

Polymerization: Closed, stainless-steel kettle with agitator and jacket for heating and cooling.

Drying: Standard type driers.

Rolling: Rolling mill as above.

Grinding: Grinder and screens.

POLYVINYL BUTYRAL RESIN INTERLAYER FOR SAFETY GLASS

Equipment used for producing polyvinyl butyral resin interlayer for safety glass:

Mixing: Special dough mixer.

Filtering: Plate-and-frame press.

Extrusion: Special equipment, including pump and an extrusion chamber with controllable orifice.

Seasoning: Water trays.

Embossing: Special embossing equipment.

Manufacturers of Kneaders and Mixers

Abbé Engineering Co.	New York, N. Y.
Abbé, Paul O., Inc.	Little Falls, N. J.
Albert, L., & Son	Trenton, N. J.
Alsop Engineering & Mfg. Co.	Milldale, Conn.
Baker, Perkins, Inc.	Saginaw, Mich.
Brokenfeld & Co., Inc.	New York, N. Y.
Cavagnaro, John J.	Harrison, N. J.
Colton, Arthur, Co.	Detroit, Mich.
Daigger, A., & Co.	Chicago, Ill.
Dunning & Boschert Press Co.	Syracuse, N. Y.
Elmes, Charles F., Engineering Works	Chicago, Ill.
Farrel-Birmingham Co.	Ansonia, Conn.
Gruendler Crusher & Pulverizer Co.	St. Louis, Mo.
Hendrick Mfg. Co.	Carbondale, Pa.
Loomis, Evarts G.	Newark, N. J.
Martin, Frank M.	Springfield, Mass.
Patterson Foundry and Machine Co.	East Liverpool, Ohio
Read Machinery Co.	York, Pa.
Robinson Mfg. Co.	Muncy, Pa.
Sprout, Waldron & Co.	Muncy, Pa.
Stokes, F. J., Machine Co.	Philadelphia, Pa.
Struthers-Wells Corp.	Warren, Pa.
Thropp, Wm. R., & Sons Co.	Newark, N. J.
Wolf Co., The	Chambersburg, Pa.
Zallea Bros., & Johnson	Wilmington, Del.

Manufacturers of Resin Kettles

Alloy Fabricators, Inc.	Newark, N. J.
Baker Perkins, Inc.	Saginaw, Mich.
Blaw-Knox Co.	Pittsburgh, Pa.
Buffalo Foundry & Machine Co.	Buffalo, N. Y.
Drever Co., The	Philadelphia, Pa.
Devine, J. P., Mfg. Co.	Mt. Vernon, Ill.
Glascote Company	Cleveland, Ohio
Groen Mfg. Co.	Chicago, Ill.
Hendrick Mfg. Co.	Carbondale, Pa.
Lee Metals Products Co.	Philipsburg, Pa.
Liberty Coppersmithing Co.	Philadelphia, Pa.
Loomis, Evarts G.	Newark, N. J.
Martin, Frank M.	Springfield, Mass.
Oat, Jos., & Son	Philadelphia, Pa.
Orange Roller Bearing Co.	Orange, N. J.
Patterson Foundry & Machine Co.	East Liverpool, Ohio
Read Machinery Co., Inc.	York, Pa.

Sowers Mfg. Co.	Buffalo, N. Y.
Stokes, F. J., Machine Co.	Philadelphia, Pa.
Struthers-Wells	Warren, Pa.
Van Alst Metalsmiths Co.	Long Island City, N. Y.

Manufacturers of Condensers

Aldrich Pump Co.	Allentown, Pa.
Blaw-Knox Co.	Pittsburgh, Pa.
Hendrick Mfg. Co.	Carbondale, Pa.
Ingersoll Rand Co.	New York, N. Y.
Loomis, Evarts G.	Newark, N. J.
Patterson Foundry & Machine Co.	East Liverpool, Ohio
Pennsylvania Pump & Compressor Co.	Easton, Pa.
Stokes, F. J., Machine Co.	Philadelphia, Pa.
Struthers-Wells	Warren, Pa.

Manufacturers of Polishing Press Plates

Baldwin Southwark Corp.	Philadelphia, Pa.
Burroughs Engineering Co.	Newark, N. J.
Loomis, Evarts G.	Newark, N. J.
Martin, Frank M.	Springfield, Mass.

Processing Machinery

TYPES AND MANUFACTURERS' DESCRIPTIONS

Abbé Engineering Co.,
New York, N. Y.

Ball Mills and Pebble Mills. The Abbé Engineering Co., New York City, makes a variety of machines for milling, mixing, grinding, and sifting, many of which are being used in the plastics industry. Perhaps the most important of these are the pebble and ball mills. The principle of this type of equipment is fairly simple; it consists of a revolving cylinder about half-filled with pebbles or balls which grind the mixture to the desired fineness by striking against one another. The smaller the balls, the more grinding surface available and the finer the resulting material is ground. When the desired fineness is obtained, a grate cover is put on the cylinder and it is revolved until the material is emptied, leaving the balls or pebbles in the mill.

In wet grinding, a similar procedure is followed, but the mill is only about one-third filled if balls are used, and emptying is accomplished through special valves. The choice of a ball or pebble mill depends on several factors; ball mills are generally used for faster grinding and greater output for a given mill size, pebble mills for grinding materials affected or discolored by contact with steel, and for lower costs where time is not important and power is cheap. Ball mills require a greater power consumption, but actually are about as cheap on a basis of output for a given time. Ball mills are recommended for grinding coating materials and pigments for the lacquer of styles for both wet and dry grinding, and may be fitted with numerous accessories. Flint pebbles and steel or porcelain balls are standard equipment, with special balls or pebbles of stainless steel, bronze, wood, rubber-covered metal, and the like, available. Mills may be jacketed for heating or cooling.

Jar Mills. These are used for the same purposes as the ball or pebble mills but in instances where production is on a smaller scale. The machine consists of porcelain or metal jars mounted on a revolving motor-driven frame. They are available in single or multiple units with capacities from 1 qt. to 60 gal. Jars are also available made of bronze, Pyrex, steel, and rubber-covered metal.

Rotary Cutters..These are similar to cutters described elsewhere, consisting of rotary knives acting against stationary blades, the material leaving the machine through a screen in the bottom and falling into a hopper. Available in sizes from laboratory (30 to 100 lb./hr.) up to 3000 lb./hr. All working parts may be made of stainless steel if desired.

Mixers and Sifters. The mixers, available in sizes from ¼ to 330 gal., have an efficient mixing action consisting of a baffled cylinder with a rotating, ribbed disk at the bottom. The material is fed to the disk which throws it up against the cylinder where it strikes the baffles and is thoroughly mixed.

The sifter is compact and fast, operating on the turbine principle and requiring less power than other types of sifters. Machines are available in various sizes capable of productions from 30 to 5000 lb./hr. in sizes from 6- to 300-mesh. One model capable of 5000 lb. of sifted material per hour requires only a 1½-hp. motor.

Impact Grinding. This mill receives material from a hopper into a grinding chamber where it is reduced by the action of rotating beaters on grinding rings. Material may be reduced to fine powder in one pass, being ground five times. Cleaning is easy, and the ground material is discharged at the bottom.

TABLE 85. CAPACITIES

	Floor Space	Capacity	Horsepower	Weight
Size B	20 by 24 in.	400–1200 lb. per hr.	2–3	200 lb.
Size C	28 by 35 in.	1500–4500 lb. per hr.	5–7½	600 lb.

Beach-Russ Vacuum Pumps. Assured high vacuum about 29.75 in. Hg for chemical distillation, drying, cooking, curing, packing, etc. Patented rotary design and lubrication system assure high volumetric efficiency at low power consumption and low operating speed. Corrosion resistant construction and precision fitting assure maximum efficiency and long service life. Capacities from 15 to 1100 cu. ft. per min.

Paul O. Abbé,
Little Falls, N. J.

Rotary Cutters. These are similar in operation to those elsewhere described, consisting of a cutting chamber containing fixed and rotating blades. Permanent discharge boxes may be attached for dustless discharge. Following is a list of sizes and specifications:

TABLE 86. SPECIFICATIONS

Number of Machine	Floor Space	Speed (r.p.m.)	Horsepower	Screen Size (in.)
0	3 ft. 1 in. by 1 ft. 5 in.	900 to 1200	2–5	10 by 17
1	4 ft. 6 in. by 2 ft. 10 in.	600 to 900	7–15	20 by 24
2	5 ft. 8 in. by 3 ft. 6 in.	600 to 900	15–40	20¼ by 27½
2½	8 ft. by 3 ft. 3 in.	500 to 800	20–45	35 by 35
3	8 ft. 6 in. by 3 ft. 7 in.	500 to 750	30–60	50½ by 29½

Lump Breaker. This consists of revolving hammers which beat the material until it is fine enough to pass through the required steel screen. It is used to restore caked powders to original condition, not for grinding. Several models of disk mills supplied are also used for this purpose.

Ball Mills. These are similar to other ball mills with a few special features which include motor control of mill speed; custom-made dust housings; patented discharge valve; and hinged cover with cam bar for easy opening. A number of Abbé Pebble Mills are also used in the plastics industry for grinding scrap and colors.

SPECIFICATIONS (STANDARD MODELS)

Inside diameters and lengths of cylinder	15" dia. and 21" length to 72" dia. and 102" length
Total contents cylinder (no balls)	2 cu. ft. or 16 gal. to 282.7 cu. ft. or 2115 gal.
Hp. needed (wet grinding)	1 to 60
Hp. needed (dry grinding)	Approx. 2 to 120
Speed (r.p.m.)	40–50 to 15–19
Floor space required	3'6" × 2'3" to 20'6" × 8'
Shipping weight (lb.)	400 to 13,800

Jar Mills. These are made with practically any type or composition of jar. Dry charge capacities range from 1½ to 15 lb.

Mixers. A wide range of models are available, all similar in general to those described under J. H. Day equipment (mixers).

American Brass Co.,
Waterbury, Conn.

Flexible Metal Tubing. An important consideration on any press using steam is the application of that steam to moving parts of the press. In a press where steam must be supplied to movable platens at an average pressure of 150 lb., the supplying lines must be strong and yet have flexibility. The American Brass Co. manufactures tubing for this purpose with several important features. The tubing is entirely seamless, flexible, and made of 98¾ per cent true bronze and 1¼ per cent tin. When attached to the presses, the tubing is usually hung with free loops to facilitate changing of molds. Couplings, unions, and any other fittings necessary can be supplied. This type of tubing is also used for carrying liquids for processing steps, and for heating and cooling the presses.

Besides flexibility and efficiency, this tubing is cheaper than most rigid steam systems because of elimination of breaking pipe lines and simplified installation. It is also not necessary to repack joints.

Everdur. A copper-silicon alloy for storage tanks and processing equipment where resistance to chemical action is required.

Anaconda Brass Pipe. Made in two grades for medium and special corrosion resistance.

Anaconda Copper Tubing. Specially deoxidized for corrosion resistance, this is assembled with threadless fittings. Suitable for oil, air, or steam pipe lines.

Processing Equipment. The American Brass Co. furnishes equipment or raw materials for many uses in the plastics industry. The products vary with individual requirements in some cases but the most standard equipment is listed here.

Banbury Mixers. *Uses.* Mixing, converting, and densifying.

In the mixing of phenolic resins, a combination of the first and third steps is common practice. The dry, ground resin is first mixed with wood flour, dye, and filler in the mixer. Application of heat at the same time densifies the mix, after which it is ground and piled and is then ready for molding.

With ureas, the Banbury mixer is used principally for heating in order to densify the mixture. The temperature is held at approximately 190° F. which makes the material partially plastic, thus more easily handled for final molding.

With acetates, the Banbury mixer is used principally for conversion of the acetate powder (with plasticizer and coloring) into a plastic material. The resulting mix is of uniform color and, after sheeting and grinding, is ready for molding.

Mixers find their chief application in the plastics industry with phenolics, vinyls, ureas, and cellulose acetates. Not all require a Banbury mixer or even roll mills. The mixer is used mostly for blending and shrinking, or densifying. With cellulose acetate sheeting, rolls are used in conjunction with the Banbury mixer.

Design. The Banbury mixer consists of two rotors enclosed in a mixing chamber which may be either heated or cooled. The batch is held in the sphere of mixing operation by an air-operated weight. In the larger mixers, there is also an air-operated discharge door which allows the mixture to be discharged onto a conveyor or onto a mill for sheeting.

Sizes are from 2-hp. units (½-lb. batch) to 600-hp. units (600-lb. batch).

Production. One man, using a 40-hp. motor, 800 lb. per hour.

Pot Mills. These are for materials that cannot be ground in plate or disk mills. The machine consists of an enclosed motor-driven bowl in which free cast-iron balls are tumbled.

Pebble Mills. These are a variation of ball mills, designed for heavy duty and large quantity grinding. Large grinding surfaces make grinding on this type of mill economical. Working capacities run from 80 to 840 gal., pebble charges from 400 to 5000.

Kneading and Mixing Machinery. In general, these machines are for uniform mixing of batches of material by the action of mixing blades rotating in an enclosed chamber. The chamber may be tilted to discharge the mixture. Monel metal blades and interiors are available. The mixing blades may be obtained in sixteen different shapes, thus ensuring the desired type of mixing action in any machine. The blades, or agitators, may be mounted in any of three positions with the following characteristic action:

Postion 1.—Small power required, little heating action, long period of mixing action.

Position 2. — Somewhat greater power needed, shorter mixing time, more heating of material due to partial masticating action of blades.

Position 3. — Maximum power consumption and heating of material, minimum mixing period. Capacities run from 0.3 to 630 gal.; hp. from ⅙ to 3 per gal. of capacity. Several models of experimental mixers are made which are especially useful in the mixing of plastics powders in small batches. Heating or cooling jackets can be furnished on some models.

Screening. For the screening and sifting of plastics powder, a wide variety of single- or multiple-screen equipment is supplied. Features include rebounding ball cleaning of the mesh screens, which lengthens the life of the screen cloth and gives better screening action; aluminum inspection ports which may be used while screen is in action; and uniform agitation of the entire screen assembly. Applications of these machines include screening of casein, wood flour, wood chips, mica, and hexamethylenetetramine.

Sifting and Mixing. Machines for mixing dry paste, or liquid forms of plastics, resins, or raw materials or fillers, are available. In some of these machines two actions, mixing and sifting, are performed. Machines run in size from hand-operated models for small batches to large motor-driven mixers capable of handling up to 4000 gal. of material. The material may be discharged from the end bottom, or center bottom of the tank. The latter method is generally used for plastics mixing. In operation, a paddle blade or agitator, of the required design for the mixing operation involved, thoroughly mixes the material against the walls of the chamber and then discharges it through the outlet in the bottom (or through a mesh, if screening is desired).

Evarts G. Loomis,
Newark, N. J.

General Equipment. The Loomis Co. is the representative for several firms in the plastics machinery trade, including Cavagnaro and Farrel-Birmingham, as well as the maker of many types of equipment. The plant is fully equipped to design or build any machine to order. Much work is done to specification for certain fabricators, but the various types of machinery are more or less standard in design and operation. Much of the described equipment is used for processing or working cellulose nitrate plastics by du Pont and Monsanto.

Sheeter. This machine is used by most cellulose plastics fabricators today, replacing former types which were unreliable and which produced sheets of varying thickness. The sheeter is a heavy planing machine consisting of a sliding table with an overhanging cutting knife. The block of plastics material which is to be sheeted is clamped securely to the sliding table, which runs in hard-faced channels to ensure uniform cutting and to reduce wear, and passed back and forth under the blade. The blade planes a sheet of the desired gauge from the block on each forward pass. Special design of support for the blade allows the return of the table and the attached block without scoring the plastics material. The cutting blade, supporting standards, and controlled feed are all planned to assure uniform sheets and minimum wear on the sheeter.

In sheeting metal, the blade tends to push the block down, but in sheeting plastics the opposite effect results and the sheets are likely to have a thicker section at the end on which the cutting begins. This makes it necessary to have close tolerance on the table slides, and a design which minimizes wear on all affecting parts.

The block of material is usually in a hardened, or set, condition when sheeting takes place, but in some cases it is in a semiplastic condition and the sheets are formed into various shapes immediately after sheeting and before they can set.

Polishing Press. This consists of a multiple of platens, often eight to ten, mounted in a heavy frame with a hydraulic plunger. Sheets of plastics, either plain or laminated, are placed on each platen and sheets of highly polished chrome steel are placed on each sheet. Application of pressure results in a surface luster or polish on the plastics equal to that on the metal sheet. Stippled or polished effects may be obtained by varying the polishing plates.

A *Multiple Opening Press* is similar in design to the polishing press but is used for laminating many sheets of plastics at once, or for pressing plywood with resin binder.

Vacuum Mixer. These are of sturdy construction, either side- or bottom-discharge design, and have several needed features. All edges and corners in the mixing chamber are rounded to prevent collection of any material which might contaminate the next batch. All bearings affecting the mixing area are connected with packing chambers making entry of dirt or oil into the mixing chamber impossible. Mixing blades are heated or cooled by an ingenious system of water flow, and both blades and chamber are chromium steel throughout. Tilting is accomplished by a motor-driven shaft which raises the cover and tilts the chamber, emptying the batch into waiting trucks.

The company can also provide: filter presses; Farrel rolls and calenders; laboratory injection molding presses; hydraulic equipment; swing joints; and extruding presses.

Dehydrating Press. A dehydrating press consists of a large, cylindrical material chamber over which a hydraulic ram is mounted. Material is put into the chamber, alcohol is flushed through, and the ram compresses the mixture until only a minute amount of alcohol is left. This rapidly evaporates. The piston die at the bottom of the cylinder is cored bronze drilled and grooved to allow the alcohol to pass through. A wire-cloth screen serves to keep the material cake in the chamber. Dehydration of the nitrocellulose material is an extremely dangerous step unless proper precautions are taken. The Loomis press is designed to eliminate all hidden pockets and corners where material might collect. The method of processing is also considerably safer than in the old type of press. In the old style, alcohol was pumped into the material well, after which the ram stroke was applied. Air was often trapped in the chamber and explosions resulted. In the Loomis press, the alcohol is pumped through the bottom of the chamber, displacing the air before high pressure is put upon the ram. Other advantages of the press are as follows:

1. No chance of leakage into the alcohol of the material chamber.
2. Pressure used is 560 tons.
3. Uniform percolation of alcohol through material assured by bottom feed.
4. Stanchion design gives greater strength, minimizes breaking due to sudden stresses.
5. Safety latches protect operator from any danger of falling ram in case of hydraulic line failure.

Steeping Presses (Cellulose). ***Application.*** Steeping cellulose pulp in caustic soda solution as the first step in the manufacture of rayon or cellophane by the viscose process; then the subsequent reduction of the caustic soda content of the pulp by application of hydraulic pressure.

Type. Horizontal platens with double-acting ram. The material handling space is formed by an open top steel tank in which the moving platen operates. The sheets of cellulose are placed on edge in this tank between vertical steel division plates, the platens and division plates riding on side rails. The tank holds the caustic soda solution during the steeping process and catches the excess when pressure is applied. The larger presses include an end gate in the pressure head which allows dumping of the pulp without handling.

Power. H.P.M. hydraulic system mounted over cylinder on a reservoir base.

H. K. Porter Co. Inc.,
Pittsburgh, Pa.

Ball and Pebble Mills. This company makes lined and unlined ball and pebble mills of a wide range of capacities. They can be either jacketed or not, as desired. The jacketed type is designed to give full coverage to the mill and to reduce heating or cooling costs. The mills run from dimensions of 16 by 21 in. to 8 by 10 ft., with capacities from 10 to 3350 gal. (lined) or 12 to 3650 (unlined). There are twenty-four different capacities within these limits.

Other Equipment. *Agitators.* These are portable machines consisting of one or more propellers mounted on a shaft which is driven by a motor. The unit is clamped to the kettle and mixes the batch at whatever speed is desired. Monel metal shafts and propellers are generally used. Capacities are from 1/8 to 1½ hp. and speeds up to 3600 r.p.m.

Double Cone Blenders. Used for mixing free-flowing dry powders, usually for mixing a small quantity of one into a large quantity of another. These machines mix a batch in a maximum time of 10 to 15 min. with a resulting uniformity which does not vary more than ½ to 1 per cent. The cone bodies may be made of any desired metal.

Laboratory Mills. This is a simple machine consisting of motor-driven rubber-covered pipe rollers on which jars are placed and rotated. Two different sizes may be used at the same time without using adapters.

Raymond Pulverizer Div.,
Chicago, Ill.

Manufacturers of roller mills, flash dryers, pulverizers, closed circuit grinders, laboratory mills, screen mills, mechanical air separators, and bowl mills.

Standard Tool Co.,
Leominster, Mass.
Agent for Parks Standard Acetate Dryer.

Acetate Dryer. As a part of the processing of cellulose acetate, it is precipitated in water, washed, and dried. After these steps, as well as in injection molding, the material must be dried. A unit used effectively for drying, especially before injection molding, is made by the Standard Tool Co. and is known as the Parks-Cramer Acetate dryer. Built in cabinet form containing from one to five sections, each containing three trays, the dryer is capable of drying as much as 600 lb. per hour. This figure reduces to 10 lb. per tray every 15 min. In actual practice about 8 lb. is dried, as the average cellulose acetate injection molding machine handles a little more than 7 lb. in 15 min. The trays are purposely small, and designed to supply material in quantities approximating the demand in order to eliminate overdrying, which tends to destroy certain of the properties of the compound, and to avoid a surplus of material which tends to absorb moisture from the air if left too long in the feed hopper. Common practice is to have as many separate trays as there are injection units operating. The cabinet containing the trays has in its base, motor, electrical heating units, and fan for circulating the heated air. The entire unit is run with thermostatic control, and the trays are so constructed that material cannot fall from one into another. The size of the machine is 50 by 30 by 72 in.

Farrel-Birmingham Co.,
Ansonia, Conn.

Roll Mills. These rolls were designed especially for working Celluloid and pyroxylin materials. The machine consists of two accurately ground, chilled iron rolls, each of which may be controlled by a special coil clutch and brake. This latter feature, being mechanical, is especially desirable when working with flammable materials as it reduces the fire hazard.

The company makes many sizes of rolls, some of the largest ever made being used in the plastics industry.

Chas. F. Elmes Engineering Works,
Chicago, Ill.

Accessory Equipment. This company makes the following: High- and low-pressure pumps, both hand- and motor-operated and in horizontal, vertical, and rotary types; hydraulic accumulators and accumulator systems; air-ballasted accumulators; by-pass, check, safety, and regulating valves; shock alleviators; laboratory presses for molding; preheaters — rotary ovens, automatically, electrically heated for four, six or eight charges of compound.

Wm. R. Thropp & Sons Co.,
Trenton, N. J.

Laboratory Mills. Miniature mills are important in the laboratory for testing materials and compounds before actual production starts. The mills of the Thropp Co. are especially valuable for plastics testing as the speeds and frictions are in the same proportion as those on large producing mills. The ability to mix minimum amounts on the laboratory mills lowers the amount of material wasted. The mill consists of two motor-driven rolls with lubrication system and provision for heating and cooling. Under the rolls is a pan which catches the material after it has passed through the rolls. The motor is equipped with a device which protects it from over- or under-load. These mills may be used for mixing plastics and shellac compounds or for grinding colors for plastics.

SPECIFICATIONS

Mill Sizes (in.)	2 × 6	3 × 8	6 × 12	6 × 16
Horsepower required	½	2	5	5

Calender. A laboratory calender is also available with hollow chilled iron rolls and controlled speed and pressure.

J. H. Day Co.,
Cincinnati, Ohio.

Processing Machinery. This firm makes a wide variety of equipment for mixing, sifting, grinding, and otherwise processing powders, resins, and materials of all kinds. The equipment is extensively used in the plastics industry. The types and uses are so varied that only the general types for each process, with the most pertinent specifications, will be described.

Crushers. Two crushers of fairly large capacities are made for coarse grinding of materials. Usually, crushers of this type are used to grind up larger pieces (such as scrap) before pulverizing. Capacities are, for the smaller (Rainbow) crusher, 4000 to 8000 lb. per hr.

Disintegrator. In this machine the material enters the mill and is pulverized by two sets of beaters acting against corrugated disks until it is fine enough to pass through steel screens of the desired mesh which are fastened onto the mixing chamber.

Grinding Mill. Material is fed from a hopper into two crushers, thence onto a crushing conveyor which reduces it further and conveys the mix to a grinding disk which grinds to fineness desired. The grinding plates are self sharpening.

Patterson Foundry & Machine Co.,
East Liverpool, Ohio.

Mixing and Processing. To date no satisfactory method has been developed for continuous mixing and processing of plastics with one machine in a way that will give uniformity of product or control. For this reason the batch system is still the leading system. The *Kneadmaster Mixer* (Patterson) is designed especially for mixing plastics, and some of its possible operations are listed here:

1. Mixing and compounding plastics materials with various fillers and reagents.
2. Masticating, breaking down, or developing dispersions of plastics materials.
3. Mixing and wetting of pigments preparatory to grinding.
4. Surface coating and compounding fibrous or filler materials with natural or synthetic binders.
5. Liberation and removal of volatiles from plastics materials during mixing and kneading operations.
6. Combining chemical reaction and physical treatment in one apparatus.
7. Treating fibrous material without destroying original structure.

The Kneadmaster may be adapted for heating, cooling, pressure, or vacuum and is available in a variety of metals. Tilting mixing chamber for easy dumping of the batch, automatic lubrication, and scientifically designed mixing blades are featured.

Mixing Equipment Co.,
Rochester, N. Y.

Mixers — Propeller Type. Although present tendencies seem to be toward the building of complete container and agitator units by the various processing industries, many cases may be found where the propeller type of mixer is both practicable and economical. This is especially true of odd-shaped vessels and storage tanks. Another advantage is that materials may be mixed in a container and left there as long as desired, whereas in the case of integral mixing units the batch must be moved to make way for successive batches. Many factors must be kept in mind when selecting a mixer. Viscosity, materials in suspension, shape of container, depth of tank and level of liquid, heating coils, or other obstructions must all be considered. Following are some of the factors affecting selection of mixers:

Portable mixers should be used for open tanks up to 8 ft. deep, and permanent mounting with step or angle bearing for greater depths. For pressure or vacuum tanks (closed), tripod mounting and flange adaptation should be used for depths up to 8 ft., and tripod and step bearing for greater depths. Where depths are over 10 to 12 ft., or headroom is restricted, side or bottom entering mixers should be used. The Mixing Equipment Co. supplies a comprehensive work sheet, and it is suggested that any manufacturer wishing data on mixers suitable for any purpose should consult the company.

Portable Type. For mixing liquids, either semi-fluid or in suspension, in tanks, drums, or other containers, a portable mixer is available. Used alone or in multiple, the mixer may do its work and be moved to a new job without transferring the material in each container. Mixers are made with gear drive for low speeds and with direct drive for speeds up to 1150 r.p.m. Attachment to container is by means of clamp and swivel so that the correct mixing angle may be obtained in all cases.

Top Entering. For permanent mixing setups, or in cases where pressure, vacuum, or heat are necessary, mixers should be mounted on the top of the vessel and to one side. Direct or gear drive may be used, and the mixer is fitted to the tank in such a way that it is completely leakproof.

Side Entering. For large tanks, horizontal tanks, or in tanks where headroom is limited, side entering mixers are best used. The unit is attached through the tank at a specified angle by use of a flange or by utilizing an existing manhole. Tanks with a capacity of as much as 450,000 gal. may be successfully agitated by this method.

NOTE. The mixers and blades are of a great variety of shapes, sizes, and metals in order to suit any purpose.

Baker Perkins Inc.,
Saginaw, Mich.

Mixers. *Standard.* These are general utility mixers for light and medium duty. There are eight sizes ranging from a laboratory model of ¼-gal. working capacity to a large, jacketed production unit of 580-gal. working capacity. Construction is of stainless steel, powered by silent chain or gear and pinion drives.

Vacuum. There are two machines of this class with capacities of 100 and 200 gal. Vacuum mixers are used when it is desirable to remove solvents, gases, or air from the batch. Observation windows in the cover are jacketed to prevent condensation.

Heavy Duty. These mixers were especially designed for the plastics industry and the heavy mixtures that have to be handled. They are compact and sturdy, and because of the lower investment for the equipment, are often more economical than roll mills or masticators for the same operations. Rams can be supplied to keep the mix in the mixing zone, thus hastening the mixing action. Tilting of the machine for discharge of the mix is done by an independent motor tilt. The four models in this class have capacities of 0.7, 10, 100, and 300 gal. All models are jacketed for temperature control.

Shredders. American rayon plants are almost 100 per cent equipped with Universal shredders. Serrated blades tear the soda cellulose to " crumbs."

THE DESIGN OF RESIN PLANTS[1]

(SYNTHETIC RESINS)

General Principles. The production of resins, regardless of type, to high physical and chemical specifications is controlled by the following factors:

1. Correct design and, in particular, correct choice of the means of agitation of the resin-producing kettle;
2. Correct design of the condenser and correct choice of the auxiliary pump apparatus;
3. Correct choice of the materials of fabrication;
4. Correct processing procedures and timing for the individual processing steps;
5. Proper purity of the chemical ingredients used in the manufacture of resin not related to the mechanical design of the plant units.

Resin Kettles. For most resins, the resin-producing kettle is the scene of (1) the chemical reaction that produces the resin, (2) the refluxing period during which the resin-producing reactions are driven to completion, and (3) a dehydration step that frees the resin of the water of reaction and/or the water in which any of the reactants may have been dissolved. For the successful accomplishment of all of these steps, the kettle must be designed to:

1. Promote intimate contact between the reacting materials;
2. Bring the reacting charge in contact with a maximum heating or cooling area;
3. Promote the maximum heat transfer in connection with both the liquid and vapor phases that have to be handled during the various processing steps;
4. Expedite the refluxing and dehydration phenomena through the provision of vent and reflux pipes of proper dimension for the amount of vapors to be handled per unit of time;
5. Contain adequate provision for instrumentation and control equipment as well as for inspection of the kettle during and after operation.

In the course of promoting the separate stages of the resin-producing procedure, the following are hindrances or obstacles to optimum operation, some or all of which may be encountered:

1. " Foaming " of the mass and, in the worst instances, fouling of the reflux and/or vent openings;

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[1] Prepared in co-operation with A. Brothman, Hendrick Mfg. Co., N. Y. C.

2. Building up on the kettle wall of chilled resin during the cooling cycles in the processing of some synthetic resins;
3. Some resins are sensitive to local overheating;
4. Some resins require the distribution of carbon dioxide as an antioxidant;
5. Some resins involve the use of starting chemicals that are liquid only at low temperatures and gaseous at the reaction temperature, thus requiring that the resin kettle be designed for positive as well as for vacuum pressure;
6. Some resins are sensitive to mechanical bruising by overvigorous agitation or by the direct shearing action exerted by the mixer assembly.

All things being equal, the outstanding problem for the designer of resin kettles is the choice and correct mechanical design of an agitator assembly. The horseshoe or anchor type which, when designed for close clearance of the arms from the kettle wall, has the advantage of preventing excessive build-ups on the wall in kettles where cooling of the reaction mass is desirable, was most frequently used until the past three or four years.

Difficulties are involved in the use of the horseshoe type for a vertical interchange of portions of the batch in the kettle and for agitating a resin-reaction mass in which carbon dioxide must be distributed to prevent oxidation of the produced resin. Another difficulty is the necessity (because the high weight causes a tendency to produce large shaft deflections, especially when the shoe shaft is of the free end or cantilever type) of providing a foot guide bearing, especially where the arm-to-wall clearance is a minimum. The problem in such instances is to provide a bushing member for the bearing assembly which either is impervious to corrosion by any of the reactants or will not set up in the presence of a water solution of inorganic materials a galvanic couple with the shaft, which would promote corrosion of one of the members and consequent discoloring of the produced resin. Duriron bushings are likely to offer a solution to the problem where the shaft material permits its use, e.g., a Duriron bushing would be unsatisfactory in the instance of a Tobin Bronze shaft but permissible for nickel or stainless steel shafts.

For all the above reasons, the horseshoe agitator has been discarded as a means of agitating resin kettles unless special circumstances require its use. If the necessity in some kettles of scraping the kettle wall of "build-up" arises, a modification of the usual horseshoe agitator is used, in which the arms of the shoe bear scraper members that run in actual contact with the wall. A scraper member of suitable material is hinged to the horseshoe arm and is kept pressing against the tank wall by means of rectangular plate spring members distributed so as to produce "even contact" with the wall.

The problem of choosing a suitable scraper material is as difficult as the choice of a suitable bushing member for the agitator shaft guide bearing and has to be solved with special reference to each specific instance. One thing to be remembered in connection with scraper mechanisms where the material of construction of the kettle is a steel or ferrous alloy is the possibility that such members may pick up steel particles which would then cause sparking, an eventuality to be avoided in all cases but especially with inflammable solvent materials. The method of avoiding this danger is to polish the kettle wall to at least a No. 4 polish. The peripheral speed usually given scraper mechanisms is 250 to 275 ft. per min. maximum.

Such scraper mechanisms may function alone or in conjunction with other agitator mechanisms to form a combination type of agitator assembly. Combination agitator assemblies are as a rule avoided because of complicated stuffing box assemblies required where the kettle functions under either vacuum or pressure at any stage of its operation. Where the scraper mechanism is used alone, the rules for number of square feet of opposed blade area and for " powering " the unit are roughly the same as used for gates and horseshoes of a similar construction. The exception to this generalization is the increase of power consumption to the extent of 20 per cent over that required by normal types of gates and horseshoes (i.e., the scraper type of unit will take 20 per cent, approximately, more power than the normal form of the shoe unit).

Crossarms running in paddle fashion from one arm of the shoe to the other are sometimes used. They increase the number of square feet of opposed blade area (reducing the tendency of the shoe to confine its mixing action to the periphery of the mass and serving to reduce the concentration or localization of the mixing action), give continuity to the mixing action (from the center of the kettle to the periphery, preventing spread of the arms of the shoe and vibrations that might be produced under shock load, etc.) and provide, when properly designed, a distributed " power takeoff." The uppermost member of such crossarms should be at a sufficient distance below the level of the charge to accommodate an adequately long thermowell. The use of several points of attachment of the shoe to the agitator shaft provides a stiffening influence on the shaft.

Summing up from the functional aspect, it will be found that for the mass consistencies normally encountered in resin kettles paddle units do not give a uniform enough agitation. In either semi-viscous or low viscosity resin-forming formulations they are easily surpassed by either propeller type agitators or turbine type agitators. Thus the pure paddle agitator, like the horseshoe agitator, is confined to unique problems and, in particular, to those instances of resin formulations that suffer through the application of anything but the most moderate kind of agitation. Even here, paddle performance is inferior to the horseshoe type when the latter is designed with an adequate number of square feet of opposed blade area and with crossarm members as previously described, because the horseshoe offers the advantage of vertical continuity of mixing action. Since high viscosity reaction masses are usually encountered where an exceptionally moderate type of agitation is demanded, the continuous close sweep of shoe arms will do much to maintain a maximum rate of heat transfer.

However, if paddle application is used, the following design hints should prove of value. Paddle agitator assemblies, because they do not depend upon close blade-to-wall clearances, do not require foot guide bearings for the agitator shaft. Paddle assembly agitator shafts may be designed for operation as cantilever shafts. Agitator shaft design formulas are given in the equipment section. For large paddle agitator assemblies, it has been found to be good practice to place an intermediate guide or steady bearing in the region of the shaft above the charge level and to design the shaft according to principles in which the length of free end or cantilever shaft is taken to be the length of shaft below the steady bearing. This obviates the difficulties of a bearing submerged below the level of the liquid charge. The " build-up " of paddle units, by bolting blades cut from plate to cast hubs, is more practical than casting complete paddle (integral hub-and-blade) units. This saves pattern costs, rules out casting defects in the blades which would cause the rejection of the entire unit, and allows for the easy disassembling of the unit in repair or overhauling work. The vertical center-to-center distance of paddle members on the paddle shaft would give uniform spacing. (See page 542.) " Buffing " with paddle agitators should not be neglected. The functioning of paddle units is based upon an application by the paddle of a rotation couple to a cylinder of material as wide as the width of the paddle and of a diameter conforming to the spread of the blades. Where the friction of the mass on the kettle walls is insufficient to counter the action of the rotation couple, swirling of the mass results. If structural members are used to " baffle " the tendency to swirl, there is danger that, as the consistency of the mass increases, baffle members may act to produce " agitational dead spots," which may lead to local overheating of the reaction mass and are an obvious danger to the resin as well as to the rate of transfer of heat effected in the kettle.

SUMMARY

1. The horseshoe or anchor type of agitator should be used as a means of agitating resin kettles where a close sweep or actual scraping of the kettle wall to prevent build-ups is required.
2. Paddle agitators, or still better, horseshoes equipped with enough crossarms, may be used advantageously in resin reaction masses in which the maximum operating viscosity assumed by the reaction mass at any stage of the kettle operations is greater than 50,000 centipoise.
3. Propeller assemblies are economical more for small resin kettles (laboratory and semi-commercial sizes). Propellers should not be used for kettles involving resin reaction masses which at any time during operation assume a viscosity in excess of 20,000 centipoise.
4. Turbines will provide the most efficient type of agitation for instances where the maximum operating viscosity does not exceed 50,000 centipoise and where wall build-ups are not a factor. Such turbines should be provided with stator shrouds for best performance and should be equipped with adequate " baffling."
5. Wherever possible, submerged guide bearings should be avoided.
6. The usual design principles must be followed for efficient operation of any unit within the range of its possibilities and also for correct " powering " of the units.

Tank Design.[2] Choice of the proper design of the tank and tank attachments (openings, etc.) is as important as choice of the proper type of agitation for a resin kettle. The factors to be considered in the design of the tank proper are the following:

1. The material of construction.
2. Shape.
3. Size of openings (such as discharge, reflux opening, vent openings, etc.), and the manner of construction of sight glasses, manholes, etc.
4. Means of suspension and manner of heating and cooling.
5. Plate thicknesses required for various portions.

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[2] Tank and kettle have been used previously indiscriminately. Tank is here taken to mean the shell proper rather than the entire assembly. Kettle will hereafter refer to the entire assembly.

The designer should consider each of these in relation to any or all of the following factors: the properties of the product, the timing or rates of achieving of the resin-kettled operations, and the economies of production, i.e., the way in which the cost of production of the kettle, the expected life of the unit, and the efficiency (functional) are affected.

Materials. The materials of construction of resin tanks are difficult to generalize about in view of the tremendous variety of processes used today in the production of resins.

From the standpoint of corrosion, the choice of a material must be based on two factors: first, the effect of the starting components of the formulation; and second, the effect of the metal upon the physical properties of the produced resin.

The following table indicates the materials that have been used for each of the two major classifications of resins:

Alkyds	*Phenolics and Phenolic Modifications*
Nickel	Nickel
Aluminum	Aluminum
Monel	Copper
Chromium-Nickel-Iron Alloys	Mild Steel
Inconel	Monel
Mild Steel	Inconel
Copper	Chromium-Nickel-Iron Alloys

The metals are listed from top to bottom according to the comparative qualitative effect of each upon the clarity and paleness of the resins, the metals at the head of each list giving highest degrees of clarity and paleness.[3]

The listing is not a complete indication of the comparative merits of the various metals because, as in the cases of mild steel and copper in phenolic type resins, the product was filtered before comparison with other samples.

The extent of penetration of the metal per year at the temperature of operation must also be considered. In some cases corrosion of a substance upon a metal may be high and yet have an insignificant effect upon the clarity of the produced products, because in some instances the products of corrosion tend to accumulate on the wall of the tank. Mild steel and copper are used only where the components of resin-producing reaction require them.

Summarizing, the following factors have to be considered in the choice of a material for the construction of a resin tank:

1. The corrosive effect of the components of the reaction upon the tank metal.
2. The effect of the tank metal on the clarity of the product.
3. The rate of corrosion in penetration per year of the metal by the resin under the conditions of operation. To this should be added the loss of allowable working stresses at each temperature of the kettle and the temperature difference for each metal. These factors are especially important where direct firing of the tank is contemplated for heating the unit.

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[3] **The listing and the method by which it was arrived at is contained in a paper by Richard T. Barnes, Jr. of the Development and Research Div. of the International Nickel Co.**

TABLE 87. CORROSION TESTS IN ALKYD RESINS

Temperature — 450° to 500° F. average
Time — 240 hr. over a period of 30 days

Material	Average Corrosion Rates		
	Milligrams loss per sq. dm. per day	Penetration per yr. continuous oper.	Inch penetration per yr. average serv.
A.			
Nickel	1.16	0.002	0.0001
Monel	0.86	0.0001	less than 0.0001
Inconel	0.18	less than 0.0001	0.0001
B.			
Nickel	17.8	0.0029	0.001
Monel	3.86	0.0006	0.0002
Inconel	3.51	0.0006	0.0002

The figures under Section *A* are the corrosion of the metal above the charge level by vapors, and the figures in Section *B* are the corrosion of the metal in contact with the liquid phase.

TABLE 88. CORROSION TESTS IN THE PRESENCE OF REPRESENTATIVE PHENOLIC RESINS

Temperature — 530° F.
Time — 240 hr. over 30 days

Material	Average Corrosion Rates		
	Milligrams loss per sq. dm. per day	Penetration per yr. continuous oper.	Penetration per yr. average oper.
A.			
Nickel	25.6	0.0041	0.0014
Monel	21.6	0.0035	0.0012
Inconel	6.0	0.0010	0.0003
B.			
Nickel	42.1	0.0068	0.0023
Monel	5.8	0.0009	0.0003
Inconel	2.0	0.0003	0.0001

Steels, particularly alloy steels, Inconel, Monel, and nickel demonstrate in short-time tensile tests no significant change in strength over the temperature range from room temperature to 600° F. Considering the listed metals in a general way from each of the factors named above, chrome-nickel-iron alloys (particularly 18–8 stainless steel), Inconel, Monel, and nickel are favorable materials of construction for resin kettles. Practice confirms this judgment, as most resin kettles today are fabricated out of these metals. With stainless steel and nickel, the trend today is toward the use of nickel-clad steel and stainless-clad steel. For most instances of resin kettle construction where nickel would be a satisfactory metal, 10 and 20 per cent nickel-clad steel has been found to be satisfactory, 20 per cent clad being used in light gauges of metal and where the corrosion rates are moderately high. Stainless-clad steels have been found to be mechanically unsatisfactory owing to the large difference between the coefficients of expansion of the clad and the backing, a factor of great importance in kettles functioning at high temperatures.

Shape. The elements entering into the determination of the optimum shape for resin tanks may be reduced to the following:

1. The effect of the tank shape upon the efficiency of the agitator assembly.
2. The conditions, as the temperature and pressure under which the resin-producing reaction is run.
3. The means of heating the kettle and hence the number of square feet of heating area required.
4. Mechanical considerations such as the strength of the shape, etc.

The last determining factor is kettle shape (so far as the ratio of total height of the tank to tank diameter is concerned — up to now, only the ratio of working height to tank diameter has been considered as a determining factor in kettle shape). In most resin kettles, the operations involve the heating up of the reaction mixture as a means of inducing the resin-forming reaction, a refluxing period for the removal of the heat of the reaction (most resin-forming reactions are highly exothermic), and finally a dehydration operation the object of which is the production of a bone-dry resin. In some instances, the dehydration operation is carried out under atmospheric conditions of pressure until the last amounts of water have been evaporated, and sometimes it is effected under atmospheric conditions for the most part, with the residual small amounts of water being driven off under vacuum. If the produced resin will not stand up under the temperature of boiling water at atmospheric pressure for any considerable length of time, or where the produced resin is particularly readily oxidized, the entire dehydration operation may be carried out under vacuum. Any of the circumstances lead to the necessity of a vapor space above the liquid charge, such that " bumping " and consequent spattering of the reaction mass through and into the cover nozzles is guarded against, loss of vacuum due to friction is a minimum, and the reduction in linear velocity of the steam and/or air particles is a minimum. The height of the vapor space will vary from about 0.33 of the tank diameter to 1.25 of the tank diameter, the lower limit for squat type kettles and where the total dehydration is carried out under atmospheric conditions, the higher limit where any or all of the dehydration is carried out under vacuum, and especially where the shape of the liquid charge portion of the kettle is of the " long " type. Wherever vacuum is employed to drive off any considerable portion of the water at a fairly good rate, the height of the vapor space should be equal to the diameter. The problem of an adequate vapor space is somewhat lessened in the instance of resins produced as an aqueous dispersion.

Heating. Means of heating kettles may be divided into two major classes:

1. Direct firing of the vessel by gas or oil burners, or the direct application of electrical resistance elements to exterior of kettle.
2. Circulation of liquids or vapors in a jacket assembly, or immersion of the kettle in a jacket assembly to which direct firing may be applied or in which a system of heating and cooling coils may be laid down (an example is the combined functioning of a jacket for circulation and as an immersion bath).

Heating of resin kettles (for the production of synthetic resins in distinction to general resin cooking, as performed in plants in which paint bases are compounded) is done principally by means coming under the second main classification. The important trends may be divided as follows:

Type of Resin	*Means of Heating Kettle*
Phenolics and phenolic modifications	1. Steam circulation 2. Hot water immersion 3. Oil immersion bath
Urea resins	1. Steam circulation 2. Hot water immersion 3. Oil immersion bath
Alkyd type resins	1. Dowtherm circulation 2. Hot oil circulation 3. Oil immersion bath

The particular type of heating method best suited to any particular instance is determined by the following factors:

1. Temperature to which the reaction mass must be raised in order to promote the reaction.
2. Speed of production and B.t.u. per hour required to establish a desired time cycle for any processing step.
3. Rate of heat input and temperature required for the " flashing " of the water of reaction.

However, if there is choice among Dowtherm or steam or oil immersion bath members, the possibility of " flashing " of high temperature oils may be a major hazard if the oil system fails close to the " flashpoint " of the oil or if there are sudden difficulties with circulating apparatus.

The design of jacket assemblies is an important item in the consideration of the heating of resin kettles. Besides the question of " split " jacket assemblies, a further major point to be considered is the question of full jackets (jacketing for the bottom head components of the tank as well as the cylindrical drum components) as opposed to jackets that are confined to the cylindrical drum components. The following are some of the reasons for the use of the full jacket type:

1. Naturally, the increased heating area afforded, and hence the possibility of better kettle shape and higher heating rate.
2. Reduction of the necessity for increased temperature of circulating medium in order to compensate for reduced heating area.
3. Advantage is taken of the strong eddy currents produced, particularly in the case of turbine and propeller agitation, at the knuckle radii of the bottom heads in producing higher heating rates.
4. Advantage is taken of the fact that bottom head is a locale of maximum turbulence in the case of propeller and turbine agitation.

Consideration was given previously to the problem of giving the kettle a shape such that the contact area of the batch with the tank walls would conform to heating area requirements of the vessel as calculated from the following factors:

1. B.t.u. to be transmitted to the batch per hour.
2. The over-all coefficient of transfer.
3. The temperature potential between the heating medium and the mean temperature of the batch.

In resin-kettle practice, the pressure range in commercial sizes of units may extend from 29.4 in. of vacuum to several hundred pounds of positive internal pressure. Hence, the inner tank, in a jacketed assembly, must be designed to withstand the maximum positive internal pressure as well as the maximum external or collapsing pressure which the inner or reaction tank may experience.

PART V

Processing and Fabrication

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CHAPTER XV
Methods of Processing and Fabrication

CHAPTER XVI
Methods of Finishing Plastics

CHAPTER XVII
Equipment for Molding Plants

CHAPTER XVIII
Molds

CHAPTER XV

METHODS OF PROCESSING AND FABRICATION

METHODS OF MOLDING

Plastics like other raw materials are only useful when formed into articles of commerce. Several methods for molding exist. These include the following:

Compression molding
Injection molding
Transfer molding
Extrusion
Casting
Cold molding
Blow molding
Laminating
Calendering

COMPRESSION MOLDING

Certain plastics, more particularly the thermosetting type, are only partially chemically reacted in the form sold to the molder. They require heat and pressure to complete the chemical reaction. During this treatment they go through a pseudo-liquid stage and can be made to flow into mold cavities.

Compression molding is the technique applied to the process of flowing thermosetting compounds into mold areas, taking advantage of their plasticity when heated under pressure. It is by far the most widely used method of plastics fabrication.

The procedure for compression molding consists of several simple steps:

1. The mold is heated, preferably by steam, and a measured charge of molding compound is put into the lower half of the mold (cavity). This charge may be a weighed amount of material, or a predetermined size pill, or a volumetric amount.
2. The mold is slowly closed until the material starts to flow, at which time the rate of closing of the mold is slowed down to nearly an imperceptible speed. After the excess material has flashed out and the upper part of the mold (punch) has seated on the cut-off areas (lands) of the cavity, the mold is allowed to remain closed for a definite period of time (cure period). This length of time is dependent upon a variety of factors, namely, speed of cure of the molding compound, thickness of the molded piece, overall size of the piece, and temperature of the mold.
3. After the mold has been closed for the requisite period of time, it is opened and the piece ejected hot, either by knockout pins or air blast.
4. The molded article thus produced is sent to the finishing department where such operations as de-finning, buffing, and inspection take place.

This is the general picture of compression molding. Unfortunately it is not this simple because there are many factors which must be carefully considered in each step.

In the first place, the proposed piece must be properly designed, including freedom from undercut, sufficient draft on side walls, proper consideration of bosses, and other similar constructional features.

Then there is a variety of types of molds, including the positive, semi-positive, and flash types. Some materials work better in one type of mold, others in another. The proper plasticity of material must be chosen, which relates naturally to the size of the molded piece and the pressure available. Then again, materials with different cure rates may have to be considered.

After the proper mold has been built, the necessary plasticity of molding compound chosen, the problem of molding is only partially solved. It remains to work out a simple molding cycle. In some instances, and by far too few, all that is necessary is to load the mold, run it shut, cure, and take out the piece. In many instances, particularly with urea plastics, it is necessary to incorporate a breathing operation and even a holding period.

Breathing a mold consists of releasing the pressure momentarily. This allows trapped air and other gases to escape. There is no set time at which to breathe the mold. In some instances the breathing is incorporated just after the mold is completely closed. Again, it may be better to breathe just before or after this stage. Trial is the only way of determining this point.

In obstinate cases, particularly where the wrong plasticity is being used, it may be necessary to arrest the closing of the mold for a few seconds. This is known as holding. During this period the molding compound becomes more fluid and will react chemically further. Breathing and holding operations are delicate and must be introduced in the right place.

It is essential in compression molding to use the correct amount of molding compound. Too little results in pieces with unfilled areas. Too much is wasteful and requires added pressure. Usually 3 to 10 per cent excess material is required, over and above that in the finished piece. It is better in molding small objects such as buttons and wall plates to use pills of proper weight. Where this is not feasible, loading boards or cups are required. Inaccurate methods of loading invariably increase production costs.

Thermosetting compounds must be left in the mold long enough to cure, but they can be left in too long, causing over-cure. In addition, the compound can lie in the cavity so long before molding that pre-cure results. Therefore, it is necessary to have adequate timing devices to aid the operator in maintaining the proper cycle.

Many molders are attaching automatic press operating devices to their equipment. These work fairly well provided the molding compound is kept under uniform storage conditions and is thoroughly blended prior to use.

Automatic presses are rapidly coming into use and these will be discussed later.

The equipment required for compression molding is essentially as follows:

Presses
Molds
Loading equipment
Preforming machines
Compressed air
Hydraulic equipment
Heating equipment
Finishing and inspection equipment

Presses. Small, manually operated *hand presses,* either hydraulic or mechanical, play only a small role in the present molding industry. Their use is confined to experimental jobs, or for use in the metallographic laboratory or perhaps in dental laboratories. Such presses are available up to pressures of 10 to 15 tons.

Mechanical presses, involving variations of the screw principle or the toggle were previously more popular than they are now. Their use is limited because of their lack of versatility. While these machines are on their way out, they are survived by one type of machine (Stokes & Cropp), which is truly mechanical in application of pressure. It is spring and screw operated, but completely automatic. It has a wide margin of utility because of the combined action of screw-spring operation.

The more popular presses are *hydraulically* operated. These may be self-contained units or dependent upon an accumulative pressure system. For the most part, water is used to convey the pressure to the working parts. But this is not the only medium available because oil is being used successfully. The versatility of the hydraulic press makes it ideal for compression molding. With any given line pressure, any reasonable number of presses may be operated, the pressure available at any press being controlled by the area of its ram. Presses may be equipped with hydraulic reducing valves, but this is not usually recommended.

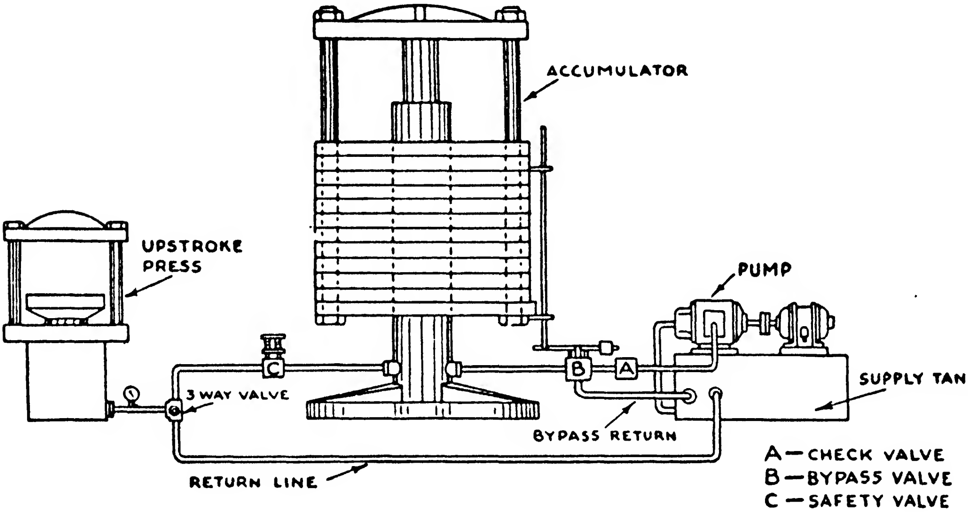

FIG. 15.1 — Piping and valve arrangement for up-stroke press.

The principle of the hydraulic press is illustrated in Fig. 15.1. There are several varieties utilizing the same principle but with different directions of ram movement.

The *up-stroke press* (see Fig. 15.1) is the commonest. Here the hydraulic ram and cylinder are mounted on the floor and the upper plate remains fixed, the lower platen traveling up to close the press. With this press it is common to use auxiliary cylinders and rams, known as pull-backs, to open the press. In most instances these rams are continually under pressure so that the actual pressure available is the total pressure produced by the main ram less that of the two pull-backs. Where the pull-backs are unusually large they may be operated separately.

The *down-stroke press* (see Fig. 15.2) differs from the up-stroke press in that the bottom platen remains stationary while the upper one moves because it is fixed to the ram which is mounted above the press.

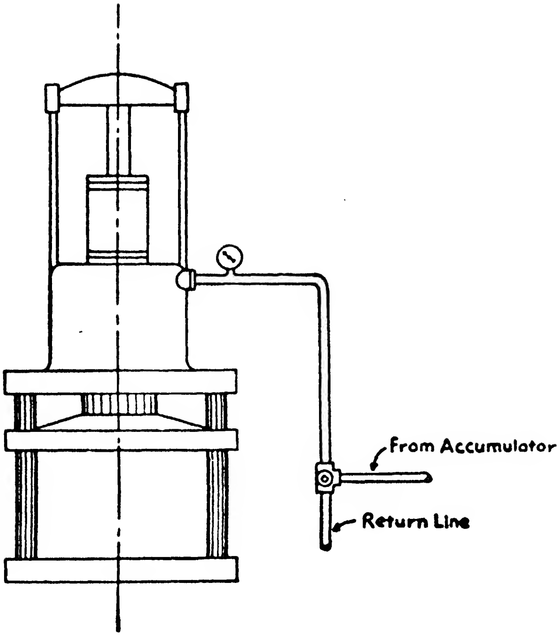

FIG. 15.2 — Location of two-way valve on down-stroke press.

The *angle press,* frequently called the side-angle press, was developed to allow pressure to be applied to the mold in a perpendicular direction, allowing for commercial consideration of split molds. Such molds are required for certain designs involving undercut, external threaded parts, and the like. See Fig. 15.3.

There are other adaptations of the hydraulic press including tilting-head presses, multi-platen presses, and rotating-table presses. Some of these will be discussed under Molding Presses and Equipment.

Hydraulic presses can be built to any size. In general, however, the sizes range from 15 to 1500 tons. Of the latter size few are in use in this country. A survey of press size distribution by molders appears elsewhere.

In some plants, two hydraulic systems are used, one to produce large quantities of low-pressure water for rapid closing of the press, and a high-pressure system to give the final ultimate squeeze on the molding compound.

Automatic Hydraulic Presses. Of late there has been an influx of semi- and completely automatic presses. Characteristic of these is the Lauterbach molding press. This machine utilizes the practice of rotating some twenty individual hydraulic rams around a central shaft. Attached to the shaft is a special valve which regulates the operation of the press by alternately applying oil pressure to the ram as it revolves in position, keeping the pressure on this ram as it revolves until a certain position is reached, namely, the discharge point, when it releases the pressure allowing the ram to open. As each of the twenty molds passes the loading point it automatically receives a charge of compound, is rammed shut, and remains until it is discharged at press point. The machine is ingenious but is not adapted to all types of molding. It is limited to small draw items (not over 3 in. high), and preferably narrow molding such as bottle caps. The machine is equipped with a special ejector. For best operation, the piece should be designed with a molded thread so that the piece is pulled out of the cavity and remains on the punch. The ejector consists of a whirling rubber disk which then spins off the piece. Properly placed air jets clean out the discharged mold and blow the molded piece into a chute, thence to the tumbling equipment. The efficient operation of these machines depends upon several factors:

1. Clean oil in hydraulic system, preferably with a constant temperature. The rate of closing of the ram depends upon the viscosity of the oil, pressure of the oil, and the

rate of revolution of the machine. As the hydraulic pressure is controlled by the escapement of the oil through two slots as the valve assembly rotates, the faster the machine rotates the faster the ram travel. Obviously, these slots are minute and the least particle of dirt may clog them. Unfortunately, the valve is located inside the press assembly and to get at it requires tearing down the machine — several hours' job.

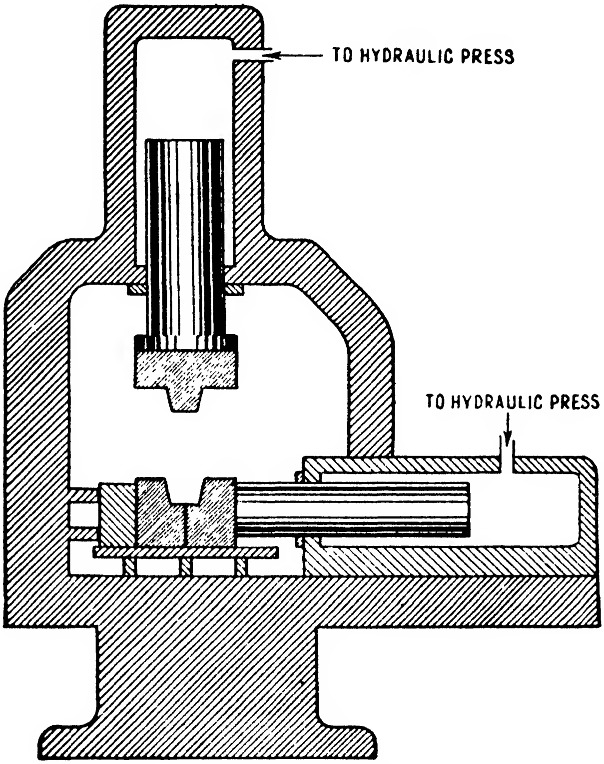

FIG. 15.3 — Angle press.

2. Simplicity of design of molded piece.

3. Type of mold construction with this machine, more than any other, is mold construction tantamount to production of good pieces. These presses have little " daylight " and loading wells must be kept to a minimum. This necessitates the use of molding powder having a minimum bulkiness. For best operation a semi-positive mold is indicated with a definite degree of positive entrance of the punch into the cavity. Typical mold construction for this type of machine for most molding compounds is shown in Fig. 15.4.

Other automatic compression molding machines include the Stokes 10- and 15-ton presses, the Cropp 12-ton press, and the Sayre press.

Molding Presses.[1] The Boonton Molding Co. has developed the Sayre Automatic Molding Machine for thermosetting materials.

A rack holding a drum of molding material is attached to the machine. This drum

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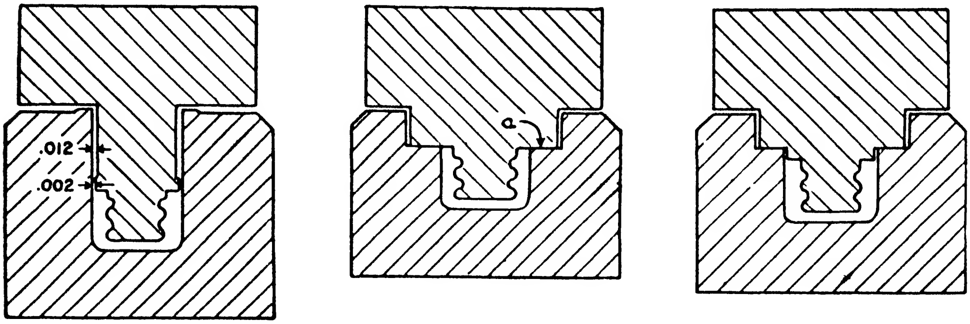
[1] Described by George K. Scribner, Boonton.

is tilted to spill the powder into a hopper and then onto a conveyor. The conveyor takes it to a blending box to assure correct mixture of fine and coarse granules. A distributing system next takes the powder to the individual cups, then to a preform press where the molding powder is preheated under pressure, actually a preliminary molding operation in itself. After this it is ready for the standard molding press.



A

Semi-positive with positive entry. Best type, but draw too long to fit in press.

B

Semi-positive. No positive entry. Poor construction since material lies on ledge, *a*, sealing in air.

C

Semi-positive. Partial-positive entry. Fair compromise.

Fig. 15.4 — In the design of a mold limits of the press must be considered.

After heat and pressure are applied to the molded piece a train enters the press, removes the molding, cleans out flash and deposits new powder tablets. This machine is suitable for small parts without inserts as bottle caps, radio cabinets, and trays.

Injection Molding

Injection molding is commercially adaptable to the fabrication of molded articles of thermoplastic materials and in principle is the simplest form of molding. The thermoplastic compound as its name implies is heated in a plasticizing cylinder and as soon as the liquid stage is reached it is forced into a cold mold, more or less the opposite of compression molding where cold material is molded in hot molds.

No effort or money has been spared in this country in the development of automatic injection molding machines and there are several companies producing machines of various capacities. These are discussed elsewhere. While various machines involve different mechanical details such as method of feeding the compound to the mold, and holding the mold halves together, the principle of operation is the same and best visualized by referring to Fig. 15.8, page 560, Fig. 15.25, page 580, and Fig. 17.9, page 666.

The plunger forces cold material in granular form into the heated plasticizer chamber, where the compound becomes quite fluid. Further plunger movement forces this fluid through the nozzle into the cold mold. While the plunger is returning to its original position to pick up more material the mold is opened and the piece ejected.

Machines vary in details of operation. For example, the plunger may be mechanically operated, as by a screw, or it may be hydraulically operated. The mold may be opened and closed either by a hydraulic ram, or by a toggle or other mechanical means. In any case the force keeping the mold closed must be greater than that applied in forcing the material into the mold, otherwise the mold will open slightly and produce large parting lines.

Some presses operate with the feeding device and mold placed horizontally. Obviously, this enables the mold to be easily emptied. Vertically operated presses are better adapted to the molding of larger pieces.

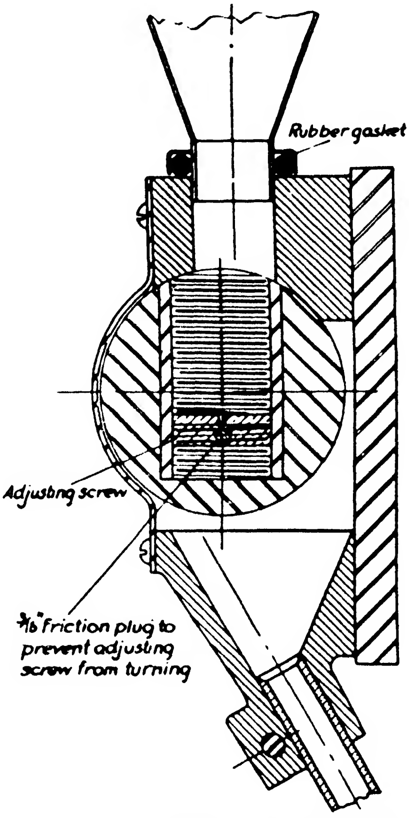
Injection machines can be made to operate automatically, although for the most part it has been found more economical to have an operator for each press particularly if multi-cavity molds are used. The operator can then utilize part of his time removing the gate and sprues.

The molding cycles are unusually short, in the neighborhood of 20 seconds or less.

While the operations seem foolproof, nevertheless difficulties are encountered. The material must be uniformly heated in the plasticizing chamber. To facilitate this, a refinement is added which is technically known as a torpedo or spreader.

Injection machines are rated upon the quantity in ounces capable of being injected in one shot. These vary from 2 to 36 ounces.

Equipment needed for injection molding includes an injection press, de-finning devices, grinder for scrap, and finishing barrels.



Courtesy of Machine Design.

FIG. 15.5 — Automatic press. Sectional end view of a powder metering device. Capacity may be adjusted by means of screw plugs.

Design of Injection Molding Machines. Sprue bushing (see Figs. 15.8 and 15.9) should be of hardened steel so that occasional driving out of a stuck sprue with a brass rod will not injure it. If the steel is too hard it may crack under pressure of the nozzle against it.

Runners should be of ample size to convey material quickly to cavities, but their size is limited by the desire to keep runner scrap to minimum. The best shape is round.

Standard pressure for injection molding is 20,000 lb. per sq. in., but experimental data indicate pressures approaching 40,000 lb. per sq. in. will give better results.

The diameter of the sprue opening at the point of contact with the nozzle should be at least 0.020 in. larger than the nozzle opening.

TRANSFER MOLDING

Transfer molding is a technique developed for thermosetting compounds whereby use is made of a preheating chamber from which the molding compound is ejected into the

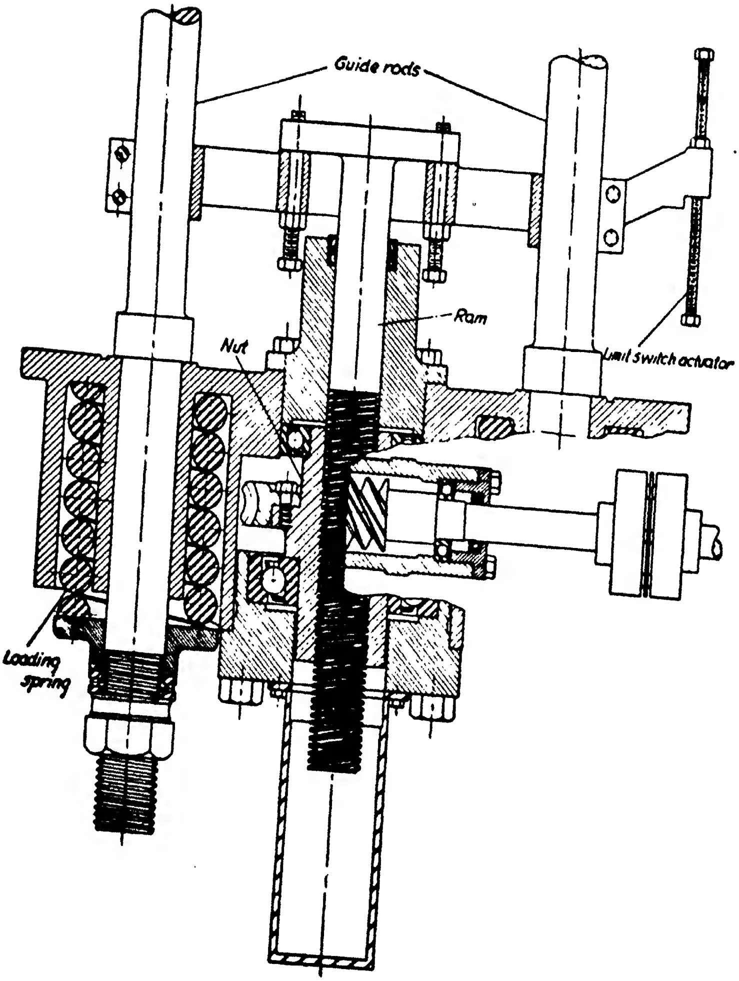
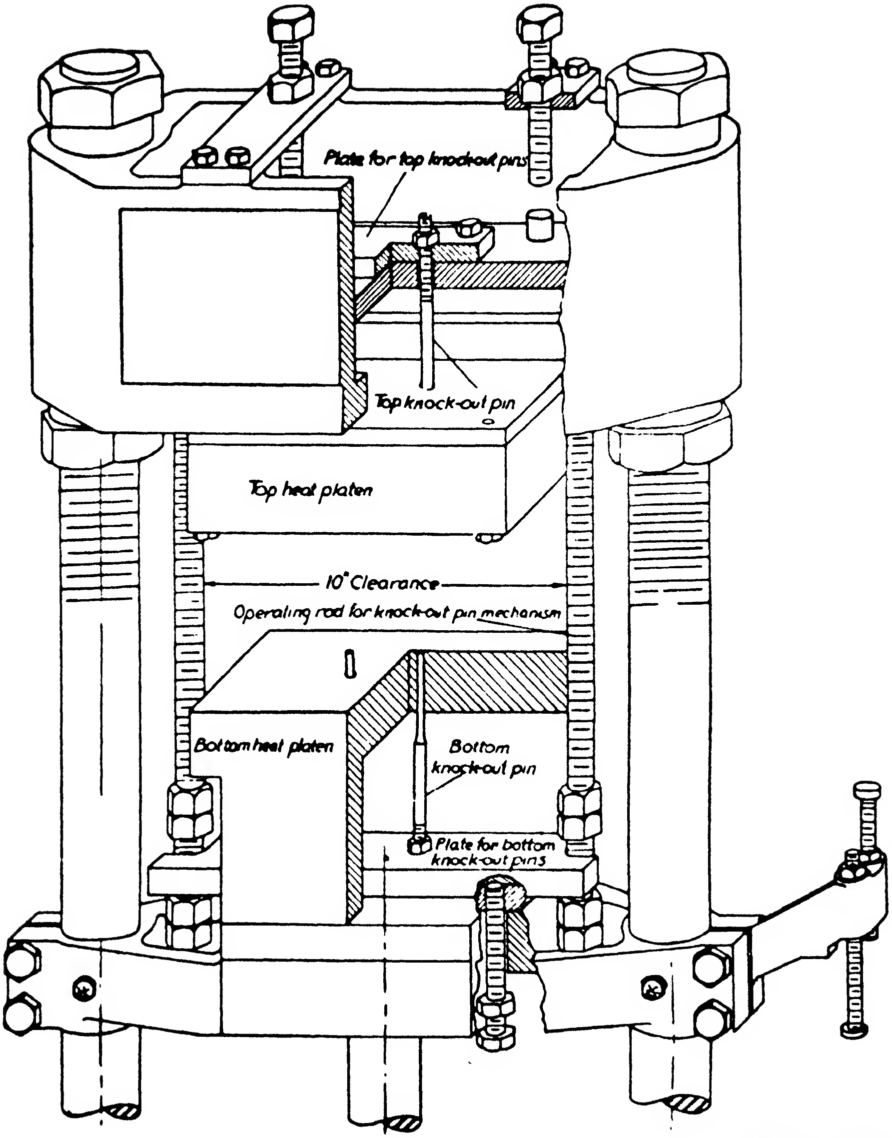


FIG. 15.6 — Automatic press. Sectional view of worm and wheel ram drive shows location of loading springs in gearbox away from heat.

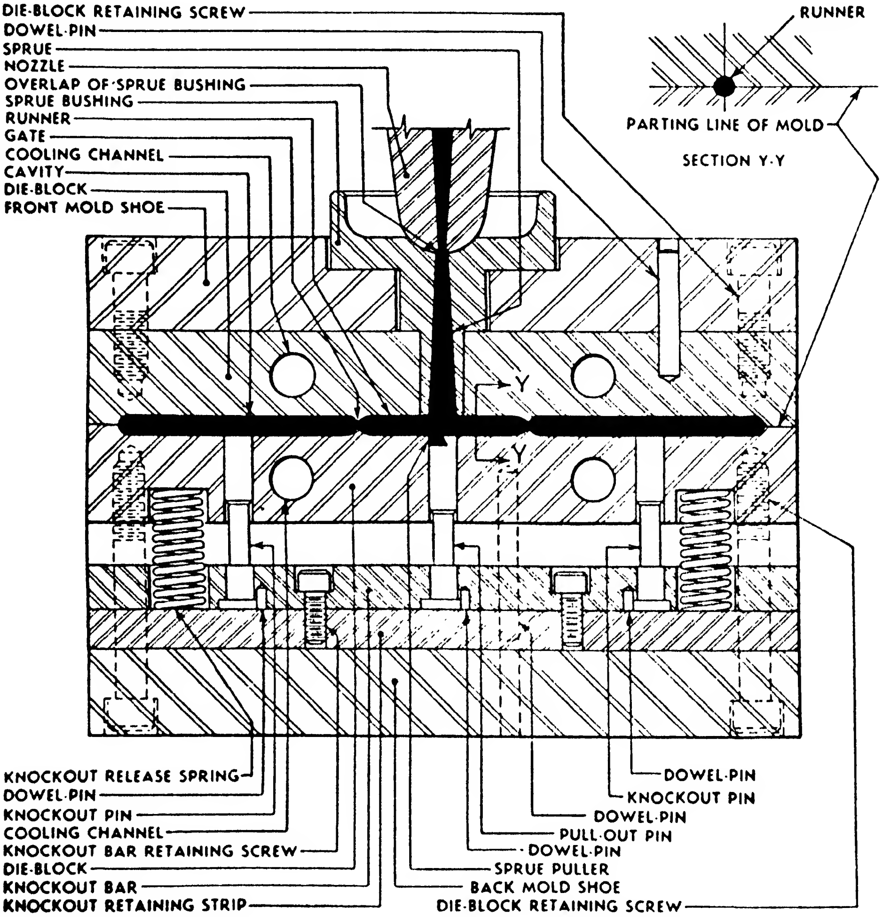
Courtesy of Machine Design.



Courtesy of Machine Design.

FIG. 15.7 — Automatic press. Location and mode of operation of knockout pins are shown in isometric press platen assembly.

mold proper when correct plasticity is reached. Transfer molding is limited to the phenolic materials at the present time. By proper gating and with adequate pressure even the fabric-filled phenolics can be transfer molded.



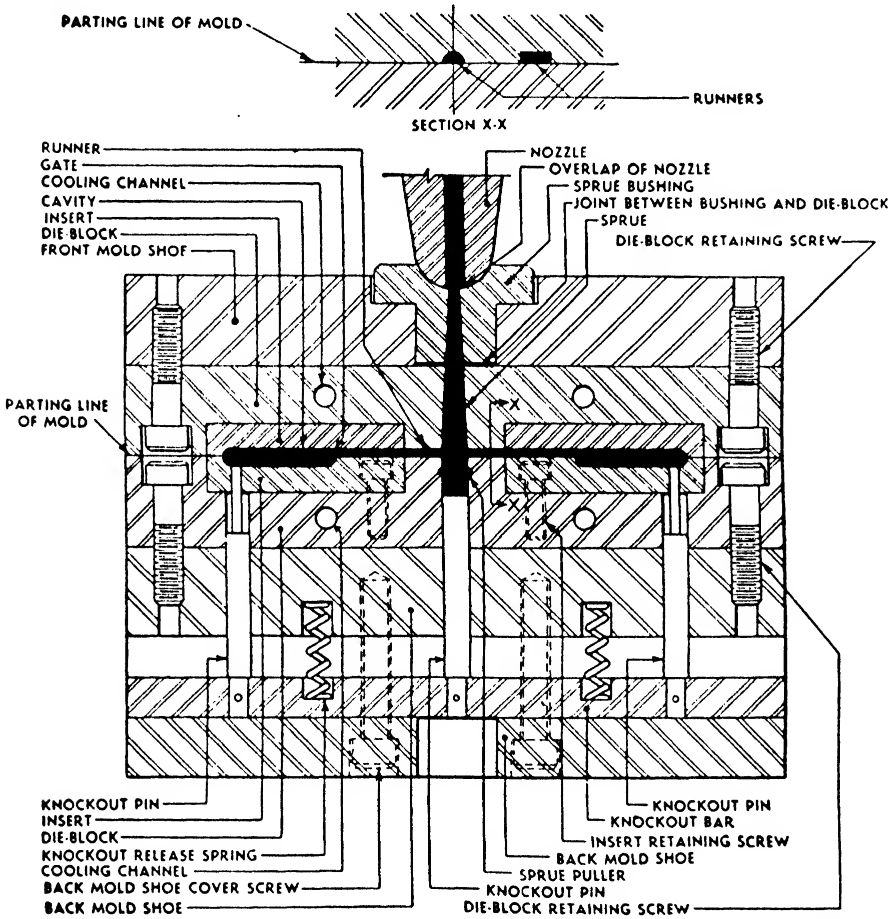
Courtesy Machinery, June, 1941.

FIG. 15.8 — Injection molding machine. Correct design.

Due to the fact that the molding material is rapidly heated in thin sections before entering the mold cavity, the molding cycle is substantially shortened, frequently as much as 50 per cent.

Regardless of the number of mold cavities, only one charge of material is required, thus the time otherwise used in filling each individual cavity is saved. Due to the fact that the preheated material flows into the mold in soft condition and at very low pressure, there are no surges, caused by high pressures, to displace or distort fragile cores or inserts. Many products with delicate glass inserts have been successfully molded in large volume.

As the mold cavity is closed at the time the preplasticized material enters, it is obvious that the finished product will be of absolute dimensional accuracy and have uniform strength and quality through its entire structure; also, that flash or fins are entirely eliminated, this resulting in lower finishing costs. Because molding material is preheated and softened before entering the mold cavity, abrasion of the polished surface of the mold, caused by preforms or hard compound, is reduced to a minimum. This



Courtesy Machinery, June, 1941.

Fig. 15.9 — Injection molding machine. Incorrect design.

does away with the necessity for buffing, with the attending danger of exposing the filler underneath the pure resin skin of the molded article.

Gases and occluded air within the molding compound are dispelled in the preheating chamber, the result being complete elimination of losses due to blisters or flow marks. The primary advantages of transfer molding may be summed up as follows: Improved quality — ability to mold intricate shapes that cannot be produced by any other known method — extreme accuracy in location of inserts — reduction of molding cycle — substantially lower finishing costs — elimination or substantial reduction of rejects.

A characteristic transfer mold is shown in Fig. 15.10. One of the chief advantages of transfer molding is that it approaches the skill of hand operation. Recently, however, side-angle presses have been adapted to transfer molding, putting the operation on practically an automatic basis.

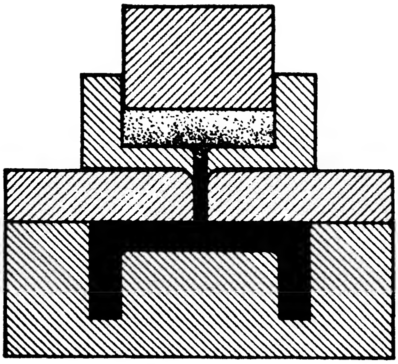


FIG. 15.10 — Characteristic transfer mold.

The equipment required for transfer molding is similar to that used in compression molding procedure; however, in addition to heated steel platens on the presses, the work table must also have heated steel areas. Each mold or set of molds must have available pots of appropriate size. The molds themselves do not have to be so elaborate as the usual compression molds.

EXTRUSION

A recently developed means of fabricating plastics is the so-called dry extrusion method which utilizes thermoplastic molding powders and relatively small extrusion machines of a design which has been used previously for other materials, principally rubber. Two of several types of dry extrusion machines are made by the American Hard Rubber Company, New York, the National Rubber Machinery Company of Akron, Ohio. These consist essentially of a hopper, a screw-feed mechanism, a heating chamber, and a nozzle and die.

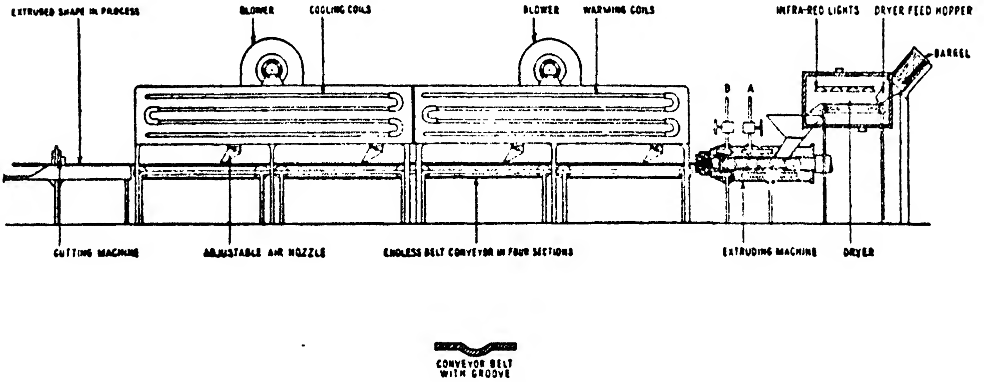


FIG. 15.11 — Schematic cross section through an extrusion machine.

The powder which is introduced into the hopper falls by gravity into the screw conveyor section where it is forced forward through the heating chamber, the nozzle, and finally through the die from which it emerges in semi-liquid form with cross section roughly resembling that of the die. The extruded form is picked up at once by a conveyor belt in the manner indicated in Fig. 15.11, and then passes in a continuous strip under cooling blasts of air.

Many of the different steps involved in this process are subject to regulation and the art of extrusion is anything but standardized or well established at the present time. Those who are successful at extruding complicated shapes have hit upon the actual method used by a long process of trial and error. Some of the points which are subject to variation are the following:

- Condition of molding powder:
  - a. temperature at time of delivery to hopper
  - b. moisture content
  - c. size of grain
  - d. type of plastic
- Design of extrusion machine:
  - a. length of heating chamber
  - b. speed of screw conveyor
  - c. temperature throughout the heating chamber
- Design of nozzle:
  - a. temperature of material in nozzle
  - b. velocity of material in nozzle
- Design of die:
  - a. cross section of aperture
  - b. kind of metal
  - c. length of die (distance of travel of material being extruded)
- Design of conveyor belt:
  - a. distance of belt from outside surface of die
  - b. height of belt in relation to center of die
  - c. speed of travel
  - d. cross section
  - e. length
- Design of cooling system:
  - a. number of nozzles
  - b. location of nozzles
  - c. temperature of air blast at each nozzle
  - d. velocity of air at each nozzle
  - e. shape and position of nozzle

Frequently such a small item as the difference in grain size of molding powder will mean success or failure in extruding certain shapes, and the difficulty of adjusting all the variables in the process may be judged from their number.

Materials Used. Continuous extrusion was started with cellulose acetates but nearly all of the thermoplastic materials may be used. Some that have been used are as follows:

- Cellulose acetate
- Cellulose acetate butyrate
- Ethyl cellulose
- Vinyl chloride
- Vinylidene chloride
- Vinyl acetate copolymer
- Polystyrene
- Methyl methacrylate

The last two materials seem to require special extruding equipment. They are being successfully extruded by the Plax Company, Hartford, Conn., in company-built machines of proprietary design. These differ from the machines previously mentioned in the greater length of the heating chamber and nozzle section, which may be anywhere from 20 to 40 ft. The Plax Company is regularly extruding crystal clear methacrylate rod in sizes 2 and 2½ in. in diameter. It is also extruding polystyrene in rods up to 2 in. in diameter but, strangely enough, the polystyrene, although introduced to the machines in the form of a powder which will make crystal clear moldings, comes out of the extruding die as a dull finished rod which must be polished to give it full clarity.

Tubes and some simple shapes, such as square rods and moldings, have been made on these long special extruding machines, but they apparently are not well adapted for extrusion of complicated shapes. They do, however, handle acetate powders and are regularly in production on acetate rods.

For complicated shapes, the butyrates have met with the greatest success. For tubes, the acetates and ethyl cellulose have been used with success, and for fibers and simple sections vinylidene chloride has been popular. In fact, this latter material under the trade name Saran seems particularly well suited to the extrusion of monofilaments, some of which, produced experimentally, have shown tensile strength as high as 60,000 lb. per sq. in. The behavior of this material is in some respects unique among plastics. If the molding powder is heated to extrusion temperature and then chilled quickly, it assumes an amorphous or super-cool condition in which it is soft and flexible. This phenomenon is described more fully under Injection Molding.

The possibilities of producing stock material by the dry injection method seem extensive indeed. Some of the different shapes already being produced are illustrated in accompanying sketches, all of which are extruded in cellulose acetate-butyrate or cellulose acetate or vinyl compounds.

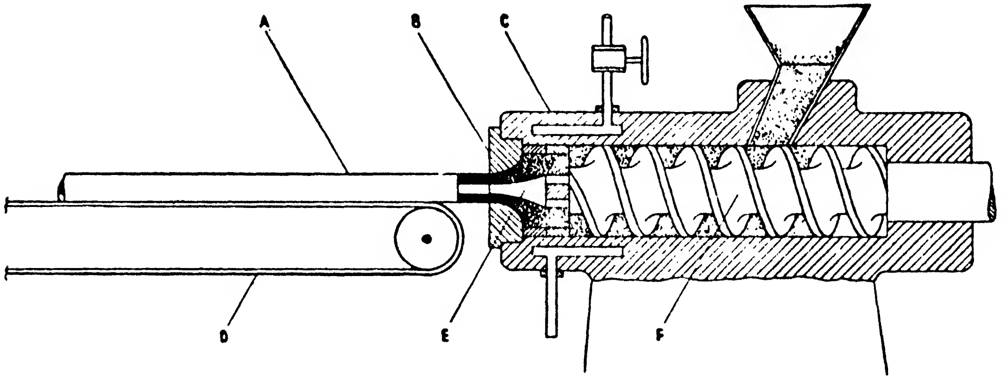


FIG. 15.12 — Type of extrusion machine used for extruding acetate tubing.

A. Extruded tubing being carried along by conveyor belt.
B. Die.
C. Heating zone.
D. Endless conveyor belt.
E. Mandrel located concentric with the die to produce the inner opening.
F. Screw type conveyor.

Equipment. A typical arrangement of equipment for extrusion is shown in Fig. 15.11. A special design used principally for tubing is shown in Fig. 15.12. This gives approximately the arrangement of an actual installation. The tubing, as shown, is carried along by a conveyor belt so that it continues at the same level at which it emerges from the machine. As indicated, the hopper arrangement permits continuous operation. The heating zone, as well as the nozzle (not shown in Fig. 15.12) and the die itself are frequently provided with independent heat control. The heating zone normally contains a jacket through which hot oil is circulated. The nozzle and die block are more frequently heated electrically, although even in this instance circulating oil may be used. Variable-speed motors are employed both for the conveyor screw and for the belt conveyor.

It is important, of course, to synchronize the speed of the belt conveyor with that of the extruded material. The normal arrangement is to place the cooling blowers every 5 or 6 ft. along the length of the belt. It is also usual practice to have the conveyor belt from 40 to 60 ft. long in order to give sufficient cooling time to harden the form before it is cut to length and dropped into a storage box. Either an automatic cutoff device or a hand-operated cutoff is placed at the end of the belt, although strips or many small sections may be wound directly onto spools.

Dies used with the standard screw-type extrusion machines are relatively simple in design, but the difficulty in their use comes through the dissimilarity between the die opening and the desired cross section. In some complicated shapes, this dissimilarity may be so great that even an experienced operator could not tell from the die opening what the finished piece would be like. Therefore, while the die itself may cost in the neighborhood of $100, it may cost $1500 for the initial experimental work to determine the proper opening.

The inside corner shown on Fig. 15.13a may have a die with an opening more closely resembling a deformed type of H. If the shapes leaving the die are too soft, they may collapse. To help overcome this tendency, belt conveyors with grooves are sometimes used to give better support during the early soft stage. Back pressure on the material is necessary to the process.

Usually the die opening is somewhat larger than the cross section of the finished piece to allow for a certain amount of stretching to size on the conveyor belt. This stretch is a desirable feature as it improves surface finish. The speed of production varies greatly with the size of the cross section, but some idea of the average speed may be gained from the fact that a 1-in. strip, ⅛ in. thick, is produced at approximately 750 ft. per hr.

The Extruded Materials. Stock shapes produced by extrusion are potentially one of the most important of plastics materials. These, of course, should not be confused with wet or doughlike extruded forms produced as one stage in the manufacture of certain plastics, principally the acetates. Such intermediate forms must be hardened and seasoned after extrusion, and, therefore, form an entirely different class of materials.

Shapes produced by dry extrusion usually issue all polished and (after cooling) ready to market. The vinylidene chloride fibers and monofilaments, as mentioned, display unusual strength and wearing properties and are used for fishline, for " rattan " to be woven into bus and railway coach seat cushions, and many similar items described in the section on applications.

Tubing made of butyrate may be used for many applications in exactly the same manner as copper tubing is used, i.e., it may be flared at the ends and applied to any regular metal coupling designed for use with copper tubing. In handling the butyrate tubing, the tools used should be warm (not hot) and the end of the tubing to be formed should be held in hot water for about 30 seconds. As soon as the flare has been made, the end of the tubing, while still in the tool, should be dipped in cold water. Tubing joined in this way is water-tight and strong.

Fig. 15.13a.

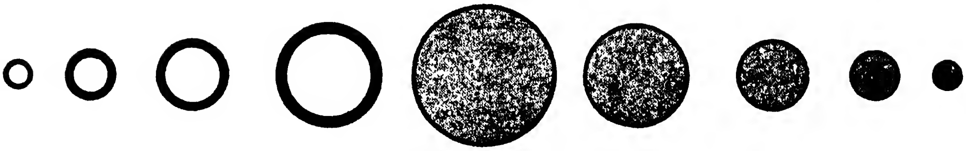


Fig. 15.13b.

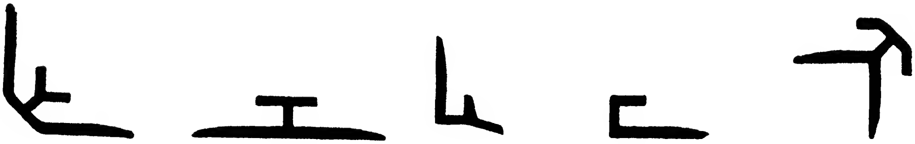


Fig. 15.13c.

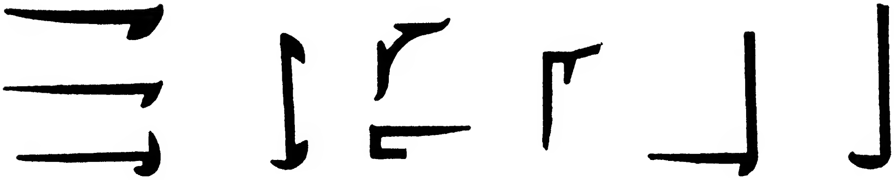


Fig. 15.13d.

Extruded forms for architectural uses.

The following is a list of properties of butyrate tubing as supplied by the Plastics Shapes Division of Julius Blum & Company:

1. Can be heated to 160° F. for forming without changing its physical composition.
2. Is unaffected by aging at ordinary temperatures.
3. Shows signs of softening at continued exposures to temperatures above 140° F.
4. May be cut with a sharp knife or with a hacksaw (cannot be filed).
5. Water absorption is 1.1 to 2.0 per cent by wt. in 24 hr.
6. Is uninjured by contact with most vegetable and mineral oils (see Table 89).
7. Exposure to sunlight has no effect on the transparent material. Colored materials are subject to fading with the exception of a limited range of lightfast colors.
8. Parts may be joined by the use of acetone. Surface must be smooth and clean, but when properly done an excellent bond is possible.

TABLE 89. CHEMICALS AND REAGENTS HAVING NO EFFECT ON CELLULOSE ACETATE BUTYRATE (EXTRUDED)

(Tests conducted at 70° to 80° F. for 48 hr., unless otherwise noted)

- ALCOHOLS
  - N-Butyl
  - Sec-Butyl
  - n-Amyl
- ETHERS
  - Di-isopropyl Ether
- POLY-ALCOHOLS
  - Glycerin
  - Ethylene Glycol
  - Propylene Glycol
  - Triethylene Glycol
- HYDROCARBONS
  - White Gasoline
  - Cyclohexane
  - Kerosene (65 hr.)
- ACIDS
  - 30% Acetic
  - 10% Acetic
  - 5% Acetic
  - 40% Sulfuric
  - 40% Sulfuric (7 days)
  - 40% Sulfuric (2 weeks)
  - 10% Hydrochloric
  - 5% Hydrochloric
  - 10% Citric
  - 10% Lactic
  - 50% Lactic
  - 5% Boric
- BASES
  - 10% Sodium Hydroxide
  - 5% Sodium Hydroxide
  - 2.5% Sodium Hydroxide
  - 20% Ammonium Hydroxide
  - 10% Ammonium Hydroxide
  - 5% Ammonium Hydroxide
  - 2.5% Ammonium Hydroxide
- SALTS
  - 2.5% Borax
  - 2.5% Calcium Chloride
  - 2.5% Sodium Chloride
  - 2.5% Sodium Bicarbonate
  - 2.5% Sodium Carbonate
  - 2.5% Magnesium Carbonate
  - 2.5% Silver Nitrate
- ESSENTIAL OILS
  - Vanilla (Imitation)
  - Terpinol
  - Terpineol
  - Lavender
  - Lemon
  - Sweet Orange
- CLEANSING AND DISINFECTING AGENTS
  - Sano-Genic Cleanser (sat. sol'n.)
  - Lava Soap (sat.)
  - Old Dutch Cleanser (sat.)
  - Lighthouse Cleanser
  - Lighthouse Soap (sat.)
  - Bon Ami (sat.)
  - Red Seal Lye (sat.)
  - 35% Formaldehyde
  - 5% Hydrogen Peroxide
- MISCELLANEOUS
  - Milk (sweet) at 39° F.
  - O'Cedar Furniture Polish
  - Vick's Va-Po-Rub
  - Vick's Va-Tro-Nol

TABLE 90. CHEMICALS AND REAGENTS THAT CANNOT BE USED WITH CELLULOSE ACETATE BUTYRATE

(Tests were conducted at 70° to 80° F. for a period of 48 hr.)

- ALCOHOLS
  - Methyl
- ESTERS
  - Methyl Acetate
  - Ethyl Acetate
  - Isopropyl Acetate
  - n-Propyl Acetate
  - Isobutyl Acetate
  - Sec-Butyl Acetate
  - n-Butyl Acetate
  - Isoamyl Acetate
  - Cellosolve Acetate
  - Methyl Cellosolve Acetate
  - Methyl Cellosolve
  - Ethyl Lactate
  - Ethyl Propionate
- CHLORINATED COMPOUNDS
  - Methylene Chloride
  - Ethylene Chloride
  - Propylene Chloride
  - Chloroform
  - Dichlorodiethyl Ether
  - Tetrachlorethane

TABLE 90. CHEMICALS AND REAGENTS THAT CANNOT BE USED WITH CELLULOSE ACETATE BUTYRATE — *Continued*

KETONES
- Acetone
- Methyl Ethyl Ketone
- Methyl Isobutyl Ketone
- Methyl n-Butyl Ketone
- Di-isopropyl Ketone
- Diacetone Alcohol
- Phorone

ETHERS
- Methyl Cellosolve
- Ethyl Cellosolve

HYDROCARBONS
- Benzene

TABLE 91. EFFECT OF SOME CHEMICALS AND REAGENTS ON CELLULOSE ACETATE BUTYRATE

(Tests conducted at 70° to 80° F. for 48 hr. unless otherwise noted)

Reagent	*Effect*
ALCOHOLS	
Ethyl, denatured	Rather soft
Isopropyl	Soft; slightly sticky
n-Propyl	Slightly soft
Tert-butyl	Slightly soft
Isoamyl	Very slightly soft
Tert-amyl	Soft; slightly sticky
CHLORINATED COMPOUNDS	
Carbon Tetrachloride	Slight surface softening
HYDROCARBONS	
Toluene	Rather soft
Xylene	Slightly soft
BASES	
50% Sodium hydroxide (112 hr.)	Surface hydrolysis; slight surface softening
ESSENTIAL OILS	
Turpentine	Tacky, but not soft
Oil of Palma Rosa	Slight softening
Eucalyptus	Very slight softening
Citronella	Very slight softening
CLEANSING AND DISINFECTING AGENTS	
5% Phenol	Soft and sticky

The general physical properties of extruded butyrates, as well as for other extruded materials, are similar to those listed elsewhere for physical properties of the respective materials. (See under Chap. XXI of Part VII for applications of extruded material in industry.)

As example the Julius Blum & Company moldings are intended to be applied by nailing, which is a severe test. Actual location of the nails cannot be closely controlled because of error due to careless carpenters. Therefore, one requirement has been that, even should a nail be placed closer than 1/16 in. from the edge, the material must not crack. No material other than butyrate has been found which will have sufficient hardness to keep straight alignment, and still have sufficient elasticity and tenacity to permit nailing when cold. In winter, carpenters frequently work in a temperature close to 0° F.

Special plastics wallboard moldings have been designed for use in flexible and rigid wall covering materials such as plywood, linoleum, plastics, metal, and glass. The finish is polished and permanent and may be maintained by waxing. The moldings are not affected by water and may therefore be used in bathrooms and kitchens. It is suggested that the moldings be supported for their entire length in order to give the necessary support to the wall covering material used. Figures 15.14 and 15.15 illustrate plastics wallboard shapes.

This company also stocks the plastic shapes shown in Figs. 15.16, 15.17, and 15.18. They are designed for use with flexible and rigid wall and counter covering materials such as linoleum, rubber, and plastic. Edgings are available to cover the joints between top surfaces and bases of tables, counters, and cabinets. Figures 15.19 and 15.20 illustrate the shape used and method of application. For the best results the groove in the wood should be ⅛ in. by 9/16 in. The Interlox[2] plastics tee may be formed with ease around square or round corners. It is not necessary to heat or otherwise soften the material.

Figure 15.21 illustrates a wide variety of plastic sections which are available in almost any thermoplastic material.

Molding Powders for Extrusion. Standard molding powders are used for extrusion, but the grain size is usually smaller than when specified for molding. A maximum grain of ⅛ to 3/16 in. seems to give best results in standard extrusion machines.

The Tennessee Eastman Corporation gives the following details governing extrusion of its Tenite II (cellulose acetate-butyrate). The machine consists essentially of a feed hopper, a heating cylinder, a screw conveyor within the cylinder, and a die to form the desired section. Steel for cylinder and screw is satisfactory if kept from rusting. The cylinder usually has more than one oil-circulating system so as to provide greater heat at one end than at the other. Electric heat is more convenient but less uniform in results than oil.

Screws are ordinarily run between 25 and 35 r.p.m., depending upon the flow rate of the molding powder and the cross-sectional area of the extruded piece. A screen may be installed behind the die or in the die behind the orifice to assist in homogenizing the material. Such a screen may also reduce turbulence caused by the feed screw. Bronze wire screen of 50 by 30 mesh has been found satisfactory, although a 100 by 20 mesh has also given good results.

The screen may be supported by a perforated plate containing holes ⅛ to 3/16 in. in diameter. Screens cut down the speed of extrusion and are not used by some of the most experienced extruders. As might be supposed, a long rectangular die is not used to secure a flat section. This is because there is more friction at the edges than at the center, which causes the strip to taper at the edges if the die opening is the exact shape of the desired cross section. A correct die for a rectangular section is concave toward the center to compensate for the edge friction. Similarly, with tubing, the die opening is not necessarily circular. Some extruders use air pressure on the inside of the tubing to keep it from collapsing during the soft period just after it leaves the die. For this purpose, a pressure of from 1 to 3 lb. is supplied through a hole in the core or mandrel. Variations in pressure of such an air jet may cause bulges in the tubing, and to offset this possibility, equalizing tanks are set in the line close to the die.

The molding powder should be specified with as hard a flow as is otherwise suitable. The harder the flow, the quicker the set, and thus the hardness of the flow and the design of the cooling device are intimately associated in the process. The initial cooling blast may be as close as ¼ in. from the orifice of the die.

Operations. Where three heating systems are used, they may be 400° F. at the hottest point, then 300° F. for the intermediate section, and 200° F. at the nozzle end.

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[2] U.S. Patents applied for, Julius Blum & Co., Inc.

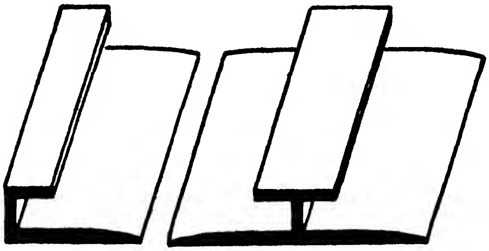


FIG. 15.14.

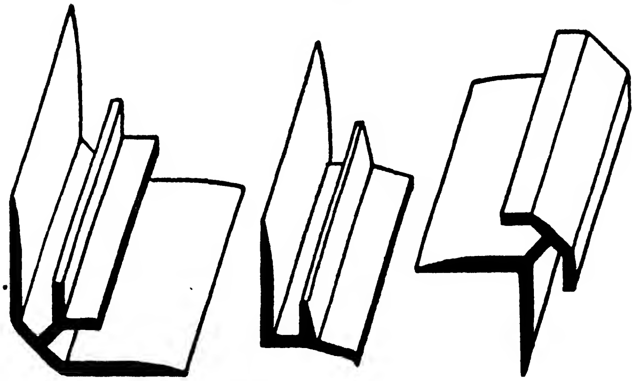


FIG. 15.15.

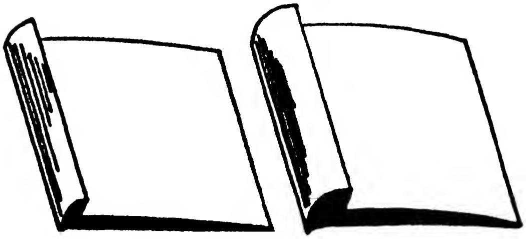


FIG. 15.16.

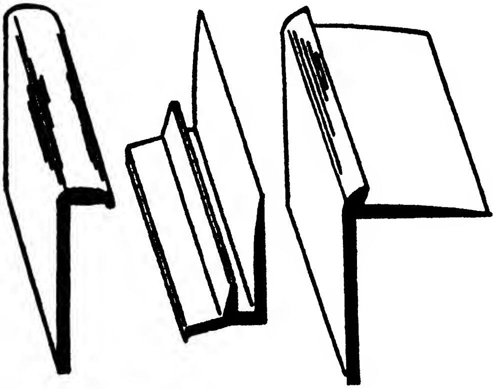


FIG. 15.17.
Some typical extruded sections for use in connection with wallboard.

As the extrusion rate is increased, the cylinder temperature must be raised, and thus the actual temperature for each job is determined only by trial.

The higher temperature, of course, is greater than the material will stand unless it is kept steadily moving. Cellulose esters will char if submitted overlong to temperatures that are necessary for continuous extrusion. To prevent this, when closing down a machine the heat is turned off first and extrusion continues until the material has become cool enough not to be charred.

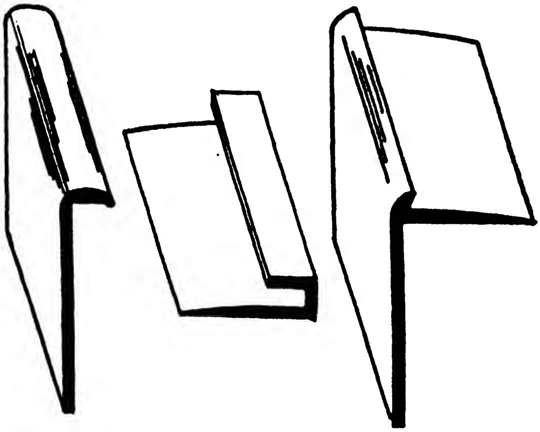


FIG. 15.18 — Some typical extruded sections for use in connection with wallboard.

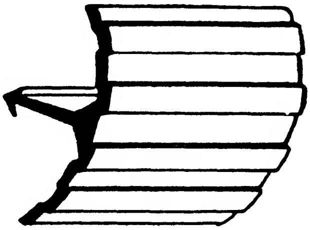


FIG. 15.19 — Interlox tee section.

In the design of extrusion machines, a shallow screw thread exposes more material to the hot wall of the cylinder than does a deep thread. Heat required in extrusion is about 150 B.t.u. per pound of molding powder. A machine with a cylinder 2½ in. in diameter and a die opening 0.1 sq. in. in area will ordinarily deliver 50 lb. of extruded shapes per hour.

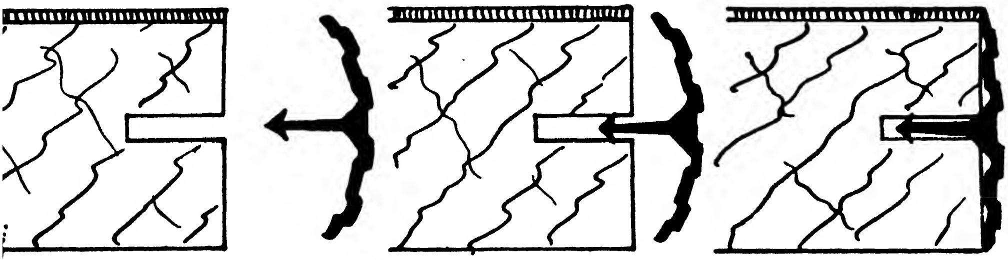
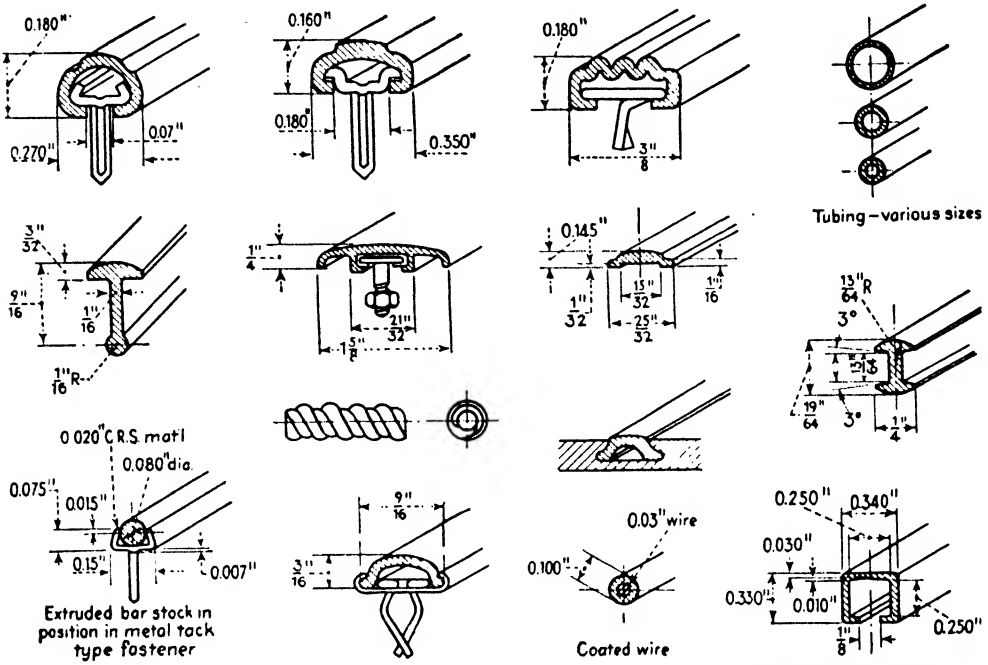


FIG. 15.20 — Successive steps in applying Interlox on table edging.

Drying of the powder prior to extrusion is highly important. This is conveniently done under infra-red lamps, as indicated in Fig. 15.22. Typical drying cabinet has an upper and lower section in each of which are three 250-watt lamps, 12 in. above the material, which should be not over 2 in. deep. Often the drying is combined with a conveyor, and the depth of the materials is regulated by the speed of the belt. Drying time with lamps is 15 to 30 min., compared with 2 to 3 hr. with air dryers.

Materials. The cellulose acetate butyrates have contributed most to this method of fabrication, but ethyl cellulose is important. Data on other materials in reference to extrusion will be found in the Materials section. Ethyl cellulose plastics for extrusion carry large amounts of plasticizer and are handled by heat alone. A normal extruding



Detroit Macoid Corporation.

Fig. 15.21 — Typical extruded plastic sections which are now available in almost any thermoplastic material.

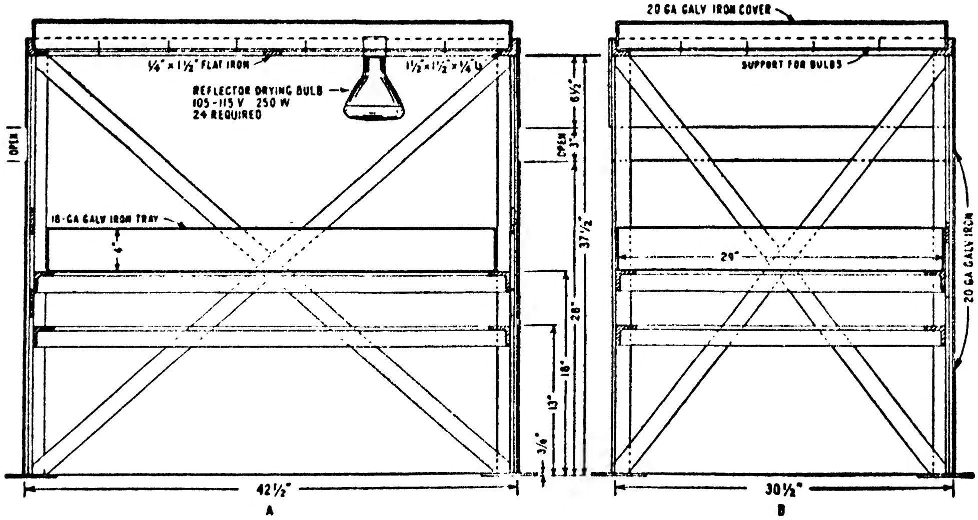


Fig. 15.22 — Dryer for drying tenite before extruding.

temperature is from 80° to 100° C. (176° to 212° F.) in the die and from 100° to 130° C. (266° F.) in the extrusion chamber. Blistering or distortion occurs when the extruding die is too hot. A scored extrusion usually indicates that the die is too cold.

Fifty parts ethyl cellulose and 50 parts of chlorodiphenyl extrudes readily into thin-walled tubing of great flexibility. It can be knotted and has high tensile strength. Extrusion is often carried out over wires or other cores, and extruded coatings can be produced down to a thickness of 1 mil.

The plastic has good electrical resistance. Nonsticky, tough, flexible, waterproof coatings for cables and extruded cable insulants are made from it. Extruded bands are woven to make furniture, decorative articles, etc.

CASTING

Formation of plastics items by casting is probably the simplest form of fabricating. Such a process is limited to casting resins, discussed elsewhere in this book.

The equipment consists of master patterns or mandrels around which lead molds are formed by a simple dipping process. The casting resin, usually phenolic, is poured into the lead molds and cured in baking ovens for 3 to 12 days. Pieces may be removed from the lead molds by pneumatic pressure or the lead may be de-plated away from the casting. The finishing operations are usually lengthy and require considerable hand operation.

COLD MOLDING

Cold molding is one of the older fabricating methods and is limited to special cold molding compounds. These consist of a binder of mixtures of synthetic and natural gums and pitches with fillers, for the most part mineral, such as asbestos. One part of binder to three of filler is commonly employed. Small additions of lubricants, plasticizers, and solvents are kneaded into the cold molding mass to obtain proper consistency.

This raw material is compressed under high pressure (10,000 lb. per sq. in.) in cold steel molds utilizing fast-operating presses. The number of cycles approaches punch-press operation (300 to 400 per hr.). The piece thus molded is far from being finished. It must be cured by a baking treatment under carefully controlled conditions, starting out with a low temperature and gradually raising it to 400° to 500° F. In some instances the piece is coated with an alkyd resin finish prior to baking. Obviously, this operation is limited to single shapes of limited draw.

There are two general classes of cold molded compound:

Nonrefractory types: Bituminous base; phenolic resin base.

Refractory type.

Binders commonly used are: Bitumen; gilsonite; pitch; asphalt; copal; shellac; bentonite clay; sodium silicate; Portland cement.

Fillers generally employed: Asbestos; iron oxides; slates; clays.

Solvents: Naphtha; alcohol.

Drying oil: Linseed.

Equipment used in mixing: Mixing kettles; mechanized agitators; beaters for fluffing fillers; screens; air-tight containers.

Molding procedure: Charges are added to cavities on a volumetric basis using loading boards or pills. Presses are closed slowly at first, followed by abrupt bumping. Pieces are ejected by knockout pins of large area.

Processing: The pressed pieces are air dried, then baked from 24 hr. to several days.

Advantages of cold molding process: Cheap raw materials; excellent heat resistance; rapid molding cycle; inexpensive press equipment; relatively inexpensive molds; no need of heating molds; good electrical properties.

Disadvantages: Restricted color possibilities; long after-treatment; variable shrinkage; poor appearance; poor mechanical properties; bulky baking equipment; high pressing pressures; limitations of design; high mold wear; limited use of inserts; easy crumbling during assembly; low surface hardness.

BLOW MOLDING

Blow molding is hardly a standard molding procedure. It is more nearly a forming operation. Split closed molds are used. Sheets of thermoplastic material are laid between the hot mold halves and air or steam is introduced between the plastic layers, blowing them up to fit the contours of the mold, cooling the mold prior to removal of the piece.

Equipment used consists of: Split molds; low pressure presses; air or steam pressure; de-finning devices (tumblers).

Advantages of blow molding: Hollow shapes; medium-priced raw materials.

Disadvantages: Limited raw materials; poor reproducibility of design; single-cavity operation; necessity of cooling mold.

LAMINATING[3]

Engineers in their search for better materials found that molded or cast plastics had definite limitations. Lack of strength, cold flow, and brittleness were a few of the qualities that made it necessary to find a material having a combination of properties that could be used to advantage as materials of construction rather than one that would have beauty, optical properties, or other esthetic values.

Laminated plastics are reinforced with a strong web of paper or cloth, which have important qualities alone as materials of construction. This combination of resin and finished cloth or paper produces a complementary effect whereby the weaknesses of one are vastly strengthened by the other, and the result is a well-balanced reinforced plastic suited to an almost infinite number of uses. See Figs. 15.23 and 15.24.

The most important properties of laminated plastics are as follows:

Electrical. High dielectric strength, low power factor, low moisture absorption, low dielectric constant.

Mechanical. Light weight (one-half the weight of aluminum). High impact, tensile, compressive, and flexural strength. Sound and vibration absorbing. Low thermal conductivity. Low coefficient of expansion. Toughness, hardness, and minimum cold flow. Heat resistant to 300° F. with no tendency to soften under heat.

Machining. Easily and economically machined by ordinary methods; handles about the same as brass or aluminum.

Chemical. Corrosion resistant to a high degree, it is effective in resisting many acids and alkalies, salts, gases, oils, solvents, and water.

These are only a few of the important properties and they exist only if the proper balance is obtained in the kind of raw materials, the types and quality of cloth or paper reinforcement, and the properties of these selected. The requirements of industry today are such that about 250 different types are necessary.

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[3] Prepared in co-operation with R. R. Titus, Synthane Corporation.

Laminators can control more variables than any other plastics manufacturers. Cloth in strength, count, and weave can be controlled. Paper in type, strength, purity, weight, and thickness can be secured from many sources. An unlimited number of resins are available by selection of the type of basic materials, catalysts, and modifying agents. After this selection of raw materials the laminated plastics manufacturer can then vary the proportions of resin and cloth or paper, the degree of cure, finish, hardness, flexibility, penetration, and can make any one general quality predominate if necessary to meet a particular problem.

MANUFACTURING FLOW SHEET

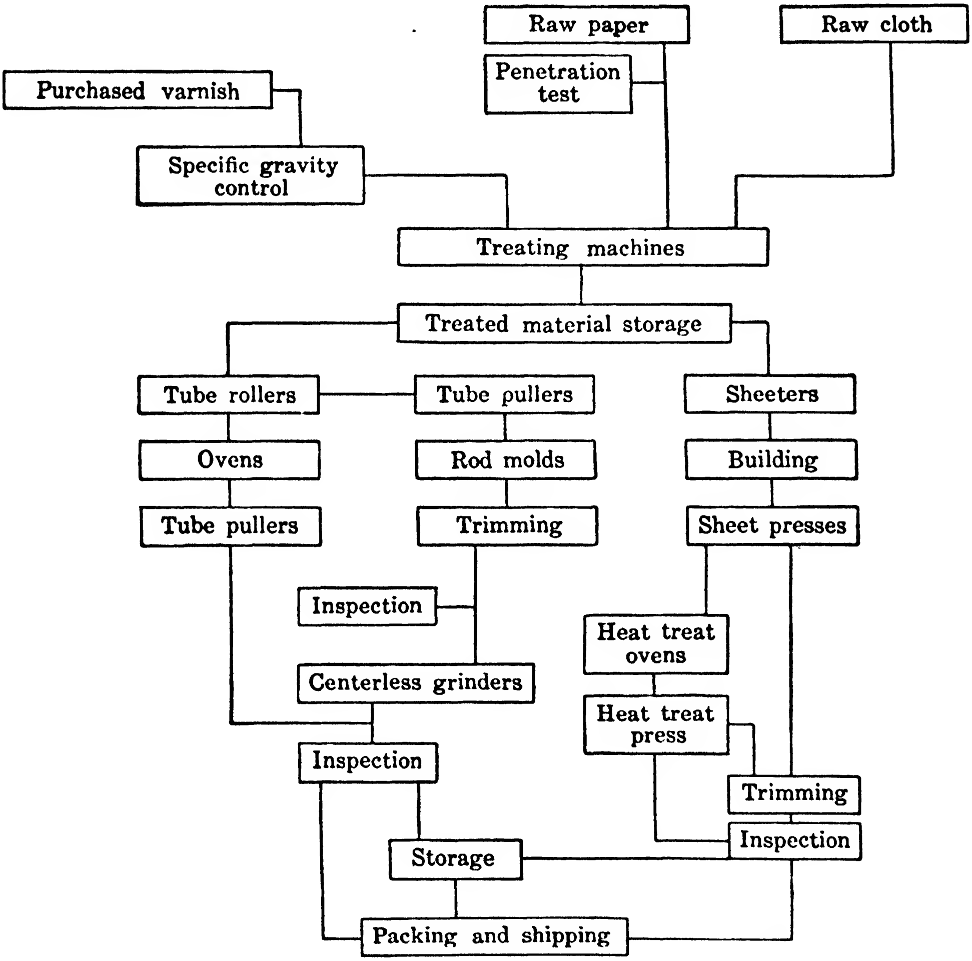

FIG. 15.23 — Characteristic plant for making phenolic laminates.

In the manufacture of laminated plastics the success or failure of the finished product depends upon the exact control of small details all through the process. The following is representative of the methods used in the industry: Cloth or paper is dipped into a pan containing resin dissolved in a solvent, run through squeeze rolls and led into a dryer, either vertical or horizontal, where the solvent is removed and the resin is converted from the A or soluble and fusible stage to the B or insoluble and partially fusible stage. It is then wound up and either used from the roll to make tubes and rods, or cut into lengths for pressing into sheets at about 300° F. and 1500 lb. per sq. in. pressure. Polished plates are used against these sheets if a shiny surface is desired, or grained, brushed, or sandblasted plates may be used if this finish is called for. The final application of heat and pressure consolidates the structure and converts the resin to the C or insoluble and infusible stage.

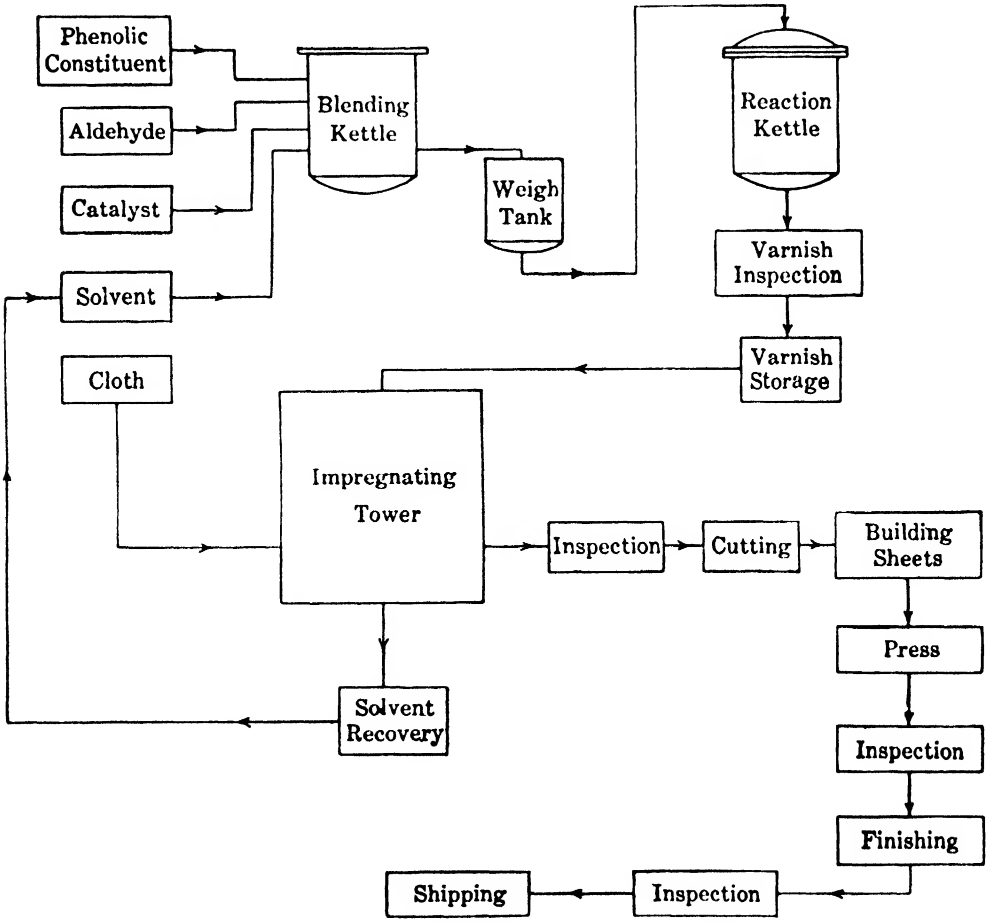

FIG. 15.24 — Flow diagram for phenolic laminates.

Two types of tubes are made, molded and rolled. In both cases the cloth or paper is rolled on a mandrel having the correct inside diameter, but the molded tube is pressed between the two halves of a split mold, while the rolled tube is placed in an oven and baked for several hours. Each of these types has certain advantages for different applications. The manufacture of rods is the same as the procedure for making tubes except that a small mandrel is used which is withdrawn before molding.

Another type of laminated plastic is "macerated molded." Cloth or paper impregnated with resin is cut into small pieces and molded to various simple shapes in much the same way that molding powder is handled, but finished pieces are produced which have much higher mechanical strength.

Other laminated plastics are those that may contain graphite for self-lubricating purposes and those that may contain varying amounts of plasticizer so that punching or machining is made somewhat easier. (See also phenol formaldehyde-laminate.)

APPLICATION OF PLASTICS TO FABRICS BY CALENDERING[4]

Plastic type materials for coating or impregnating cloth include: Dispersions of nitrocellulose, other cellulose derivatives, vinyl type polymers and copolymers, drying oil base varnishes, and fatty acid modified alkyds.

The methods of application involve brushing as in the case of airplane dopes, spreading with a doctor knife for various cellulose derivatives, rolling on a hot melt, and dipping through tanks. These materials are essentially fluid solutions of some basic material.

In one further type of fabric coating the machinery for application is a calender (such as is used in the rubber industry), consisting essentially of three hollow rollers held at the desired temperature. The plastic mass, heated or masticated to the proper condition on a two-roll mill, is placed in the nip between the upper and middle rolls where it forms a bank. These two rolls have a speed differential which applies a smearing action and a film is formed which is carried around the middle roll to the point at which it meets the lower roll.

From this point one may choose three different operations. The simplest removes the film by rolling it up, with or without a liner to prevent adhesion. This is known as calendering or filming. If a sheet of fabric is introduced between the middle roll holding the film and the bare lower roll, one obtains either of two effects. When the bottom roll runs slower than the middle roll, the film is mashed or frictioned into the interstices of the cloth and we obtain something approaching impregnation without solvent. If the speeds of the middle and lower rolls are equal, the pressure may be adjusted so that the film adheres to the cloth and releases from the middle roll. This is called skim coating and the film lies essentially on the surface of the cloth although enough studding in is obtained for proper adhesion. With this latter adjustment, one may coat paper as well as fabric.

This technology originated in the rubber industry and has been adapted to the application of many types of plastics. The operations are similar in all respects, except that for plastics higher temperatures are usually necessary and larger crowns may be needed for the upper roll. This crown or convex surface is necessary in all calenders for strain and may vary from a few thousandths for rubber up to eight or ten thousandths for some synthetics. The higher the viscosity of the plastic at the operating temperature, the greater must be the crown.

The basic reasons for employing the skim coating technique are to avoid the expense and hazard of solvents, to prevent excessive penetration, and to obtain a smooth surface which would otherwise be impossible unless the fabric were first carefully sized.

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[4] Prepared in co-operation with H. F. Wakefield.

Both thermosetting synthetics have been applied by means of the calender. The method is extensively used in coating paper with vinyl chloride-vinyl acetate copolymer. Considerable development work has been directed toward the calendering of cellulose nitrate and ethyl cellulose. Plasticized polyvinyl chloride and the vinyl copolymers are very successfully used in cloth coatings and in some cases it is being applied as a surface coat by the skim coating technique. The thermoplastic coatings are merely cooled after leaving the calender and the product is complete except the embossing which is a typical plastic phenomenon. When thermosetting resins are used, the coated cloth must be submitted to a baking operation which is comparable to the vulcanization of rubber although the baking cycle may be shorter.

Since 1930, flexible heat-hardening resins made from substituted phenols have been applied as surface coatings on textiles. Application by means of a solution was undesirable because excessive penetration decreased flexibility and limpness, and it was difficult or impossible to obtain a smooth surface free from nibs and protruding specks caused by the formation of resin beads around loose fibers. To avoid these difficulties, the skim coating technique was adopted. In comparison with rubber, the viscosity of the mass was higher, its cohesion was lower, it was short and tended to become shorter at the higher roll temperature, and of course, it would cure if it were held too long in the bank. The peculiarities of the phenolic resin served to draw attention to the basic factors necessary for skim coating. First, the filmed material must follow the middle roll, which is accomplished by the speed and temperature differentials between the two rolls. Second, the force of cohesion of the plastic film must be greater than the sum of its adhesion to the steel roll and to the cloth, and third, the adhesion to the cloth must be greater than the adhesion to steel. When these three conditions are met, any plastic material may be calendered if the calender is designed and powered to fit the consistency of the plastic. In the case of the phenolic resin mentioned, the first specification to be met was that the film be uniformly 0.002 in. thick across a 40-in. roll. To accomplish this, the upper roll was given the necessary crown. The second specification was that the film be pressed uniformly into a cloth about 0.010 in. in thickness. To do this, the bottom roll was given a concave cut so that it conformed to the distortion of the middle roll. Minor variations in consistency may be compensated for by varying the temperature of the rolls. The limiting factors are the large increase in viscosity at lower temperatures, while at high temperatures the cohesion is decreased, thermosetting resins becoming short and thermoplastic resins becoming fluid.

The thermosetting coatings have found application in part because they do not have such a marked tendency to deform or become tacky at elevated temperatures. Thus, asbestos cloth coated with such a resin is used as a cover on a laundry roll where it shows great resistance to the combined action of heat and steam. The absence of plasticizer or driers makes it suitable as a waterproof backing for rubber-base adhesive plaster. The coated cloth shows a very long shelf life, there being no changes due to slow oxidation or loss of plasticizer.

In addition to the resins which have been mentioned previously, there are others which may be expected to receive attention in the future. Among these would be the thermoplastic resins such as polyvinylidene chloride, the polyamides, certain polyesters and alkyds which may be heat-convertible, or such thermosetting resins as those derived from cashew nut shell. Development work has been carried out on some of these materials and their application has been described in the patent and technical literature. The process is particularly adapted to those coatings which require no baking, which harden by cooling, or which react by heat without oxidation. Thick layers may be deposited in this manner in a single operation with no trouble from trapped solvent or surface skinning. Further developments in this field may reasonably be expected as the synthetics are developed with properties to fit this basically simple operation.

Molding Thermoplastics[5]

INJECTION MOLDING

Injection molding involves, essentially, heating a molding material in a cylinder to a plastic state, then forcing it by means of a plunger through an orifice into cavities of a cold (or relatively cool) mold. The cavities are connected with the nozzle of the heating cylinder by channels through which the plastic material flows.

Advantages. Fast production of thermoplastics is one advantage of injection molding. In compression molding, the mold is heated with the material in it, closed when the material has become sufficiently plastic to flow, and then chilled. Obviously, it is necessary to heat and cool a sizeable mass of metal as well as the material. In the injection-molding process, it is not necessary to alternately heat and cool the mold; the hot plastic is injected into a mold which is kept at a constant temperature, usually cooled by the circulation of water. Injection molding presses can operate at a rate of four to six cycles per minute, compared with an average cycle of about six minutes for compression molding. A two-cavity injection mold operating at four cycles per minute would produce forty-eight pieces in six minutes. To attain the same output by the compression method, a forty-eight-cavity mold would be required, and the cost of the compression mold would be considerably greater.

Injection molds, being smaller, are more easily handled, reducing " set-up " time and, of course, storage space.

Injection permits the molding of articles which are impractical or impossible to make by the compression method. For instance, in making a long, thin-walled tube of small diameter by compression molding, the force which forms the tube core might easily flex under pressure of the granular material. Such an article can be very satisfactorily made by injection.

Metal cores can be covered by injection molding — practically an impossibility by compression molding. It is unnecessary that the core be anything more than the general shape of the finished plastics-covered piece. No expensive finishing of the insert is necessary, as in preparation of a metal die casting for plating. Covering a metal core combines the toughness and beauty of plastics with the rigidity of metal.

Another advantage of injection molding is in the re-use of scrap. Scrap, if kept clean, can be granulated and fed again into the hopper, affording 100 per cent utility of the plastics. Scrap from injection-molding operations is much more easily kept clean than overflow scrap from compression molding.

It should be noted that Tenite I and Tenite II cannot be mixed in molding. Since the

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[5] Based on a study by Tennessee Eastman Corporation covering its own materials, Tenite I and Tenite II.

two plastics are incompatible, the scrap from each must be kept separate in order that it may be molded again.

Distinctive variegated color effects are obtainable in injection by mixing plain color granulations in different colors and degrees of flow.

The finishing operations on injection-molded pieces are usually simpler than on pieces molded by compression. There is no flash to be trimmed from the parting line of the mold, trimming being confined to cutting off the sprue, which ordinarily is attached to the piece at but one point.

Injection-molding Machines. Various makes and sizes of injection-molding machines, admirably adapted to use with the acetates, are available. All are operated automatically or semi-automatically. An injection-molding unit consists essentially of a hopper, an injection cylinder, and a mold. From the hopper, material is fed in granular form into the injection cylinder, heated to a plastic condition, and forced under high pressure from a restricted nozzle through the sprue and runners into the cavities. (See Fig. 15.25.)

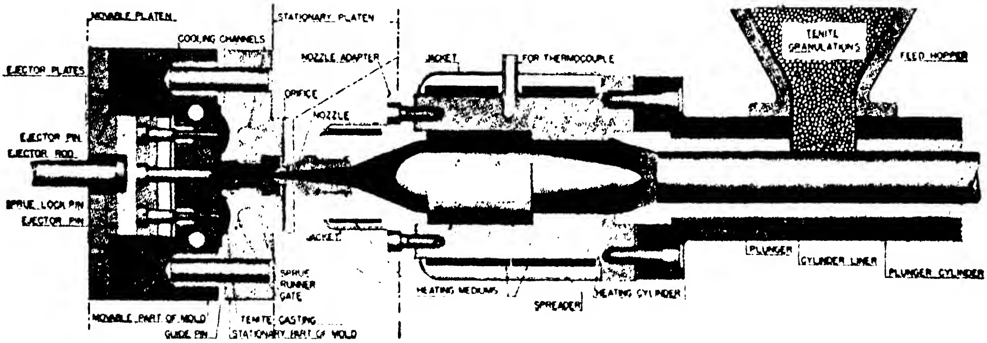


Fig. 15.25 — Section view illustrating general method of injection molding.

One control moves a plunger in the injection cylinder; a second closes and opens the mold. Ejection of the molded piece is usually automatic. The only connection, other than electric, is for carrying cooling water to the channels of the mold. In some machines the water is recirculated.

The injection cylinder is usually heated by a series of electric coils thermostatically controlled, or by the circulation of hot oil or other heat-transferring liquid. Steam at ordinary pressures does not give sufficient heat. Various sizes of orifice nozzles are supplied for the injection cylinder, since it is frequently desirable to use orifices proportional in size to that of the castings.

Injection-molding Temperature. In injection molding, the material must be forced into the mold at such a speed that the mold is completely filled before the plastic starts to set through contact with the cooler mold. Speed and high pressure are necessary also to produce a lustrous finish on the molded article. A partial chilling of the surface before the cavities are filled will cause flow marks and strains, which make a piece more likely to warp under varied atmospheric conditions.

The temperature of material in the injection cylinder must be considerably higher than that of material in a compression mold, because the material chills rapidly in its travel through the runners and into the mold. At the instant the mold is filled, the temperature of the plastic must be at least as high as corresponding material in a compression mold at closing. Further, the temperature of the oil or the electric heating units in an injection cylinder is always much higher than that of the material which, in traveling through the cylinder in operation, never reaches the temperature of the heating medium.

The temperature of the injection cylinder itself, or of the heating medium, will usually vary between 350° and 420° F. depending on the formula, flow, and size of mold, although the limit of temperature of the material in the cylinder is about 385° F.

Approximate cylinder temperatures for the various flows of injection-type Tenite under average conditions are as follows:

Flow	*Injection-Cylinder Temperature, °F.*	*Mold Temperature, °F.*
H5	480	200
H4	470	185
H3	460	170
H2	450	
H	440	
MH	430	
M	420	
MS	410	
S	400	
S2	390	
S3	380	
S4	370	
S5	360	
S6	350	
S7	340	
S8	330	

Free-flowing formulas for many thermoplastics are available which, though of soft flow, " set up " hard when injected in the usual manner into a cold mold; nevertheless, it is sometimes found advantageous to use harder flows and inject into a warm or hot mold, in order to secure greater heat resistance in the molded product. In molding the harder materials, the heating cylinder must be at a higher temperature; the mold is also maintained at a higher temperature, since setting of the material is a matter of temperature differential.

These temperatures will vary with the section thickness and size of the mold.

Injection molds heated electrically afford the most satisfactory control of temperature. If the heat loss is substantial, molds can be heated by steam under very low pressure to the temperatures shown above, or steam can be merely bled through the mold. If the mold is heated by steam, the mold ports must be at the lowest point in order to permit draining of condensate.

The proper temperature conditions for each job can readily be determined by trial.

With proper adjustment of temperature and pressure, the harder materials can be injected into a hot mold on the same cycle as the more common flows into a cold mold. If the mold is insufficiently heated, there will be difficulty filling it or the pieces will be lacking in strength; if too hot, the molded pieces will stick and may show shrinkage or distortion. The proper temperature range is determined by these two conditions.

If material, insufficiently heated in the cylinder, is injected by the use of excessive pressure, the castings will have surface flow marks and considerably lowered resistance to impact. The lack of strength is due to strains set up through partial chilling before the mold has filled.

Cellulose ester plastics, like most molding materials, have high specific heat and also are poor conductors of heat. In injection molding, the material is brought to plastic condition by conduction of heat from the side walls of the cylinder and from the variously termed torpedo, pineapple, billet, breaker, or core in the middle of the cylinder. Other things being equal, heat transmitted to the material will vary directly as the contact area of heated metal, and inversely as the thickness of the plastics section exposed. If there were no center core, the smaller the diameter of the cylinder, the more effective would be the heating. Thus, in such a cylinder it would be logical to lengthen the injection cylinder rather than to increase the diameter to secure additional capacity. Some cores are themselves heated by conduction from their points of contact with the walls of the injection cylinder; others are heated by induction.

When a relatively large amount of plastic is being injected into a mold at each cycle, more heat is absorbed by the material, and the temperature of the injection cylinder can therefore be higher. Since cellulose ester plastics have such high specific heat, to secure maximum pounds per hour of material heated to plastic condition, it is necessary to keep the cylinder and core as hot as possible without risk of scorching the plastic. To accomplish this, the injection cylinder is ordinarily kept at a much higher temperature than the plastic material will stand unless it is steadily moving through the cylinder and out through the orifice. Cellulose ester plastics will char at such temperatures as are ordinarily used in injection molding if submitted to that temperature too long. To prevent charring of material left in the injection cylinder when the machine is stopped, it is desirable to turn off the heat and continue injecting the material until it has become sufficiently cool so that it makes incomplete castings, failing to fill the cavity, or even until the material can no longer be forced out of the injection-cylinder nozzle.

Charring is most often caused by too high a temperature in the injection cylinder, or exposure to the heat required for injection for too long a time. The heat generated by the compression of trapped air may leave a charred spot on an injection-molded piece, usually at the point farthest from the gate. (See Venting, page 597.)

The heat resistance of cellulose ester plastics themselves is an altogether different matter from the heat resistance of particular colors. The former has to do with the stability of the cellulose ester and plasticizers, the latter with the stability of the coloring agents used in producing any particular shade.

The most stable coloring agents available, suitable for use with cellulose ester molding materials, should be employed. For achieving any certain shade, the coloring agents may represent less stability than those available for achieving other shades. No coloring agents are used which have not been tested to withstand the heat required for injection over the normal period of time the material remains in the injection cylinder.

Tests on clear transparent acetate made at 420° F. for 10 min. resulted in no appreciable change in color. Similar tests at 440° F. for the same length of time produced a slight darkening. On the other hand, 20 min. were required to cause any darkening at 400° F. These figures give some indication of heat resistance as it relates to time and temperature.

Injection-molding Pressure. Hydraulic pressures used in injection will usually vary from 7 to 10 tons per square inch on the material. The pressure required is largely dependent on formula, flow, and size of cavity, as well as the cross-sectional area of the cylinder orifice, sprue, runners, and gates. All injection machines have provision for variable pressure.

Choice of Flow of Material. *Medium-soft* flow material is used most frequently in injection molding, and is the most logical one with which to make initial trial.

For use as fillers for injection molding, compression-type materials in flows harder than M are usually supplied. By a " filler " is meant a small amount of a color to be used with a very much larger proportion of another color, to obtain a variegated or mixed color effect. A hard filler prevents too great a blending of contrasting shades in the course of injection. If, in injection, an S flow is used as the base or predominating color, contrast will be secured by H or H3 flow in the filler, while if the base or predominating component is S8 another relatively soft flow such as S2 in the filler will gain the desired effect.

Effect of Moisture on Flow in Injection Molding. Depending somewhat on flow, butyrates absorb about the same amount of moisture as the nitrates do. This is about half as much as is absorbed by cellulose acetate plastic. However, it is true of all materials that the greater the moisture content the greater the flow. Cellulose ester plastics will absorb moisture from the atmosphere. The amount of moisture which they will absorb is a function of the relative humidity and the temperature. At 70 per cent relative humidity, acetates in a representative formula subjected to 110° F. will absorb about twice as much moisture as when subjected to 40° F.

Relative humidity is about the same outdoors in most sections of the United States in winter as in summer, but when cold air from the outdoors is heated to room temperature the humidity markedly drops. It is to such a condition that a molding material is ordinarily subjected in storage and use in the winter months. Thus, from a practical standpoint, a cellulose ester molding composition will flow more freely in summer than in winter under usual operating conditions.

It might be assumed from the foregoing that the presence of moisture is desirable since it increases flow. Such is not the case. Excessive moisture will sometimes cause minute surface bubbles, frequently termed " mica " by the trade. Such minute surface blisters can be eliminated by longer sustained pressure in injection molding or by enlarging the gate and runners. The latter accomplishes the same purpose as the former. The thicker the sprue, runners, and gates, the longer the material takes to solidify and the longer the pressure is sustained on the moldings to drive out the gas which occasions the surface bubbles. The gas is due to moisture vapor or moisture vapor in combination with the plasticizer.

Some molders find it desirable to dry the powder just before using it so as to keep flow uniform as far as possible regardless of moisture present in the air. It is also possible to compensate for flow variance by changing temperature and pressure.

To secure the most odorless product, particularly in the case of the butyrates, it is essential that the granular material be dried. The material should be taken directly from the dryer to the molding machine, since it will, particularly under warm and humid conditions, regain moisture fairly rapidly.

Cabinets for drying powders are easily constructed of galvanized iron with angle irons which support aluminum trays, about 2 in. deep and spaced vertically 4 to 6 in. apart. To permit adequate circulation of air, there should be also some space between the edges of the pans and the walls of the cabinet. Steampipes or electrical heating elements in the bottom of the cabinet warm the air which is circulated by a small fan. Vents are provided at the top and bottom. Average drying is accomplished in 3 to 6 hr. at temperatures between 110° and 140° F.

Choice of Form of Material. For injection molding, the powder is often used in the form of granulation, in 5/16 in., 3/16 in., or sometimes ⅛ in. particle size. To produce variegated effects by injection molding, granulations are supplied as component colors shipped in separate containers, to be mixed by the molder in proper proportions before being placed in the hopper of the machine. If a variegated effect is submitted as a sample, or described, samples of plain colors will be prepared and proportions recommended in which they should be mixed to achieve the desired variegation or mixed color. Only a portion of the sample should first be mixed, so that the rest is available for further trials with altered proportions of the components, should that appear desirable after examination of the configuration obtained in the first moldings. Powder in the form of separate components is much more flexible in the molder's hands than a variegated material supplied as such. Variegated configurations also depend upon temperature, the size of the molded piece, and the cross section of the cylinder orifice, sprue, runners, and gates.

As previously stated, the components used to produce variegations may be of different degrees of flow as well as of different colors. Wavy pearl effects are commonly produced with components of different hardness but of the same color.

COMPRESSION MOLDING

In the compressing molding process, the powder in granular or blank form is placed in the cavities of a mold, and the mold and its contents are heated to the required temperature, as the mold closes.

When the mold is closed, cold water is turned into its channels until the temperature has dropped to the ejection point. The mold is then opened, and the castings are removed. Since no chemical action takes place when acetate is heated, there is no advantage in keeping the press or material hot any longer than is required for closing the mold. Sustained heat will frequently cause " heat marks " which have the appearance of surface air locks. The speed of the molding operation depends upon the rapidity with which the mold can be heated and cooled.

Except in the rare instance where a positive-type mold is used, the mold charge should include a small amount of overflow, to provide the necessary back pressure. An excessive charge is wasteful, slows the time cycle, and sometimes causes heat marks because of the higher temperature or prolonged heating required to flow out the excess material.

Advantages. The compression method permits the molding of articles too large for injection, or of such thickness that excessive shrinkage might be encountered by the latter method.

By compression molding variegated edge-grain blanks, more sharply defined striations can be secured than by injection molding. Edge-grain blanks are discussed on page 587 under Choice of Form of Material.

Compression Molding Presses. Hydraulic presses are recommended for use with acetate. A hydraulic press applies an even pressure and closes as the material reaches plastic condition. The operator of a mechanical press must judge whether or not the stock is in proper plastic condition and then close the mold.

Semi-automatic presses are obtainable with timing devices which operate the valves controlling hydraulic pressure, steam, and water. The operator merely loads the mold and throws a lever which starts the cycle. This method of operation minimizes rejects by precise timing and saves labor. An operator can take care of more than one semi-automatic press.

The most modern mechanical presses are provided with clutches which permit partial closing or " creeping up " on the material. Nevertheless, this requires an operator's attention during the entire closing operation. With hydraulic presses the valve is thrown, after which the operator is free to perform other work, such as attending to another mold or inspecting the moldings from the previous cycle until the press has closed.

Compression Molding Temperature. In calculating appropriate steam pressures to supply the heat required, allowance must be made for the heating efficiency of the press or mold. Hand molds, occasionally used, which secure their heat by conduction from the press platens, will require a much higher steam pressure or a longer time to heat than a channeled mold where the steam passes through the mold itself.

Approximate average mold temperatures for the various flows of compression-type acetate are as follows:

Flow	*Compression-Mold Temperature, °F.*
H6	358
H5	350
H4	342
H3	335
H2	328
H	322
MH	315
M	309
MS	303
S	297
S2	291
S3	286
S4	281
S5	276

The most desirable molding temperature must be determined by experiment with the given die. Temperature is ordinarily controlled indirectly by the establishment of a definite time cycle for the particular molding job. The steam pressure regularly used

(150 lb.) would overheat the mold and cause heat marks in the molded piece were the mold permitted to attain its maximum temperature. In other words, to have the mold heat up quickly and give a good production time cycle, it is necessary to catch it on the rise.

Speed of operation can be increased by preheating the material in blank form on a steam table. Excessive or unnecessarily prolonged heating should be avoided. The former will cause blisters and the latter decrease the flow through some vaporization of the plasticizer.

Steam-table heating is preferable to oven heating of plastics blanks, because it provides direct contact with the heating medium and thus quickens softening. It is difficult to maintain an oven at the necessary temperature when it relies on the conduction of heat by air, since the door is opened and closed frequently in charging and withdrawing stock. Electric heating is often spotty. A very efficient preheating table is one heated by steam from a reservoir of water, which is in turn heated underneath by electric coils. This combines electric thermostatic control with uniform heating by steam.

The blanks should be protected from dirt and prevented from sticking to the steam table during preheating by layers of cloth. One or more blocks of wood with handles and covered with a lint-free cloth are placed on top of the blanks. Sometimes it is necessary to turn a thick blank over to get it thoroughly heated.

Compression Molding Pressure. A pressure of 2000 lb. per square inch is sufficient for compression molding, but production is usually increased by using a pressure of about 3000 lb., and the higher pressure is to be recommended; as far as acetates are concerned, still higher pressure may be used.

Powder should be thoroughly heated in the mold before the final pressure is applied. This is usually accomplished by closing a press with a low-pressure hydraulic supply and then following with hydraulic high pressure. Often an automatic high pressure is employed, so that when the press has traveled under low pressure to a certain position, say, within ⅛ in. of the closed position, the high pressure automatically goes on, thus eliminating the manual movement of an extra valve. City water is often used for low pressure.

Choice of Flow of Material. For all ordinary compression-type applications, *medium-soft* and *soft* flows of plastic are most suitable. *Medium* flow is sometimes used, *medium-hard* and *hard* but rarely.

Effect of Moisture. Powder stock should be kept dry. A satisfactory piece cannot be molded from stock which is actually wet; the strength of the finished piece is impaired by the presence of moisture even though there are no visible defects. Frequently, compressed air lines used for blowing out the mold cavities contain water from condensation. Air lines should have a water separator.

Choice of Form of Material. Compression molds are charged either with blanks cut from molding sheets, or with granular material. Granulation can be measured either by weight or volume. It is possible to get a more accurate charge by weight than by volume when using granulation, because the method of filling a volume measure will make the density vary slightly from one time to the next. The slightest jar acts to tamp the granulation and thus give a greater weight for the same apparent bulk. Measurement by volume is obviously the less expensive method, particularly in the case of a large multiple-cavity mold, where a loading tray is used and all cavities are filled at once by a slide-dumping device. The flash-type mold is adapted to loading by volume; only for a mold of positive or confined type, and occasionally for a semi-positive type mold, is it necessary to weigh the mold charge.

In compression molding, granulation is most suitable for a mold having a relatively narrow cross section and a deep cavity. Blanks from molding sheets are best suited to thin, molded articles where there is no great depth of cavity and where the granulation would have a tendency to spill out. Where a number of different pieces are being molded in the same color, it is necessary to maintain but one stock of plastic in granular form, while in the case of blanks, material must be available in various sizes and weights appropriate to the pieces being molded.

If the mold has projecting pins to form holes in the molded piece, it is better to use granulation. Blanks frequently bend or break such pins, even under low pressure, unless the mold is closed very slowly and carefully as the material becomes heated through.

Acetate granulation is rarely preformed; it is generally more advantageous to use blanks cut from molding sheets. A blank is susceptible to preheating, and when it is placed in a hot mold, the mold can be closed immediately. The total time cycle then becomes largely a question of the speed with which the mold can be chilled. In charging a multi-cavity mold with small blanks, however, more time is frequently saved through the use of a loading tray than otherwise could be saved by preheating. Blanks preheated in a loading tray will usually stick to the tray to such an extent as to make such procedure impractical, and small pieces heat through fairly rapidly after they are in the cavity.

Molding sheets are as dense as the finished molded piece, while the bulk of granulation relative to the finished molded piece is approximately 2½ to 1. The use of blanks, therefore, frequently reduces the size of the mold required and thus not only the cost of the mold, but also the time cycle, since there is less metal to be alternately heated and chilled.

Beautifully grained variegated effects are obtainable through the use of blanks cut from acetate molding sheets. Variegated colors may be obtained by mixing granulations of contrasting shades, but they lack the distinctive striated effects obtained with blanks and instead show more of a " salt-and-pepper " effect.

The striated effect on the edge of a variegated molded sheet differs from that on the top and bottom and is usually more attractive. For this reason, blanks are often cut from a molding sheet in such a way that when placed in the mold cavity this striated edge becomes the top or appearance surface of the molded piece. To assure the appearance of the grain on the desired face of the blank, it is suggested that in ordering such blanks the thickness of the sheet from which they are to be cut be given as the last dimension, and specified in decimals. Such edge-grain blanks can be supplied in the maximum length in which the plastics sheets are made; but the width of the blank is limited by the maximum thickness in which sheets are made, usually not over 1 in.

Users of sheet blanks almost invariably find it advantageous to purchase them already cut to size rather than to do the cutting themselves from sheets. Particularly is this true when the molding sheet is of a heavy gauge, since it is difficult to heat such heavy stock sufficiently to get a smooth shear cut by use of the steam-table facilities ordinarily available to the molding trade. This cutting is done at an additional charge which depends on the size of the pieces.

Frequently, it is desirable to specify only two dimensions of the blanks (slightly less than cross-sectional dimensions of mold cavity), leaving the third dimension to be determined by the minimum weight, which is the controlling consideration as long as the blanks fit the mold cavity.

Plastics blanks, particularly small ones, can be more accurately measured in grams and fractions of grams than by dimension specifications alone. Pieces of appropriate thickness are supplied from which blanks can be cut to determine the most suitable dimensions and weight for molding an article. Or, if sample blanks are desired cut to finished size for trial, dimensions should be given for blanks which fit the cavity, and mention made of the minimum weight.

The minimum weight of a cavity charge, granulation or a blank, is approximately 10 per cent more than the weight of material in the finished molded piece. The percentage of flash is subject to variation, depending on the type of mold. A flash-type mold will require more than 10 per cent flash to give the necessary back pressure. The amount of flash in the case of a semi-positive mold will depend upon the room provided for the escape of the overflow.

Being thermoplastic, acetate overflow and trim scrap can be remolded after being granulated, if kept clean. Defective molded pieces can also frequently be salvaged by the simple process of remolding with the addition of a small amount of new granular material.

Length and width tolerance of plus or minus 1/32 in. is required in cutting blanks from acetate molding sheets, a thickness tolerance of plus or minus 0.0125 in. and a weight tolerance of plus or minus 5 per cent (or 10 per cent all plus). Thus if a minimum weight, 10 per cent in excess of the weight of the finished molded piece, is specified, the weight of blanks will vary between 10 and 20 per cent more than the weight of the finished piece. In calculating costs, it would thus be logical to use in such a case the mean weight — 15 per cent in excess of the weight of the finished piece.

While sheets or blanks for molding are supplied in a thickness of 1 in., it is available in sample form up to 3 in. thick for the machining of models which would in production be molded. Where greater thickness of stock would be required, it is usually possible to make a model by machining it in parts and cementing the parts together.

THERMOPLASTIC MOLD DESIGN

For the purpose of ultimate economy, it is advisable first to make a machined model of the piece which is to be molded. This is true even though an experimental single-cavity mold is made in advance of a production mold. Plastic is supplied in blocks and heavy sheets for making samples by machining. Making such a model provides the opportunity to visualize the molded job and often suggests changes which will make the piece not only more suitable mechanically but also more artistic. Frequently, it is desirable to make the model from clear material. Rarely is there any application for plastics where appearance should not have at least some consideration.

The possible use of inserts should always be considered. It is usually less costly and structurally more satisfactory to have threaded inserts molded in the original piece than subsequently to drill and tap it. Inserts, by giving a greater bearing surface, operate to reduce cold flow in an assembly where some strain necessarily exists. On the other hand, shanks with knurled heads are sometimes assembled to knobs merely by pressing them into the molded holes.

The gate to an injection-molded piece should always be on a nonappearance surface if possible. Finishing cost is thus minimized.

Large, flat areas should have reinforcing ribs. In the case of injection-molded pieces particularly, such ribs frequently act, so to speak, as runners within the molded piece which help the cavity to fill more quickly and more uniformly.

Oblique holes or any holes not in line of draft mean cores which must be pulled. Such constructions invariably entail higher mold costs. Since most thermoplastics are readily machined, such holes are often more economically drilled than molded.

To facilitate ejection, the mold cavity should have the maximum amount of draft which considerations of function and appearance permit. Sometimes an undercut is intentionally molded on a piece to ensure sticking in the cavity or on the mold force. Such an undercut is sheared off in the ejection operation.

Ejector pins are to be preferred to a stripper plate. The choice is determined largely by what is to be the appearance surface of the article in use. Ejector-pin marks on an appearance surface are of course undesirable. A stripper plate is necessarily loose around the forces, and to keep removing material from between the stripper and force plates is a nuisance. If material gets between, the mold will not close evenly.

Sharp interior corners set up strains. Substantial radii and fillets are highly desirable.

The product design should usually be such that letters on molded pieces are in relief rather than intaglio. The former merely means that the mold must be engraved, while the latter ordinarily involves planing away a surface of the mold to leave the raised letters. Intaglio lettering is sometimes satisfactorily achieved without planing away a substantial surface area, by having the raised letters on a piece formed by impressions in a small section of the mold which also serves as a means of ejection.

Application of the fundamental principles of structural strength is a pertinent consideration in the designing of parts to be molded from any plastic.

Brass inserts may be oxidized by baking, so that they will not show conspicuously through transparent molded pieces.

Exterior threads are readily formed on most molded pieces. Interior threads in compression molds usually involve a separate mold part which is unscrewed after the piece is removed from the cavity. Interior threads on an injection-molded piece involve a core operated by a rack and pinion or a motor-driven unscrewing device. It is frequently more economical to tap an interior thread than to mold it.

An exterior thread is less satisfactorily molded by compression than by injection because of the flash which must necessarily be cleaned from threads at the parting line of a compression-molded piece. To the extent of the thickness of the flash, the threaded section is out of round.

It is best to have the cavities as well as the forces hardened, particularly in compression molding. However, for molding a comparatively small number of pieces, this procedure is not absolutely essential.

A new mold, no matter how well polished, has microscopic projections which slowly wear off. Thus, the longer a mold is used, the brighter the polish becomes and the less tendency there is for molded pieces to stick.

In other words, a mold usually has to be "broken in" before it runs perfectly smoothly. This applies in the case of all molded plastics.

Chromium plating of a mold is desirable only for the purpose of maintaining a permanent polish. Furthermore, it is sometimes impossible to plate with sufficient uniformity in remote recesses of a mold so that no subsequent peeling will occur. A thickness of 0.002 in. of chrome plating flashed directly on the steel is recommended.

The usual type of hardened steel mold should be greased before storing to prevent pitting by rust or corrosion.

Shrinkage of acetate subsequent to molding, as distinct from mold shrinkage, whether by compression or injection, is about 0.003 in. per inch at ordinary temperature, depending somewhat on the formula and flow of the material and the shape and thickness of the molded part. About two-thirds of this shrinkage takes place in the first 48 hr. after the piece has been removed from the mold.

Shrinkage subsequent to molding will be increased by submission to greater than ordinary atmospheric temperatures. For instance, at 110° F. for 50 days a typical formula and flow of acetate will show shrinkage depending on the thickness as indicated below. Loss of weight and shrinkage approach equilibrium at the end of 50 days.

Thickness in Inches	*Loss in Weight Percentage*	*Shrinkage Inch per Inch*
0.1	1.8	0.008
0.2	1.2	0.005
0.3	0.9	0.004
0.4	0.7	0.003
0.5	0.5	0.002

Mold shrinkage is discussed separately under the sections Injection Mold Design (page 591) and Compression Mold Design (page 599).

Hobbing and Machining of Molds. Cavities of a multiple-impression mold, where each cavity is located in a separate insert fitted in a mold block, can be either hobbed or machined.

Hobbing permits the exact duplication of cavities at less expense than machining. Some cavities cannot be satisfactorily hobbed because of insufficient means for the escape of the metal as it is displaced. An example of this would be the cavities of a comb mold. Where multiple cavities are located in one piece of steel they all must be machined as it is not practical to hob more than one cavity in any one block of steel. The hobbing of the second cavity would distort the first cavity.

Cavities that are not of intricate design can be machined by ordinary methods. When a number of like cavities are to be machined, the use of a duplicating machine working from a master model is the most economical method.

For hobbing cavities, a hardened steel master is employed. The block of steel to be hobbed is located in a hardened chase or heavy ring of steel. This assembly and the master hob are then placed between the platens of a hobbing press, and the closing of the platens under heavy pressure forces the master hob slowly into the mild machine steel. As the steel block being hobbed is confined in the chase, the steel displaced by the master hob flows upward around the hob. This upper face is later machined to give the desired depth to the cavity. In some cases the block of machine steel, prior to being hobbed, is machined to approximately the shape and size of the finished cavity. This is done to reduce the amount of metal that must be displaced by the master hob. This method is used when a cavity is narrow and deep or where the metal must flow quite a distance.

Whether cavities are hobbed or machined they should, for best results, be subsequently hardened. A mild machine steel is used when cavities are hobbed and this grade of steel is ordinarily pack-hardened. For machined cavities also, a mild machine steel is sometimes used and then pack-hardened, or, more usually, an annealed tool steel is used which is subsequently heat treated and hardened either by quenching in oil or water, or by air cooling.

Polishing disks and circular cup-shaped brushes, driven by high-speed electric or air motors, are used for polishing molds. Kerosene and fine emery powder are first employed to gain a smooth, dull surface. A polishing compound is then used to secure the final lustrous finish.

Parts of cavities which cannot be treated in this way must be polished by hand. This is done ordinarily with a cherrywood stick, again using fine emery powder and kerosene first and subsequently a polishing compound.

Information Required for Designing Molds. Suggestions for designing molds are furnished by powder manufacturers. To make practical recommendations in the form of drawings or otherwise, for either injection or compression molds, it is desirable that the following information be supplied:

1. Samples or drawings of the pieces to be molded, preferably both.
2. Estimate of production required.
3. Possible alteration of design to facilitate molding, obtain a shorter cycle, or effect economy of material.
4. Preferred means of ejection — knockout pins or stripper plate.
5. Make of machine, if the piece is to be injected.
6. Platen and hydraulic cylinder area of the press, as well as line pressure if the piece is to be compression molded.
7. Preferred means of assembly to the press platens — cap screws, clamps, or bolts to T slots.

INJECTION MOLD DESIGN

An injection mold consists of two major parts. The stationary part of the mold is fastened to the stationary platen of the machine and in operation directly contacts the nozzle in the end of the injection cylinder. The movable part of the mold is fastened to the movable platen of the machine and ordinarily houses the ejector mechanism. Each of these parts has a face, or land, contacting one another when the mold is closed. These lands are ground and lapped to fit in order to prevent flash.

A balanced mold — one with the cavities arranged symmetrically with respect to the sprue, giving an even distribution of flow — is the best design. Should the shape or size of the pieces to be molded be such that a balanced mold is not feasible, the land should be symmetrical to minimize strain on the machine.

Two or more guide pins of adequate size must be provided for lining up the mold, especially when locating the mold in the machine. Guide pins should, if possible, be press-fitted in the stationary part of the mold, with hardened bushings located in the movable part of the mold. This arrangement gives better clearance for the ejection of the molded pieces. Provision must be made for fastening the mold parts to the platens of the machine. The method of attaching and the location of mold-carrier bolts vary with different makes of injection molding machines.

The cavities of an injection mold can be machined in the mold proper, or each cavity can be located in a hardened steel insert which is fitted in the mold blocks. Such inserts can be replaced easily and with minimum expense if the cavity is accidentally marred, but they make for a larger mold. Cavities forming the outside of the molded piece are best located in the stationary part of the mold. Cores forming the inside should be located in the movable part of the mold. This is because molded pieces tend to shrink clear of a cavity and to cling to a core. Having the cores in the movable part of the mold ensures the retention of the molded pieces with that part until the ejector mechanism operates.

The mold blocks are made of wrought steel. Channels for cooling are generally drilled holes, and a proper placement of them to secure uniform cooling of the cavities is desirable. Cooling channels should be in both parts of the mold but not too close to the mold entrance, since the material should remain plastic there longest.

Area of Mold. The projected area of cavities, runners, and gates of an injection mold must be within that which the machine can hold closed under the injection pressure. Certain advantages are secured by restricted runners and gates, and others by relatively large ones. The smaller the orifice, sprue, runners, and gates, the less the scrap, the easier the trimming operation, and the better the polish, provided the channels are sufficiently large to permit filling of the mold before the material starts to set through chilling. The larger these channels, the less are the mold shrinkage and any tendency toward flow marks. It is only by nice balancing of the various factors involved that the best construction can be determined for any special application. Theoretically, the projected area of the sprue, runners, and cavities alone, and not including the land area, is that which must be held closed against the force of injection. Nevertheless, it is desirable to make the lands as narrow as possible. The narrower the land, the easier it is to secure a perfect lapped fit. Where the lands are wide or comprise the entire area of the mold not covered by the cavities, it frequently happens that material will find its way between the surfaces. When this happens, it in effect increases the cavity area, and thus there is an accelerated tendency for the mold to open.

Pressure. If 7 tons per sq. in. pressure were used in the injection cylinder and transferred to, let us say, 20 sq. in. of mold cavity area, the pressure tending to open such a mold would be 140 tons, were the mold filled with oil or water. However a thermoplastic material, such as acetate, sets up its own resistance, through chilling, as it goes into the mold. Hence the pressure tending to open the mold is usually somewhat less than half the pressure which would be transmitted by a liquid. The pressure will vary considerably with the section thickness. Other factors being equal, the thicker the section of the molded piece, the greater the pressure required to hold the mold closed.

Capacity. Another requirement is that the weight of the molded piece or pieces be within the capacity of the machine for supplying plastic material per shot, and for continuously supplying material heated to the point of plasticity at the maximum rate of molding otherwise possible. There is no object in building, for example, a four-impression mold if it is necessary to wait half the cycle for the material to heat. A two-impression mold operated twice as often would give the same production with less mold cost.

Sprue. The sprue hole (or mold entrance) is a tapered, polished channel through the stationary part of the mold. It is directly in line with the injection-cylinder-nozzle orifice. The small end of the taper is toward the nozzle and is slightly greater in diameter than the orifice to facilitate pulling the sprue. The large end of the sprue hole feeds the runners. The sprue should be centrally located in a hardened steel bushing press-fitted into the stationary part of the mold and having a shoulder to prevent the bushing from bearing on the movable part of the mold. This bushing also provides a seat, usually cup-shaped, for the nozzle of the injection cylinder.

In a single-cavity mold, the sprue usually leads directly to the cavity, and there is no runner. The same is true of a multiple-cavity mold fed from an injection-cylinder nozzle having a corresponding number of orifices.

Runners. The runners are channels leading from the sprue to the individual cavities. The runners should, in most cases, be in the ejector half of the mold. This is to increase the tendency for molded pieces to remain in that half when the mold is opened. They should be polished, and as short and direct as practical. This fact must be given consideration in locating the cavities. Separate runners to each cavity are preferable, but when this is inexpedient and branch runners are necessary, the cross-sectional area of the main runner should equal or exceed the sum of the cross-sectional areas of the branches.

The friction between metal and plastic in its soft stage is high. In an injection cylinder without a core, the material at the center will flow faster than that at the sides, in spite of the fact that the material in direct contact with the hot walls is more plastic. From this it may be seen how desirable it is to have as little surface friction as possible in the entrance and runners of a mold. Therefore, it follows that the best shaped ones are those with the least friction surface — that is, round. Reduced injection pressure permits filling dies of greater cavity area without forcing the mold open.

In nearly all injection molds there is a small depression where the mold entrance meets the runners. This depression fills first, taking any little relatively cool piece of plastic which may first come through the orifice. This prevents a smudge or flow mark in the molded piece which might otherwise be caused by the leading cold bit. Another purpose of this arrangement is to facilitate the flow of the material through greater clearance at this 90-degree turn.

Gating. Successful injection molding is largely a function of proper mold gating. The gate is the restricted portion of the runner at the point where it joins the cavity. The molded piece is separated from the sprue scrap more readily if the gate is shallow. No definite rule can be given for the depth of a gate, as the shape, size, thickness, and details of the molded piece each have an influence in determining the size of a gate. The pressure on the material, the temperature of the material, and the temperature of the mold are factors to be considered.

A good practice is to start with a gate approximately 0.025 in. in depth and then, with varying pressure and temperature, gradually increase the depth of the gate until a perfect casting is obtained from the mold.

Runners and gates held to minimum size obviously reduce the amount of sprue scrap even though such scrap can be remolded. On the other hand, runners and gates of substantial cross-sectional area minimize the chances of a " cold shot." This occurs when the material has partially solidified in contact with the mold before it is " home." In such a case, the surface will show flow marks or smudges.

When the design of a piece or the finishing operation precludes the use of a gate having a substantial cross-sectional area, it is sometimes advisable, in order to avoid surface imperfections, to leave uncooled, or even to heat (up to 200° F., depending on the formula) the part of the mold which forms the appearance surface.

The other part of the mold containing most of the molded part is cooled. The heating of part of the mold serves to keep the material directly contacting it sufficiently hot to weld together to give a smooth, lustrous finish and prevent flow lines or creases. The remainder of the mold which forms the bulk of the piece, being water-cooled, solidifies the piece sufficiently for ejection. The use of this method lengthens the molding cycle somewhat. The extent of this decreased molding speed depends on the proportion of the piece formed in the heated part of the mold.

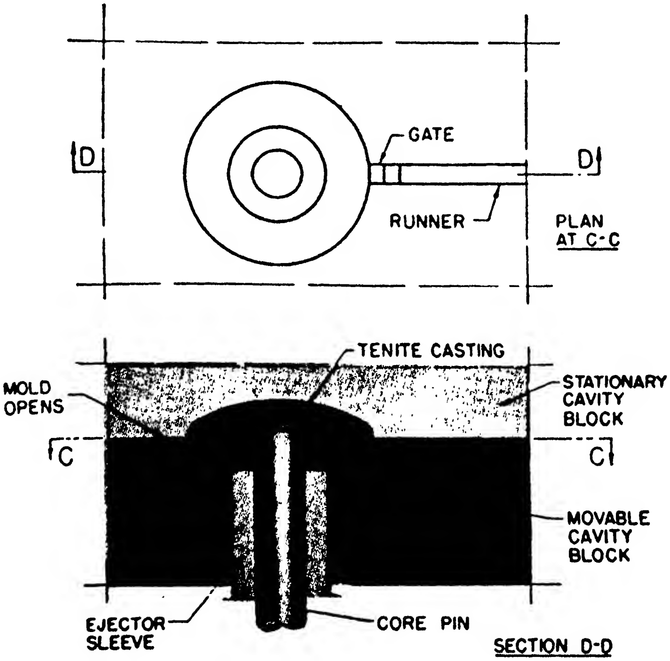


Fig. 15.26 — Standard gate.

Gates should be located as near the appearance surface as practicable. The final mass of material entering the mold is generally the hottest and gives the best weld and finish. When a core is used, a gate near the appearance surface causes the weld to occur at a point farther removed from that surface than it would be otherwise.

Types of Gate. There are four distinctive types of gate, each of which is described below, and illustrated in Figs. 15.26 to 15.29.

A standard gate is adaptable to most articles injection-molded of acetate. It is ordinarily used when there is a multiplicity of small cavities in the mold. It minimizes the finishing operation.

A fan-type gate is used generally for thin, flat pieces of large area. It functions to spread the material out and reduce the hazard of surface flow lines.

A ring gate is employed in molding hollow cylindrical pieces. The runner and gate both encircle the core pin and cause the material to flow into the cavity more evenly, thus eliminating the weld which would occur if the material entered at one side, flowed around the core pin, and joined on the side farthest from the entrance. The finishing operation on this type of gate consists in removing the ring from the piece.

A disk gate is most advantageously used for flat, annular pieces. The sprue hole leads directly to a disk which causes the material to flow evenly from the center into the cavity, eliminating a weld. It is the opposite of a ring gate where the material flows in from the periphery. The finishing operation consists in punching out the thin disk which forms the gate.

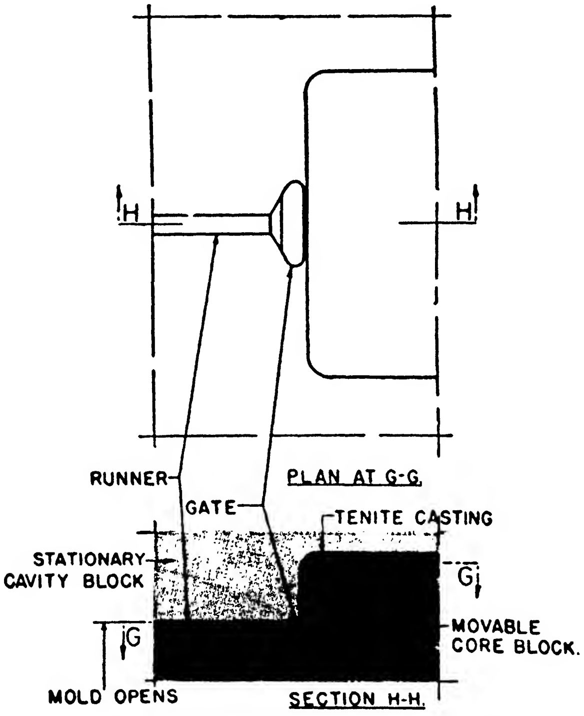


FIG. 15.27 — Fan gate.

A plurality of cavities is possible if a multiple-orifice nozzle is used with sprue holes leading directly to the center of each cavity. An extra mold plate can serve the same purpose.

Sprue Lock Pin. The sprue lock pin is located where the small depression at the mold entrance meets the runners. It is fastened to the ejector mechanism and runs through the movable part of the mold in direct line with the mold entrance. This is a straight, round pin with the end machined as a hook for pulling the tapered sprue. The castings themselves are ordinarily held in the ejector half by having greater

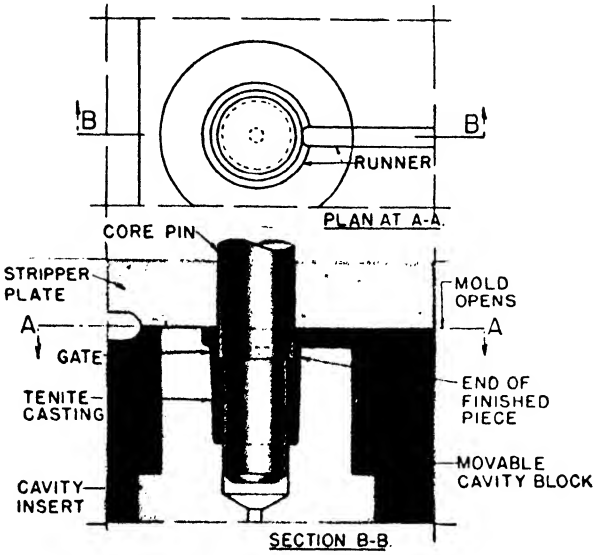


Fig. 15.28 — Ring gate.

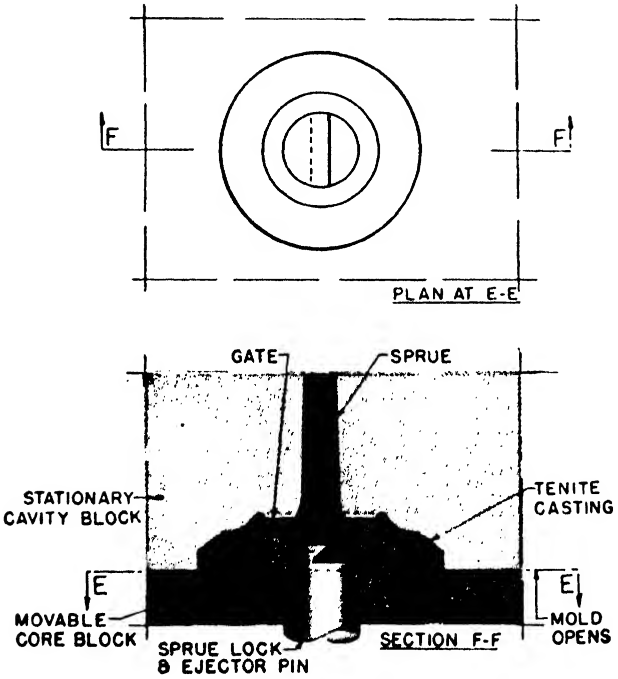


Fig. 15.29 — Disk gate.

clearance in the cover half of the mold. Sometimes an undercut is also made in the piece to hold it in the ejector half. Undercuts are sheared off at ejection.

Mold Shrinkage. Allowance for mold shrinkage must be made in making a die for an article demanding dimensional exactness. Mold shrinkage is the difference in size between the cold mold and the molded article immediately after it is ejected. It is measured in linear inches per inch. Mold shrinkage is distinct from shrinkage subsequent to molding, discussed on page 590.

The gate and runners should be somewhat proportional to the thickness of the section in the molded article, in order to avoid shrink marks. Shrink marks are caused by cooling under insufficient pressure. In compression molding it is necessary to maintain pressure on any thermoplastic until it is set by chilling. While an injection-molded piece chills very much faster, due to the fact that the cavity is constantly cooled, the same principle applies. If the gate and runners are small, and the section of the molded piece relatively large, the gates and runners " freeze " first and thus cease to give continued pressure on the casting during the two or three seconds in which it is setting; this causes shrinkage. Increasing the size of the runners and gate is about the only means of overcoming this difficulty. In other words, it is necessary for the material in the source of pressure to remain plastic approximately as long as the molded piece, in order that it may add material to compensate for the contraction of cooling as long as any substantial shrinkage is taking place.

Injection-mold shrinkage is influenced by the thickness of the piece, size of gate, pressure employed, temperature of material in the injection cylinder, and temperature at which the piece is ejected. Where the section of the molded piece is about the same thickness as the gate, runners, and cavity entrances, normal mold shrinkage is about 0.002 to 0.003 in. per linear inch. As the thickness of the molded piece is increased with respect to the cross section of the gate and runners, mold shrinkage will increase. To eliminate the necessity of very large sprue, runners, and gate to prevent shrinkage in a piece which must of necessity be molded solid, it has sometimes been found expedient first to injection-mold a core, which is in turn used as an insert over which a coating is injected as a second operation. Shrink marks in such a molded insert are of no great importance because they are subsequently covered. The coating, being a relatively thin section, requires but a small gate which is easily trimmed. Another advantage is that scrap can be used in the core unless it is so dark that it will show through the coating.

Along the same line of thought, it is desirable in any injection mold to have, as far as possible, sections of approximately equal thickness. A thin section leading to a thick section in an injection mold has the same effect as too restricted runners or gates. To prevent shrink marks, a piece which has both a thick and a thin section should be gated at the thick section. If this is not feasible, the thick section should be cored. A long, thin article with a gate at one end will have greater bending strength than one with an entrance at the center, with the material flowing in both directions from that point. On the other hand, a cup-shaped article, not subjected to any particular bending stresses, would logically be gated at the center of the bottom.

Venting. When injection is made around variously shaped cores or inserts, a better weld is sometimes effected at the point farthest removed from the gate by venting at that point. The first relatively cold bits coming together flow on out of the mold. The material just following is hotter and therefore welds better. Ejector pins frequently are designed to operate against such vent pieces, since a mark on them makes no difference, the bit being removed in the finishing operation. This vent is short, and the opening to it from the cavity is usually the same size and shape as the cavity entrance.

Trapped air will cause minute flake-like bubbles on the surface of a molded piece, usually at the point farthest removed from the cavity entrance. Charring may also occur at the same point due to the heat generated by the compression of trapped air.

A vent facilitates the escape of air which if trapped will prevent filling. Since injection pressure reduces the air in a cavity, if wholly confined to approximately one five-hundredth of the space it normally occupies, the air generally finds its own way out. Nevertheless, it does occasionally happen that the surfaces of molds are lapped and ground so well that the mold becomes virtually airtight. A vent which need be no more than a scratch leading away from the cavity, made with a diamond-pointed tool on the hardened steel mold, is sometimes necessary to permit the rapid escape of air.

Baffles are frequently employed to advantage in cavities to direct the flow of material and so prevent air locks. They are located in such a way that the indentations from them in the moldings come on a nonappearance surface.

On account of the risk of trapping air, it is not good practice to machine a deep cavity in a solid block. It is better to machine through the block and fasten a plate on the bottom. A scratch on this added plate will ordinarily provide sufficient escape for the trapped air. Where no other effective means of venting to prevent trapping of air is convenient, a small hole not more than 0.025 in. in diameter is drilled in the cavity, serving a much larger hole in the mold block as an outlet. If the bit of plastic which enters this hole following exit of the air breaks off from the piece when it is ejected, the fracture is so very small that it is noticeable only on minute examination of the molding. The next " shot " forces out the bit of plastic remaining in the hole, which should have a substantial taper away from the cavity.

Ejection. Removal of castings from the mold is generally accomplished by the travel of the mold when opening. Three methods are in general use: ejection by means of pins; stripping from cores by means of sleeves around core pins; or removal by a stripper plate.

An ejector mechanism is usually housed in the movable or body part of the mold and is actuated by the opening or backward travel of that part. Ejector pins or stripping sleeves are located by, and fastened to, the ejector mechanism. The ends of these pins or sleeves come in direct contact with the molded piece, and the movement of the ejector mechanism forces the molded pieces from the cavities or off core pins.

When a stripper plate is used and the core pins or " forces " are fastened in the stationary part of the mold, stripper bolts fastened in the movable part of the mold actuate the stripper plate to pull off the castings. When core pins or forces are in the movable part of the mold and the stripper plate is used, it is usually actuated by ejector pins. Whether ejector pins operate against a stripper plate or directly against the castings, suitable provision must be made to return the ejector mechanism to proper position when the mold is again closed. This return is made by springs or, more positively, by knockout return pins. When a stripper plate is used, the closing of the mold usually fixes the plate in its proper molding location. Where core pins not in line of draft have to be pulled, racks and pinions fastened to the platens of the machine can be utilized, or an auxiliary air cylinder can be used. Where core pins form a thread inside the molded piece, a motor-driven unscrewing mechanism can be used, or a train of racks and pinions operated by the opening of the mold.

Air-cooling Small Core Pins. Long pins mounted to a plate are cooled with difficulty by conduction, and the use of water as a cooling medium for core pins of ½ in. diameter or less has often proved impracticable, due to the number of small connections. In such instances, compressed air passing through a small tube, expanding into a larger hole drilled in the core pin and exhausting to the atmosphere, has proved a successful means of cooling. (See Fig. 15.30.)

Typical Injection-mold Designs. Application of the foregoing principles of mold design may be seen in the illustrations of typical injection-mold designs.

COMPRESSION–MOLD DESIGN

There are several types of compression molds. One classification has to do with method of operation and a second has to do with the extent to which the material is confined. The first class is divided into hand and semi-automatic molds. A hand mold is heated by contact with either steam or electrically heated platens. Cooling is accomplished either by circulating cold water through the press platens after the mold has closed or by transferring the mold to another press. A semi-automatic mold is one whose parts are fast to the top and bottom platens of a hydraulic press and which is heated and cooled by the alternate circulation of steam and cold water through channels which are directly in the mold.

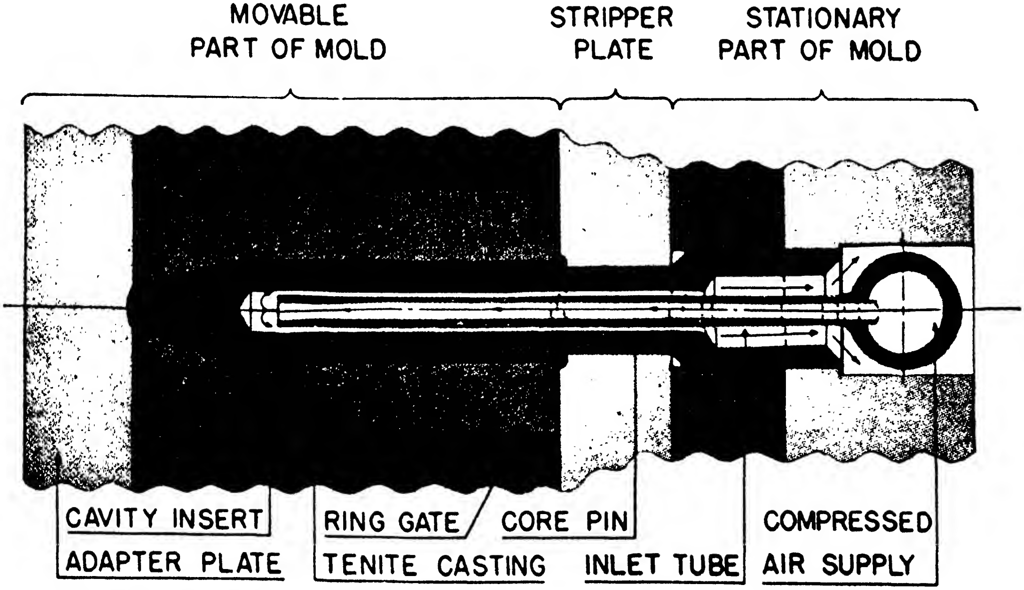


FIG. 15.30 — Air-cooling small core pin.

The second classification of molds, by the extent to which the material is confined, includes positive, semi-positive, and flash types. A positive mold is one which fully confines the material, the travel of the force being limited only by the material in the mold. It has no land or cutoff. The mold charge must obviously be very accurately weighed, since it determines the thickness of the piece. Such a type mold is used very rarely, almost never with thermoplastic materials.

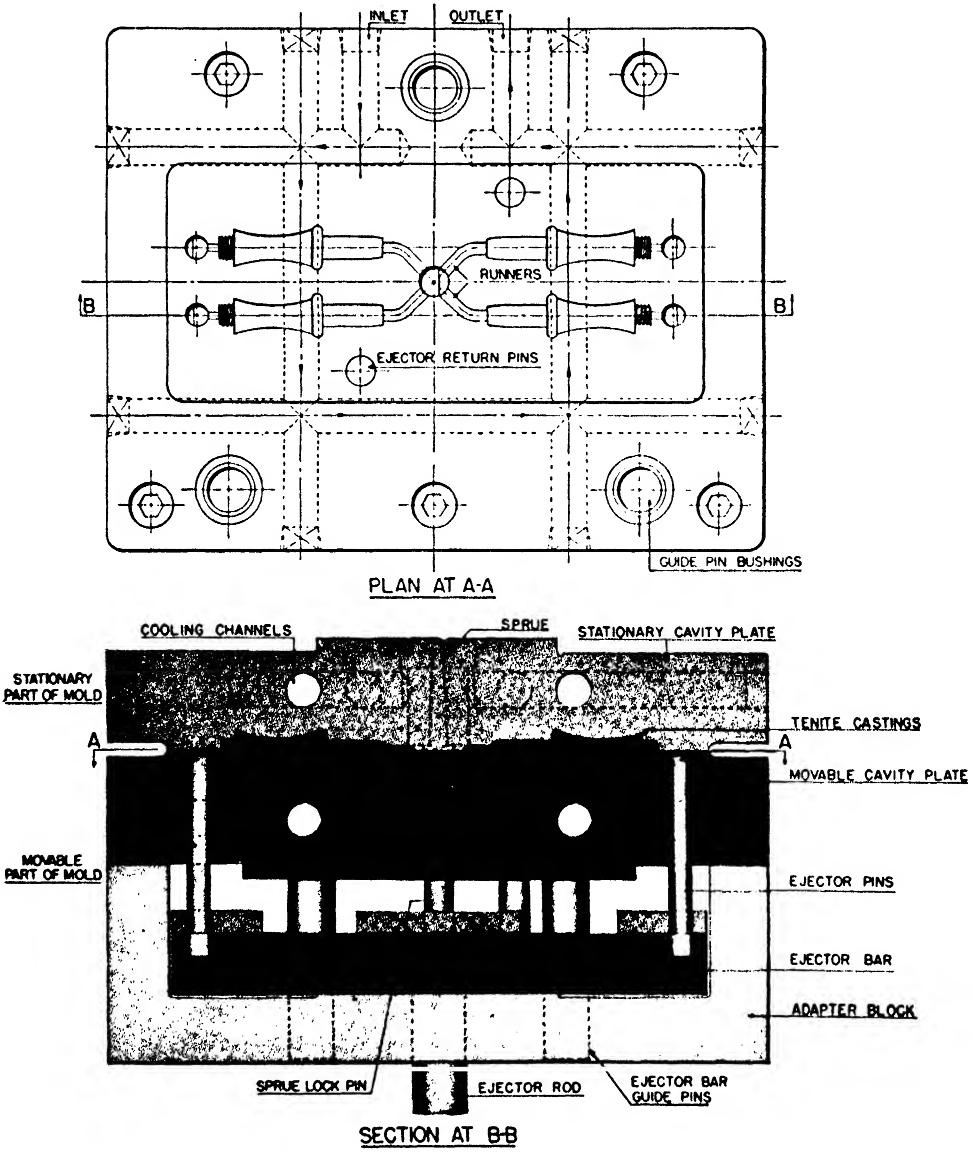
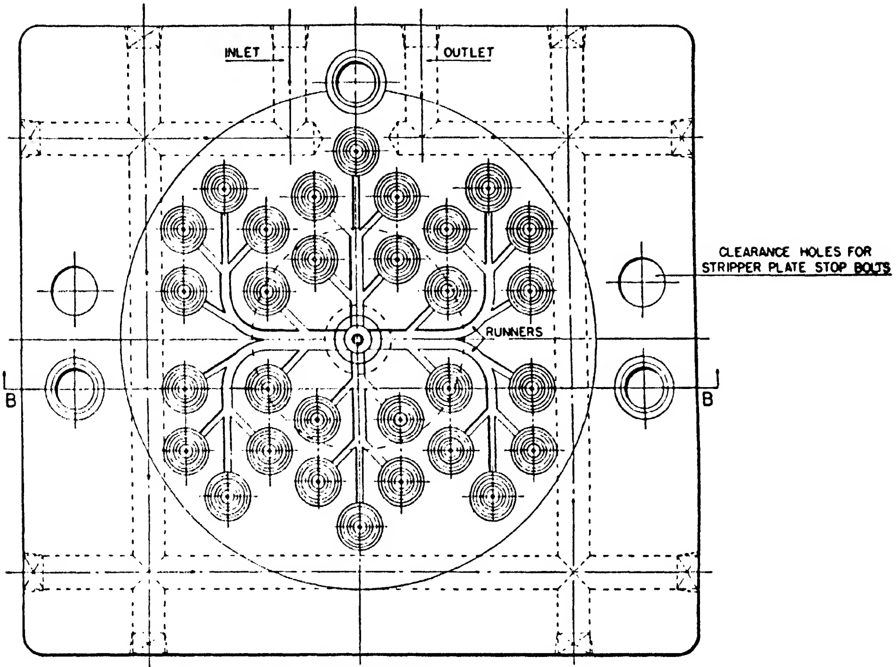
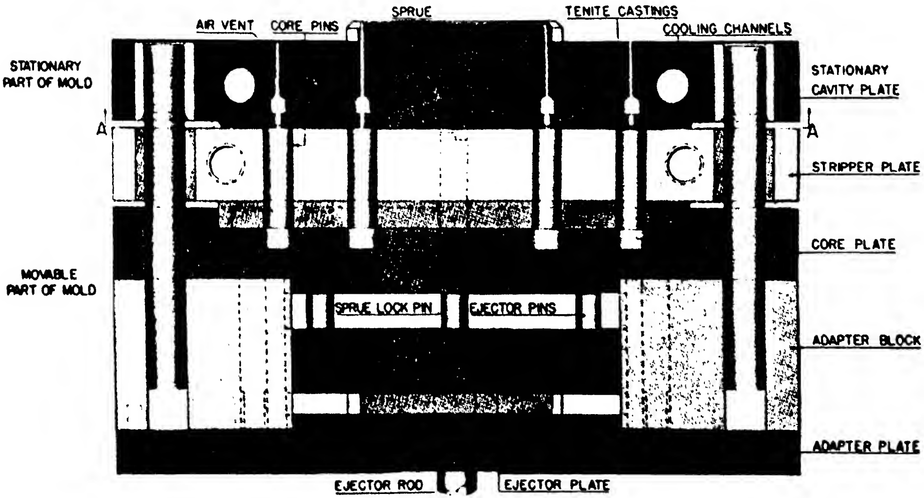


FIG. 15.31 — Organ-stop mold.

A semi-positive mold is the type of compression mold most frequently used. The material is partially confined but has some provision for overflow, the mold charge being slightly in excess of the weight of the molding.



PLAN AT A-A



SECTION AT B-B

FIG. 15.32 — Battery-seal mold.

A flash-type mold is one in which the material is not confined or restricted within the cavity until the instant of final closing. It is best adapted to thin, flat articles and is, as a rule, more suitably charged with blanks than granulation.

Another type of mold infrequently used and not included in the three classifications mentioned is a common loading cavity mold — one having a plurality of subcavities within a main cavity and but a single main force. It may be of positive or semi-positive construction.

A common loading cavity is not advisable where there are interchangeable dies contained in one mold, as inserts. The reason is that the material finds its way into the cracks between the inserts and the body of the mold.

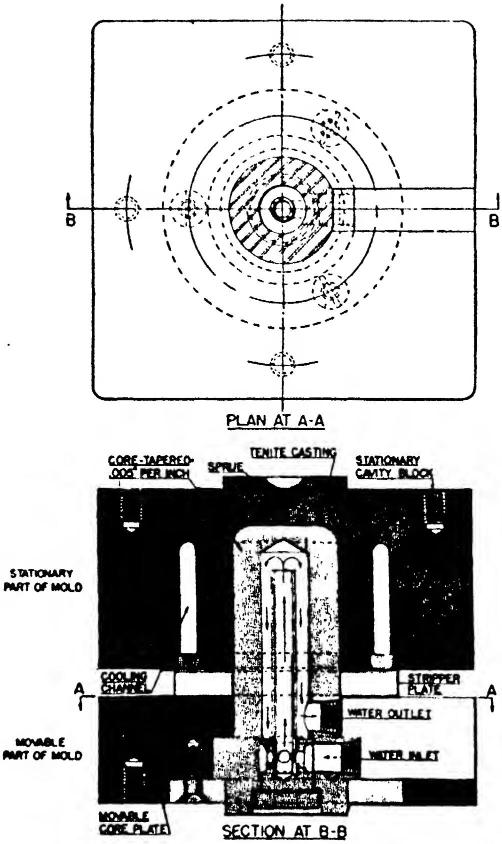


Fig. 15.33 — Oil-cup mold.

The advantage of a common loading cavity mold is speed of loading. Where a number of small pieces are to be made, granulation is poured over the cavities without any particular attention to uniform distribution. It is thus necessary to weigh but one mold charge. A secondary advantage of this procedure is that all the pieces, when ejected, are held together by a thin flash easily broken apart. Frequently, it proves possible to remove all the flash at one time by a gang punch, taking advantage of the tough quality of plastic which makes the pieces hang together on this thin flash — the quality which at the same time admirably adapts plastic to the punching operation.

For a small number of pieces, a hand mold may be used, but for any substantial production, a semi-automatic mold is logically employed.

To avoid relieving the pressure on a hand mold after it is closed in order to transfer it to the press with cold platens, the mold is frequently brought to within a fraction of its closed position, and then completely closed the instant it is placed in a chilling press.

While thermoplastics may be molded somehow in any type of compression mold, in planning new molds it is well to keep in mind that characteristic of the plastic which distinguishes it as a thermoplastic material. This requires only heat and pressure for molding, and sets on being cooled. Molds should therefore be designed to accomplish the heating and cooling rapidly, as there is no other limit to the speed of operation, such as allowing time for a chemical reaction. Two points should be considered paramount in building a mold for thermoplastics — the mold should be planned for uniform cooling, and it should be planned for quick cooling.

Uniform cooling is accomplished by so proportioning the mold parts that there will be equal weights of mold metal for equal cooling surfaces. That is, the channels in the top and bottom halves of a mold should be of equal size if the weights of the top and bottom are about the same. Should the bottom half of the mold be heavier, there should be more channels in it.

Bearing in mind the desirability of uniform heating and cooling of the mold, it follows that cooling usually can be only as rapid as the speed with which the slowest cooling part can be reduced to the ejection temperature.

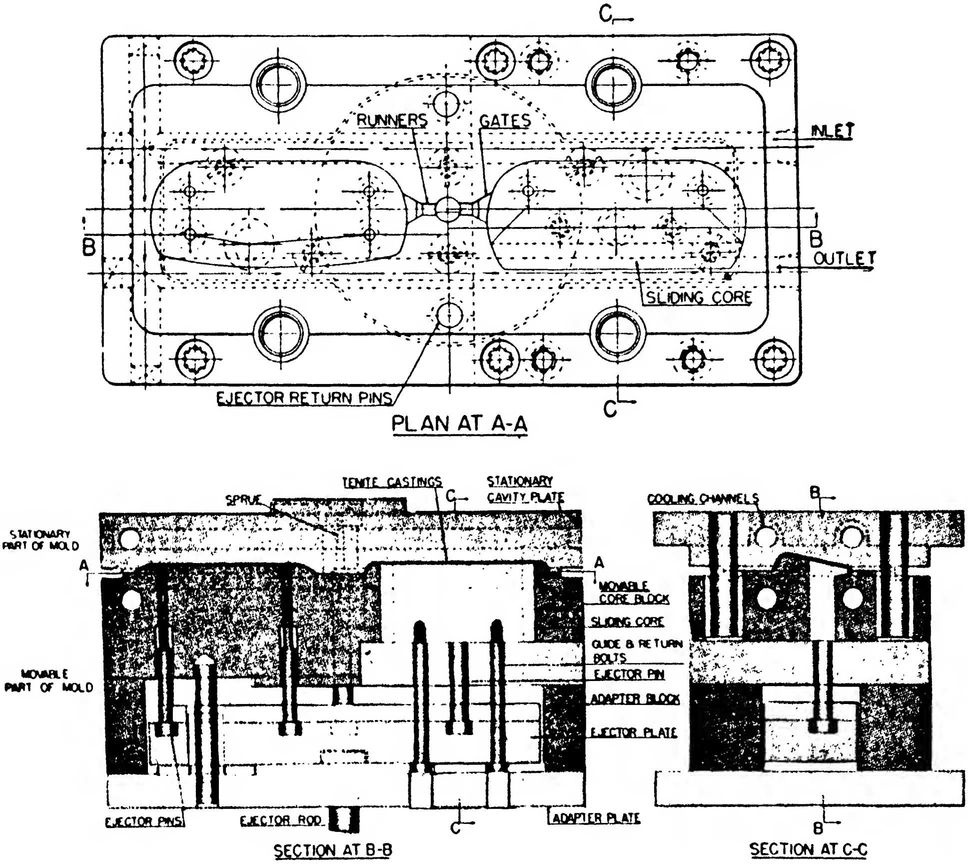


FIG. 15.34 — Spectacle-case mold.

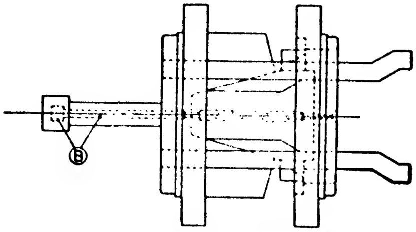
Too much heat on the mold will cause heat marks which have the appearance of surface air locks. Excessive heat will cause blisters and bubbles. Insufficient heat will give inadequate flow to fill the cavity completely, or will result in an incompletely welded piece, lacking in strength.

Too much heat on a part of the mold will sometimes result in the closing of the mold before all parts of the piece are in a plastic condition. In such a case the overheated material spills out as flash before the remaining portion has flowed into place. As far as possible, all parts of a mold cavity should be held within a range of plus or minus 20° F.

Size and position of the mold channels and velocity and temperature of the cooling water determine the speed at which a mold cools.

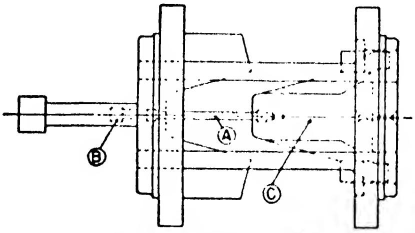
The mold channels should be as large as considerations of product design and mold strength will permit. It is often possible to put fins on the wall which is in contact with the steam and cooling water, so as to increase the surface of metal exposed. It is sometimes advisable to flow the water around the cavity, making the cavity itself an insert in the mold plate.

In connection with the problem of fast and uniform heating and cooling, it should be remembered that it is much easier to put heat into metal with condensing steam than to take away the same quantity of heat with flowing water. Any mold which will cool quickly will also heat properly if the construction permits prompt discharge of the condensate.



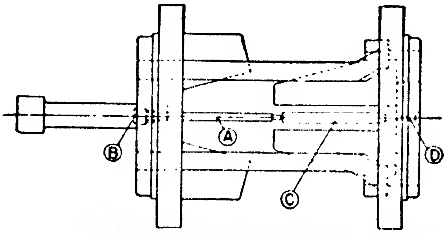
MOLD IN CLOSED POSITION

Fig. 15.35a.



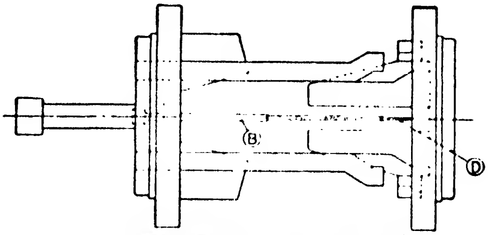
CAMS IN POSITION TO OPEN IMPRESSION BLOCKS CORE PINS Ⓐ PART DRAWN BUT HOLDING MOLDED PIECE Ⓒ

Fig. 15.35b.



IMPRESSION BLOCKS OPEN CORE PINS Ⓐ CLEAR OF MOLDED PIECE Ⓒ SPRUE LOCK PIN Ⓑ IN POSITION TO DRAW SPRUE Ⓓ

Fig. 15.35c.



IMPRESSION BLOCKS REMAIN OPEN SPRUE Ⓓ CLEAR

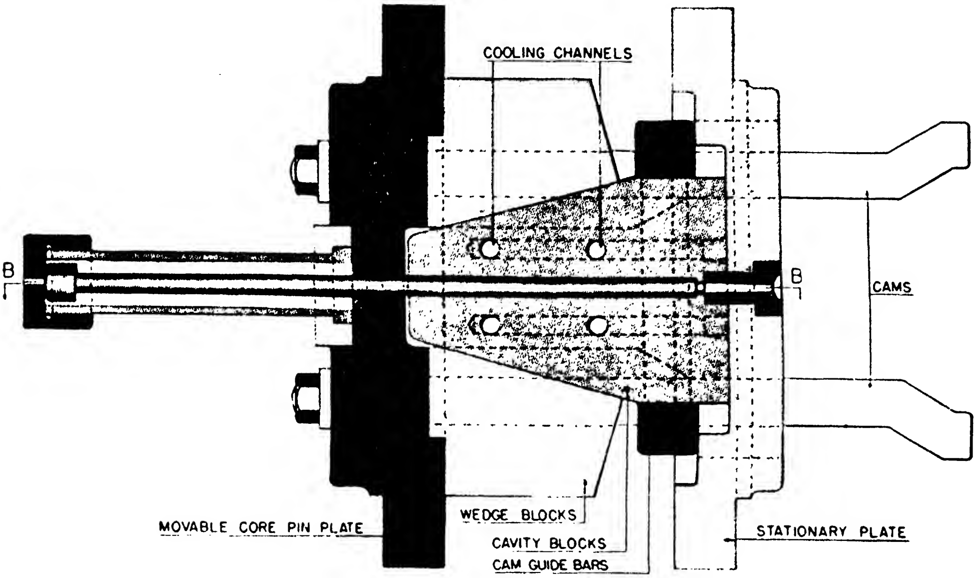
Fig. 15.35d.

Figs. 15.35a, b, c, d — Operating diagram for pencil-barrel mold.

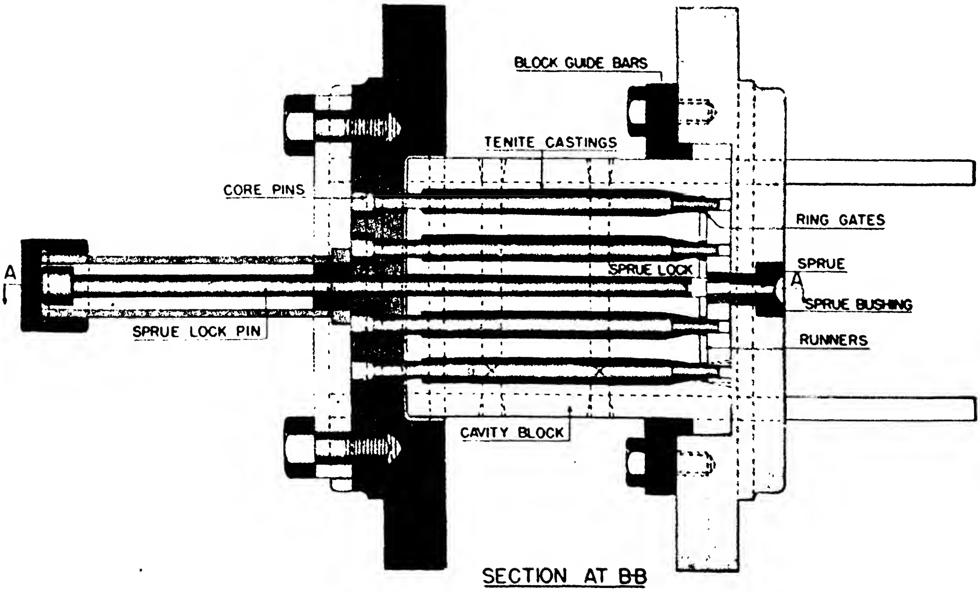
To get a good finish on compression-molded plastics pieces having large, flat areas, particularly when they are molded from granulation, it is essential that the mold be relatively confined, so that there will be plenty of pressure on the material. It should be borne in mind that it is a simple matter to increase the clearance which permits the escape of flash, but that when the mold as originally constructed gives too much clearance it is practically impossible to reduce it subsequently.

It is essential that there be no cracks in a compression mold into which the material can flow. This is because the material, having once entered the crack, does not cease to flow. Each time the mold is heated, the Tenite again becomes plastic and is forced farther into the crack. The pressure may become so great as to strip the threads on screws holding the plates together. Another important point is to be certain that parts fit together tightly wherever heat is expected to flow across a joint. A thin film of air is a barrier to heat transfer.

Sometimes a mold lubricant is helpful to facilitate ejection, particularly in the case of a new mold, or to secure a thinner flash or quicker closing, by reducing friction between the material and the surface of the mold, especially where there is a large flash area as in a mold with a common loading cavity. Finely powdered carnauba or montan wax is recommended. Carnauba has the advantage of being almost colorless. A cloth bag containing the powdered wax is struck between the surfaces of the compression mold, and sufficient powder flies out to give a very, very thin film of wax. This method also gives reasonably uniform distribution of the lubricant and is much to be preferred



SECTION AT A-A



SECTION AT B-B

FIG. 15.35e — Pencil-barrel mold.

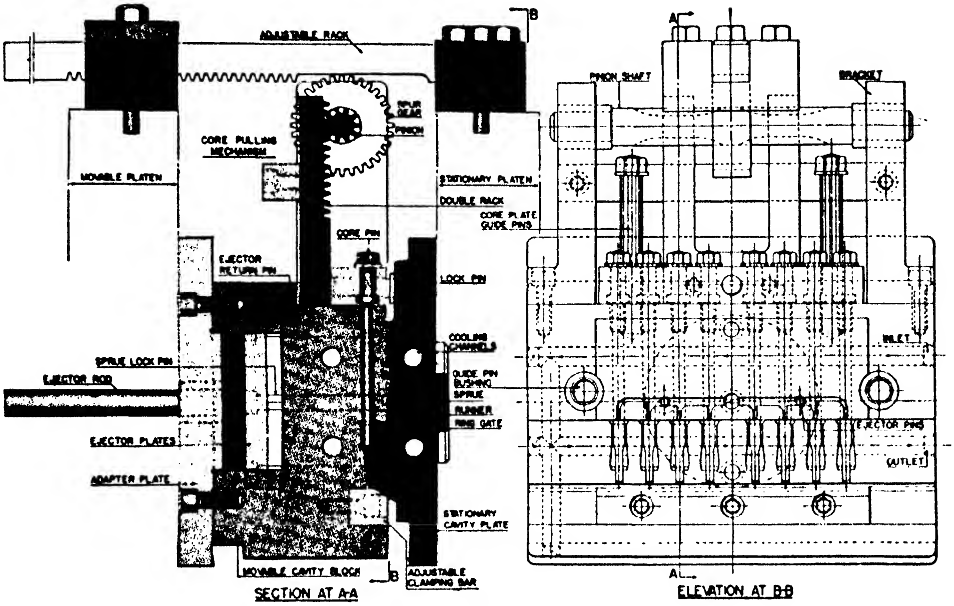


FIG. 15.36 — Cigarette-holder mouthpiece mold.

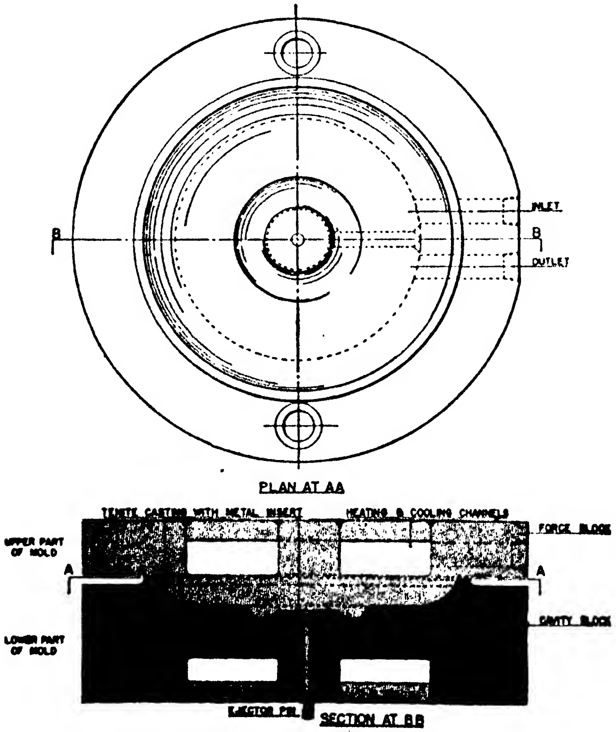


FIG. 15.37a — Bowl-base mold.

to the method of rubbing wax on the mold. More than the most minute film will cause a blemish in the molded piece.

Venting. In molding a long, thin piece where the force does not extend far down toward the bottom of the cavity end, and the material is compressed without much displacement, it has been found desirable to vent the cavity at the bottom in order to effect some flow of the material. An example of such a piece is a pen taper.

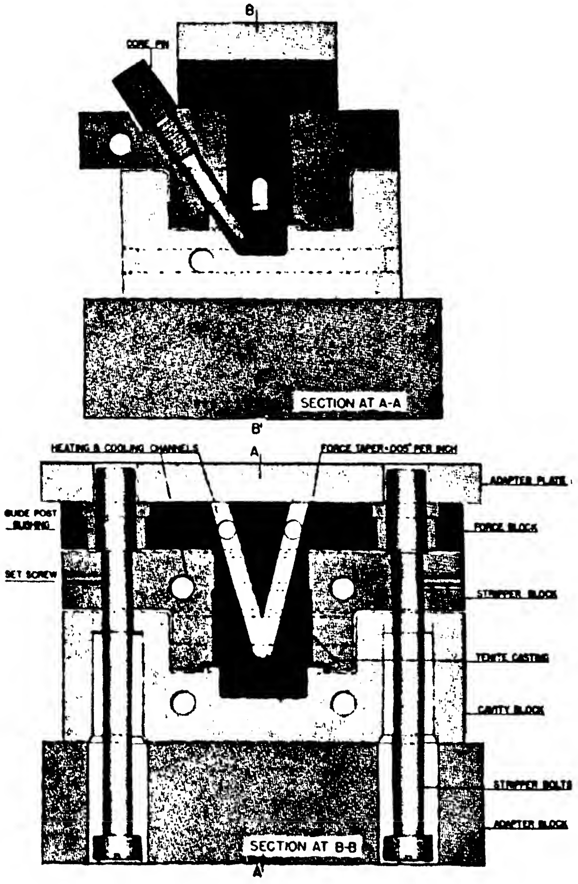


FIG. 15.37b — Inkwell mold.

A similar vent is sometimes placed in the top of the forces when pieces are molded having a sizable section formed in that part of the mold. This vent in the forces gives the material a tendency to flow upward and fill out the piece when it might otherwise have a tendency to spill out through the regular overflow clearance before that portion in the extreme top of the forces had completely filled.

Mold Shrinkage. Since compression-mold shrinkage is to a certain extent a function of the temperature at which pressure is released, figures for shrinkage are computed on the assumption that the molded article is chilled to approximately 125° F. before ejection. A plastics molded piece withdrawn from the mold fairly hot will have greater shrinkage than one which is permitted to chill more completely. As example, shrinkage of acetate in a flash-type mold is 0.008 to 0.009 in. per linear inch, and for a positive type, 0.002 to 0.003 in. It is, of course, exceedingly rare that any mold is entirely positive in action, and pieces made in an ordinary semi-positive mold affording the plastic some means of escape, although restricted, should have an allowance for mold shrinkage of about 0.006 in. per inch.

TRIMMING AND ASSEMBLING

Trimming Gates of Injection-molded Pieces. The bulk of sprue scrap is usually removed from the moldings by the operator at the injection press. Final trimming of the gate is of importance insofar as an injection-molded piece normally needs no other finishing operation. If it is cut cleanly and neatly, it may be unnecessary to sand, turn, or even touch the molding to a polishing wheel. Ordinarily, the most effective means of cutting the runner from the casting is to employ a hand, kick, or punch press with a positioning fixture. To give the best appearance and to prevent the runner from breaking into the molding it is desirable that the gate be cut from both sides, not merely from one side. The blades should have a long taper on both sides, and be so adjusted in the press that in the closed position they come within a few thousandths of an inch of meeting, being prevented from actually touching by stops on the press itself.

Removing Flash from Compression-molded Pieces. It is much better to remove the flash from a compression-molded piece by an action which is of a cutting nature than by one of a filing or sanding nature. The reason for this lies in the resilience of most thermoplastics. A material which is relatively brittle, such as the phenolic or urea resin compositions, lends itself to filing, sanding, or burring, but it is preferable to cut, turn, punch, or scrape articles molded from thermoplastics.

Cementing. Tenite can be cemented to itself in a bond which is practically as strong as the molded piece. The two surfaces to be joined should be made as smooth as possible to provide the maximum cementing area. The surface must be absolutely clean. The presence of a slight film of oil, perspiration, or polishing compound will effectively prevent a good job. It is sometimes desirable to scrape the two surfaces of plastic which are to be cemented to remove the " skin " in order to obtain the most perfect bond.

If the surfaces to be cemented are perfectly smooth and clean, an excellent bond is obtained by the use of acetone alone. This is sometimes applied from an oil can with a pinhole nozzle which is run along the joint.

Another convenient method of applying cement is to place some in a saucer or other shallow container with a heavy piece of felt in the center which projects slightly above the level of the cement. The surface to be cemented is wiped along or touched to this felt. Only a small amount of cement should be poured out of a stoppered container into the saucer at one time, since the solvent evaporates rapidly. For the same reason, thinner (solvent not containing a dissolved cellulose ester) is required from time to time. Care should be taken not to drop cement or solvent on the piece since it will leave a spot.

Where the surfaces to be cemented are not perfectly smooth, it is best to use a cement with some body. However, such cement or solvents cannot be expected to fill in depressions, since the most viscous cement still shrinks on drying in approximately the proportion of 1 to 4. Rough surfaces cannot be cemented together effectively.

It is almost essential to keep cemented pieces under the pressure of a clamp or weight until the cement has set, at least partially, by drying.

Assembling Tenite Molded Parts with Other Materials. Threaded inserts are frequently molded into plastics pieces, as such inserts usually provide the most satisfactory means of assembly by screws to parts made of other materials.

Sometimes, plastics parts are assembled to those made from other materials by the molding of a slight undercut in the plastics piece. Such an undercut need not be so great that it prevents ejection from the mold. The resiliency of plastics gives enough elasticity so that it can readily be forced into a correspondingly tapered surface in the part with which it is to be assembled.

Another very satisfactory way of attaching plastics to other articles is by molding on the back of the piece short lugs which enter into holes on the piece to which the part is attached and onto which speed nuts are pushed.

There are cementing agents which will bond most plastics fairly well to wood, metal, other materials, etc.

Shearing, Blanking, Punching. In order to obtain a smooth edge in shearing, blanking, or punching operations, it is necessary to warm the sheet. The greater the thickness the more care is required to see that the piece is warmed to the center without heating it to a point where the surface polish is destroyed.

When a plastics sheet is heated, it becomes somewhat pliable and the weight of the knife, blanking cutter, or punch compresses the material to a slight extent. When the pressure is removed after cutting, the material resumes its former size and one edge is thus slightly concave and the other convex. It is impossible to secure both a very smooth cut and a straight edge at the same time, particularly in a thick sheet. The curved edges are more or less unnoticeable in thicknesses below 0.1 in. which may exist in molded pieces.

Machining. The physical properties and appearance of a fabricated model will approximate rather closely the results procurable by molding. It is not possible to duplicate exactly by molding, particularly by injection molding, the configuration in a piece of variegated plastic in sheet form from which a model is machined. In most instances, however, the general color effect can be rather closely duplicated. The color effect obtained by machining an acetate pearl, however, is usually quite different from the appearance of such a pearl when molded by compression or injection.

Plastic is satisfactorily worked with tools used for wood or metal. They should be run at such a speed that the piece does not overheat to the extent of causing it to gum. Oil is sometimes used for cooling and to secure a smoother cut. This cannot be done if the scrap is to be re-used. Scrap contaminated with oil or other foreign material cannot be satisfactorily molded.

Drilling. Drills with large flutes and large helix angle are desirable since they expel the shavings with less friction and so avoid overheating with consequent gumming. A substantial clearance on the cutting edge of the flutes makes a smoother hole. Best results are obtained at a speed of approximately 5000 r.p.m.

Sanding. Plastics pieces are commercially sanded on machines made for this operation having an endless abrasive belt. Such machines are of both bench and upright types. The belt runs at a speed of approximately 2000 ft. per min. Both coarse and fine abrasive belts are used; frequently, a preliminary sanding is done on the coarse belt and a final sanding on a fine belt. The work should be pressed but lightly on the sanding belt in order to avoid gumming of the material through overheating. It is often desirable for an operator to sand one piece partially, then go to the next and so on, coming back to the first piece after it has cooled.

Sawing. Plastics can be sawed on either circular or band saws; the former are preferred for a smooth cut, despite the fact that they tend to get hotter than band saws.

When using a circular saw, it is essential that the spindle bearing be tight so that the saw will not wobble. The saw should be hollow ground with no set, similar to a milling cutter. For cutting pieces 3/8 in. thick or less, a saw having eight teeth per inch is recommended. For cutting a thicker section, a saw having six teeth per inch is most satisfactory. The spindle speed should be approximately 3000 r.p.m. which represents a peripheral speed of about 6000 ft. per min. on an 8-in. saw.

If a band saw is used, the guides should be set as close as possible to the material to be cut.

CHAPTER XVI

METHODS OF FINISHING PLASTICS

FINISHING OPERATIONS

Ashing and Lapping. A plastic molded piece is seldom ashed or lapped. This is necessary only in abrading toolmarks from models machined from blocks.

Ashing produces a satinlike surface, but subsequent polishing is required to secure a lustrous finish. The operation is done on a wheel built up of muslin disks, preferably not sewed together. Such a wheel is usually 4 to 6 in. wide and is 12 to 14 in. in diameter, and runs at a speed of approximately 1200 r.p.m. The operator works on the periphery of the wheel. Sometimes a cornhusk or carpet wheel is used where a greater and quicker abrasion is desired. The operation is then termed " rubbing."

Wet pumice, usually grade 0½, 1, or a mixture of the two grades, depending on the abrading action desired, is applied between the work and the ashing wheel. The pumice is wet to accelerate the cutting and also to retard excessive dusting. The article should be washed as soon as it is ashed, and promptly dried.

Since an ashing wheel has a natural tendency to fling the wet pumice off, such wheels are invariably hooded. These hoods are usually made of sheet metal. Naturally the front of the hood must expose the wheel where the operator works. There should be plenty of room for him to manipulate the work. The bottom of this hood forms a pan which receives the wet pumice as it falls inside, and serves as a reservoir for the wet abrasive compound. The operator should wear a rubber apron.

Ashing wheels are made hard or soft, depending on the type of article and the speed of abrasion desired. A soft wheel is made by placing small muslin disks called spacers between the larger ones which form the working surface of the wheel. Spacers are about 6 in. in diameter. Even a relatively hard wheel has frequently one spacer to every two disks, and a somewhat softer wheel, two disks and then two spacers.

The purpose of using loose muslin disks rather than disks sewed together is that the wheels can thus be changed in hardness by adding or removing spacers. Wheels which have worn down may be disassembled and the disks used for spacers. The width of wheels can also be varied if the disks are not sewed together.

Muslin disks are purchasable from suppliers of buffing equipment.

Lapping is an operation similar to ashing, differing in that the work is done on the side of the wheel instead of the periphery.

A lapping wheel consists of a flat, metal disk 10 to 12 in. in diameter on the end of an arbor or shaft. To the surface of the flat metal is cemented heavy felt. To this is applied wet pumice, and the flat piece to be abraded is pressed against the surface.

Lapping wheels are usually hooded as is an ashing wheel. In the case of a lapping wheel, the hood can extend entirely around the wheel since the operator is working at the end. Lapping wheels are run more slowly than ashing wheels (about 400 r.p.m.).

Polishing. Most thermoplastics take a polish as good as the surface of the die in which they are molded. Since it is economical to have a brilliant, mirrorlike surface on most molds, wheel polishing and buffing are normally confined to the edge from which flash is removed in the case of compression-molded articles, or the gate in the case of injection-molded articles.

Buffing is not abrasion but a minute surface flow of the material.

A relatively hard wheel is used for polishing flash lines and gates, while polishing pieces as a whole to impart a final lustrous surface usually consists more or less of a mere wiping on a relatively soft wheel.

Wheel polishing is done on a buff made of muslin disks about 12 in. in diameter. The hardness is regulated by the use of spacers as described under " Ashing." Polishing wheels are run at about the same speed as ashing wheels — 1200 r.p.m.

In the case of a hard wheel it is often necessary to use smaller diameter buffs to get into depressions and avoid " burning " the edges of the recessed section.

Where a large number of identical pieces require wheel polishing, it is advantageous to employ automatic buffing machines.

Tumbling Polishing. It is exceedingly rare that thermoplastics moldings are tumbled to remove flash. In removing the flash the surface of the entire piece might be abraded to the same extent and require subsequent tumbling to polish. Moldings made from other types of composition which have a relatively brittle flash are sometimes satisfactorily cleaned by tumbling.

When tumbling is used for abrasion purposes, wet rottenstone and pumice are usually employed, mixed with small stones or balls to give weight; when used for polishing, jewelers' rouge and special polishing compounds are used, mixed with sawdust, leather scrap, wood pegs, etc. This is a specialized operation; there are companies which supply equipment and methods for best results in individual applications.

Lacquering. Only lacquers specifically recommended for use with a cellulose ester molding composition should be used for either dip or spray finishing. Many lacquers which give, when first applied, a smooth lustrous coat without wrinkling and with adequate adhesion will develop tackiness when submitted to body heat and humidity. This is caused by migration of the plasticizer into the lacquer coating, its concentration causing the surface to become gummy. Thus, a lacquer must be used which has no greater affinity for cellulose ester plasticizers than does the cellulose ester plastic itself.

The same consideration applies where an acetate molded piece is assembled to some other part made for instance of wood or metal which has been coated with a lacquer. In such cases when the finished part is subjected to a warm and humid atmosphere, particularly when the article is confined in a small space as in a cardboard box, the plasticizer is liable to migrate from the molded part into the lacquer on the other piece and cause it to become tacky or gummy.

If a thermoplastic is to be lacquered, the fact should be stated in ordering, as some formulas are better adapted to lacquering than others.

Stamping and Embossing. A trade-mark or brand can be molded into a plastics article, but it sometimes happens that the same piece will carry more than one brand. In such cases the ability of plastics to take a neat, permanent, and attractive stamp is most useful, saving the cost of additional molds.

" Blind " stamps, trade-marks, and decorative effects can be produced on plastics pieces by placing the article to be stamped in a fixture and pressing a hot die, usually brass, against the surface, ordinarily by means of a hand or kick press. When it is desired that such a trade-mark or decoration be plainly visible, it is subsequently filled in with appropriate lacquer.

Colored foils can be embedded permanently in the surface of the plastic to give very beautiful effects. This is accomplished in the same way as stamping or branding, a piece of the foil or metallic leaf being laid over the area to be decorated. Attractive inlays in all kinds of metals can be embedded in molded pieces by a cold inlay process.

Finishing Molded Bakelite or Vinylite Parts[1]

Molding materials, both thermosetting and thermoplastic types, give a faithful reproduction of the surface of the mold in which they are formed. This characteristic of plastic molding offers one of the greatest advantages of plastics as against other types of raw materials used in manufacturing and construction. Highly polished mold surfaces impart with true fidelity the corresponding high finish to the molded piece. If it were possible by methods of mold construction or molding technique in compression molding to produce parts without parting lines, or joints, or, in the case of thermoplastic materials, without the gate or sprue connection, no finishing would be required. This is not possible and, therefore, these evidences in the form of flash or fins and gates or sprues must be economically removed from the molded pieces. The finishing of molded parts revolves primarily around this problem.

In the plastics industry the term "finishing" is broadly used to cover those operations subsequent to or supplementing the actual molding or fabricating processes. The process of finishing in this case will be limited to removal of gates, sprues and runners, flash or fins, hand filing, barrel tumbling finishing, wheel polishing and buffing.

Plastics as taken from the mold cavity are first subjected to what is known as rough finishing; that is, the removal of the flash from the parting line and the openings in the molded pieces. Then follow drilling and tapping operations, together with any other machining which may be necessary, after which a final buffing or polishing is added to produce the desired quality and luster of finish.

There are no set rules for the removal of these parting lines although proper consideration in piece design and mold construction will do much to avoid excessive handling, hand filing, buffing, polishing, etc. The following methods and examples have been found to be economical practice and will serve to assist in suggesting ways and means of finishing parts.

Most of the subsequent finishing operations require the same type of experience, method, and equipment employed by both the metal and woodworking industries, but with such changes and improvements as are required to meet the conditions and physical properties peculiar to molded plastic parts.

At this point, it might be desirable to stress the importance of a more or less continuous process of inspection, occurring at each individual step from the time the piece leaves the mold until it is completed.

Although the finishing process begins when the piece leaves the mold, nevertheless the mold itself plays an important part in the finish imparted to the piece. Periodic

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[1] Transcript from *Molding Technic for Bakelite and Vinylite Plastics*, copyright 1941 by Bakelite Corporation.

inspection of mold surfaces is desirable. A high degree of finish should be imparted to all surfaces, particularly where the production run is to be large. The higher cost of a polished mold will be more than justified by the savings effected in subsequent handling.

Hand Filing. Hand filing is probably one of the costliest methods found currently employed on odd-shaped parts and irregularly formed pieces. Among the numerous pieces often requiring hand-file finishing are the sprue marks appearing on injection molded items. These require careful hand filing in order not to mar the finish on the molded article. The file bench should be equipped with a complete assortment of files in double cuts, single cut, fine and medium, flat, square, round, half-round, pillar, knife edge, three square, and crossing. Suitable file cards and brushes should be available for proper cleaning. Operators should learn to clean files frequently to ensure the best results. All files should, of course, be provided with handles for the safety of the operator. Wood and metal jigs can frequently be adopted to advantage to protect corners and edges, particularly where parts are handled rapidly.

Sanding. In the finishing of many plastic molded parts, the use of flexible abrasive belts is particularly adaptable. This is true in medium and larger molded items. To be recommended is the new Minnesota Mining and Manufacturing Company's Wetordry Tri-M-Ite cloth which employs a silicon carbide abrasive grain bonded by synthetic resin. These abrasive belts with grits of No. 24 to 600-mesh size are available, and grades ranging from 220 to 320 mesh have been found most useful for rough finishing plastics and for the removal of sprue projections and heavy flash lines on both thermoplastic and thermosetting pieces. As indicated, these belts may be operated dry or in conjunction with a water-spray nozzle with belt speeds ranging from 2000 to 3000 ft. per min. on the surface. Thin and narrow belts may be readily adapted to irregular surfaces. One molder has found these abrasive belts to be particularly well adapted to heavy production. Carefully recorded tests proved that this type of belt will outlast the general sandpaper belt by three times. Some of the advantages of using Wetordry Tri-M-Ite cloth with water for sanding molded plastic articles are:

1. Elimination of dust.
2. Lubrication of the belt cutting action which eliminates burning or distortion that would be developed through frictional heat in dry sanding.
3. Eliminates clogging and filling of the abrasive coating on the belts.
4. The yield per belt in wet sanding is from three to four times greater than the belt yield when used dry, due to the fact that the use of water lubricates the cutting action, thereby increasing the life of the belt. The cutting action is cool and fast, eliminating a filling condition which is ordinarily encountered when using dry belts.
5. Finer grades of belts can be used for the reason that filling is generally eliminated through the use of water as a lubricant. As a result, the object being finished can be buffed to a high luster in less time than when coarser grades of dry belts are used. This naturally speeds up the final operation.

When the cloth is used dry on molded plastics, it will produce four or five times greater yield per belt than a dry belt bonded with ordinary glue, as the resin bond is not affected by frictional heat generated in the sanding operation.

There are a number of machines on the market which have been designed especially for the use of these new belts. They are provided with water connections. Pulleys are properly enclosed to confine excess water that might be thrown off belts while in use. It is also possible with a few simple changes to adapt dry sanding equipment for the use of these belts. These changes consist of the addition of guards, open drains, and the installation of water connections with the use of the proper type of water-spray nozzle.

Cementing. *Thermoplastic Moldings.* It is often desirable to cement two plastic parts together instead of joining them by some mechanical means. With cold-set plastics, a properly cemented joint will have 60 per cent of the strength of the plastic; hence it is often preferable to cement from the standpoint of strength.

For a properly cemented joint, it is necessary that exactly the right amount of cement be applied to the parts to be joined. This operation is usually performed by girls who either skillfully brush on the cement with a camel's hair brush or press the part on to a piece of felt, which has been saturated with the cement.

After the proper amount of cement has been applied, the two parts should be held together under slight pressure until they are fairly dry. Special forms may be constructed, or the spring type of clothes pins may be used for this purpose. With thermoplastics, care must be taken to assure that the vapor from the cement is not confined, or the surface of the piece will be etched.

The cementing of plastic parts must be confined to parts molded of the same type of material, as dissimilar plastics do not bond together. Mechanical methods must be used to hold dissimilar material parts together.

For the strongest bond, special phenolic cements are recommended depending on the type of plastic. With the thermoplastics, where only a fair bond is necessary, solvents may be used for cementing. Acetone with or without dissolved cellulose acetate has been used with success for the cementing of cellulose acetate parts. Ethyl acetate has been used with equal success on polystyrene parts. Acryloid B-72 cement has been used satisfactorily on parts molded from vinyl plastics molding materials.

High-speed Spindle Carving Machine. *Thermoplastic Moldings.* For the removal of flash, sprues, and runners from thermoplastics moldings, the use of a carving spindle will be found to be economical. These spindles, operating at high speeds, can be equipped with a number of rotary cutters and tools which permit quick removal of sprues and gates, giving a fine clean surface requiring little or no polishing.

Punch Press Work. *Thermosetting Molded Parts.* Pieces molded of fabric-filled materials frequently have lateral type fins which are difficult to remove other than by the use of hand files for the rough edges. When properly handled, punching, blanking, shearing, trimming, and shaving can be done on molded pieces, and the cost of the tools employed will be more than offset by the speed and economy in producing the finished part.

Trimming. *Thermoplastic Molded Parts.* In some cases, runners, sprues, and gates can be removed on punch presses. Making use of the fact that a punch press employs a shearing or shaving operation, a complete shot of injection-molded parts can be placed in a trimming die and the gate and sprues removed with a single stroke. Raised gates are removed by a shearing cut on the die. This type of gate can be used only when the underside of the piece can have a rough finish.

Pieces of an irregular shape which must be finished carefully usually have gates removed on a single-blade punch press. If the piece is of circular or simple geometric cross section, dies may be constructed which will effect the removal of the gates in one operation.

It is desirable that all thermoplastic parts be at room temperature (at least 70° F.) or above before punching. Cold pieces tend to fracture back into the part on punching, thereby leaving a rough broken surface. Many molders remove the gates immediately after molding when the inner core of the part is still quite warm. This latter method can be used with success on polystyrene or vinyl molded parts when removal of the gates on the same punch press, at room temperature, would cause fracture of the pieces. When there are only two or three cavities in the mold, the press operator often skillfully removes the gates with a pair of sharp " snips " or wire clippers at the press.

De-finning by Tumbling. *Thermosetting Molded Parts.* For the polishing of phenolic or urea molded pieces only one operation is necessary, i.e., the luster finishing operation. However, for these molded parts a de-finning barrel is used to remove the rough die flash. This operation is preliminary to the polishing operation, and the dust acquired by the moldings in this operation must be removed by an air blast before starting the second operation.

On articles molded from urea or phenolic molding materials there are certain types of pieces where, due to the design, very sharp edges, or other structural reasons, the de-finning operation cannot be used and they must be filed or sanded. For this type of part the luster finishing operation is used. Furthermore, the de-finning operation is limited to articles such as buttons, slides, bottle and jar caps, knobs used for furniture, automobile and hardware trimmings, moldings for the electrical trade, and all other moldings alike in design and size. Based on experience it is estimated that 75 per cent of these molded parts can be de-finned in a de-finning barrel. In general, jar caps up to 3 in. in diameter are successfully de-finned and polished in tumbling barrels, and moldings with metal inserts are de-finned and polished without injury to protruding metal parts or the molded sections. The de-finning operation requires from 3 to 15 min., depending on thickness of flash. Wood pegs are used on certain types of moldings, such as those with protruding metal inserts, to prevent chipping. Barrel speeds from 20 to 40 r.p.m. are required. On sharp tin sections a speed closer to 20 r.p.m. should be used.

A de-finning barrel constructed from hard maple, octagon type, with alternate staves of screen and maple, has proved the most practical. Certain classes of molding require a particular kind, type, and mesh of screen and, therefore, the screen staves are constructed so that they can be removed easily and quickly to install a different size mesh or type of screen. The screening barrel can be supplied with a metal enclosure to confine the dust arising from the operation. The dust can then be driven into a collector system.

Polishing by Tumbling. *Thermosetting Molded Parts.* For the polishing operation a solid, octagon-type, hard maple barrel is used, usually with two pockets. The two-pocket barrel is the more practical, as different colors or different sizes and types of molded parts can be finished at the same time without mixing. The polishing operation is simple: a special luster wax compound developed for this purpose is used with shoe pegs of various sizes as a carrier and burnishing medium. The time required is from ½ to 5 hr., depending on the quality of finish desired. A short run of ½ hr., using a very small amount of compound, will clean the parts and leave them with an ordinary finish, whereas, if the standard amount of 1½ oz. of compound is used and moldings are run for 3 to 5 hr., a high quality luster finish is obtained.

The barrel is emptied into a dumping box placed underneath the barrel, and the shoe pegs are separated over a screen of the correct mesh which holds up the parts and permits shoe pegs to drop through. This operation can be performed by hand screening boxes or by an automatic screen separator. Molded parts are completely finished in the luster finishing operation; and no other operations, such as wiping or cleaning, are necessary.

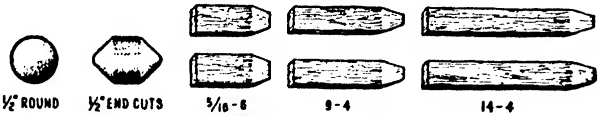

FIG. 16.1 — Shoe pegs. Wood fillers and carriers for polishing.

The size of the shoe pegs or other wood fillers and carriers (Fig. 16.1) for each class of molded parts must be chosen with care. Otherwise, they will crowd into holes or crevices. Then it becomes necessary to dislodge the pegs or filler and clean the molded parts out by hand.

Thermoplastic Molded Parts. Cellulose acetate parts produced by the injection process should first have gates, runners, and sprues removed by clipping, filing, or sanding. Parts may then be placed in polishing barrels. Usually 10 to 20 hr. are required for finishing these items in one barrel operation, as compared to 2 or 3 hr. required for fabricated or machined parts. The use of wooden pegs and luster finishing cream will give the highest gloss finish.

Polishing by Buffing Wheel. *Thermosetting and Thermoplastic Molded Parts.* For larger pieces and some small parts requiring an extra fine surface finish, hand polishing or wheel buffing is necessary. The first important factor in hand polishing is, of course, the correct equipment. The correct speed of lathes for thermosetting plastics using a 10- to 12-in. diameter wheel 4 to 5 in. wide is approximately 2500 r.p.m. A speed of approximately 1500 r.p.m. is used for thermoplastic materials. It is desirable to work with manufacturers of polishing supplies, as it has been proved that a certain amount of experimenting is necessary, depending upon the material used and the design of the part, to determine optimum speeds for different compositions and different wheel constructions. Skill of the individual operator is most important. Long experience and care in handling molded parts against high-speed revolving wheels is essential, or discoloration due to frictional burns or irregular surfaces may result.

Articles molded from plastics can be buffed and polished with fabric wheels of the standard types with only the general precaution that a very light pressure be used on the work. If the pressure is too great, sufficient heat may be generated to soften the stock and to cause sticking to the fabric wheel. For general purpose work, a muslin wheel with 1½-in. sewing, operating at 3700 surface ft. per min. may be used. A " Matchless Plastic Buff " is also recommended. A fine compound, such as " Acme White Finish " or " Matchless No. 259 Coloring," will, if used sparingly, produce a good luster.

Where appreciable amounts of stock are to be removed during a polishing operation, particularly for the removal of wheel or machining marks from unfilled compounds, it is best to use a cutting compound such as " Lea Grade F " on a loose cotton wheel operating at approximately 6100 ft. per min. Another buffing compound, " Matchless X-66 Tripoli " composition, is also recommended for this purpose.

" Matchless White Liquid Rouge " can be used to recondition slightly scratched sheets by applying domett flannel, allowing to dry, and then rubbing lightly with a clean piece of the same material.

If the polishing operation can be performed wet, very good results are obtained with a suspension of finely divided pumice in water supplied to a loose muslin wheel operating at a peripheral speed of approximately 6100 ft. per min. A constant stream of water and pumice fed to the wheel produces the best results. This operation is similar to the " ashing " commonly used in the polishing of all plastics, and is the most effective way of obtaining a good surface luster on a production basis..

In dry buffing and polishing articles molded from vinyl plastics, it is sometimes desirable to use wheel impregnants which improve the adhesion to the wheel of those standard buffing compounds just mentioned. This can be accomplished by any one of four methods:

1. Impregnate the cloth wheel with a mixture of 3 oz. of rosin dissolved in 1 gal. of turpentine. Immediately after impregnation, press out the excess solution and place the wheel in an oven at 225° F. Hold at this temperature until the turpentine has been driven off. Three to four hours is usually sufficient, although the wheel may feel soft until it is thoroughly cooled.
2. Add directly to the revolving wheel a block made of parts by weight as follows: 100 of triethanolamine, 202 of stearic acid, and 124 of " Snow Floss."
3. Add directly to the revolving wheel a compound of parts by weight as follows: 144 of rosin, 10 of calcium hydroxide, 23 of cup grease, and 204 of fine pumice.
4. Precoat the cloth wheel with straight carnauba wax.

Polishing operations are generally divided into two classes — rough finishing and fine polishing — depending on the condition of the surface of the article.

1. *Rough Finishing.* Often, coarse tool, file, or sanding marks are made by rough finishing methods. Fine scratches and fine tool marks may be removed by buffing on a muslin wheel. For most buffing in plastics, the use of a soft wheel is recommended. The desired softness can be obtained by several methods, among which are the insertions of spacers between disks and the insertions of sewed muslin. Sewed muslin buffs lubricated with emery cake or tripolin compound of high tallow or stearic acid content give the best cutting action and keep the work cool.

For removal of rough edges on parts molded from canvas base phenolic material, sewed muslin buffs lubricated with emery cake prove satisfactory.

The use of Lea compound grade " C " on " B " loose muslin buffs at 2200 r.p.m. will be found to give a good bright buffed appearance and will greatly eliminate the possibility of burning the work. Soft buffing wheels for polishing are made by the use of spacers between individual buffs. Buffs produced in this manner do not burn work as readily because of greater ventilation between buffs. They also yield easily to curved surfaces.

2. *Fine Polishing.* Fine polishing, usually referred to as coloring, on the buffing wheel is done to give a final wiping or bright luster. (Learock S-28, produced by the Lea Manufacturing Company, is very satisfactory for this purpose.)

Also, the finishing of many pastel colors in urea materials has been carefully worked out, and tinted or colored Learock polishing compounds are available for producing high luster finishes. These materials are also obtainable for special work in any tint.

The Hanson-Van Winkle-Munning Company also makes an excellent line of polishing materials suitable for thermosetting and thermoplastic materials. United Laboratories No. 501 White Coloring Compound has been very successfully used for polishing parts molded of polystyrene.

Buffs made from flannel are often employed in polishing plastics and are operated at slightly higher speeds than in rough buffing. Frequently, stained surfaces can be cleaned, using soapy water solutions and flannel buffs. Final wiping should be done on a clean, dry flannel or soft muslin buff.

Articles produced in properly polished molds require little else than one polishing or wiping operation on the buff. The foregoing, however, is given in detail in view of the fact that the molder is often confronted with the full complement of rough and fine polishing when parts are taken from unpolished or poorly polished mold cavities or in cases where subsequent machining has created smudge and dirt problems.

Machining. *Thermosetting and Thermoplastic Molded Parts.* Most molded parts can be machined — some quite readily. It is important in designing molded parts to eliminate the necessity of all possible subsequent machining operations. However, there are often instances where machining is necessary, such as the drilling of small holes, particularly those at an angle which does not permit ready molding. Also, where accuracy is essential and low tolerances must be obtained, machining is necessary. It is, of course, best to do as little machining as possible on molded plastics in order to avoid breaking through the molded resin surface. If the surface is broken, the part's chemical, electrical or mechanical properties may be impaired.

All plastics are poor conductors of heat. Therefore, heat generated by the friction of cutting tools has to be carried away by the tool, by air, or by applying coolants. Most machining of plastics is done dry. In the thermosetting types of plastics — phenolics and ureas — which frequently contain abrasive fillers, tools are dulled easily. By the improper application of speeds and feeds, tools will even burn. It is important to experiment and to determine the highest speed at which the machine may be operated to avoid overheating of the tool or of the plastic. It will be found frequently that in machining plastics the plastic surface will become heated and rendered gummy, causing tools to build up a film of burned resin which in the case of high-speed drills will cause sticking and possible cracking, with consequent inaccurate work.

Cutting tools possessing the ability to take punishment in hard wear and continued cutting for such long periods, at speeds which would cause failure of ordinary or best steel tools, make it desirable to use tools designed and built for this purpose. Standard " Haynes Stellite " metal-cutting tools are excellent for the machining of all types of plastics and will be found most economical for long production runs.

As in all fine machine work, the necessity of keeping tools sharp and of lapping or honing the cutting edge cannot be overlooked.

Drilling. *Thermosetting Molded Parts.* In order to gain the maximum efficiency in drilling holes up to ¼ in. in diameter, it is recommended that drills especially designed for plastics, as shown in Fig. 16.2, be used. These drills are available in 60 to 90-degree included-angle points with polished flutes, which are wider than the standard machine drill and have a slow helix. Tests indicate that a 60-degree included angle is desirable for sections up to 3/16 in. thick, and a 90-degree point for thicker sections. A slow helix works best for through holes and a fast helix is best on blind holes. A 15-degree lip clearance is provided.

Drills must be backed out and cleared frequently to free chips, especially in drilling deep blind holes. The use of an air jet directed into the hole and on the drill point will increase the production of the standard drill some twenty to thirty times before re-sharpening is required.

Speeds of 100 to 300 ft. per min. are ordinarily used, but for materials containing inert or abrasive fillers a slow speed of approximately 75 ft. per min. should be used.

Thermoplastic Molded Parts. For cellulose acetate and polystyrene molded parts use a slow drill speed to minimize heating tendency. In order to prevent the material from softening, the use of water as a cooling medium may be desirable. It will be found that soap can be used as a lubricant for holes over ⅛ in. in diameter. Chips should be backed out frequently and light feeds should be used to avoid strain and the tendency of the material to chip or develop strain cracks after being worked. In the machining of thermoplastic materials, it has been found advisable to use highly polished or chromium-plated drills to prevent subsequent cracking or crazing of the piece.

Parts molded from vinyl plastics can be drilled in much the same manner as other synthetic materials. Standard drills and the usual feeds are used. For deep holes (holes whose depths exceed twice the drill diameter), it is recommended that drills having extra large flutes be used. For best results, recommendations on drill grinding are available upon request.

Where the drill is relieved to reduce its end resistance, the area of the cutting surface has been reduced to approximately one-third of normal. This, of course, is for the purpose of reducing the amount of heat generated so that faster drilling can be accomplished.

For drilling small holes, speeds of 4000 to 6000 r.p.m. are recommended. It is desirable that the feed be as high as possible in order that the drill may be in the stock for the shortest practical length of time. The shorter the drilling time, the less is the tendency for the bit to raise burrs around the edge of the hole.

If the vertical movement of the drill is operated by a cam, the cam should be so designed as to give the following general action: (1) move the drill to the work as rapidly as possible; (2) move the drill tip slowly, as it starts to work, for about 0.010 in. or until it is through the surface; (3) speed up the feed to the conclusion of the full vertical displacement; (4) dwell 2 to 5 revolutions at the bottom of the hole; (5) withdraw the drill as rapidly as possible.

When the hole is being drilled properly and the operation is most efficient, the chip will emerge in a tight spiral similar to that produced while drilling mild steel. It should be noted, however, that this type of chip is not always produced — the chips are smaller if greater amounts of filler are present in the resin.

In the design of jigs for drilling, close-fitting drill bushings should be avoided. They may increase not only the friction on the drill but also the tendency of the chips to plug up the drill flutes. If the operation is such that a drill bushing is absolutely essential, a floating leaf or templet should be employed. When using a templet, the hole should be spotted with the templet in place, using the drill size corresponding to the final hole size, then the templet should be removed and the hole completed. Pilot holes should be avoided, except in special instances when the hole is to be reamed or counterbored.

High-speed steel drills having polished flutes are generally recommended. The use of soapy water or water as a coolant will also facilitate the drilling operation.

Reaming. *Thermosetting and Thermoplastic Molded Parts.* It is not common practice to ream in molded plastics. Reaming is used primarily to remove light fins or flash in holes.

Where it is necessary to offset tapered holes, or required to remove the core pins in the molding operation, good results can be obtained if an expansion reamer is used. In conjunction with a self-centering floating holder, a fast feed and slow speed — one not over 50 to 100 r.p.m. — should be used. On thin sections not over 1/8 in. thick holes should be drilled within 0.001 in. of size and then, rather than ream the holes, a hardened and polished rod can be used to burnish the holes to the desired dimensions.

Threading and Tapping. *Thermosetting and Thermoplastic Molded Parts.* The use of high speed nitrided and chromium-plated taps would prove best in the threading of small tap sizes with speeds ranging from 40 ft. per min. to 54 ft. per min., using three flutes rather than four, as commonly used in machine work. A negative rake of about 5 degrees on the front face of land will be found to help avoid binding in the holes when backing out. Small holes can be tapped dry. Water proves a better tapping medium than lard, oil, or kerosene. Machine taps 0.002 to 0.005 in. oversize are to be recommended, thus giving 75 per cent of full thread to prevent the tap from breaking. A slight chamfer or countersink avoids up-lifting of material around the edge of the hole. This chamfer should be provided for on the core pins in the mold. In thermosetting molded plastics holes larger than 1/4 in. in diameter should be produced in the mold rather than attempting to thread or tap them later, except where very thin sections are concerned.

Standard machine and pipe tapping and threading dies can be used satisfactorily on parts molded of vinyl plastics. The traverse should be single and uniformly continuous, and the speed, which should be moderate to slow, is again limited only by the rate of heat development. On lathe operations, the threading or chasing tool should be relieved considerably in order to reduce side friction. Any form of thread can be used, but the American National Standard (sometimes called the Sellers or U. S. Standard) for machine screws is probably the most satisfactory.

In the problem of drilling and tapping of small holes in molded pieces, there is always the possibility of using threaded brass inserts. Sometimes on side or oblique holes on molded plastic housings it is desirable to use inserts which later can be drilled and threaded because of the difficulty of flash entering the threaded holes due to their positions in the mold cavity. Another problem confronting the molder is that of re-shaping or re-tapping of threaded holes in the brass inserts or directly in the molded parts which have been already cut. This is sometimes necessary due to shrinkage variations of the finished molded dimension.

Usually, drilling and tapping operations can be expedited by the use of multiple drilling and tapping machines used in conjunction with a suitable drill jig. Tool manufacturers are constantly endeavoring and succeeding in developing drills and taps suitable for use with plastic materials, and it is recommended that these manufacturers be consulted when difficulties are experienced.

Lathe Operations. *Thermosetting Molded Parts.* In turning, facing, and boring operations on thermosetting molded parts, tools having less clearance and more rake than those used for steel or other metals are recommended. Cutting speeds of 200 to 600 ft. per min. are advocated for high-speed steel tools and 500 to 1500 ft. per min. for " Haynes Stellite " metal-cutting tools, manufactured by the Haynes Stellite Company.

Thermoplastic Molded Parts. In the turning of thermoplastic acetate and polystyrene molded parts, tools should have zero rake and plenty of clearance set at an angle of 60 degrees to the spindle. Cuts should be made at a surface of about 65 degrees per min. and a feed of 0.010 in. per revolution. A smooth surface is obtained with a 0.020 in. depth of cut.

For parts molded of vinyl plastics materials simple turning, facing, boring, and chasing operations can be performed satisfactorily with most ordinary metal-cutting tools provided that the front and side clearances of the tool are increased by about 50 per cent over the clearances used to machine steel. The added clearances reduce the rate of heat formation and produce good surface finishes and free-flowing chips. An increase in rake angle, made by hollow grinding the top cutting face, offers some advantages in directing the chip away from the work. However, the accompanying reduction of cutting angle results in a greater tool wear. Surface speeds of between 250 and 300 ft. per min. permit depths of cut as high as ¼ in. and rates of feed up to 12 in. per min. Higher speeds and feeds can of course, be used with lighter cuts.

Cutting-off tools should also be ground with increased front and side clearances, and, in using them, the surface speed should be reduced to approximately one-half that used while turning. Slower speeds tend to roughen the cut surface, whereas faster speeds may cause overheating of the material.

Milling Operations. *Thermosetting and Thermoplastic Molded Parts.* Milling of molded parts is not as a rule feasible, but where it is required, milling speeds and feeds of the range used for brass are recommended. A speed of 400 ft. with carbon steel cutters and 1200 to 1600 ft. are recommended with carbide cutters. Single- and double-bladed fly cutters are sometimes used at high speed with fine cuts. Where little material has to be removed, a high-speed woodworking shaper with a carbide-tipped tool can be used to advantage.

The same general rules that apply to turning, facing, and boring operations also hold for milling parts molded from vinyl plastics. Standard cutters can be used, but higher speeds are feasible if extra clearances are ground on the cutter blades. Here again, it is desirable and may be necessary to use an air blast to assure proper chip removal from the milling cutter. Wherever possible it is recommended that spiral milling cutters be used, and that the number of teeth in the cutter head be such that at least two of them are in contact with the work at all times. Plain cutters are to be avoided, because of overheating caused by side friction. Milling cutters and blades should be given the same general care as turning, facing, and boring tools in order to assure that a minimum of surface friction is developed during machining.

In designing fixtures for milling parts molded from vinyl plastics materials, it is essential that the fixture grip the work in a manner that will not cause distortion of the work. Since parts molded from vinyl plastics materials are less rigid than metals and hence more easily distorted, the stock should be well backed up during the milling operation and should be positioned so that the pressure of the milling cutter is against the backing. When possible, cutters should be operated so that the chips are discharged from the leading edge of the cutter in contact with the work. The use of a cutter in this manner implies that the machine must be in good mechanical condition. Considerably less friction is developed if the cutter takes the heavy part of the chip first, as in climb milling.

Sawing Operations. *Thermosetting Molded Parts.* The sawing of molded thermosetting parts is done chiefly on circular and band saws. These saws are to be recommended at times for straight cutting because they run cooler than circular saws.

Band saw manufacturers advocate saw teeth set to clear, some advocating one-half the thickness of the blade on each side so that saws give a width of cut double their thickness. Narrower saws and more set are needed for cutting curves than for straight cuts. Band saws just soft enough to permit filing are recommended, but saws must be kept sharp. Dull saws, of course, cause chipping and might result in saw breakage. Sawing is usually done dry, but some recommend water for cooling. Saw teeth should have little set and 8 to 9 teeth per inch — turning at 1800 to 2500 ft. per min.

Thermoplastic Molded Parts. Sawing of cold-set polystyrene or cellulose acetate can be done with circular saws having 9 to 12 teeth per inch for thin sheets and 6 teeth per inch for thicknesses over ¼ in. Saws 6 to 9 in. in diameter are run at speeds of 3000 to 3600 r.p.m. and should be hollow ground. They usually are 1/32 to 1/16 in. thick. The use of a water spray gives a cleaner cut. One large saw manufacturer recommends that pieces be cut with a stream of water running in the kerf while the saw is cutting. This applies to both circular and band saws; otherwise, the cold-set type of material will fuse. The circular saws recommended are 14 in., 12 and 9 gauge, 130 teeth, 10 degrees rake to be operated at 3000 r.p.m. and made of a special alloy steel stock.

For band sawing, manufacturers suggest a band saw which is 19 to 20 gauge, having 20 points to the inch and hardened and tempered. It should be operated at 4000 to 4500 ft. per min.

When large gates must be removed, it has often been found advisable to saw them off just after removal from the machine. Portable saw tables which can be placed in a convenient position for the operator facilitate this operation. After sawing, it is necessary to sand or buff the pieces in order to remove the saw marks.

Satisfactory sawing of parts molded from vinyl plastics, like other machining operations, is dependent on the prevention of local overheating and consequent softening of the resin. Anything, therefore, which reduces or dissipates the heat generated is desirable.

Therefore, the most satisfactory method of sawing parts molded of vinyl plastics is with an underwater saw as, for instance, the " Hudorkut " machine. When sawing unfilled resin, this equipment should be fitted with hardened steel saws. The surface speed recommended is 3500 to 4000 ft. per min. (1200 r.p.m. for a 12-in. saw) and the saw should carry 10 to 14 teeth per inch. The teeth should have no set. Good operation indicates an average speed of saw travel through the stock of approximately 3 to 4 in. per min. It is possible, in some cases, to use speeds up to 12 in. per min.

The finish of the sawed surface and the possibility of the stock chipping at the leaving edge are affected by the rate of travel of the saw through the stock, the sharpness of the saw, and whether the stock being sawed is a solid piece or several smaller ones clamped together.

While filled resin compounds can be satisfactorily sawed with an underwater saw in a manner similar to sawing the unfilled compounds, the effective life of the saw is materially reduced by the filler. Fine-abrasive saws are preferable to metal saws. The abrasive saws will produce an equally good finish on the sawed surface at a considerable increase in saw life. Rubber-bonded cutoff wheels are not usable, but resin-bonded saws are perfectly satisfactory. Notching the saw helps to promote self-cleaning.

For smaller production, and where slower cutting speeds are permissible, parts produced from unfilled vinyl molding materials can be sawed dry on band or circular saws such as are commonly used in woodworking. It is imperative, however, to use fine-tooth saws (10 to 14 teeth per inch) with no set. Similarly, filled resin compounds can be sawed dry with abrasive saws, if the grade and grain are such as to cause a minimum of " loading." The special band saws available for cutting other plastics will also work satisfactorily on parts molded from vinyl molding materials.

Cutoff Abrasive Wheels. *Thermosetting and Thermoplastic Molded Parts.* Frequently, the problem of sawing off gates, sprues, runners, etc., is solved with the use of cutoff abrasive wheel machines. The use of cutoff abrasive wheels frequently offers better advantages. These machines are constructed to supply a water feed directly to the wheel and to the work, and foot feeds are constructed so that the operator can handle them very easily and efficiently. Abrasive wheels 4 to 8 in. in diameter and 0.020 to 0.125 in. thick are operated by a one-half horsepower motor. These machines will cut stock up to 1 in. in diameter very rapidly.

MACHINING PLASTICS

Plastics parts, on occasion requiring certain machining operations, differ from metals in two respects. First, they are inherently poor heat conductors. This in itself makes for high localized temperatures resulting in rapid tool deterioration. Second, plastics are heterogeneous and amorphous and react differently to tooling than do the metals which are crystalline in character.

At the outset it is not advisable to machine the thermosetting molded plastics. Wherever possible, the piece should be so designed that such processes are incorporated into the piece during molding. Obviously the laminates must be machined, so must extruded and cast plastics.

Sawing. Ordinary circular woodworking saws may be used for urea and phenolic laminated plastics. Speeds should be between 1500 and 2500 r.p.m. The saws should have a diameter from 12 to 14 in. Sharp saws without any set are satisfactory. Band saws of the woodworking type are satisfactory and should travel at 5000 to 10,000 ft. per min. Blades may be ½ in. wide with 5 points per inch. It is common practice to use 19-gauge blades. For defense materials several inches thick, it is advisable to use a blade with 3 points per inch.

Molded phenolic and urea plastics dull saws very rapidly and burn the points.

The sawing of such materials is to be discouraged because it is not a commercial operation.

Thermoplastics may be readily sawed if the blades have 9 points per inch.

TABLE 92. SAWS FOR LAMINATED PLASTICS[2]

Band Saws

Type of Work	Speed in surface feet per min.	Width, inches	Thickness, inches	Teeth per inch
Scroll	4000–5000	1/4–3/8	0.037	6
Circular disks — up to 5 in. diameter	4000–5000	1/4–3/8	0.037	6
Circular disks — over 5 in. diameter	4000–5000	1/2	0.037	5
Strips or blocks	4000–5000	1 1/4–1 1/2	0.042	5

Circular Saws

Material Cut	Speed in surface feet per min.	Diameter, inches	Thickness, inches	Teeth per inch
Sheet—1/16 in. thick	2500–3000	10	1/16	6
Sheet—1/8 in. thick	2500–3000	14	3/32	4
Sheet — 1/4 in. and over thick	2500–3000	14	1/8	4
Tubing under 1 in. O. D.	2500–3000	15	1/16	8
Tubing over 1 in. O. D.	2500–3000	17	3/32	5

Drilling. Laminated plastics may be drilled with general drilling equipment, but special drills must be used which have steeper twists and wider flutes. This provides for cooler operation and entails less tendency to burn either the plastic or the drill. For small holes, high-speed drills are recommended. In any case, it is always advisable to raise the drill occasionally to cool it and to remove chips.

Molded parts may be drilled to a limited extent with high-speed special alloy drills. Carboloy drills are frequently used but they must be kept sharp and frequently backed out of the hole.

Cast parts may be readily drilled.

The thermoplastics, however, offer more difficulty and it is important to control the speed of drilling and the rate of drill feed. If the thermoplastic gets warm, it will clog the flutes creating tearing, and result in oversized holes. Generally, 500 r.p.m. is the correct speed.

Turning. Laminated plastics may be turned on the usual woodworking or metal-working lathes. They react much like brass. Turning tools should have a slight top or negative rake, and will help produce a better looking finish. As a rule, a speed of 250 to 600 ft. per min. is recommended for turning.

Thermoplastics may be turned, and for this operation, tools should be held at a negative angle.

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[2] Laminated plastics may be sawed with circular or band saws, the latter being used for other than straight cuts. Reprinted from the *American Machinist*, June 28, 1939.

Punching. Laminated materials may be punched but the degree of success depends largely upon the thickness of the piece and the proportion and type of binder. About 1/8 in. is the maximum for satisfactory punching operation. Some grades of phenolic may be satisfactorily punched cold, while with others it is better to heat the material or dies. There is a shrinkage of the punched hole (3 per cent) so it is advisable to use a punch somewhat larger than the desired hole.

Compression-molded thermosetting materials cannot be readily punched.

Thermoplastic sheets can be easily punched.

The N.E.M.A. lists the following punching properties of various grades of laminated phenolic plate:

TABLE 93. LAMINATED PHENOLIC PLATE — PUNCHING PROPERTIES OF VARIOUS GRADES

Grade	Comparative Rating	Maximum Thickness in Inches at Which Satisfactory Results May Be Expected — Using Good Punching Practice	
		Room temp.	Heated to 120°-140° C. (250°-280° F. approx.) before punching
X	Not quite so good as XX for hot punching	1/32	3/32
P	Best paper base punching grade, does not require quite so much heat as other grades	1/16	1/8
XX	Good hot punching	1/32	3/32
XXP	Better than XX for intricate shapes	1/32	1/8
XXX	Poorest paper base grade from punching standpoint. Use only where essential from moisture resistance and cold flow	..	1/16 (simple shapes, compound dies only)
XXXP	Almost as good as XXP in punching but more brittle	..	3/32
C	Excellent punching, but rather coarse edges	1/16	3/16
CE	Good hot punching in thin sizes	..	3/32
L	Best cold and hot punching grade, better edges than C	1/16	3/16
LE	Good hot punch grade, better edges than CE	1/32	3/32
A	Poor punching quality	..	1/16 (simple shapes only)
AA	Poor punching quality and coarse edges	..	1/16 (simple shapes only)

Shaving. Shaved outside edges, particularly in thicknesses over 3/32 in. are sometimes desirable. Shaving cutters are hollow dies in the desired shape with a 45° bevel cutting edge brought to a sharp edge. The material is forced through the die by the use of a brass or soft steel plunger in the ram of the punch press. The work should be well heated and oiled.

Shearing. Shearing of laminated sheets can be done successfully on metal squaring shears with a straight knife. In general, all grades should be sheared hot in thicknesses over 1/32 in. In such cases the stock should be treated to approximately 280° F. Softer grades will require a lower temperature and some of the punch stocks may be sheared cold in 1/16 in. thickness. Cloth base grades may be sheared cold up to and including ⅛ in., but in thicknesses over 3/32 in., smoother edges are obtained by sawing.

Tapping and Threading. This operation at best is difficult and various manufacturers resort to different methods for producing the desired results.

The same type of tool may be employed as with metal, with the exception that the drill used for the hole should be slightly larger than for metals to obtain best results. Lubricant should be used in all tapping operations.

Milling cutters at high speed and with adequate clearance will give most satisfactory work on rods or tubes. Self-operating dies, in general, are more satisfactory unless for small work. For very fine threading a single-point lathe tool may be employed.

Drilling.

1. *Laminated Plastics.* The lip should be ground thin, with little rake. Plenty of clearance tends to prevent splitting and grabbing. It should not be forced; the drill should be kept sharp and light pressures used. Since the material shrinks, a slightly oversize drill should be used. Through holes should be backed with solid material below or jig plates used above and below. When drilling parallel to laminations a flat or " bottom " drill may be used to avoid splitting.

2. *Cast Phenolics.* Drills sometimes cut about 0.003 in. undersize. The highest possible speed which will not burn should be used and backed out often. Negative rake helps to clear the drill. A drill ground as in Fig. 16.2 sometimes is used for drilling small holes, as in buttons. A half-round drill or boring tool, ground as in Fig. 16.3, is useful in drilling deep holes when the work is turned, as in a lathe.

3. *Thermoplastics.* For *acetate,* standard drills are satisfactory, but a long tapered point is desirable. Avoid overheating and gumming at the point. Oil aids in producing smoother holes and helps to keep the drill cool. For acrylic, standard drills and feeds are satisfactory. Soap should be used as lubricant for holes under ⅛ in. in diameter. See the following table for recommended drilling speeds.

Drill Size, Inch	*Speed, r.p.m.*	*Feed per Rev. Inch*
1	750	0.014
¾	1000	0.012
⅝	1200	0.011
½	1550	0.010
⅜	2000	0.008
¼	3000	0.006
3/16	4000	0.005

GRINDING, POLISHING, AND BUFFING

Grinding operations are commonly employed to remove parting lines, truing cast rods, and for the removal of rough edges, saw marks, and the like. Grinding operations should be kept to a minimum particularly on molded thermosetting compounds. With phenolics there is a tendency to expose the filler and with urea, there is an aftereffect — crazing.

Centerless grinding operations are extensively used for the removal of taper from cast articles.

Grinding of plastics (using a wheel instead of abrasive paper or cloth) is done on machines similar to those used for metal. On laminated plastics it is recommended that plenty of water-soluble lubricants or kerosene be used to wash away grindings and keep the wheel free.

Sanding. Sanding with abrasive belts is done extensively on both molded and non-molded plastics. On the former it is used for fin removal, facing and the like, and on the latter for facing and shaping surfaces. The cast phenolics and some other cast materials also are shaped on disks faced with sand or garnet paper. The following practice is recommended:

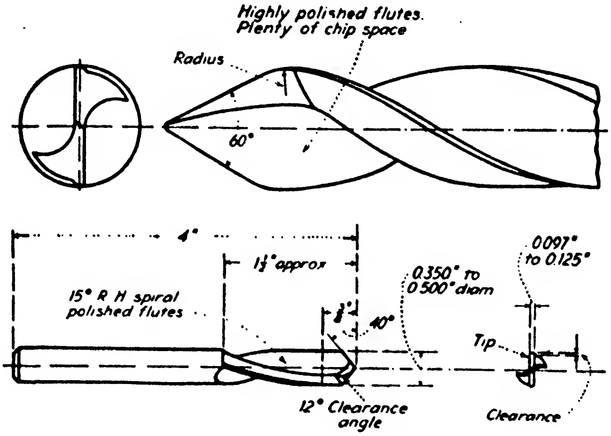
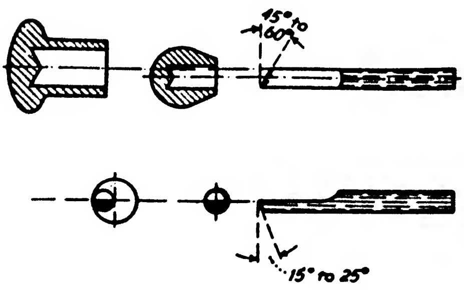


Fig. 16.2 — Drills for plastics usually have 60-90 degree included angle points and highly polished flutes. This drill is recommended especially for drilling thermosetting plastics. Carbide-tipped drills often are used for plastics, many of which contain highly abrasive materials. The drill shown was designed especially for laminated plastics. In this drill the web is ground to 0.015 in. at the point and increased to 0.060 in. within ⅛ in.



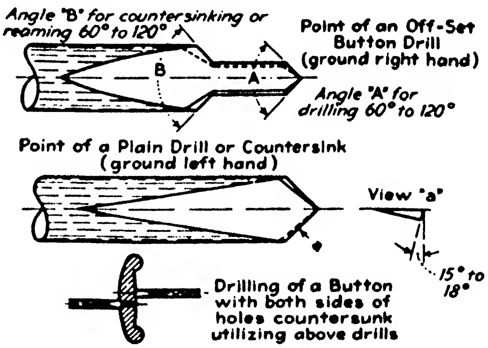


Fig. 16.3a — Half-round drills of the type shown are useful when drilling or boring deep holes in cast phenolics. Sketches at the left indicate maximum and minimum diameters which can be drilled or bored in one operation.

Fig. 16.3b — For small holes, as in buttons, drills of this type frequently are used when drilling cast phenolics. Drills and counter-sinks frequently are used in pairs as shown in the lower view.

1. *Molded Phenolics.* Common grit is No. 60, but for rough operations No. 30 is used. No. 320 abrasive cloth is used on disks where minimum disturbance of the resin surface is essential.

2. *Cellulose Acetate.* Belt running at 3000 ft. per min. recommended often with coarse grit followed by fine. Overheating should be avoided.

3. *Cast Phenolics.* Speed should be the same as for sanding wood. Garnet paper clogs less easily than sandpaper. Overheating must be avoided. One fabricator uses 8-in. diameter disks of Nos. 00 and 0 sandpaper, turning at 4500 to 7000 r.p.m.

4. *Laminated Phenolics.* Sanded with No. 220 grit and buffed with tripoli or with polishing compound.

Tumbling. Urea moldings are usually tumbled in barrels containing maple pegs saturated with waxes.

Tumbling in pumice and then in polishing compounds often is done on small plastics parts as a substitute for, or supplement to, wheel ashing and polishing. Tumbling also is done extensively, especially on thermosetting moldings, merely to remove thin fins. As a rule, the dry process is employed, but for cutting down with pumice and for subsequent polishing on acrylics, tumbling in wet pumice is advocated.

Recommendations on Polishing Compounds for Tumbling of Urea Moldings

1. Use a mixture of 60 per cent winter wheat and 40 per cent maple pegs, ⅛ in. square and ½ in. long. The pegs may be purchased, among others, from E. B. Esters & Sons, New York City. This mixture is put in the barrel to a level of about 3 in. below the shaft. Then add ½ pt. of hot turpentine, and tumble for ½ hr. Repeat this process until 1 qt. of hot turpentine has been added. After the last addition of turpentine tumble the barrel 4 hr. The buffing compound is made of 4 oz. carnauba wax, 2 oz. whiting and ½ gal. of turpentine. First melt the carnauba wax, add this to ½ gal. of hot turpentine, add whiting and stir thoroughly.

2. Put ½ pt. of hot, mixed buffing compound in barrel and tumble for 1 hr.

3. If mixture and barrel are wet at the end of this operation, dump the mixture and allow to dry. When dry it is ready for use.

Repeat step 3 when material ceases to buff moldings properly.

Polishing and Buffing. Polishing and buffing are carried out on nearly all types of plastics, either to improve the finish, as on some molded parts, or to remove sanding or tool marks left by preceding operations. Special compounds containing wax and sometimes a fine abrasive are used for polishing. Similar materials are used for buffing.

1. *Molded Phenolics.* Muslin buffs 8 to 14 in. in diameter turning at about 1800 r.p.m. followed by a flannel buff for coloring. Chrome polish helps to bring up luster on surfaces previously sanded.

2. *Cast Phenolics.* Ash with No. 00 wet pumice in 12-in. soft muslin wheels at 1700 to 2500 r.p.m. Some advocate a stitched muslin wheel. Polishing is done on similar soft, unstitched muslin wheels after washing the parts free of pumice.

3. *Cellulose Acetate.* Ash wet, usually with Nos. ½, 1 or 1½ pumice or a mixture of these grades, on soft muslin wheels ranging from 12 to 14 in. in diameter and turning at 1200 to 1500 r.p.m. Pieces should be washed and dried promptly. Quicker work can be done in some cases on corn husk or carpet wheels. Buffing, in which some cutting occurs, sometimes is done on 12-in. wheels at 800 to 900 r.p.m., using red tripoli. Luster is brought up usually on soft muslin wheels of 12-in. diameter turning at 1200 r.p.m.

4. *Laminated phenolics.* After grinding or sanding with No. 220 grit, cotton buffing wheels with tripoli or other polishing compounds will restore luster. Buffing without prior sanding can be done with tripoli to restore surfaces which have not been scratched too deeply in handling.

FINISHING AND ASSEMBLING CAST PHENOLICS[8]

Lathe and Screw Machine Production. Regular machine-shop equipment is used in producing parts from cast phenolic, involving only differently ground tools and ranges of feed and speeds adjusted to the requirements of the material. There are few hard and fast rules governing the machining, but high speeds and light cuts are preferable in general. Nearly all work is done dry, although coolants of the non-alkaline type may occasionally be employed. In producing parts on an automatic screw machine, where the taper common to rod stock may hamper the feed of material, the rods may be obtained centerless ground to close tolerance and uniform diameter.

In turning, tools are sharpened as for brass work. There should be plenty of clearance, 18° to 20°, and a slightly negative or zero rake. The tool should be set at right angles to, or 1° to 2° above, the center of the material. Cutting edges should produce long ribbon shavings. Tool honing is of advantage for the smoothest cuts. Special grades of tool materials are not required although many hard bronze tools are employed. These have the advantage in that they may be filed in the holders.

Stellite cemented carbide or high-speed tools may be used when it is desired to get the longest possible runs without resharpening or resetting.

Spindle speed in turning operations ranges from about 450 to 6000 r.p.m., depending on the specific work being done and the diameter of the material, and should be regulated to a surface speed of 600 ft. per min.

In general fabricating practice, the use of large lathes is avoided wherever possible. Through the application of a little ingenuity, operations may be reduced to their simplest form and frequently executed on bench lathes or similar light and flexible equipment.

Jigs are, of course, invaluable in securing fast and accurate production. With tools properly set, sharpened, and fed, screw machine or lathe production may go directly into the first stage of the hand polishing or tumbling operation.

Where large production is required, especially in the formation of beads and other turned pieces, cast phenolic is worked on automatic abrasive forming machines. These machines usually comprise two stone wheels from 6 to 10 in. in length and from 4 to 6 in. in diameter revolving in opposite directions and parallel to each other.

One stone acts as a stop and guide and therefore has a flat surface, whereas the other is formed with diamond cutters into multiples of the shape of the part and functions as the actual cutting unit.

The rods, after being previously cut to convenient lengths, are placed in a hopper and automatically dropped between the stones. The constant flood of water removes the cuttings, cools the material and prevents the stone surfaces from becoming clogged. Thus, the rods are quickly and smoothly formed into from three to fifteen or more units depending on the length of the rod.

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[8] Originally written to cover Catalin but applies to cast phenolics in general. Prepared in co-operation with Catalin Co. engineers.

Drilling and Carving. For small holes, drill speeds of about 2800 to 12,000 r.p.m. are commonly used. Drills of ¼ in. in diameter and over should have large flutes for efficient material removal, and cutting edges should be ground with a negative rake.

Turned parts, requiring center holes, are drilled while being turned by means of a turret head attachment, whereas odd-shaped castings or parts are easily drilled with the usual type of high-speed vertical drill.

Cast phenolic may be easily tapped on vertical or horizontal tapping machines. Standard taps are used, and greater strength is obtained by using fairly coarse threads. Tapped holes should be checked with plug gauges, because the abrasive action of the material causes wear.

Carving is done with rotary steel cutters fastened to the end of a small motor shaft. Cutters average about 1 in. in diameter and rotate at about 2200 r.p.m. The number of teeth in 1-in. cutters is usually 20 to 36. Because they make possible a greater accuracy and effect substantial time savings, the use of portable carving units is gaining in popularity.

Forming Cast Phenolic. In general fabricating practice, it is often necessary to curve or shape cast phenolic sheet and rod stock to various radii. Provided the radius is not less than ½ in., depending on the thickness of the material, this can be accomplished readily by heating the material to about 180° F. in hot water until it is of the same temperature all the way through and then placing it over or about the form and allowing it to cool. Inasmuch as hot water does not harm the finish, it is advisable to polish the material before forming. It will expand somewhat at this high temperature but will return to its original dimensions when fully cooled.

Cutting and Sawing. Of all machines used for cutoff purposes, those employing abrasive cutoff wheels are most widely used. They involve a high-speed spindle, to which is fastened the abrasive disk (mounted to a swinging arm on the other end of which is the motor). The weight of the motor acts as a counterbalance and permits the operator to feed the wheel down into the cast phenolic, which is held in place by hand against adjustable stops governing the angle of the cut and the thickness of the blank. A flood of water on the material prevents scorching and produces a smooth, easily polished cut with a minimum of waste. This equipment is used extensively for cutting button blanks and handles from profile-shaped rods or slabs.

Most of the cutting disks range from 0.020 to 1/16 in. in thickness, and from 5 to 20 in. in diameter. The spindle speeds range from 3500 to 6000 r.p.m., depending on the diameter of the cutting disks. The rate at which blanks are produced varies with their diameter, ranging from 20 per min. to 250 or more.

A hand-operated adaptation of the abrasive forming machine is available for use in multiple cutting of round and rectangular rods. This machine will cut simultaneously 40 poker chips, 1½ in. in diameter by ⅛ in. thick, at a rate of 10,000 per hr. Rectangular shapes, such as mah-jong blocks, dominoes, cutlery handles, etc., can be cut ten times faster than with a single-blade cutting machine.

Sawing is done at 1200 to 1300 or more ft. per min. The saw may be circular, jig, or band type, and the set of the teeth should be just sufficient to permit proper clearance. Best finish results are obtained on a band saw with 14 to 15 teeth per inch. On a jigsaw the generally accepted blade for intricate work is a No. 3 jeweler's blade with 22 teeth to the inch, and No. 4 or No. 5 blade for production or stacked work.

Polishing Cast Phenolic. Hand polishing of cast phenolic is usually done on a 2-hp. double-spindle buffing lathe equipped with soft muslin disks 12 to 14 in. in diameter, which will run at a speed of 1500 r.p.m. However, any common buffing head with that wheel equipment may be employed.

The first operation is ashing. This is done with a mixture of No. 00 pumice and water, mixed to a thick paste, which is applied frequently and generously to the wheel and the work. After a few brisk rubs the parts should be rinsed in water to remove all traces of pumice.

The next operation is done on a second wheel like the ashing wheel to which is applied special cast phenolic polishing compound or tripoli.

To harden the finish and remove any excess polish, a final buffing operation on a dry, clean wheel produces a permanently lustrous finish.

Sanding Cast Phenolic. It is seldom necessary to resort to " sanding " the surface of well-machined pieces, but sanding can be done on the flat or convex surfaces with garnet or sandpaper, which can be used in belt form or in rotating disks. The finer the paper and the slower the cutting, the less pronounced are the abrasive marks. Facets and other surfaces can be cut in this way, but in all cases care must be exercised to avoid overheating the work, since such " burning " may result in discoloration. The surface speed in sanding cast phenolic is about the same as in wood sanding.

Tumble Polishing. Tumbling of cast phenolic parts is more commonly used than the more expensive hand operations already described. Because of the number of variables involved in tumbling practice, it is much better to run tests or have them made by specialists in the field than to follow any set rules. However, the following instructions have been used extensively by large manufacturers, and with a few modifications, may be made to fill most tumbling requirements.

Wet Tumbling. If the articles to be polished are very rough, or if the generation of heat is undesirable, wet tumbling should be the first operation. For small lots it is advisable to use a 10- or 15-gal. keg, mounted so that rotation is end over end. A square barrel of the same capacity, made of soft wood, will also serve, and each should be watertight with a watertight cover. In no tumbling operations should the barrel be loaded above the center line.

In loading all barrels, 4 oz. of FFF pumice should be mixed with each standard water pailful (12 qt.) of parts and just enough water to cover the articles. Where heavy grinding is necessary and the articles will withstand it, about 2 qt. of coarse 1-in. diameter gravel should be added to this mixture.

At 30 r.p.m. a good mat finish will be had in about 1 hr. running time, and the load should be thoroughly washed and dried immediately to remove all pumice or gravel.

Dry Tumbling. In most cases, wet tumbling is unnecessary, particularly if the parts have been well machined, and the following dry tumbling instructions will apply:

This operation is the equivalent of the ashing operation in hand polishing.

Use a hexagonal or octagonal hardwood barrel, operating at 30 r.p.m., from 5 to 12 hr., depending on the condition of the articles. It should be loaded with 3 parts pegs, 2 parts articles, 1 cup of FFF pumice, and 1½ cups of flushing oil or paraffin oil.

At the end of the running time, the articles should be thoroughly cleansed of pumice, using kerosene-soaked sawdust (2 qt. of kerosene to 12 qt. of coarse hardwood sawdust) in a small barrel or keg operating end over end for about 5 min. Proportions of half sawdust and half articles should be used. The parts should then be removed from the sawdust, which may be used again, and thoroughly dried.

Grease Burnishing. Pegs used in wax burnishings, which have outlived their usefulness, can be employed in this operation. If new pegs are used they should first be wax treated (see Wax Finishing).

The barrel should be loaded with 3 parts pegs, 2 parts articles, 1 pt. of grease sawdust, and 1 cup of precipated chalk. This will diminish the grease film, and the finishing operation will not be so long. One hour before taking the articles out of the barrel, add another cup of precipitated chalk. The finish can readily be determined by wiping one or two articles on a piece of cloth. They will show a luster after the grease film is removed, which indicates their progress. From 3 to 12 hr., running time at 30 r.p.m. will be required, depending on the size and condition of the articles.

GREASE SAWDUST MIXTURE FORMULA

One bag coarse, dry, hardwood sawdust, lb.	100
Precipitated chalk (325-mesh), lb.	25
Double ground tripoli, lb.	5
Beef tallow (inedible rendered), lb.	20
Flushing oil, qt.	2

In preparing the grease sawdust, proceed as follows:

Use the barrel in which the grease operation is performed. Put in one bag of sawdust, then add tripoli and precipitated chalk, and allow barrel to run for 5 min. or until thoroughly mixed. Melt beef tallow and flushing oil, and while hot, add the treated sawdust and run for 10 min. Remove the mixture from the barrel and use as directed, storing unused portion in covered container.

Wax Finishing. Pegs in this operation should be new, clean, free from dust, and stored in covered containers.

To every 25 lb. of new pegs, add (while hot) 4 oz. of wax mixture and about 2 oz. each time they are treated thereafter. Pegs need only to be treated about once a day with continuous use and can be allowed to run until they have a slippery and glossy appearance. Do not add wax while articles are in the barrel.

An octagonal hardwood barrel, equipped with four screened sides, loaded with 3 parts pegs and 2 parts articles, and operating at 30 r.p.m., will furnish a high luster in from ½ to 1½ hr. running time.

WAX FORMULA

Stearic acid	4 oz.	Carnauba wax	4 oz.
Spermaceti	4 oz.	Flushing oil	4 oz.
Paraffin wax	4 oz.	Beeswax	2 oz.

The ingredients should be melted, thoroughly mixed in a 1-gal. can, and diluted with enough turpentine to fill the can. On cooling, it will harden and should therefore be heated before using. The barrel in which this operation is performed should be cleaned occasionally with a cloth soaked in turpentine and used exclusively for this operation.

Shrinking Cast Phenolic. The problem of permanently fastening cast phenolic handles or knobs to metal shanks is solved by shrinking. In the assembly of cutlery handles the hole to receive the tang is drilled about 0.006 in. smaller than the diameter of the tang. The handle is then immersed in water to the depth of the hole, subjected to a temperature of 180° F., and allowed to remain long enough for the immersed part to become thoroughly heated.

While still hot, the tang may be easily pushed (but not forced) into the hole and allowed to cool. If the tang is knurled, a permanent nontwist and nonslip grip is assured. This principle applies to all shrink-fit assemblies, whether tangs, inserts or bushings.

Many of the following processes, although described for cast resins, apply also to laminates.

Printing Cast Phenolic. There are many and varied types of machines available for imprinting cast phenolic to the manufacturer's requirements.

Although specifications are varied, the theory of operation is the same. Roll leaf, composed of either metallic or pigment colors mounted on paper tape, is placed on a bar in front of the head of the press, providing a means of carrying colors through the machine. The leaf winds down underneath the die, which is attached to the head, and into the roll-feed attachment which is gauged to pull as much leaf as is necessary for a particular impression. Thus, new leaf takes the place of the old at each impression. It is possible to transfer the leaf with heat. The head of the press is therefore electrically heated and controlled by a switch, or thermostatically controlled to ensure uniform temperature at all times. Machines are equipped with various mechanical handling and compensating devices which take care of any variations in thickness and shape of the article being stamped. Most platen presses in good mechanical condition can be equipped with a roll-leaf attachment and can produce first-class hot stamping or embossing.

Flat stamping may be done with dies that are usually attached to the press by screws or, if they are ¼-in. dies, by gluing to the die plate. Dies that are actual type or type-high may be inserted in a special chase and locked in position.

Inlaying Cast Phenolic. Of the many methods of inlaying, the most practical for use with cast phenolic is a recently patented process that involves four steps:

First, a recess following the design of the inlay is made in the material with a pantograph or engraving equipment.

Second, a thin strip of metal about half as thick as the depth of the recess is placed in the bottom of the recess.

Third, the inlay, which is slightly convex (or concave on the back), is placed above and supported by the thin metal strip, which is harder than the inlay.

Fourth, with pressure applied to the top, the base metal causes the inlay to spread out on all sides, penetrating the walls of the recess and permanently locking the inlay in place.

Engraving Cast Phenolic. Using conventional tools and methods, cast phenolic lends itself admirably to hand engraving, but in mass production this operation may prove expensive. Machines have therefore been developed to operate on the principle of the pantograph, and engraving is accomplished by cutting the letters or designs with a rotating cutter driven by a standard motor. After the design is cut (approximately

0.005 to 0.015 in. deep) it is filled in with gold, silver, white paste, or lacquer, according to the contrast desired.

The machine will engrave flat, curved, or oval surfaces and the result is permanent since it is cut with sufficient depth to prevent the wiped-in color from wearing off.

Metal-plating Cast Phenolic. Because of its nonporous surface, cast phenolic is not easy to plate with metal, but patented solutions have been devised which render these surfaces capable of taking electroplate and retaining it.

The treating method is comparatively simple and may be accomplished in any shop equipped with electroplating apparatus. The articles to be plated are first cleaned, then placed in a bath of the patented solution where they are agitated by compressed air for about 1 hr. After this, they are re-rinsed and placed in a second bath of another patented solution where they are tumbled about 5 or 10 min. Rinsing again prepares them for the plating bath. Surfaces may be entirely plated, or they may be masked out to take the plating wherever it is desired.

Die-cutting Cast Phenolic. Because cast phenolic may be secured in a wide variety of special profile-shaped rods from which blanks of any desired thickness may be cut or sliced, it is rarely economical to die-cut sheet stock.

However, when production requirements are too high for jig-sawing and too low to warrant the investment in dipping arbors, die-cutting offers a practical solution.

Sheets thicker than 3/16 in. cannot be die-cut, but for stock of that dimension or thinner, satisfactory results may be obtained by heating the material to about 150° F. and stamping it with a steel-rule die.

METAL–PLATING PLASTICS

The production of hard metallic films of any desired thickness directly on the surface of plastics materials is made possible by the intermediate formation of a very thin metal deposit which acts as a base for the final deposit. The process is applicable to all the usual organic plastics: Celluloid, cellulose acetate, phenolics, ureas, casein, and rubber, as well as wood and papier-mâché. The well-cleaned surface to be plated is first exposed to the action of reducing chemicals, such as hydroquinone, pyrogallol, stannous chloride, and ferrous sulfate, preferably in a liquid medium which will exercise a solvent or swelling action upon the plastic and promote imbibition of the reducing agent. As example the following detail for one plastic is given.

Method for Copper-plating on Urea-formaldehyde. If the surface was originally polished, it must first be roughened by immersion in 10 per cent HCl and the piece washed with water before being placed in a 1 per cent ammoniacal ferrous sulfate solution for 15 min. The piece is then washed and placed for a short time in a 2 per cent solution of copper sulfate at 30° C. Further washing is followed by a vigorous reducing treatment by immersing the piece for 1 hr. at room temperature in a solution containing 800 cc. of water, 30 gm. of stannous chloride, 10 gm. of hydroquinone, 5 cc. of hydrochloric acid, and 200 cc. of ethyl alcohol. The plastic is then washed thoroughly and transferred to an ammoniacal silver nitrate solution (0.5 gm. per liter) in which it is left for a few minutes. All excess reagents are then washed away thoroughly first with water and then with a dilute solution (2 gm. per liter) of sodium lauryl sulfate. A very thin metal deposit or " haze " is left on the surface, capable of taking a much heavier, complete metal coating.

The final coat is deposited from a bath composed of 28 gm. of crystalline copper sulfate, 12 gm. of caustic soda, 36 gm. of seignette salt, 30 cc. of formalin, 750 cc. of water, and 0.3 gm. of sodium lauryl sulfate.

Plating is carried out at 25° C. (77° F.) for a time ranging from a few minutes to several hours depending on the thickness of the film desired. The coating serves as an excellent electrical conductor and may serve as a foundation for other coatings of other metals to be deposited by standard chemical or electrochemical processes.

Metalized plastics in many applications have advantages over plated metals. Acrylic resins electroplated with narrow bands of metal are used for electrostatic shields to cover the directional loop radio antenna on Northwest Airlines' Lockheed planes and have proved better than metal. For jewelry, cigarette holders, razors, fountain pens, and similar articles, metalized plastics are lighter, usually cheaper, and in some cases more efficient than metal.

One of the greatest economies expected from the process is in making false teeth. Gold- and silver-plated false teeth can now be produced that weigh less and cost less and have the advantage, not destroyed by plating, of heat insulation for the protection of the delicate tissues of the mouth.

The bond coat[4] applied to the plastic to make the metal adhere to its glossy surface consists of two chemical substances applied separately by tumbling or agitation, and gives the plastic a smoky gray surface which, when immersed in the plating bath, has a natural affinity for metal plate. A plating of any thickness up to 1/100 in. can be applied, but usually 1/3000 in. is sufficient for commercial wear.

FORMING CELLULOSE ACETATE SHEETS[5]

As an example the sheets of one manufacturer are described here. These are clear transparent, cellulose acetate base thermoplastic sheets ranging in thickness from 0.050 to 0.125 in. and over. Flat sheets can be readily formed into two- or three-dimensional forms after softening by means of heat. At the proper forming temperature the surface of the sheets does not unmold and show return of the original sheet lines.

Innumerable shapes can be made by working the heat-softened material on suitable forms, molds, or special devices. Examples of formed pieces are airplane cockpit enclosure sections, gas mask face pieces, gas mask eyepieces, helmets, etc. Each particular shape presents an individual problem, some of which are apt to challenge the ingenuity and resourcefulness of the fabricator. For this reason it is impossible to set up in detail specific methods of forming.

Heating. The first step in a forming operation is to heat the material to the forming temperature so that it becomes soft and pliable. The material has a forming temperature at about 250° F. The sheet or blank is hung vertically in an air oven heated to a temperature of 250° to 275° F. until sufficiently soft for forming. The time of heating will vary depending upon the thickness of the stock, and may range from 4 to 10 min. for sheets in thicknesses from 0.050 to 0.125 in. Over-heating should be avoided. The important factor is to control the temperature and time of heating to obtain the proper softness without unmolding or otherwise marring the surface. The sheets may

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[4] Patented.

[5] Prepared by the Plastics Division, Celanese Corporation of America.

be heated for 15 min. at 250° F. without surface impairment. Sheets or blanks, particularly in the softened condition, should be handled with clean cotton gloves to prevent finger impressions, and it is good practice to handle them along the marginal edges.

Bending. To bend flat sheets into shapes of single curvature a form is used. The form is usually made of hard wood or a smooth metal, and is covered with a soft cloth such as billiard-table felt. A softened blank is taken from the oven and immediately placed on the form. One edge may be clamped under one edge of the form. The blank is then drawn down smoothly over the form and clamped under the opposite edge. The material is then allowed to cool to about room temperature before it is removed from the form.

One variation of the above method is to hinge along one edge of the form a flexible metal or fabric band covered with billiard-table felt. The band is as wide as the form and at least as long as the peripheral length of the curved surface. It is provided with a clamp to fasten to the edge of the form opposite the hinged edge. A softened blank is placed on the form with one edge close to the hinge. The flexible band is then pulled over the form and clamped down so as to press the blank smoothly against the form. After cooling, the band is released and the formed piece removed.

Bends in two directions may also be made. In this case when the softened blank is drawn across the form it will bridge the low areas. It must, therefore, be pressed in against the form at these areas. This may be done in several ways, such as by means of hand rolls, by fluid pressure exerted through a flexible or elastic membrane, by curved blocks or by other means. It is important that the shaping be done as quickly as possible, while the material is in a softened condition, and that the material be held against the form surface until cool enough to hold its shape. Care should also be taken against mechanically marring the surface of the stock.

Curved surfaces may have a slight tendency to unform after removal from the form, particularly if formed at too low a temperature or, if not cooled sufficiently long on the form. This is usually of no great importance because the material is sufficiently flexible at normal temperature to be fitted into supporting frames. If the formed piece is to be unsupported, and if an objectionable spring back is experienced, it can be compensated for in the design of the form.

Drawing. Dome shapes and complicated three-dimensional shapes can be formed from acetate sheets by drawing and forming operations. The most suitable method of forming will depend upon the size and shape of the piece, the amount of draw and thickness of the stock. Shapes having only a slight curvature can frequently be formed by draping a heat-softened blank over a wooden form covered with billiard-table felt, and drawing the blank down around the edge of the form.

For a deep draw, a forming die mounted in a hand or power press is used. In its simplest form the die consists of an open, metal die plate, a metal stripper or hold-down plate, and a shaped former or plunger. The shaped former may be polished metal or smooth hand-polished wood. The opening of the die plate and hold-down plate corresponds to the projected dimensions of the former plus an allowance for the thickness of the stock with about 0.500 to 0.010 in. over for clearance.

A heat-softened blank from the oven is placed between the die plate and stripper plate. The former or plunger is then lowered by means of a hand lever or by power so that it passes through the die plate, drawing the stock around it. The plunger is held at the end of the stroke until the stock cools sufficiently to set. The plunger is then withdrawn and the piece removed from the die. There is a flange left on the piece between the die and stripper plates that must be cut off. The rate of drawing is best determined by experiment. It should not be so fast as to tear the stock or so slow as to permit premature cooling of the stock. The stripper plate should exert sufficient pressure on the blank to keep it flat, but it also should permit the stock to slip into the die as it is drawn.

With some irregular shapes, the stock during drawing will bridge over indented areas on the former. In this case it is sometimes possible to place an elastic rubber membrane or a heavy sponge rubber pad under the die, so as to force the stock into the indented areas as the plunger is lowered.

Polished chromium-plated metal molds with shaped mold cavity, plunger, and a stripper plate may also be used. If they are ported for heating and cooling, the molding or forming cycle can be appreciably shortened. Molds of this type are very costly and are generally only warranted when a fairly large production is required.

Machining. Machining operations on acetate sheets are similar to those performed on wood and soft metals. Cutting tools such as band, circular, or jig saws should have little or no set. Ordinary wood or metal drills may be used. The pressure on the drill should not be so great as to cause high frictional heat which will gum up the shavings. Holes should be drilled oversize to permit the slight expansion and contraction which may result from wide fluctuations in atmospheric conditions. As the acetates are thermoplastic, an important factor in machining is to control machine speeds and feeds so that the material does not heat up excessively and soften. Machine operations should not be made on the stock when it is too cold. Sheets should be permitted to condition in a room at about 70° F. or over for about 24 hr. before machining.

Polishing. When forming and machine operations have been completed it is generally desirable to remove scratches or tool marks from the piece and bring out a high polish. This is done on buffing wheels. The following procedure is suggested:

A buffing wheel is made up of 12 in. and 15 in. muslin disks, two small disks alternating with two large disks so that the wheel will not be too hard. In this way the wheel is built up to a width of 4 in. or more depending upon the size of the article to be polished. The buffing wheel is run at a speed of about 1450 r.p.m. The following materials[6] are used:

Muslin disks	Grade L
Cutting compound	No. 1402
Wiping compound	No. 2011

The No. 1402 compound is applied to one wheel and the No. 2011 to a second similar wheel. The article is buffed first with the No. 1402 compound to remove scratches. The smudge is then removed on the second wheel with No. 2011 compound. If a higher polish is desired, the article may be wiped with a softer wheel using no compound. A softer wheel is made up by adding three small spacer disks between two 12-in. muslin disks. Buffing wheels must be kept clean and free from crusty surface.

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[6] These compounds are supplied among others by the United Laboratories, Inc., North Linden, New Jersey.

Fig. 16.4a — Connection made by forcing a plastics sheet into an aluminum H-section. Packing is a rubberized fabric.

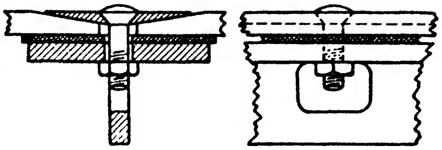

Fig. 16.4b — In thicker sections, where the edge of the sheet is beveled, a double-wedged top metal strip can be used, leaving the outer surface smooth. Base channel to which sheet is bolted is an extruded T-section with cutouts in the web for the bolt and nut.

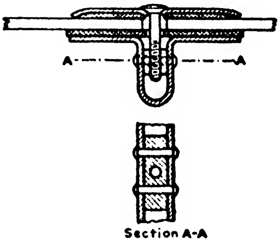

Fig. 16.4c — Two sections of plastics sheet are mounted with formed sheet aluminum alloy channel and elastic stop nuts. These stop nuts are small rectangular blocks of aluminum alloy threaded in one direction and with two small holes for rivets at right angles to the bolt hole. Called Plexiglas Elastic Stop Nuts, these were developed by the Douglas Company and were made by the Elastic Stop Nut Corporation.

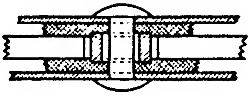

Fig. 16.4d — The use of spacers around each rivet prevents excessive clamping stresses being set up in the plastics sheet.

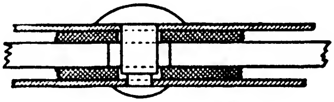

Fig. 16.4e — Shoulder rivets can be used to mount two adjoining sections, or edge of one section of plastics sheet. This method requires that the hole in the top channel strip be of different size than the one in the bottom channel strip. This, with the shoulder on the rivet, prevents drawing the channel tightly against the sheet and allows for expansion or contraction.

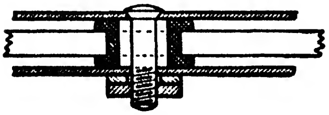

Fig. 16.4f — Plastics sheets may be mounted at the edge section using a rubber grommet or bushing. The hole in the sheet is large enough to hold the grommet and the bolt passes through the center. The joint is not watertight.

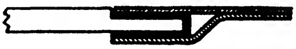

Fig. 16.4g — By routing, the outer surface may be made flush to give an unbroken smooth surface that will have a minimum of air resistance. This can also be applied to cars.

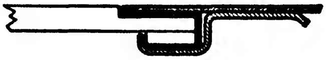

Fig. 16.4h — A routed section with a cemented reinforcement strip along the inside edge permits the section to be installed as a window from the inside with the outer surface flush.

They may be thoroughly cleaned from time to time with a coarse sandpaper or a suitable drafting tool.

Cleanliness. High standards of cleanliness should be maintained in handling polished acetate sheets and particularly in the forming operations. Dirt particles may cause scratches or pits and indentations in the formed pieces. Billiard-table felt, used for covering the formers, acts as a cushion for dirt particles which become imbedded in the felt rather than in the softened sheet. The felt should be frequently cleaned.

The acetates may be cleaned of dust and dirt by washing with soap and cold water, rinsing off and wiping dry with a clean soft cloth. Care should be taken, however, to rub the dirt off, but not into, the sheet. Grease and oil can be removed by wiping with a cloth dampened with toluol or carbon tetrachloride.

Storing. Sheets are shipped in wooden packing cases, tightly packed to prevent shifting, and interleaved with tissue paper to prevent scratching. They should be stored flat, never on end, preferably in the original cases.

Sheets should be stored in a dry room, about 50 to 60 per cent relative humidity at around 70° F. If a cold room must be used for storage, the sheets should be conditioned at least 24 hr. in a room at about 70° to 75° F. before fabricating.

MOUNTINGS FOR TRANSPARENT PLASTIC SHEETS

In this section, typical mountings are illustrated and described in Figs. 16.4a-h, inclusive.

CHAPTER XVII

EQUIPMENT FOR MOLDING PLANTS[1]

WEIGHING, MEASURING, AND PREFORMING

To produce satisfactory molded parts economically, an accurate quantity of molding material must be placed in the mold. In injection molding the charge is automatically controlled by an automatic feed device, but in compression molding the charge is usually controlled by other methods. The charge may be loose powder or it may be compressed into a preform. When loose powder is used, the correct amount is ordinarily prepared by one of the following methods:

1. By actually weighing out sufficient molding material on a scale or balance.
2. By measuring it volumetrically, either manually or mechanically.
3. By use in a molding machine which automatically measures the required charge, usually volumetrically.
4. By preforming, in which a tablet is produced mechanically on a preforming press.

WEIGHING AND MEASURING

Weighing Loose Powder Manually. In the early days of the molding industry, the individual molder prepared the charges of molding material for the different molds which he was operating. Under certain conditions this is still done and is good practice. In using single-cavity hand molds, where the pieces being produced require a fairly long cure (from 5 to 10 min.) this procedure may be the most economical. When it is used, a comparatively small quantity — approximately 10 or 20 lb. — of the required molding material is placed in a container on or adjacent to the molder's bench. This container has a cover to prevent foreign matter from contaminating the molding material. A set of scales, or a balance, is near at hand. The predetermined correct amount of molding material for each job is weighed out by the molder into paper cups, cardboard boxes, or any suitable container. This method is economical only when the molding cycle is long enough to allow the molder to weigh out his own material. Obviously, when this extra operation curtails his output, it is no longer efficient.

With the advent of faster curing materials, and multiple-cavity molds, this method became impractical. The entire time of one or more less skilled persons may be utilized advantageously to weigh out the mold charges and to maintain a supply of correct weights of materials at the molder's bench.

Volumetric Measuring of Loose Powder. The actual weighing out of individual mold charges is at best a rather slow operation. To increase the speed of this operation, measuring the charge by volume has been found successful. This may be done either mechanically or manually. With the latter method a single-cup or multiple-cavity loading fixture is employed. The cup is constructed so that its volume may be adjusted to

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[1] Prepared in co-operation with the Bakelite Corporation.

allow for variation in the apparent density of the molding material. One way is to use a telescoping arrangement to change the depth of the cup as required. When proper adjustment has been made, the two parts are held together firmly by a set screw. After filling, any excess is scraped off the top with a straight edge and the material remaining constitutes the charge to go into the mold.

An adaptation of this method is an arrangement whereby the molding material is placed in a hopper mounted on slides in such a manner that, as the hopper is moved forward, the molding material is scraped off the top of the cup.

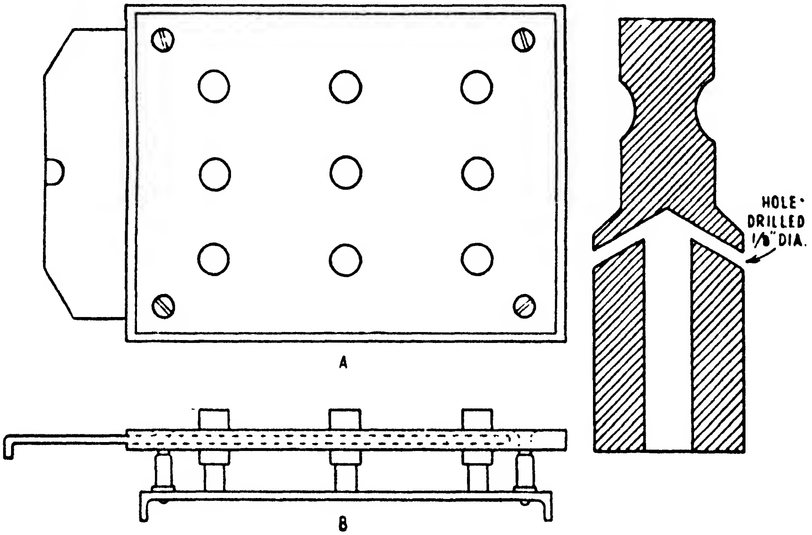


Fig. 17.1 — Diagram of loading tray.

The loading tray used for charging multiple-cavity molds with loose powder also should be constructed so that its volume may be adjusted to allow for variations in the density of the molding materials. As a rule, these loading trays consist of two parts — the upper portion or chambers and the bottom plate (Fig. 17.1). The first controls the volume and, consequently, measures the amount of molding material. The second acts as a valve.

By placing the bottom plate so that the holes through it are out of register with the chambers, the device is sealed, any excess being scraped off the top with a straightedge. Next, the loading rack is placed over the mold. It is held in proper position by dowel pins or other suitable fastenings. The molding material charge is then deposited into the mold cavities by bringing the loading tray chambers into register with the holes in the bottom plate.

Scales for weighing may be of the torsion spring type, the platform type, or the beam balance type.

A variety of such scales are manufactured and are distributed by: Toledo Scale Company, Toledo, Ohio; Dayton Scale Company, Dayton, Ohio; Central Scientific Company, Chicago, Illinois; and Exact Weight Scale Company, Columbus, Ohio.

PREFORMING

A preformed or compressed mold charge is now widely used. Without this type of mold charge — known by a variety of names, such as preforms, pills, tablets, biscuits, and briquettes — it would be practically impossible to operate the large semi-automatic molds on volume production schedules which call for several thousand pieces per hour. With the help of preforms and loading boards, these schedules are being met as daily routine on such jobs as closures and radio tube bases.

The preforming operation consists in compressing the molding powder cold into a tablet of the proper size and weight in a machine or press especially designed for that purpose. These presses may be divided into three general types — reciprocating, rotary, and manually operated.

Preforming Presses. Reciprocating presses are available in different sizes, but it is advisable to use the heavy type, particularly in small plants where often only one preforming press is used. On the heavy type of press, both large preforms, 2 in. in diameter, and small preforms may be made. On the lighter models preforms are limited to the smaller sizes, 1 in. in diameter or less. Reciprocating machines have a capacity of up to 50 tablets per minute. This capacity can be increased by using multiple-cavity dies when small preforms are required. Figure 17.2 shows a typical reciprocating press.

The reciprocating press lends itself to many types of preform. Having but two punch parts, an upper and a lower, and one cavity, it is only necessary to change these to replace one die for another. Its main disadvantage is its relatively small output.

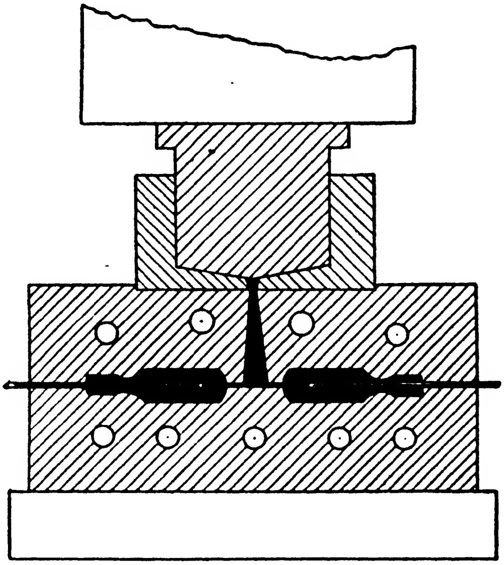


FIG. 17.2 — Extrusion or transfer molding process.

Rotary Presses. The rotary preforming press has an output of 800 or more tablets per minute. It differs from the reciprocating type because the punches and dies are mounted in a revolving table.

The proper weight is secured by overfilling the cells and adjusting the lower punches so that the excess material is scraped off. The powder charge is compressed uniformly by applying pressure simultaneously from both sides. This is accomplished by two rollers, between which the punches pass as they revolve with the table.

This type of press is well suited for producing spherical, or round and flat, preforms in large quantities, because the necessity for frequent changing of the preform size does not exist. The rotary presses have sixteen or more cavities (dies) with two punches for each. Thus, forty-eight parts or more must be removed and a like number replaced when changing the entire setup from one shape of preform to another. It is possible to operate these presses without running the full number of punches and dies. As a matter of fact, a single set may be used if the occasion warrants it. Also, preforms of different sizes and shapes may be made at the same time by placing their respective punches and dies in the table. The difficulty generally encountered with this method is in sorting the different tablets after they are formed. If their sizes and shapes are sufficiently varied, this may be accomplished by a revolving cylindrical screen, which allows the smaller tablets to fall through, while the large ones are delivered from the end. This method is only applicable to certain shapes of tablets — spherical, for instance — and in addition requires hard-pressed tablets, so that they will not be broken or chipped by the screen.

Manually Operated Presses. Some molding materials cannot be preformed on either of the automatic presses just described. These are the impact-resistant materials and long-fiber asbestos materials, which will not feed properly into the cells of automatic preforming presses. When it is necessary to use these materials in the tablet form, mold charges are generally weighed out first, and then compressed in a preform mold in a hydraulic- or percussion-type press. Also, large or complicated preforms in standard molding materials can be produced by this method, when the use of the automatic preforming press is impossible or impractical.

Density and Shape of Preforms. The question is often raised as to whether hard or soft preforms should be used. The answer depends upon the conditions under which the preforms are to be utilized. Hard preforms are very helpful to support inserts or long pins. Often they are used with a softer tablet to force material into a portion of the mold that is not easily filled out. Some very striking mottled effects may be obtained by using preforms of different densities and colors. In general, however, it is only necessary to compress the tablet to a density sufficient to withstand handling.

In most instances, tablets may be shaped to conform as nearly as possible to the shape of the finished molded piece. This rule should not be carried to extremes. For example, preforms made with a thin section and a thick section parallel to the direction of the compression are not very satisfactory. A small difference in thickness may be accomplished, but where the ratio approaches two to one, the results are unsatisfactory. The molding powder does not lend itself readily to cold flow and the thin section of such a preform is hard and dense, while the thicker portion remains soft and spongy. The real purpose has been defeated, and the resulting preform, being weak, is easily crumbled and broken.

When ring-type preforms, or preforms with holes through them, are required, it is usually necessary to reduce the speed of the preforming press to 25 or 30 strokes per minute. At the slower operating rate, the molding powder has a better opportunity to flow down around the core pins and fully fill the cavity. This provides greater uniformity in preform weights. The change in operating speed may be accomplished by any of the following methods: (1) Variable speed motor — (a) economical with direct current, (b) expensive with alternating current; (2) variable speed transmission; (3) step pulleys.

Also, in making preforms with holes through them, it is desirable to provide overflow ports in the top punch at the base of the core pinholes. This permits escapement of any molding powder which might otherwise accumulate and cause trouble.

Preforming Do's and Dont's:

1. Keep an accurate record of the molding material being compressed into preforms.

Each container of preforms should carry the material number, the batch number, and the drum number, so it may be identified immediately, should any difficulty be encountered in the molding operation.

2. Preform weights should be checked frequently by the operator to ensure uniformity.

3. Before preforming an entire drum of molding material, try out a few tablets in the mold to make sure that the correct weight has been established and that the material is suitable for the molding job.

4. Don't run the press on power until at least one complete revolution has been made by hand. Many a machine, wrecked by improper adjustment, could have been saved if this precaution had been taken.

5. Keep the preforming presses clean and free from oil, grease, and the like. This reduces the chance of contamination and trouble. Furthermore, tidy, clean machines and surroundings mean better workmanship.

6. An exhaust system should be provided to carry off dust. It will not only help keep the department clean, but will also recover a great deal of molding material otherwise lost. In one plant alone, enough molding material was recovered in a short time to pay for the installation.

7. A compressed air line and hose should be provided for each preforming machine. This is very useful to remove the fine powder which accumulates, particularly around the lower punch.

8. Use a screen when filling the hopper. A ¼-in. mesh screen placed over the hopper will retain any large pieces of foreign material that may find their way into the molding material after the drum has been opened.

9. By using a chute with a screen bottom, the tablets can be delivered from the machine to the box or container with a minimum amount of dust.

10. Don't make light-colored preforms on one machine, while black or some dark-colored material is being used on an adjacent machine. Contamination will surely result. The ideal arrangement is to provide a separate room for the preforming of light colors.

11. Preforms should be handled as little as possible. Too much handling or transferring from one container to another will cause breakage or loss of material.

12. Don't store preforms or molding materials in a damp place. They will absorb moisture which may cause trouble. An air-conditioned room with controlled temperature and humidity is the ideal arrangement for the storage of raw materials.

13. Preforming presses should be grounded. Frequently, they pick up a static charge of electricity. When this happens operators will receive continual shocks, and accidents may occur.

14. Occasionally, a reciprocating press may get stuck on bottom center with the punch jammed tightly against the charge of molding material. Don't attempt to apply extra force to free the machine. Generally, by heating the punch with a blow torch the molding material will be softened, or fluxed, enough to allow the machine to be turned over by hand.

15. When preforming punches and dies are chrome plated, they wear longer.

16. Keep preforms clean prior to molding. Much difficulty has often been encountered due to carelessness in this respect.

Preforming Press Equipment:

Arthur Colton Company	Detroit, Mich.
Defiance Machine & Tool Company	Defiance, Ohio
Kux-Lohner Machine Company	Chicago, Ill.
Standard Machinery Company	Mystic, Conn.
F. J. Stokes Machine Company	Philadelphia, Pa.

COMPRESSION MOLDING EQUIPMENT

Compression molding refers to that process where the molding material in suitable form is charged into a heated steel mold. The mold is placed between heated platens of the press, and may or may not be permanently fastened to the press. Either loose powder or preforms may be used for loading the mold. Pressure is used to close the mold which is being heated, thus compressing the material and causing it to flow into intimate contact with the mold surfaces. Upon further application of heat and pressure, the molding material " sets " to a hard, dense form.

Hand Molding Presses. The simplest form of a molding press consists of a hydraulic ram and cylinder fastened to a resisting member or head by means of four rods. These are usually small presses from 10 to 30 tons and are used generally for small quantity production where the cost of a more elaborate multiple-cavity mold is not justified. The mold is separate from the press and is loaded and unloaded from the outside and then placed between the heated platens of the press. The heat for the setting of the material passes through the body of the mold from the heated platens. These presses are either operated from a central accumulator or by a hand pump.

The tie rods hold the head permanently in position by nuts and may be adjusted for any desired daylight opening. The platens are separate and can be packed with asbestos between the head and platen, also the ram and platen.

Hand, Arbor, and Laboratory Presses:

Adamson Machine Company	Akron, Ohio
Albert & Son, L.,	Trenton, N. J.
American Broach & Machine Company	Ann Arbor, Mich.
Atlas Press Company	Kalamazoo, Mich.
Baldwin Southwark Division	East Eddystone, Pa.
Birdsboro Steel Foundry & Machine Company	Birdsboro, Pa.
Burroughs Engineering Company	Newark, N. J.
Fred S. Carver	New York, N. Y.
John J. Cavagnaro	Harrison, N. J.
Chambersburg Engineering Company	Chambersburg, Pa.
Arthur Colton Company	Detroit, Mich.
Charles F. Elmes Engineering Works	Chicago, Ill.
Farrel-Birmingham Company	Ansonia, Conn.
French Oil Mill Machinery Company	Piqua, Ohio
Greenerd Arbor Press Company	Nashua, N. H.
Hannifin Manufacturing Company	Chicago, Ill.
Hydraulic Press Manufacturing Company	Mt. Gilead, Ohio
Logansport Machine Inc.	Logansport, Ind.
Evarts G. Loomis	Newark, N. J.
Frank M. Martin	Springfield, Mass.
John Robertson Company, Inc.	Brooklyn, N. Y.
Standard Machinery Company	Mystic, Conn.
F. J. Stokes Machine Company	Philadelphia, Pa.

Terkelsen Machine Company	Boston, Mass.
S. S. White Dental Manufacturing Company	New York, N. Y.
Williams, White & Company	Moline, Ill.

Semi-automatic Presses. This type of press is generally used where there is a demand for volume production, or where the size of the piece warrants it. The semi-automatic press permits the mold to be fastened permanently and produces positive ejection of the molded pieces from either the upper or the lower side of the mold carriers, or bolsters, and parallels, which separate the mold from the bed or head of the press for ejection purposes. Ejection pins are mounted on bars placed between the parallels so arranged that when the press is opened these knock-out bars are actuated to remove the finished piece. The semi-automatic press is always equipped with pull-back cylinders or other types of return mechanisms, as it requires considerable pressure at times to separate the two halves of the mold and eject the finished pieces. These presses may be furnished in either the rod type, or the side plate type.

The mold is mounted on the mold carriers, or bolsters, and the parallels placed between the mold carriers, allowing space between parallels and bolsters for knock-out bars. The knock-out bar is actuated by the bed of the press, which moves downward, pulling down the knock-out bars which eject the piece. The bottom knock-out bars, extending up through the bed, actuate the knock-out pins as the rods hit the knock-out plates on the top side of the base of the press. Ejector bars may also be operated by top and bottom hydraulic cylinders. These presses are furnished with pressures from 75 to 500 tons and upward for special work.

Semi-automatic and Hydraulic Presses:

Adamson Machine Company	Akron, Ohio
L. Albert & Son	Trenton, N. J.
Baldwin Southwark Division	East Eddystone, Pa.
Birdsboro Steel Foundry & Machine Company	Birdsboro, Pa.
Burroughs Engineering Company	Newark, N. J.
Clearing Machine Corporation	Chicago, Ill.
Dunning & Boschert Press Company	Syracuse, N. Y.
Charles F. Elmes Engineering Works	Chicago, Ill.
Louis E. Emerman & Company	Chicago, Ill.
Farrel-Birmingham Company	Ansonia, Conn.
Hannifin Manufacturing Company	Chicago, Ill.
Hydraulic Press Manufacturing Company	Mt. Gilead, Ohio
Index Machinery Corporation	Cincinnati, Ohio
Kux-Lohner Machine Company	Chicago, Ill.
Lake Erie Engineering Corporation	Buffalo, N. Y.
Logemann Bros. Company	Milwaukee, Wis.
Evarts G. Loomis Company	Newark, N. J.
Frank M. Martin	Springfield, Mass.
National Erie Corporation	Erie, Pa.
John Robertson Company, Inc.	Brooklyn, N. Y.
Spadome Machine Company	New York, N. Y.
The Standard Machinery Company	Mystic, Conn.
F. J. Stokes Machine Company	Philadelphia, Pa.
Terkelsen Machine Company	Boston, Mass.
Wm. R. Thropp & Sons Company	Trenton, N. J.
Watson-Stillman Company	Roselle, N. J.
Williams, White & Company	Moline, Ill.
R. D. Wood Company	Philadelphia, Pa.

Inverted Ram Presses. In inverted ram presses the main cylinder is located at the top of the press. The pull-back cylinders are located on the side of the press. Both the main cylinders and the pull-back cylinders are usually under full line pressure at all times. To close the press, which on this type has a movable upper platen, it is necessary to close the hydraulic return valve and open the high-pressure supply valve. In this case, the net tonnage available for molding is the pressure on the main cylinder plus the weight of the moving upper parts less the pull-back pressure. This press is also equipped with top and bottom hydraulic knock-outs.

Angle Molding Presses. Angle molding presses are used very effectively for split molds as well as for transfer molding. For a split mold, the horizontal ram moves inward, closing the split halves of the die. The vertical ram moves down, closing the plunger of the die and forcing the heated material into the die crevices. For transfer molding the vertical ram moves down, closing the mold, and the horizontal ram moves inward, transferring the heated material into the cavities of the die. The operation of the rams may be reversed, depending upon the die construction.

Tilting Head Presses. The tilting head molding press has the decided advantage of allowing the upper die to be accessible for removing pieces, particularly where it is necessary to unscrew threaded parts. The side stanchions of the press are fixed in a vertical position. The tilting head with its end trunnions, is fitted into sliding bearings. These bearings are actuated forward and backward on top of the side stanchions by hydraulic pistons. Dogs, fastened to the ends of the trunnions, engage in fixed rollers. This motion brings the top mold to a vertical position.

Angle Presses:

Watson-Stillman Company	Roselle, N. J.

Tilting Head Presses:

Watson-Stillman Company	Roselle, N. J.
Lake Erie Engineering Corporation	Buffalo, N. Y.

Mechanical Presses. Mechanical presses are non-hydraulic and provide a self-contained unit. This type of press is operated by an electric motor through a train of gears, cam, and toggle. The toggle moves the upper platen downward, closing the mold. This motion of closing the mold brings four powerful springs into action, which maintain constant pressure during the polymerization period. These springs are mounted in cylinders at the top of the press. When the mold closes, the motor stops and the pressure during the polymerization period is maintained by the springs. These presses have limited applications.

A second type of mechanical press is termed "Electro-Draulic." This is a self-contained mechanical unit. The source of power is an electric motor, operating through a train of gears to a rack pressed into the bed. The motion of this bed brings into action four springs which maintain pressure and follow-ups on the molding material during the setting process. Here again, the motor is not being used to deliver any power while the springs are maintaining pressure on the mold. The purpose of the motor is simply to close and open the press.

Another type of mechanical press consists of a double-acting, low-pressure hydraulic piston and cylinder in the base. This unit actuates a triple toggle, moving upward against the bed of the press, which in turn closes the mold against the head of the press. The pressure is developed by a duplex pressure pump, direct or motor driven with an oil reservoir in the base. This is actually a self-contained unit with both hydraulic and mechanical features.

Self-contained Presses. Self-contained presses are units consisting of semi-automatic presses with built-in piping pump and valves.

Automatic Presses. Several types of automatic compression molding presses have recently been developed. These presses not only have the features of the semi-automatic presses, but also automatic loading and ejecting devices. It is only necessary for the operator to keep the hopper full of molding material. Automatic compression presses are used principally for thermosetting materials.

In such a press, the molding material is automatically delivered from the hopper through a measuring device to the mold. The mold is heated from electrically heated platens. The press is equipped with an automatic control for all mechanical operations. Air jets help to eject the molded piece and clean the mold of flash. An adjustment screw at the bottom of the machine provides for automatic knock-out or ejection of the molded piece. The machine is operated mechanically from a motor and the pressure is applied through compression springs.

Another type of automatic machine is operated from a pump and pressure unit at the head of the machine, through a hydraulic cylinder which applies the pressure to the mold. A hopper at the side of the machine, loaded with powder, loads a rack underneath the hopper. This rack is moved onto a sliding table, which is actuated with compressed air over the mold cavities. The work is blown out through air jets into a container on the side of the machine.

There are several other types of recently developed automatic compression molding presses. Although space limitations do not permit their description here, it can be said that they operate quite similarly to those described. When one compares the " modern " molding practices of 1931 with those of 1941, it can be truly said that the plastics molding industry has made great advances. Automatic machines have resulted in faster, more economical production with a consequent saving to the purchaser of plastic parts, as well as assurance of better molded pieces.

Automatic Compression Machines:

Adamson Machine Company	Akron, Ohio
Baldwin Southwark Division	East Eddystone, Pa.
Cropp Engineering Division	Warren, Pa.
Charles F. Elmes Engineering Works	Chicago, Ill.
French Oil Mill Machinery Co.	Piqua, Ohio
Hydraulic Press Manufacturing Co.	Mt. Gilead, Ohio
Index Machinery Company	Cincinnatti, Ohio
Reed-Prentice Corporation	Worcester, Mass.
Standard Machinery Company	Mystic, Conn.
F. J. Stokes Machine Company	Philadelphia, Pa.
Watson-Stillman Co.	Roselle, N. J.

How Compression Mold Pressure Is Calculated. In the molding of plastics materials there are the following three pressures which should not be confused with each other.

1. *Line pressure* is the pressure exerted in the feed line of the system by the pump or accumulator. This is always given in pressure per unit area, such as pounds per square inch.

2. *Ram pressure* is the line pressure multiplied by the area of the ram.

3. *Mold pressure* is the ram pressure divided by the total horizontal cross-sectional area of the piece or pieces, including land areas. This figure is the actual pressure exerted on the piece being molded, per unit of area. Therefore, this is the pressure to be considered. Experience has shown that in molding plastics materials this pressure should be from 2000 to 8000 lb. per sq. in., depending upon design of piece and material used.

Example:

Where L = line pressure; R = ram pressure; M = mold pressure; A_r = Area of ram; A_t = total horizontal cross-sectional area of molded piece or pieces,

$$(1) \quad R = L \times A_r \qquad\qquad (2) \quad M = \frac{R}{A_t} = \frac{L \times A_r}{A_t}$$

For example, an accumulator A with a total load of 17,650 lb. applied to the accumulator ram 3 in. in diameter (7.06 sq. in. area) gives a line pressure L of 17,650/7.06 = 2500 lb. per sq. in. Press B is in turn supplied with this line pressure L from accumulator A. The press ram has a diameter of 8 in., and ram area A_r is 50.3 sq. in. Therefore, ram pressure $R = 2500 \times 50.3 = 125{,}750$ lb.

It can be seen from the above that by varying the load (17,650 lb. in this instance) on accumulator A, both line pressure L and ram pressure R may be raised or lowered, However, it is general practice to keep the accumulator weight constant.

$M = (L \times A_r)/A_t$ or, as in the above case where $L = 2500$ lb. per sq. in. and $A_r = 50.3$ sq. in., $M = 125{,}750/A_t$. This formula is commonly used for determining whether there is sufficient pressure for operating a given mold in a given press. It is also used to determine the number of mold cavities that will operate satisfactorily in a given press.

If it is desirable in molding a given piece from phenolic materials to have $M = 2000$ lb., then since $M = R/A_t$, $A_t = R/M$ or $125{,}750/2000 = 62.875$ (63 sq. in.).

Hence, press B is capable of producing one or more pieces, requiring 2000 lb. per sq. in. pressure, with a total horizontal cross-sectional area of 63 sq. in. including land area.

As most of the commercial presses used today have pull-backs which are floated on the high-pressure line, it is necessary to subtract the pull-back pressure from the total pressure on the press ram. In many cases this pull-back pressure amounts to from 15 to 20 per cent of the total pressure on the ram. Thus, on a semi-automatic press the pressure per square inch on the piece would be equal to the line pressure times the area of the ram — the line pressure times the area of the pull-back rams equals the total area of the molded pieces.

Injection Molding Equipment

Injection molding is that process by which the granular molding material from a hopper is softened by heat in a closed chamber and injected by pressure through a suitable orifice into a closed mold. The finished piece is then hardened in the mold by cooling.

The term " injection " is generally used where the heating chamber is charged as a step in a repeating cycle. Injection molding is now being done automatically throughout the plastics molding industry. All so-called cold-set plastics (thermoplastics) may be molded by this process.

Transfer Molding. The term " transfer " is ordinarily used in reference to the process in which an individual charge of thermosetting material is placed in the heating chamber for each cycle. However, developments are now in progress to transfer mold thermosetting materials by an automatic injection molding process. The transfer molding process is illustrated in Fig. 17.2. (See also Fig. 15.25, page 580.)

A modified form of transfer molding may also be used on thermoplastic materials with some advantage accruing thereby in the way of a lesser order of mechanical strain in molded pieces so produced, than are present in similar injection molded pieces.

Injection Molding Machine Elements. The injection molding machine provides a fully automatic process of converting thermoplastic materials in a granular form to a finished molded piece. There are a number of makes available, each differing in many respects, but having these general elements: (1) material feed, (2) heating cylinder, (3) injection pressure plunger, and (4) mold clamp.

These machines are self-contained units equipped with individual motors for mechanical operations, pumps for hydraulic pressure, reservoir for operating oil, adjustments for clamp and injection pressures, and centralized control.

Material Feed. Feeding of the granular material into the injection cylinder is automatically proportioned to the output of material required. This ensures a continuous uniform flow of molding material from the heating cylinder and enables more rapid cycles without the danger of overheating or burning the material. It is important to avoid overheating or burning of all thermoplastic materials.

Heating Cylinder. Heating cylinders are designed so that the wall thickness of the material to be heated is kept sufficiently thin so that the heat will penetrate the material rapidly and ensure plasticization. These heating cylinders are also streamlined to eliminate friction that might develop between the cylinder and the molding material as it is forced through. It also eliminates the possibility of material lodging in pockets inside the cylinder where the material would burn and discolor as a result of overheating.

The principal methods of heating of the cylinder are: magnetic, contact or resistance heaters, and circulating fluid heating. It is important to have the die plate in front of the heating cylinder movable so that it may be moved away from the nozzle of the heating cylinder to allow for cleaning.

Injection Pressure Plunger. The injection speed determines to a large extent the production cycle. Within limits, the faster the mold cavities can be filled satisfactorily, the better the molding cycle will be maintained. A speed regulator on the injection plunger is helpful for satisfactory molding of cold-set or thermoplastic materials. Often a higher speed on the plunger will offset the necessity of extreme temperatures on the material in the heating cylinder, or heat on the die. The pressure on the plunger is and should be adjustable. Most of the injection machines use hydraulic pressure on the injection plunger. One model, however, employs mechanical pressure.

Mold Clamp. Clamping of the die in place is usually done by means of a toggle mechanism. In one type of machine, a hydraulic plunger is used. There is also a locking device to relieve strain on the toggle mechanism. It is important that there is sufficient clamping pressure to avoid overflow of material on the die when the material is injected and held under pressure while being set.

Injection Presses:

Burroughs Engineering Co.	Newark, N. J.
Clearing Machine Corporation	Chicago, Ill.
De Mattia Machine & Tool Co.	Clifton, N. J.
Evarts G. Loomis	Newark, N. J.
French Oil Mill Machinery Co.	Piqua, Ohio
Grotelite Co.	Bellevue, Ky.
Hydraulic Press Mfg. Co.	Mt. Gilead, Ohio
Index Machinery Corporation	Cincinnati, Ohio
Krehbiel Co., Inc.	New York, N. Y.
Kux-Lohner Machine Co.	Chicago, Ill.
Lester Engineering Co.	Cleveland, Ohio
Reed-Prentice Corporation	Worcester, Mass.
Standard Tool Co.	Leominster, Mass.
Watson-Stillman Co.	Roselle, N. J.

Pressure Systems. The most generally adopted method of applying pressure to molds today is by means of hydraulic pressure. It has been particularly adaptable for the molding of thermosetting materials. The pressure is automatically brought to bear as the molding material softens in the heated cavity and follows up the plastics mass prior to polymerization.

Double Pressure System. The low- and high-pressure system is recommended regardless of the type of press used. The initial or low-line pressure should be 250 to 500 lb. per sq. in. The high pressure should be from 2000 to 3000 lb. per sq. in. of actual line pressure. The advantage of this double pressure is apparent for it reduces frictional wear and tear on molds, and prolongs their life. With this system, presses are run up with low pressure, which is an economy, since a smaller capacity high-pressure installation can be used. It is more economical due to the low cost of closing presses. It prevents the displacement of inserts, and shearing of mold pins, which often happens when cracking the operating valves. In molding large volume pieces, the double pressure system is particularly advantageous because with it material may be allowed to soften at low pressure prior to application of the high pressure necessary to close the press.

Low-pressure Accumulator System. In the installation of a low-pressure system using an accumulator, the pressure is delivered by a multi-plunger, single-action pump, usually of the vertical type, either belt or motor driven, or by a horizontal steam driven reciprocating pump. Line pressure of 250 to 500 lb. per sq. in. should be available. The hydraulic accumulator is used in conjunction with the pump to obtain a steady pressure. Two distinct types are available: one is the weighted type which, in principle, is a heavily loaded piston some 6 or 8 ft. long that works in a cylinder of the same length. The pump forces water into the accumulator cylinder and raises the piston and the ram, which is loaded to the extent necessary to give the required water pressure. The presses draw their supply from this source. The other type of accumulator is one in which the water is stored against air pressure. This type of accumulator takes up far less room and is more easily installed.

High-pressure System. This generally consists of a high-pressure pump and accumulator with the necessary piping to each press and control valve. The water may be returned to a sump tank or reservoir, and from this point it is piped back to the pump again. Such a system offers simplicity and relatively low installation cost.

High-pressure accumulator systems have replaced individual pumps on some battery installations of injection machines. Where such installations have been made users report quieter and more economical operation.

Pumping Equipment. Hand pumps offer great flexibility and the lowest initial cost. They can be used only in connection with hand molding presses. The arrangement is satisfactory for small quantity production. When there are a number of various sized molds, the hand-pump method permits proper pressure on each mold.

While centrifugal pumps are used mainly for the low-pressure system, reciprocating pumps of two, three, and four plungers have been found most economical for supplying high-pressure water. The three- and four-plunger pumps naturally provide the steadiest flow.

For operation of one and two press installations, combination high- and low-pressure reciprocating pumps may be used. The press is closed, being actuated by low-pressure water during the non-working portion of the stroke. Upon encountering resistance, the low-pressure valves automatically trip out of action and the high pressure completes the stroke. Combination low- and high-pressure pumps may be set for desired maximum pressures. The capacity of flow decreases automatically as resistance is encountered, due to the building up of pressure.

High-pressure pumps are usually direct belt or gear driven, and are operated by an electric motor. With the direct connected high- or low-pressure pump, the motor runs continuously, but the pump operates intermittently because it is automatically controlled by a cutout valve from the accumulator.

Horizontal Steam Driven Pumps. In some sections of the country electric power rates are high. Therefore, some molding plants find it more economical to provide enough steam capacity to operate steam driven pumps which will supply both low and high pressure. Unless the exhaust steam is used for a feed-water heater or for other purposes, a system of this kind is not efficient.

Accumulators may be of the weighted type. These may be of adjustable cast-iron or concrete-block construction which permits adjustment of the line pressure as demanded by the molding room. Such types of accumulators require a solid base location. It is necessary as a rule to have them located in the boiler room or the basement of the building, because they are usually too heavy to be placed on the average building floor. In many instances the accumulator should be placed in a pit to provide sufficient head room.

Hydro-pneumatic Accumulator. The hydro-pneumatic accumulator was developed for light foundations and for upper floors of buildings. It is made in both the high- and low-pressure type; also, in a combination high- and low-pressure unit. In both types the accumulator proper consists of two different cylinders rigidly tied together, the smaller of the two cylinders being hydraulic.

An air reservoir is connected to the large cylinder of the accumulator. In the high- and low-pressure type the lower part of the air reservoir is also used for low-pressure water. The level of this water is controlled by a low-pressure governor or automatic accumulator stop. In operation the pressure variation is very light and shock is practically eliminated. A small air compressor is used to start up the system and occasionally to compensate for air leakage. Almost any combination of capacity or pressure can be obtained.

Water Storage and Strainer Reservoir. A reservoir is necessary in a hydraulic system, and a strainer is highly recommended. Unless pieces of packing and scales from pipelines are removed from the system, they may cause endless trouble. When such parts become lodged on valve seats, the valves cannot be closed tightly. Wire drawing and cutting will result. Such particles may also lodge in cylinder packing and will cause scored rams. When the storage and strainer reservoir is used, all the water is returned to the reservoir. The discharge pipe enters one side of the reservoir at the top. Dirt settles to the bottom. Water drawn from the reservoir to the pump must pass through the double-fine wire cloth screen. Due to the large body of fluid in the reservoir, the drawing off of water does not cause a current or agitation, and foreign solid particles remain on the bottom.

In addition to the strainer over the outlet pipe, another method is commonly used to keep water clean, that is, by having a finely divided wire chamber into which the water can be returned. In many cases, if the tank is about 6 ft. long, a double strainer is placed about 2 ft. from the end of the side where the water is discharged. Thus, the water first runs into this chamber where it has to pass through a double-fine screen.

In all reservoirs it is customary to raise the outlet pipe to the pump at least 6 in. above the floor surface so that the dirt can drop to the bottom without any chance of going into the pipe leading to the pump. The sewer or drain connection should be level with the bottom of the tank so that the dirt can be swept easily out of the tank during the cleaning operation.

Accumulators:

Adamson Machine Company	Akron, Ohio
L. Albert & Son	Trenton, N. J.
Aldrich Pump Company, The	Allentown, Pa.
Babcock & Wilcox Company	New York City
Baldwin Locomotive Works	East Eddystone, Pa.
Bethlehem Steel Company	Bethlehem, Pa.
Birdsboro Steel Foundry & Machine Co.	Birdsboro, Pa.
Burroughs Engineering Co.	Newark, N. J.
Fred S. Carver	New York, N. Y.
John J. Cavagnaro	Harrison, N. J.
Chambersburg Engineering Co.	Chambersburg, Pa.
Consolidated Produce Co., Inc.	New York, N. Y.
Dunning & Boschert Press Co.	Syracuse, N. Y.
Charles F. Elmes Engineering Works	Chicago, Ill.
French Oil Mill Machinery Co.	Piqua, Ohio
Hydraulic Press Mfg. Co.	Mt. Gilead, Ohio
Lake Erie Engineering Corporation	Buffalo, N. Y.
Logemann Bros. Co.	Milwaukee, Wis.
Evarts G. Loomis	Newark, N. J.
Frank M. Martin	Springfield, Mass.
John Robertson Co., Inc.	Brooklyn, N. Y.
Wm. R. Thropp & Sons Co.	Trenton, N. J.
Vickers, Inc.	Detroit, Mich.
Watson-Stillman Co.	Roselle, N. J.
Williams White & Co.	Moline, Ill.
R. D. Wood Co.	Philadelphia, Pa.

Pressure and Hydraulic Systems:

Aldrich Pump Co., The	Allentown, Pa.
Charles F. Elmes Engineering Works	Chicago, Ill.
Industrial Equipment Co.	Newark, N. J.
Evarts G. Loomis	Newark, N. J.
Vickers, Inc.	Detroit, Mich.
Watson-Stillman Co.	Roselle, N. J.
R. D. Wood Co.	Philadelphia, Pa.

Pressure Controllers:

Atlas Valve Co.	Newark, N. J.
Bristol Co.	Waterbury, Conn.
Brown Instrument Co.	Philadelphia, Pa.
Cambridge Instrument Co., Inc.	New York, N. Y.
A. W. Cash Co.	Decatur, Ill.
Foxboro Co.	Foxboro, Mass.
French Oil Mill Machinery Co.	Piqua, Ohio
Hydraulic Press Mfg. Co.	Mt. Gilead, Ohio
Hydro-Powers Systems, Inc.	Mt. Gilead, Ohio
Industrial Instrument Co.	Akron, Ohio
O. C. Kickley Co.	Chicago, Ill.
Evarts G. Loomis	Newark, N. J.
Minneapolis Honeywell Regulator Co.	Minneapolis, Minn.
Powers Regulator Co.	Chicago, Ill.
Standard Machinery Co.	Mystic, Conn.
C. J. Tagliabue Mfg. Co.	Brooklyn, N. Y.
Taylor Instrument Co.	Rochester, N. Y.
Tenney Engineering, Inc.	Bloomfield, N. J.

Hydraulic Valves and Fittings:

Adamson Machine Co.	Akron, Ohio
L. Albert & Son	Trenton, N. J.
Aldrich Pump Co.	Allentown, Pa.
Baldwin Locomotive Works	East Eddystone, Pa.
John S. Barnes Corporation	Rockford, Ill.
Birdsboro Steel Foundry & Machine Co.	Birdsboro, Pa.
E. W. Bliss Co.	Brooklyn, N. Y.
Burroughs Engineering Co.	Newark, N. J.
Fred S. Carver	New York, N. Y.
Chambersburg Engineering Co.	Chambersburg, Pa.
Crane Co.	Chicago, Ill.
Denison Engineering Co., The	Columbus, Ohio
Dunning & Boschert Press Co.	Syracuse, N. Y.
Charles F. Elmes Engineering Works	Chicago, Ill.
French Oil Mill Machinery Co.	Piqua, Ohio
Hannifin Mfg. Co.	Chicago, Ill.
Jerguson Gage & Valve Co.	Somerville, Mass.
Logemann Bros. Co.	Milwaukee, Wis.
Racine Tool & Machine Co.	Racine, Wis.
John Robertson Co., Inc.	Brooklyn, N. Y.
Vickers, Inc.	Detroit, Mich.
Walworth Co.	New York, N. Y.
Watson-Stillman Co.	Roselle, N. J.
R. D. Wood Co.	Philadelphia, Pa.
Yarnall-Waring Co.	Philadelphia, Pa.

Valves. A two-pressure operating valve has been designed for operating a press on a two-pressure accumulator or pump system. The operator can control the low and high pressure and discharge the water back to the reservoir at will. If the operator should fail accidentally to close the low-pressure line before admitting the high-pressure water, line checks are provided in the valve to prevent high pressure from backing up in the low-pressure system.

In these high-pressure type valves, a steel body lined with bronze or Monel metal is used. It is desirable to use a stem and removable seat of non-corrosive steel, heat treated for maximum service. The removable seat is generally softer and permits proper seating.

Power-driven timing valves may be used to time and control the molding cycle accurately. Any series of regularly timed operations that can be performed manually may be duplicated mechanically at a saving of labor, and with greater accuracy than is possible by manual operation. This type of valve control is excellent for the operation of molding presses, because all of the operations are automatically controlled. The admission of low- and high-pressure water, the release of these pressures, and, where necessary, the admission and return of steam for cooling water, are performed automatically.

Molds and Dies:

Burroughs Engineering Company	Newark, N. J.
Chicago Molded Products Corporation	Chicago, Ill.
Hamilton Tool Company	Hamilton, Ohio
Industrial Chromium & Engineering Company	Newark, N. J.
Kuhn & Jacob Moulding & Tool Company	Trenton, N. J.
Kux-Lohner Machine Company	Chicago, Ill.
Pal Tool Company	Minneapolis, Minn.
Richardson Company	Chicago, Ill.
Standard Tool Company	Leominster, Mass.

HEATING MEDIA

Heat is of primary importance in its applications to the plastics material during the molding operation. The function of heat is twofold. First, it must soften the material into a plastic state so that the application of pressure will force it into the mold cavity, thus forming a proper, dense and homogeneous molding. Second, it must, in the case of thermosetting materials, cause the polymerization of the resin binder, thereby curing or hardening the material into a solid, infusible mass.

Too low a temperature is frequently the cause of poorly molded parts. At low temperatures, materials do not soften properly and flow is greatly retarded. As a result, the material becomes stiff and does not fill out the mold cavity properly. A mold properly heated to the optimum temperature specified for any given material enables the molder to use to advantage the maximum plasticity of a material.

The polymerization of the material is equally important. A certain number of heat units are essential to transform a given quantity of molding material from the powder form to a finished molding. The quicker these heat units can be conveyed from the mold surface throughout the mass of material, the less time will be required to form a properly molded part.

In the molding of both thermosetting and thermoplastic materials, a steady supply of uniform heat is essential.

Thermosetting materials, usually compression molded, are fluxed by a uniform supply of heat to that point where they will flow adequately under applied pressure, thereby filling out the mold cavity. The continued heat application at correct temperatures carries out the heat-setting properties of the molding material.

Thermoplastic materials likewise require a carefully controlled and uniform flow of heat in either injection or compression molding. With injection molding the heat softens the material sufficiently so that the applied pressure forces it through the gates, sprues, and runners and then into all parts of the mold cavity. The mold is usually chilled to set or harden the material.

Heating Media for Compression Molding of Thermosetting Plastics. Temperatures required for compression molding range from 270° to 350° F. For some types of hot-ejected parts having uniform material sections, a temperature of 350° F. offers an advantage in molding time and consequently in molding cost. However, in the molding of many types of thermosetting materials, including light-colored materials, temperatures of 303° to 320° F. are most efficient. These temperatures should also be used in molding pieces requiring long flow or having non-uniform sections.

Four methods of heating platens or molds are used in the plastics industry for compression molding — namely, electricity, gas, steam, and superheated hot water (Supertherm). While electricity and gas are used directly to some extent, steam is generally preferred. It is recommended in most localities because of economy and heating efficiency. By using a small high-pressure boiler, the average press can be heated uniformly and controlled throughout the day to within 5° F.

It is not difficult to obtain constant steam pressures for proper molding temperatures. The usual operating pressure for ordinary molding work is approximately 125 lb. and no great attention is required to maintain this pressure.

Steam Heating. Steam boilers that operate at pressures up to 200 lb. in sizes up to 10 horsepower are satisfactory for the small medium molder and in most states do not require the attendance of a licensed fireman. By using gas or oil fuel, the steam pressure may be automatically controlled with simple equipment. Selection of fuel will depend to a large extent upon the cost in the particular territory. Gas, while seemingly more expensive, is frequently desirable in the smaller molding plants, because of the simpler equipment. Gas requires no storage, while fuel oil does, and most smaller plants have gas easily available. Very successful applications of small gas-fired boilers, ranging in sizes from 1 to 5 horsepower, have been made in a great many smaller molding plants.

For the large molding plants, where six or more presses are in use, and where it is deemed advisable that a separate boiler room be arranged, then, of course, inherent benefits of gas fuel may not become so important. A lower priced fuel, such as oil, or even stoker-fired coal, might well be considered.

Boiler capacity for heating the platens of a molding press will depend entirely on the size of the platens, and to a great degree on the type of part being molded. The average requirement is approximately 2 horsepower per press, where straight heating is used, and where the finished parts are discharged hot. There are some instances where boilers of 6 or 8 horsepower are serving as high as 10 or even 12 presses, but such overtaxed steam boiler equipment cannot be operated efficiently. Normally, slightly oversized boiler capacity should be provided, so as to assure normal boiler operation without forcing the equipment. This assures high operating efficiency and low maintenance cost.

Steam Platens. Rolled steel plates are used for platens for hand mold presses. Semiautomatic molds are steam channeled by drilling holes, as evenly spaced in the force plates and chase plates as possible. These holes should be located so as not to interfere with the mold cavities. In some cases it is advisable to core out force plugs to promote uniform heating and ensure even transfer of heat to the molding material.

A good rule in designing a mold is to consider the best channels and their relation to the cavity first and then place ejector pins, dowels, and the like in their proper locations. Steam ports should be not less than ⅝ in. in diameter and should be enlarged at the ends to take ¾-in. pipe threads and plugs. Steam ports should be placed not more than 4 in. apart between centers to ensure even heating to the mold charge at all points in the platen and cavity surface area.

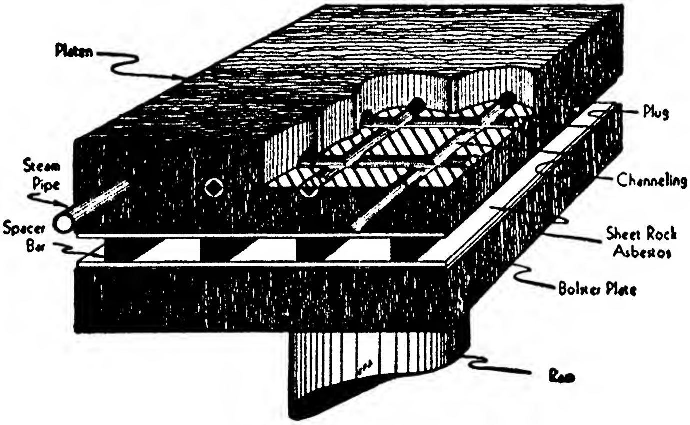


FIG. 17.3 — Steam platen showing channeling, space bars, plugs, and bolster plate.

Figure 17.3 illustrates a diagram of a correctly laid out platen free of pockets, which permits free flow of steam in a continuous pattern through the platen. Steam should never be permitted to pocket, and platens and steam-channeled molds should be designed to ensure and afford this continuity of the heating media.

The same diagram illustrates a method used to connect several bored holes by a cross channel as near the end of the plate as permissible. A ⅝-in. diameter brass baffle rod is fitted into the cross-channel holes. Turned shoulders ¼ in. in diameter permit the steam to turn the corner and flow in the opposite direction in the next port.

A good steel for platens is " silicon-kilned " firebox steel which has undergone cold rolling on a plate mill and is, therefore, free from gas bubbles and segregation. Consequently, the surface has a uniform texture and the wearing surfaces have a hard finish. This finish should be flat tooled and preferably polished. Keeping the outside surfaces of platens and hand molds smooth and clean is important. Platens dented and containing spots of cured material cause poor contact and greatly increase heat losses.

Platens should be bolted securely to the bolster plates or head of the press. Sheet-rock asbestos board, at least an inch thick, should be interposed between the platens and bolster plates. This insulation prevents dissipation of the platen heat into the heavy cast steel head, or ram, and prevents this heat from drying the ram packings. If the press permits, space bars of cold-rolled steel may be placed between the asbestos insulation board and the head and ram of the press. In this way losses will be cut down by less conduction through the smaller area and by the greater insulation offered by having air passages under these plates.

Flexible and fixed connections consisting of woven steam hose are used for piping steam from the line to the movable platens and back to the fixed return pipe. Annealed copper tubing, ⅜ in. inside diameter, coiled so as to form a helix or spiral expanding joint, is another method which offers tight connections when used on presses where alternate heating and chilling of the molds is desired. Check valves are provided to prevent steam from entering the cooling water lines. Woven asbestos covering as an insulation over the copper tubing is recommended. Patented sliding and movable angle joints are also used.

Multiple Valves. Where compression molding equipment is used when there is a quick change from the heating to the cooling cycle within the same press — as in cold-set materials, such as cellulose acetate, vinyl, or polystyrene — or where thick sections are to be chilled or mold temperatures reduced before loading cavities, a multiple steam and water valve can be used to advantage for speed in operation and its subsequent production economy. These valves are designed so that a quick change made by using one operating handle permits the rapid blowing off of the cooling water, which is left in the mold, and the quick reheating to the desired molding temperature.

Return of Condensation to Boiler. Two methods are used to return condensation to the boiler. One is the gravity system, where the boiler is located sufficiently below the platen of the press to assure gravity return. This minimum distance should never be less than 24 in. The second is the complete condensate boiler return system.

Boilers:

Babcock & Wilcox Co.	New York City
Eclipse Fuel Eng. Co.	Rockford, Ill.
Hendrick Mfg. Co.	Carbondale, Pa.
Mears-Kane-Ofeldt Inc.	Philadelphia, Pa.
Patterson Foundry & Machine Co.	East Liverpool, Ohio
Struthers-Wells Co.	Warren, Pa.
Wickes Boiler Co.	Saginaw, Mich.

Gas Heating. Gas-heated platens are used successfully for some classes of molding, such as collapsible-tube caps and similar pieces which are produced in great quantities. The system offers a compact installation at a low initial cost.

Electrical Heating. Electric cartridge and strip heater elements are used in this type of heating. The heating element should be of such design that in heat conductivity it approximates the metal in the platens. The platens should be carefully machined to ensure firm contact and heat conduction. Heater elements, while low in initial cost, are usually expensive to operate, because eight to twelve elements spaced 4 in. apart across the platen surface are required and consume about 600 watts per unit. Temperature should be thermostatically controlled. It is usually necessary to use high platen temperatures — 360° to 400° F. — to compensate for the drop in temperature when large hand molds are inserted between platens. Figure 17.4 shows an installation and diagram of electrically heated platens.

Superheated Hot Water (Supertherm). Another method of heating compression molding platens that has been introduced into several plants recently consists of the use of " superheated " or high-pressure hot water. This method offers the following advantages: no traps or other devices are required at presses; presses heat faster and are kept at uniform temperature; a large accumulation of heat is also available for peak loads; freedom from scale and corrosion in boilers, piping and platens, as well as elimination of steam losses, and greater economy in fuel costs are also effected. Figure 17.5 shows the water heating system.

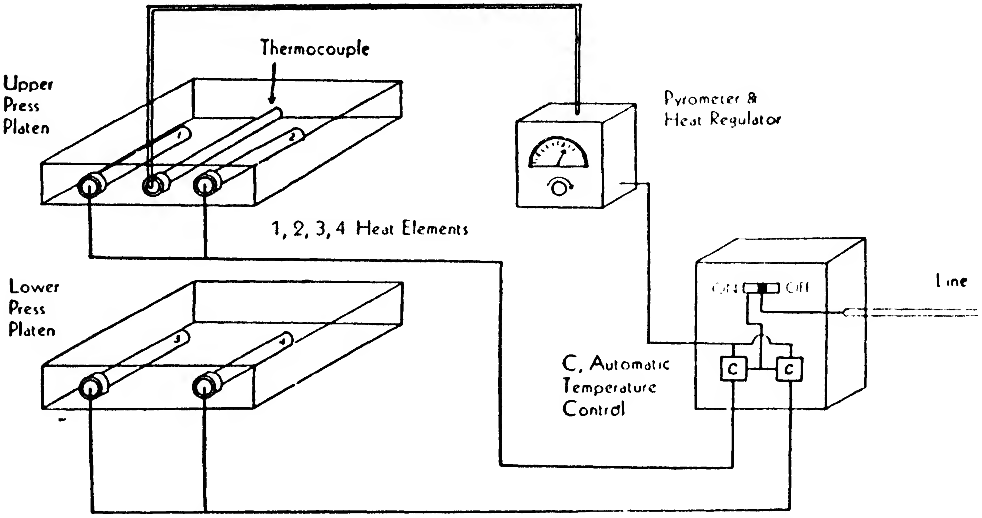


FIG. 17.4 — Left, controller panel and press equipped with electrically heated platens. Right, electric wiring hook up.

Heating Properties of Water and Steam. A comparison of the thermal properties of water and steam is interesting. At 120 lb. gauge, 350° F., water weighs 55.6 lb. per cu. ft., whereas steam weighs only 0.3005 lb. per cu. ft. One cubic foot of water contains a total heat of 17,870 B.t.u. and one cubic foot of steam contains 357.8 B.t.u. In other words, a given volume of high-pressure hot water contains fifty times the heat of the same volume of steam, which means that the use of superheated water offers a large reserve capacity to take up any sudden loads without reduction of pressure which is not the case in steam systems.

Cold spots usually found in steam systems are due to air carried over from the boiler and sometimes from heavily scaled channels. The steady recirculation and reheating of the hot water eliminates these possibilities and the positive circulation to all parts of the presses results in better and more uniform heat.

Heating Media for Injection Molding for Thermoplastic Plastics. Injection molding requires constant temperature control of two parts of the equipment, the heating cylinder (to plasticize the material), and the mold (to "set" the plastic).

The thermoplastic material is softened to a viscous mass in the heating cylinder and the ram applied at high pressures forces the proper amount of molding material through the orifice in the nozzle into the gates and runners of the mold and then into the cavities.

Thermoplastic materials are poor conductors of heat and there is a slight lag in "setting" or hardening when they contact the relatively cool surface of the mold. If proper temperature, time and pressures are employed, this lag is sufficient to permit the material to fill the cavities completely before it sets or hardens.

If the molding material is allowed to overheat in the cylinder, it will degrade and eventually change color (burn). Parts molded from such degraded material will have inferior physical properties. Too low a temperature in the cylinder will cause surface imperfections and brittleness due to improper coherence ("knitting") of the material.

Molds used in injection molding are usually channeled for continuous circulation of water or other fluids in order to maintain a constant mold temperature. In the majority of cases, in the molding of thermoplastic plastics, it is necessary to cool the mold by circulating a coolant around the cavity, and the temperature is controlled by increasing or decreasing the flow of this coolant. When using water as a coolant, particularly during the hot summer weather, in order to economize on the water consumption means should be provided to maintain this water supply at a temperature of approximately 50° F. Also, it is desirable to maintain the atmospheric humidity at a point below which a film of moisture condensate forms on the mold cavity surfaces between cycles. Such condensate will cause surface blisters and molding defects on the molded pieces.

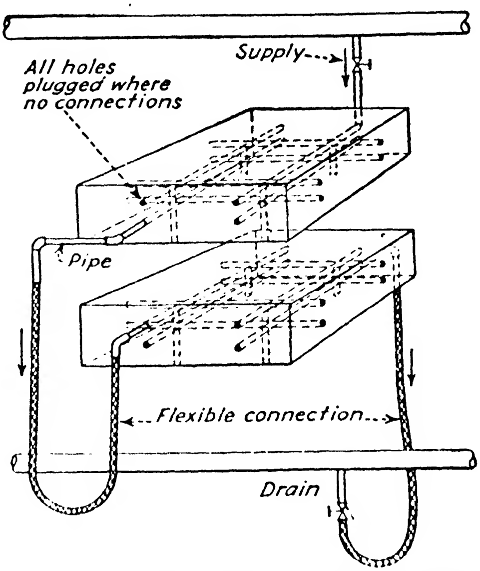


FIG. 17.5 — Mold perspective showing water connections.

Except with vinyl plastics, molds designed for the production of pieces of heavy wall section sometimes require heating to a temperature of 140° to 170° F. These temperatures are best maintained by continuous flow of hot water. Ordinary hot water facilities found in plants are usually insufficiently controlled for this purpose. Consequently, it is desirable to have a separate hot water system to circulate the water through the molds. As most molds do not need heating, it is often deemed too expensive to pipe such a recirculating system to each machine. A small portable unit has been found adequate for most mold heating requirements. This unit consists of a water tank, a heating unit controlled by a thermostat, and a hot water pump. Some molders employ similar units utilizing hot oil instead of water as a heating medium.

EQUIPMENT

Preforming Presses:

F. J. Stokes Machine Co.
Philadelphia, Pa.

Range from small hand-operated laboratory models to toggle-type presses exerting pressures up to 100 tons and making preforms as large as 4 in. wide.

1. *Hand-operated Model.* Capacity up to 100 tablets per minute. For experimental work and small output.
2. *Single Punch.* Tablets of uniform size and density. Four models.
3. *Rotary.* General production work. Five models.

TABLE 94. RANGES OF CAPACITIES—STOKES ROTARY PRESS

	B-2	BB-2	D-3	DDS-2	DD 2
Tablets per min.	400–500	1000–1200	300–350	300	500–700
Diameter, in.	1/8–5/8	1/8–5/8	3/8–1	1 3/16	1 3/16
Max. depth of fill, in.	11/16	11/16	13/16	2 1/16	1 1/16

4. *Toggle Presses.* For heavy duty preforming of large diameters at low power. Two models are available, 280 and 280-A, both requiring 80 tons pressure. Output of 15 to 50 tablets per minute. Depth of fill is 2 in. for model 280, and 4 in. for model 280-A, power required ranging from 7½ to 15 hp.

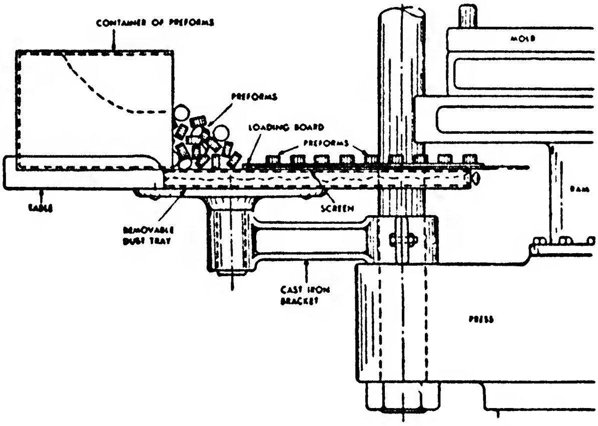


FIG. 17.6 — Bench fastened to press provides space for preforms.

A special press for testing purposes. Small, light weight, and inexpensive. Filling is done by hand. Production is from 8 to 10 pellets per minute. Depth of fill is adjustable to 1 in., and pressure up to 27,000 lb. per sq. in. may be exerted on the ⅜-in. pellet. The machine is 2 ft. high and weighs 75 lb.

Compression Molding Presses:

S. S. White Dental Mfg. Co.
New York, N. Y.

Thermostatically controlled screw press for compression molding. Suitable for laboratory work or for making samples. Used widely for making dentures. Heating units are replaceable, and temperature control may be operated manually or automatically. A

TABLE 95. PREFORMING PRESSES

Name of Press	Pressure, tons	Strokes per min.	Preforms per min.	R.p.m.	Size of Preforms, in. dia.	Max. Depth of Fill, in.	Height, in.	Power Required, hp.	Floor Space, in.	Weight, lb.
Stokes No. 280 Toggle Press*	80	Up to 50	—	—	Up to 4	2	94	7½ to 10	51 by 86	12,000
Stokes No. DDS-2	12 to 14	—	300 to 350	—	1 3/16	2 1/16	73	5 to 10	52 by 61	6400
Stokes No. R	15	Up to 50	—	—	Up to 2½	2	79½	5	36 by 66	4550
Defiance No. 18	100	40 to 65	—	—	3	1⅛	91	5	38 by 52	4650
Defiance No. 40	200	35 to 60	—	—	4	1 5/16	100	7½ to 10	42 by 56	6500
Colton Standard No. 2–B	—	100	300	100	½	½	—	½	19 by 29	285
Colton Standard No. 3–B	—	100	300 to 500	100	⅝	11/16	—	1	35 by 35	765
Colton Standard No. 4	—	90	—	360	1	11/16	—	1½	27 by 36	1300
Colton Standard No. 4½	—	60	—	360	1½	1½	—	3	24 by 56	2105
Colton Standard No. 5½	—	50	250	50	3	2⅛	—	—	38 by 76	5600
Colton Rotary No. 2	—	450	1500	325	⅝	—	—	2	30 by 30	—
Colton Rotary No. 3	—	200 to 350	1100	250	1	—	—	2½	36 by 36	—
Colton Rotary No. 5	—	200	—	—	1¾	—	—	5	48 by 60	—
Colton Dual Compression No. 14	130	—	20 to 35	900	4½	3¾	—	10	—	20,000

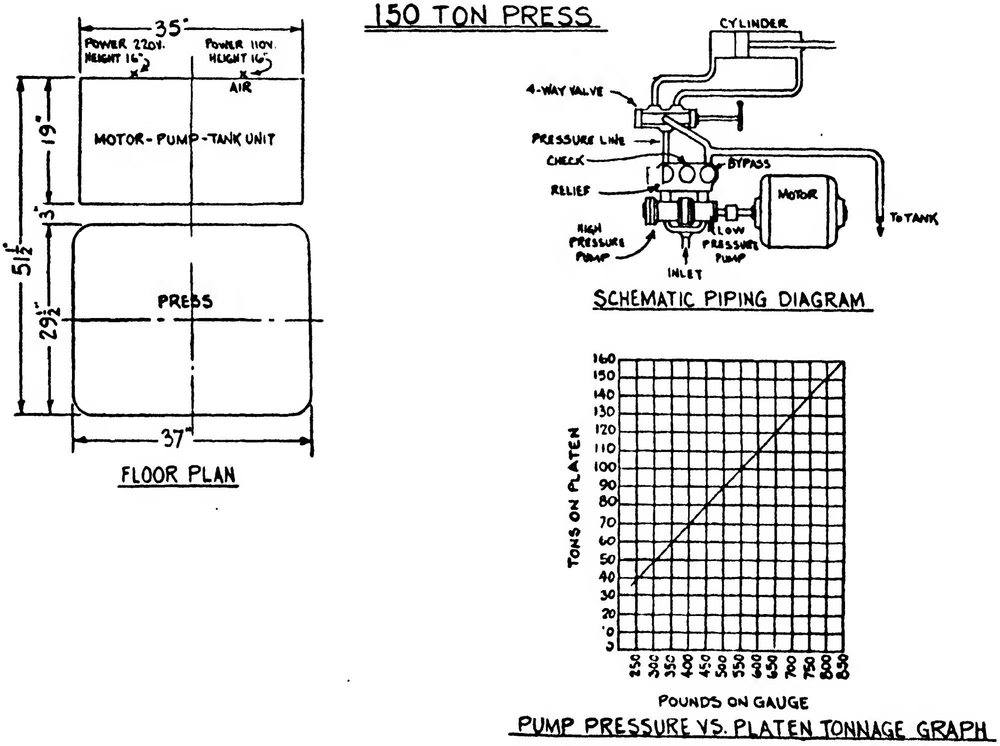
* In addition to the above, Stokes makes eleven other models.

spring in the upper platen housing applies pressure to " follow up " the initial pressure of the screw as the plastic softens in the die.

F. J. Stokes Machine Co.
Philadelphia, Pa.

Stokes No. 200 Automatic

Performs automatically all customary operations of the molding cycle — filling the mold, closing, cleaning by air-jets, curing, opening mold, ejecting the finished part and cleaning the mold. Can be set for breathing (de-gassing) when desired and can be supplied with top and bottom knock-outs, and with stripper. A small article with light wall sections can be molded in 2 min. per round, while a large, heavy piece may take 6 to 7 min. Takes articles up to about 3 in. in diameter.



Courtesy of F. J. Stokes Machine Co., Philadelphia, Pa.

Fig. 17.7 — Standard semi-automatic molding press, 150 ton.

Hannifin Mfg. Co.
Chicago, Ill.

These presses have a fast operating cycle consisting of a rapid advance stroke, short high-pressure power stroke which is much slower, followed by full power return stroke to open molds. Because the advance stroke is considerably faster than the power stroke the time required for each cycle is much less. The slow power stroke allows the material to soften and flow, and results in a smooth, dense finished product.

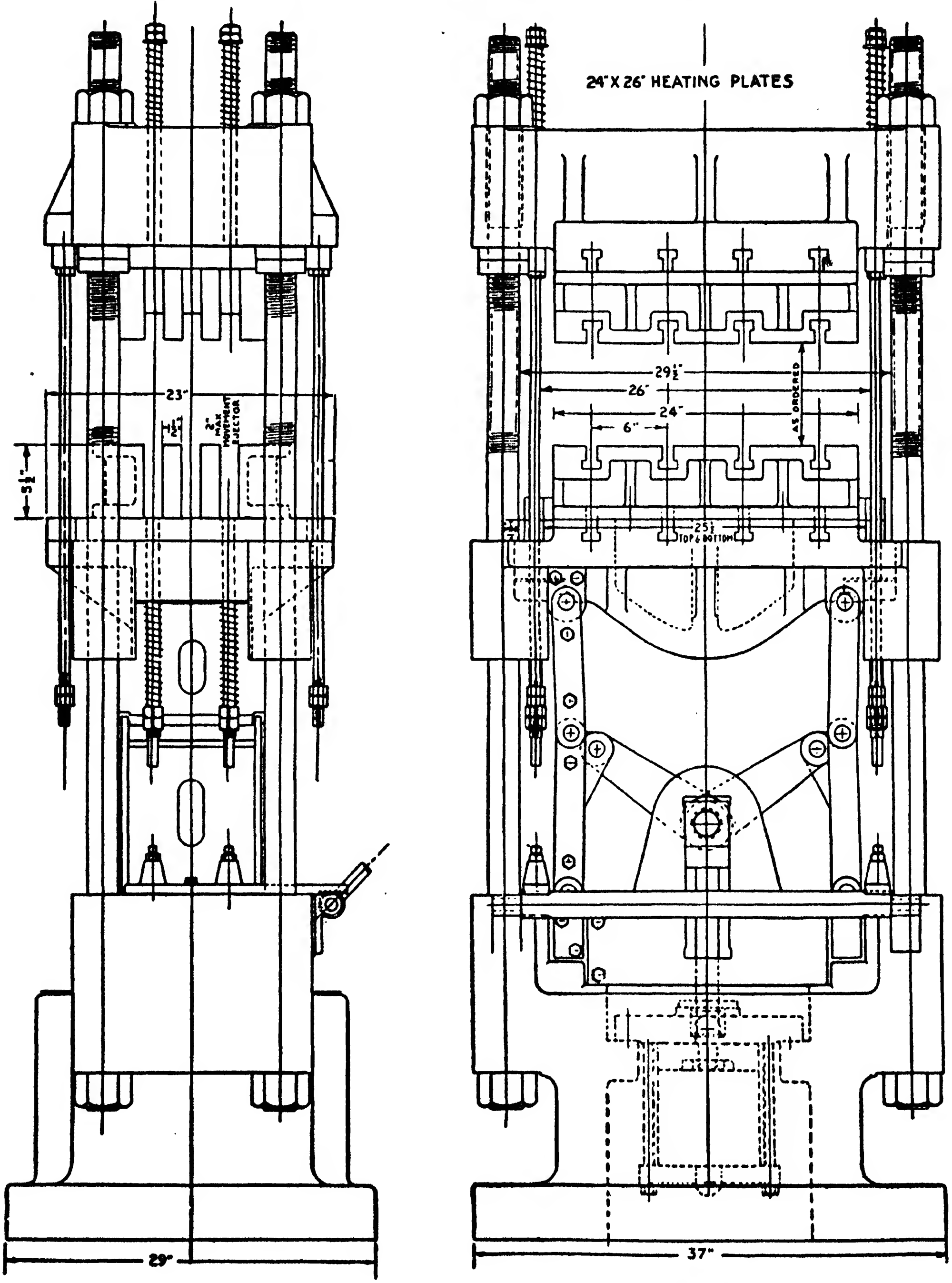
TABLE 96. COMPRESSION MOLDING PRESSES[*]

	Capacity, tons	Pressure, lb. per sq. in.	Die Area, in.	Opening between Bolsters, in.	Opening between Platens, in.	Stroke, in.	Power, hp.	R.p.m.	Height, in.	Floor Space, in.	Weight, lb.
Standard Machinery — 20	20[†]	900	7 by 12	—	—	5½	2	1200	70	—	1500
Standard Machinery — 50	50	875	10 by 20	—	—	7	2	1200	76	—	3400
Standard Machinery — 100	100	550	16 by 24	12	23	6 to 8	3	1200	97	—	7500
Standard Machinery — 150	150	800	18 by 24	—	—	6 to 8	3	1200	97	—	8000
Standard Machinery — 200	200	1000	22 by 26	—	—	8	5	1200	97	—	12,000
Standard Machinery — 300	300	1000	24 by 36	—	—	10	5	1200	117½	—	19,000
Stokes Automatic No. 200-A	10	—	3½ by 3½	—	—	4¼	3	—	78	36 by 40	2250
Stokes Automatic No. 200-D	15	—	4½ by 4½	—	—	4¼	5	—	78	36 by 40	2300
Stokes Automatic No. 202	15	—	4½ by 4½	—	—	10	7	—	91	40 by 42	2800
Hannifin — L208	15	—	—	—	7	7	—	—	—	—	—
Hannifin — L207	50	—	—	—	8	8	—	—	—	—	—
Cropp Engrg.	12	—	2½ by 5	—	10	6½	5	—	76	22 by 52	—
Greenerd — 61 NDE	15	—	—	—	—	6	5	—	—	—	—
S. S. White	5	—	—	—	4½	—	—	—	22	8 by 13	90

[*] A typical list.

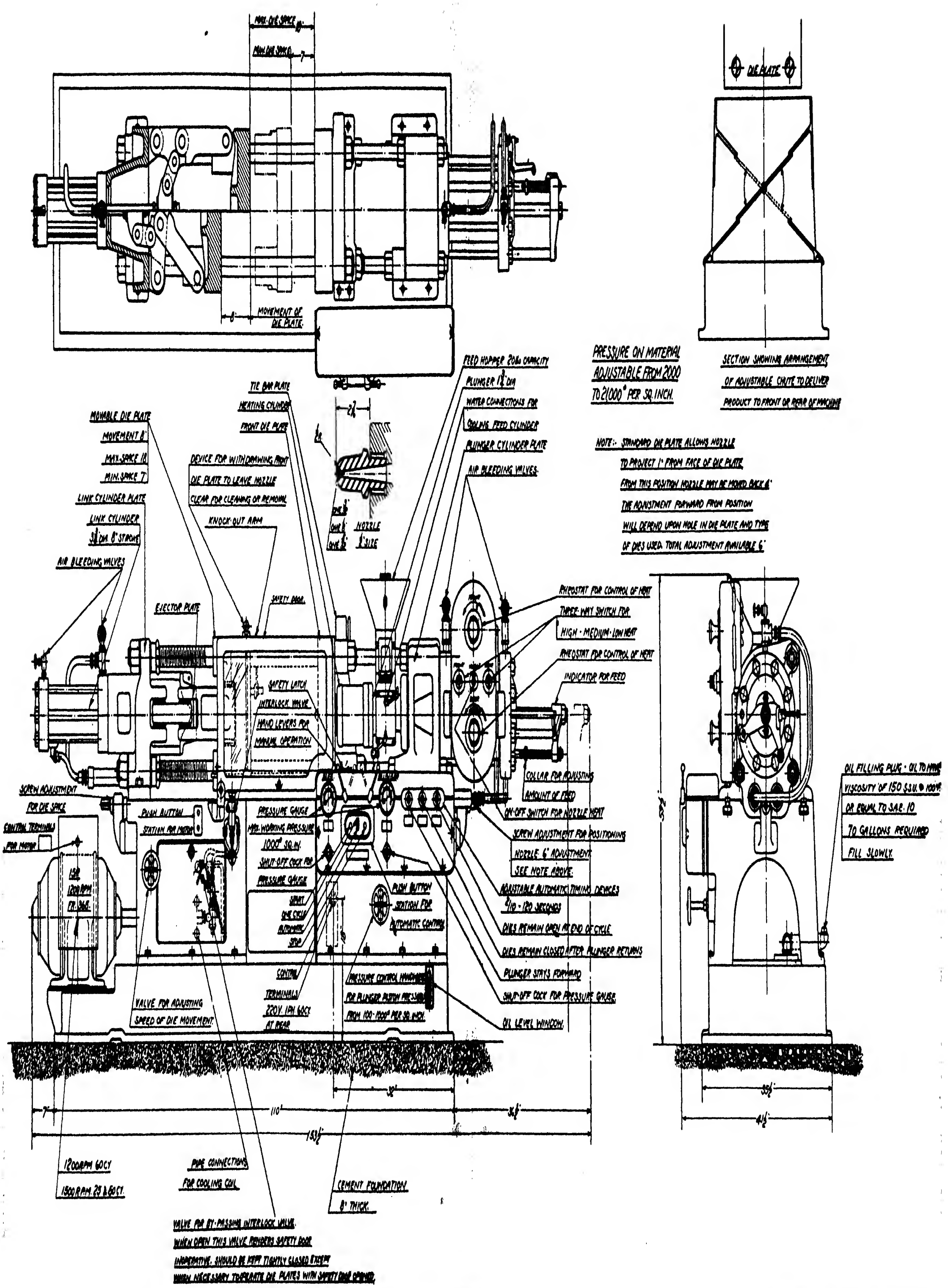
[†] Special model of this press is available; air-operated (125 lb.) without motor or pump.

The air supply necessary to operate these presses is only 80 to 100 lb. A bank of as many as six presses may, in some cases, be handled by one operator.



Courtesy of Standard Machinery Co., Mystic, Conn.

FIG. 17.8 — 100 to 150-ton molding press.



Courtesy of Reed-Prentice Corp., Worcester, M

Fig. 17.9 — Ther[illegible]c molding machine.

Laboratory Press:

Fred S. Carver
New York, N. Y.

For testing molds and molding material the Fred S. Carver Co., New York City, offers a light, compact molding press for laboratory use. The press weighs only 125 lb., and is completely self-contained, power being furnished by hydraulic pump located in the base. The press is capable of pressures up to 20,000 lb., and temperatures up to 400° F. are furnished with either electric or steam hot plates which contain thermometer pockets for checking temperatures. The electric plates are heated from an ordinary light socket.

With the use of a press of this type, research and experimental workers may determine conveniently and inexpensively the exact pressures, molding temperatures, and molding times required for various molding powders. Other applications are in mounting plastics bases of metal pieces for examination, molding of all manner of sample shapes, and testing of plastics pieces for compression strength.

Other typical manufacturers: Charles F. Elmes Engineering Works, Chicago; Farrel Birmingham Co., Ansonia, Conn.; F. J. Stokes Machine Co., Philadelphia; Wm. R. Thropp & Sons Co., Trenton, N. J.

Injection Presses:

Index Machinery Corporation
Cincinnati, Ohio

Presses developed for Index Machinery Corp., by Lester Engineering Co., Cleveland. Fully automatic type. Toggle pins are used for opening and closing the mold, but an arrangement of toggle links transmits full molding pressure to the back plates of the machine during the molding operation. Heating of powder is accomplished in a hopper-fed sleeve-type cylinder with two automatic temperature controls. Feeding of material is controllable, both heating and feeding being fully automatic once correct temperatures and quantities are established for the piece being molded.

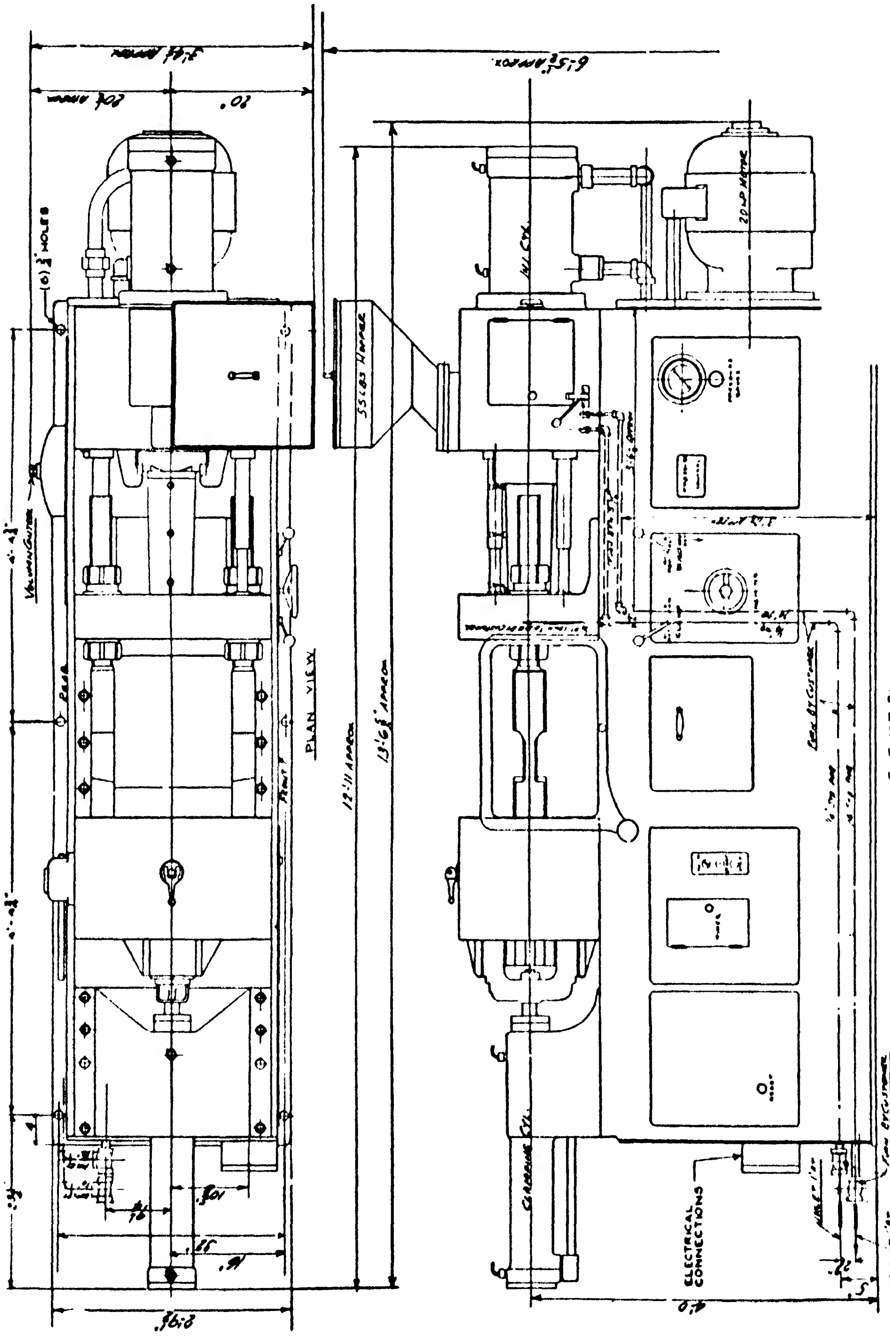
The Hydraulic Press Manufacturing Co.
Mt. Gilead, Ohio

Presses are of two main types: (1) open circuit, and (2) closed circuit. The first is for sustained pressures and the second for flash pressure in presses of rapid cycle operation. For various uses these presses may be equipped with plain pressing surfaces, with heated sub-platens, or with intermediate plates.

Watson-Stillman Co.
Roselle, N. J.

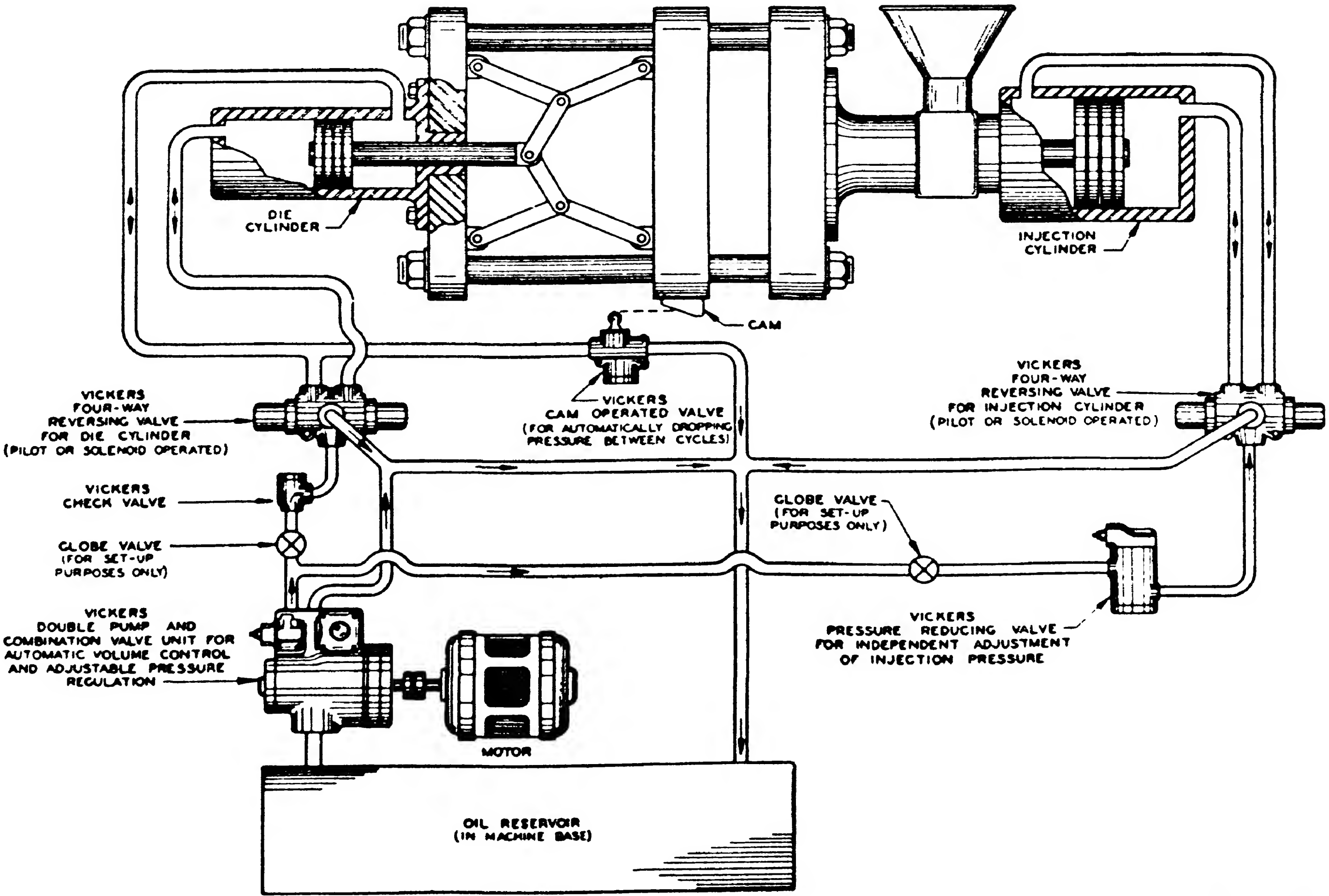
This company makes a complete line of injection molding machines including 2-, 6-, 8-, 12-, and 16-oz. capacities, also a line of automatic presses available in 25-, 50-, 75-, and 100-ton capacities.

Other typical manufacturers: Reed-Prentice Corp., Worcester, Mass.; Grotelite Co., Bellevue, Ky.



Courtesy of The Watson-Stillman Co.

FIG. 17.10—Outline assembly of injection molding machine.



Courtesy of Vickers, Inc., Detroit, Mich.

FIG. 17.11 — Diagram of typical hydraulic circuit for an injection molding machine.

TABLE 97. INJECTION MOLDING PRESSES

Model	Ounces per shot	Shots per hour	Production per hour, lb.	Casting Area, sq. in.	Capacity of Hopper, lb.	Injection Pressure, lb. per sq. in.	Power, hp.	Floor Space, in.	Stroke, in.	Weight, lb.
Reed-Prentice No. 10A	—	400	32	24	20	26,000	10	41 by 147	7	10,000
Reed-Prentice No. 10B	—	400	45	30	35	28,000	20	41 by 180	11¾	12,000
Index Machinery No. 1	4	400	50	40	—	16,000	10	—	—	—
Index Machinery No. 2	6	400	60	60	—	22,000	15	—	—	—
Index Machinery No. 3	8	350	80	100	—	22,000	20	—	—	—
Index Machinery No. 3-S	12	—	—	100	—	30,000	—	—	—	—
Grotelite No. 29A	6½	500	50	60	100	30,000	15	48 by 144	—	—
Hydraulic Press No. 25	2	360	24	110	30	13,500	7½	—	8	—
Hydraulic Press No. 40-H-2	2	360	—	154	30	13,500	—	—	12	—
Hydraulic Press No. 200-H-7	7	360	40	100	50	20,000	15	—	12	—
Hydraulic Press No. 500-V	36	240	—	—	—	20,000	—	—	—	—
De Mattia A	1	500	14	12	—	16,000	7½	31 by 34	—	3000
De Mattia B	2	500	20	18	—	20,000	10	31 by 35	—	3200
De Mattia C	4	450	30	30	—	40,000	10	30 by 108	—	7000

Extruding Machines:

John Royle & Sons
Paterson, N. J.

TABLE 98. SPECIFICATIONS FOR ROYLE EXTRUDING MACHINES

	No. ½	No. 1	No. 2	No. 3	No. 4	No. 5	8½ in.	10 in.
Cylinder diameter, in.	1⅛	2	3¼	4½	6	8	8½	10
Normal die range of standing tubing head, in. (Can be extended)	⅛ to ½	¼ to 1	¾ to 2	1½ to 3	2 to 4	2¼ to 5½	3 to 6	4 to 7
Usual motor size, hp.	1	5	15	25	50	75	125	175
Height, floor to die center, in.	36⅞	37	38	38	38	47½	47½	47½
Floor space with motor base, no motor, in.	17 by 33	25 by 45	89 by 36	95 by 52	110 by 61	118 by 70	144 by 60	162 by 72
Weights, approximate, without motor:								
Net, lb.	350	1500	3650	4630	6500	10,000	14,660	18,400
Crated, lb.	425	1675	4070	5000	7000	10,800	15,150	18,900
Boxed for export, lb.	550	1800	4150	5100	7200	11,250	16,250	23,000
Boxed dimensions, approx., cu. ft.	27	75	175	220	288	304	396	588

Note: No. ½ and No. 1 specifications are for worm drive machines, all others for herringbone drive.

Other typical manufacturers: National Erie Corp., Erie, Pa.; National Rubber Machinery Co., Akron, Ohio.

Finishing Machinery:

Porter-Cable Machine Co.
Syracuse, N. Y.

Because of difficulties of frictional heat and resultant charring or discoloring of many plastics while being ground by ordinary belt sanders, wet sanding methods are sometimes used for finishing operations. The Porter-Cable sander and grinder is especially designed for this. Applications include removing fins, seams, and rough edges. The machine consists of an endless belt covered with the desired abrasive. Water jets wet the belt ahead of the grinding point and other jets flush out the loose material after grinding. This ensures a clean abrasive surface and lengthens life of the belt. The sanders and grinders are supplied in various sizes.

S. S. White Dental Mfg. Co.
New York, N. Y.

A flexible-arm tool for finishing, shaping, or reaming plastics rods, bars, or sheets and for finishing or buffing molded pieces. The principal feature is a flexible drive shaft which enables the user to hold the tool in any position and increases the range of use. Cutting heads, buffers, drills, and a number of other heads are available for almost any type of finishing operation.

Other typical manufacturers: Lupomatic Tumbling Machine Co., Inc., New York; Rudolph R. Siebert, Rochester, N. Y.

Grinding Machines:

Pulverizing Machinery Co.
Roselle Park, N. J.

In grinding raw materials and molding powders for the plastics industry, particle size is important. Uniform powder is necessary for strength of finished product, physical dependability and dependable molding operations. The latter is especially true in injection molding, where the molding powder must be thoroughly and uniformly plasticized in the heating chamber for proper injection. Another requirement is the uniform grinding of coloring material to ensure complete mixing with the resin. Particle size can be controlled to a fine tolerance, a not unusual specification being maximum percentage through 60 mesh with minimum amount through 100 mesh.

This company's grinders have chrome-molybdenum rotor shafts and cadmium-plated nuts and bolts to resist corrosion and resultant contamination of material. An important feature for plastics work is the complete elimination of dust; important because of the need for absolute cleanliness in most molding operations, and because waste material carried off in the form of dust is costly. Dry or wet grinding methods may be used, and in the case of highly flammable or explosive materials the danger may be greatly minimized by bleeding an inert gas into the mixing chamber. There is no extra handling, as all material passes from the hopper into the grinding chamber and then directly into the receptacle provided. Four models are available, ranging from a laboratory and small production grinder to large capacity grinders.

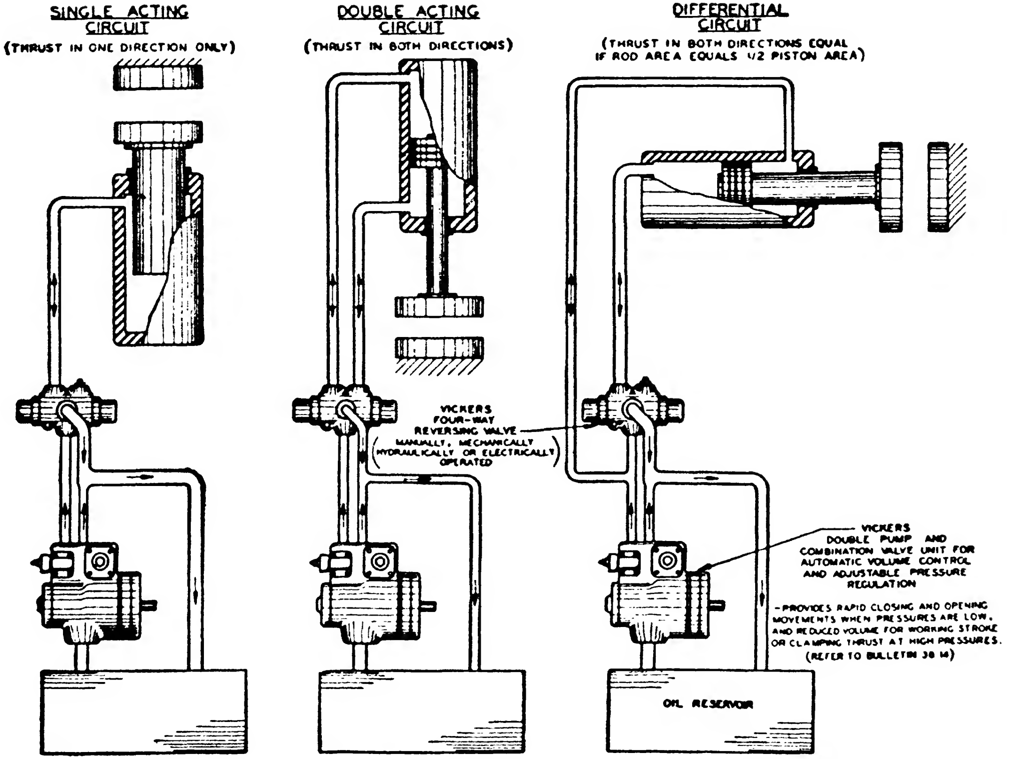
Other typical manufacturers: Mead & Co., Detroit, Mich.; National Metal Abrasive Co., Cleveland, Ohio; The Norton Co., Worcester, Mass.

Mold- and Die-Making Machines:

Kearney & Trecker Corp.
Milwaukee, Wis.

The making of molds and dies for extrusion and compression molding is an industry in itself and is usually carried on as a separate operation by plants specializing in this work. An example of a typical setup in the plastics industry shows the usual relationship between molder and die maker. The Boonton Molding Co. with a well-equipped shop for molding, cannot spare space or time for making its molds, and finds the required equipment, skilled labor, overhead and uncertain market prohibitive to doing so. Therefore, when an order for an intricate radio housing comes in, the die-making specialists, in this case the Newark Die Co., take over the job. The die is made and delivered to the Boonton Molding Co., which adds the price to production costs and does not have to invest in equipment. The Newark Die Co., on the other hand, has a steady business from a number of other molders as well and does not have to have its machines idle until orders come in, as would be the case with a molder who attempted to make his own molds.

Die making is actually an integral part of the plastics industry although often



Courtesy of Vickers, Inc., Detroit, Mich.

FIG. 17.12 — Diagram of typical hydraulic circuits for simple hydraulic clamp or press installations.

separated in actual operation. Equipment for making molds and dies has been greatly improved recently. The rotary head milling machines may be placed in the milling stand and all necessary operations performed to make the finished piece without resetting. This eliminates many planing and shaping operations. As an example, the milling time of a car-door handle die was reduced from a previous time of 56 hr. to 14 hr. In using the rotary head milling machine all angles are figured from a common base line and operations are figured from tables and adjustments which are an integral part of the machine.

Other typical manufacturers: Pratt & Whitney Division, Hartford, Conn.; George Gorton Machine Co., Racine, Wis.; R. D. Wood Co., Philadelphia.

Accessory Equipment

Modern plant equipment requires many auxiliary appliances over and above the actual molding presses for the manufacture of plastic products.

Benches. Benches must not be too large, but should have sufficient top area to provide room for a box of molding powder or preforms, loading tray, inserts, insert loaders, and in addition, space for special equipment, gauges, shrink plugs, and the like. A shelf or platform should be provided under the table top for the reception of molded parts, and the bench placed where it will facilitate the molding cycle.

Another type of bench construction is shown in Fig. 17.6. This setup is fastened to the side of the press and provides the operator with space for preforms. Excess dust or powder is sifted into a tray on the table surface. Such a loading table is recommended rather than the ordinary table or work bench, as it takes up less floor space. Flash can be cleaned up from the floor surface readily, and the exact space necessary for preform loading is allowed, thereby eliminating the tendency to clutter up the bench surface with odds and ends. Molding material drums are used as tote boxes for finished parts.

Some standard tote boxes are made with small legs or grooves in the bottom which telescope into the top of another box to facilitate stacking. The tote box sizes are determined by the work to be carried, but they should never be so large as to be unwieldy.

Folding wooden boxes are sometimes used and have the advantage of requiring less space for storage. Powder drums are extensively used for parts shipments and storage of preforms and molded pieces.

Preform, Powder, and Insert Loaders. Preform loaders are most satisfactory when constructed of laminated plastic or heavy sheet aluminum. Such construction has superior durability and pays for itself when used over a long period of time. For short run work, where the cost of laminated or aluminum loaders is not warranted, wood and hard composition board can be used.

Powder loaders follow the same principle of construction as the preform loaders, but cavities are larger to accommodate the greater bulk of the loose material. Both preform and powder loaders are preferably located over the mold by means of dowel pins in the mold and corresponding holes in the loader.

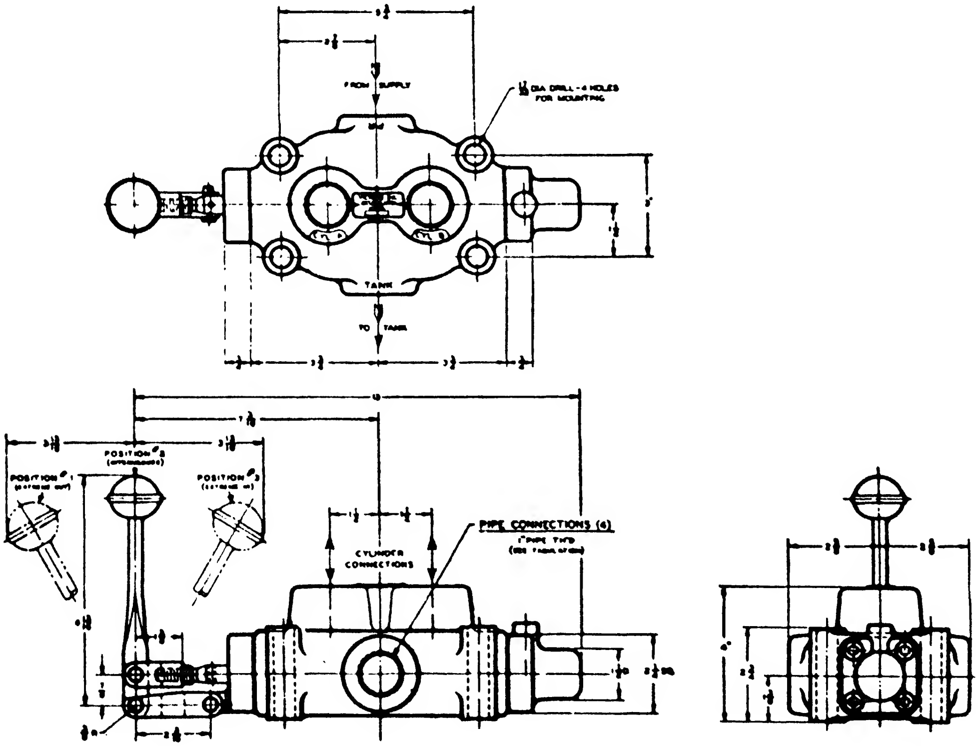
Insert loaders are widely used to hasten loading of multiple-cavity molds. The most common type consists of a heavy aluminum plate having holes drilled through it at points that line up with the insert receptacles in the mold. Small inserts can usually be held in the holes by friction, whereas larger inserts require a spring device to keep them from falling through. Inserts are driven to their locations in the mold by pins mounted in a plate.

Unscrewing Devices. The increased demand for mass production work, such as bottle caps and other small threaded pieces, created a need for satisfactory unscrewing devices. A chuck, driven by an electric or pneumatic portable drill, at the present time produces most satisfactory results.

For injection molds it is usually desirable to have the unscrewing mechanism incorporated in the mold proper so that it may work in synchronism with the machine.

Gloves are essential in a molding plant, particularly for handling hand molds. They should be made of heat-resistant materials and be free from metal inserts. Thick heat-resistant pads will also be of value.

Tools. It is sometimes necessary to use a sharp tool for digging flash from a mold. In such cases a soft metal, such as brass, should be used. Hard metal tools will scratch the mold or damage it. Likewise, hammers, required to knock hand molds apart or drive in inserts, should be made of soft metal, raw-hide, or fiber. Air-hose nozzles should be made of brass.

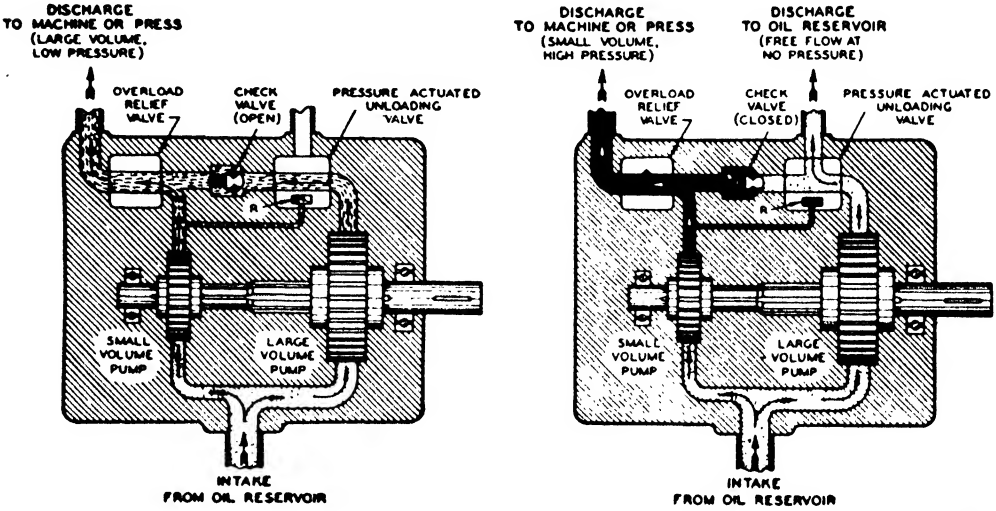


Courtesy of Vickers, Inc., Detroit, Mich.

Fig. 17.13 — Molding press, 1 in. four-way valve, lever operated.

Air Compressors. Molding plants require the use of compressed air for cleaning purposes. A central air compressor and tank are used to supply air at each point where quick cleaning is necessary. A cold blast of air at the presses provides a quick method of removing parts and flash from the mold. Air should be kept dry. Much molding trouble is caused by using air that contains water, oil, and dirt. These get on mold surfaces and due to heat are baked on, thus causing sticking on the surface of the mold.

Air jets at pilling machines, tumbling barrels in the finishing rooms, etc., are essential. Air-hose nozzles of brass should be used on polished steel molds. Flexible hose connections should be conveniently placed for the operators' use.



Courtesy of Vickers, Inc., Detroit, Mich

Low-pressure diagram: for rapid traverse or rapid closing movements.

High-pressure diagram: for feeding or final clamping requirements.

FIG. 17.14 — Schematic flow diagrams showing automatic volume control for Vickers double pump and combination valve unit.

Pyrometers. Correct results in the manufacture of plastic articles in heated or chilled molds are dependent on the maintenance of mold temperatures within limits indicated by the nature of the plastic being molded and by the size of the molded part. With the use of pyrometers, temperatures are quickly and accurately determined in checking the several cavities of a multiple-cavity mold.

Surface pyrometers permit accurate and rapid means of determining surface temperatures in the cavity. It is recognized that surface temperature indications obtained by contacting mercurial thermometers or imbedded thermocouples, or by obtaining the temperatures of the heating or cooling medium are inaccurate, since these temperatures have a variable and unknown relation to the actual temperatures of the surface.

Timing Devices. Excellent equipment is available for time cycle, temperature, pressure, and condensate control. Such equipment provides either hand or automatic control of the following operations:

1. Closing of the press on low pressure.
2. Application of high pressure at any desired time in the cycle.
3. Heating of the platens with condensate returned.
4. Cooling of the platens with direct flow to the drain.
5. Maintenance of an accurate temperature as the platens are being heated.

This type of control ensures a correct timing of all operations and overcomes any possibility of operators using other than predetermined temperatures and time.

The operator loads the press and presses the button in the controller circuit. He is immediately free to take up other duties. The steam flows freely through the mold or platens and into the return circuit while the press is closing on low pressure. When the press is completely closed, high pressure is automatically admitted and after the press has been closed the required length of time, a drain valve is reversed, sending the condensate to the trap, and the cure progresses. At the proper time, steam can be turned off, and where desired, as on heavy molded sections, water is turned on, sending the cooling water through the mold or plates and then to the sewer. After the required time interval, the controller opens the press and stops — ready for the next cycle. During this period, the operator can give his time to two or more similarly equipped presses.

Clocks. Mechanical or electrical clocks, or a combination of both, are commonly used, one timing device being allotted to each press.

Large master electric clocks are placed in the molding room where they can be observed by all. This method is subject, of course, to error and is not so foolproof as the automatic timing device which ensures a uniformly molded product. The molder is also able to maintain production schedules.

Dust Control. Molding presses on which light-colored compounds are being molded must be covered with fabrics or otherwise enclosed to prevent powders of another color or flash from nearby presses from contaminating the molding charge. This is important in the handling of preform machines. Individually enclosed compartments should be provided for handling each color. The materials used in the construction of these dust-proof compartments should permit easy and thorough cleaning when changing from one color to another.

The use of dust collectors is highly desirable. In injection molding of crystal-clear objects the least contamination will often cause rejection of the parts. Here, it is necessary to place presses in an airtight room. It is also desirable to keep this room under slight positive pressure of filtered air.

Rotary Cutters and Grinders. *For Thermoplastic Materials.* All users of injection molding machines require suitable equipment for the regranulation of gates, sprues, and defective moldings to a uniform fineness for reclamation purposes. Equipment particularly suited to this type of work has been developed.

Preheating ovens are essential for the production of certain molded parts. Such ovens employ the method of circulating hot air by forced draft. These units will do much to assist molders on the difficult molding job where moldability or technical requirements are important.

For Thermosetting Materials. Ureas are heated at 160° to 175° F. for best results. Phenolics are heated at 180° to 250° F. for 15 to 30 min.

Advantages are as follows:

1. Greater plastic flow, particularly on large cabinets and machine housing.
2. Stiffer materials may be employed, giving better appearance and finish and rapidity of cure inherent in harder or stiffer flows.
3. Uniform heating of large mass of powder or large pills overcomes the tendency to color segregation and flow streaking.
4. Ensures better chemical, electrical, and mechanical strength characteristics.

5. Assists in eliminating uneven stress and strain in the molded part due to uneven heating of cold charges. Preheated materials flow more uniformly and evenly.

6. Fast and economical production, saving press closing time and decreasing molding time upward of 50 per cent.

7. Ensures lower shrinkage.

For Thermoplastic Materials. Cellulose acetates are preheated at temperatures from 135° to 180° F., depending upon formulation, plasticity, and length of preheating time. Preheating drives off absorbed moisture in the material maintaining more constant plasticity.

Polystyrenes are preheated to a temperature of 160° F. without sintering. This is necessary only when excessive moisture has been absorbed.

For compression molding, vinyl plastics are preheated at 225° to 280° F. Solid preforms are heated by conventional methods, preferably in an oven where temperature control is more accurate. Powdered or granulated material difficult to preform by machine generally must be preheated in the mold.

Afterbaking Ovens. It is sometimes desirable to afterbake molded pieces after they are removed from the mold cavity. This is usually done to increase electrical resistivity, dielectric strength, and surface insulation, and also to ensure maximum or an absolute shrinkage of the molding. This is sometimes desired where the part is used as a chassis or mounting block for instrument parts and where aftershrinkage may cause functional troubles.

For small parts, preheating ovens can be used to good advantage. Pieces of larger size or greater quantities can best be handled in specially built equipment.

Finishing Equipment. Economical removal of flash, fins, or overflow must be provided for before the parts as delivered from the mold cavities can be considered ready for inspection.

De-finning barrels are first used to remove excess flash on small parts, after which the parts are placed in tumbling barrels.

Flash or fins when designed to be vertical to the part may be quickly removed with belt or disk sanders.

Kick presses and bench drill presses for removing flash from holes or slots are necessary equipment for all finishing departments. Ten- or twelve-inch buffing wheels should be provided for flash removal and polishing of parting lines.

Inspection Equipment. The inspection department's most effective equipment are good daylight and good eyesight. Precision instruments, micrometers, calipers common to all good inspection technique should also be available.

Packing Equipment. Where small parts are produced in great volume, an accurate counting scale should be included in equipment requirements to eliminate hand counting. Other equipment required is that found in any manufacturing concern's shipping department — plenty of storage space, sufficient bench space for efficient packing, cartons and packing cases, tape sealing machines and stitching machines.

Grinders:

Paul O. Abbé, Inc.	Little Falls, N. J.
Abbé Engineering Company	New York, N. Y.
L. Albert & Son	Trenton, N. J.
Allis-Chalmers Manufacturing Company	Milwaukee, Wis.

Grinders: *Continued*

American Emery Wheel Works	Providence, R. I.
Baker Perkins, Inc.	Saginaw, Mich.
Baldor Electric Company	St. Louis, Mo.
Ball & Jewell	Brooklyn, N. Y.
Bridgeport Safety Emery Wheel Company, Inc.	Bridgeport, Conn.
Champion Blower & Forge Company	Lancaster, Pa.
Chicago Wheel & Manufacturing Company	Chicago, Ill.
Cincinnati Electrical Tool Company, The	Cincinnati, Ohio
Cincinnati Lathe & Tool Company	Cincinnati, Ohio
Arthur Colton Company	Detroit, Mich.
Delta Manufacturing Company	Milwaukee, Wis.
De Mattia Machine & Tool Company	Clifton, N. J.
Engineering Laboratories, Inc.	Paterson, N. J.
Gruendler Crusher & Pulverizer Company	St. Louis, Mo.
Hammond Machinery Builders, Inc.	Kalamazoo, Mich.
Ingersoll Rand Company	New York, N. Y.
Leominster Tool Company,	Leominster, Mass.
Frank M. Martin	Springfield, Mass.
Mead & Company	Detroit, Mich.
Norton Company, The	Worcester, Mass.
Porter-Cable Machine Company	Syracuse, N. Y.
Power King Tool Corp.	Warsaw, Ind.
H. P. Preis Engraving Machine Company	Newark, N. J.
Production Machine Company	Greenfield, Mass.
Pulverizing Machinery Company	Roselle Park, N. J.
Raymond Pulverizer Div., Combustion Engineering Company, Inc.	Chicago, Ill.
Robinson Manufacturing Company	Muncy, Pa.
Safety Grinding Wheel & Machine Company, The	Springfield, Ohio
J. B. Sedberry, Inc.	Franklin, Tenn.
Sprout, Waldron & Company	Muncy, Pa.
F. J. Stokes Machine Company	Philadelphia, Pa.
S. S. White Dental Manufacturing Company, Ind. Div.	New York, N. Y.
Wolf Company, The	Chambersburg, Pa.

Timing Devices:

Bristol Company	Waterbury, Conn.
R. W. Cramer Company, Inc.	Centerbrook, Conn.
French Oil Mill Machinery Company	Piqua, Ohio
Industrial Instrument Company	Akron, Ohio
Leeds & Northrup Company	Philadelphia, Pa.
Partlow Corporation	New Hartford, N. Y.
Standard Machinery Company	Mystic, Conn.

Pyrometers and Indicators:

Bailey Meter Company	Cleveland, Ohio
Bristol Company	Waterbury, Conn.
Brown Instrument Company	Philadelphia, Pa.
Cambridge Instrument Company, Inc.	New York, N. Y.
Chas. Engelhard, Inc.	Newark, N. J.
Foxboro Company, The	Foxboro, Mass.
Hoskins Manufacturing Company	Detroit, Mich.
Illinois Testing Laboratories, Inc.	Chicago, Ill.

Pyrometers and Indicators: *Continued*

Index Machinery Corporation	Cincinnati, Ohio
Leeds & Northup Company	Philadelphia, Pa.
Evarts G. Loomis	Newark, N. J.
Minneapolis Honeywell Regulator Company	Minneapolis, Minn
Pyrometer Instrument Company	New York, N. Y.
Republic Flow Meters Company	Chicago, Ill.
Russell Electric Company	Chicago, Ill.
C. J. Tagliabue Manufacturing Company	Brooklyn, N. Y.
Taylor Instrument Companies	Rochester, N. Y.
Thwing-Albert Instrument Company	Philadelphia, Pa.
Wilson-Maeulen Pyrometer Company	Foxboro, Mass.

Mills:

Abbé, Paul O., Inc.	Little Falls, N. J.
Farrel-Birmingham Company	Ansonia, Conn.
Patterson Foundry & Machine Company	East Liverpool, Ohio

Sanders (belt and disk):

Black & Decker Manufacturing Company, The	Towson, Md.
Delta Manufacturing Company	Milwaukee, Wis.
Lupomatic Tumbling Machine Company, Inc.	New York, N. Y.
Porter-Cable Machine Company	Syracuse, N. Y.

Finishing and Machinery Equipment:

Tumblers

Globe Machine & Stamping Company, The	Cleveland, Ohio
Hanson-Van Winkle-Munning Company	Matawan, N. J.
J. Holland & Sons, Inc.	Brooklyn, N. Y.
Lea Manufacturing Company	Waterbury, Conn.
Lupomatic Tumbling Machine Company, Inc.	New York, N. Y.
J. S. McCormick Company	Pittsburgh, Pa.
Frank M. Martin	Springfield, Mass.
Royersford Foundry & Machine Company, Inc.	Royersford, Pa.
Rudolf R. Siebert	Rochester, N. Y.
Sly Manufacturing Company	Cleveland, Ohio
Whiting Corporation	Harvey, Ill.

Polishing and Buffing

American Rotary Tools Company, Inc.	New York, N. Y.
Baldor Electric Company	St. Louis, Mo.
Black & Decker Manufacturing Company, The	Towson, Md.
Bridgeport Safety Emery Wheel Company, Inc., The	Bridgeport, Conn.
Champion Blower & Forge Company	Lancaster, Pa.
Chicago Wheel & Manufacturing Company	Chicago, Ill.
Cincinnati Electrical Tool Company, The	Cincinnati, Ohio
Delta Manufacturing Company	Milwaukee, Wis.
Divine Brothers Company	Utica, N. Y.
Ekstrom Carlson & Company	Rockford, Ill.
Grimes & Harris, Inc.	Leominster, Mass.
Hammond Machinery Builders, Inc.	Kalamazoo, Mich.
Hanson-Van Winkle-Munning Company	Matawan, N. J.
R. G. Haskins Company	Chicago, Ill.
J. Holland & Sons, Inc.	Brooklyn, N. Y.
Ingersoll Rand Company	New York City

Finishing and Machinery Equipment: *Continued*

Polishing and Buffing

Jackson Buff Corporation	Long Island City, N. Y.
Lea Manufacturing Company	Waterbury, Conn.
Lupomatic Tumbling Machine Company, Inc.	New York, N. Y.
Production Machine Company	Greenfield, Mass.
U. S. Electrical Tool Company	Cincinnati, Ohio
Van Dorn Electrical Tool Company	Towson, Md.
Walker-Turner Company, Inc.	Plainfield, N. J.
Watson-Stillman Co.	Roselle, N. J.
S. S. White Dental Manufacturing Company, Ind. Div.	New York, N. Y.

Inserts — Inlays

Aluminum Company of America	Pittsburgh, Pa.
Brass Goods Manufacturing Company	Brooklyn, N. Y.
Chase Brass & Copper Company	Waterbury, Conn.
Etched Products Corporation	Long Island City, N.Y.
L. F. Grammes & Sons, Inc.	Allentown, Pa.
Lamson & Sessions Company, The	Cleveland, Ohio
Parker-Kalon Corporation	New York, N. Y.
Plastic Inlays, Inc.	Summit, N. J.
Probar Corporation	Orange, N. J.
Publix Metal Goods Corporation	New York, N. Y.
Stanley Works	New Britain, Conn.
William Steinen Manufacturing Company	Newark N. J.
Whitney Manufacturing Company	New Haven, Conn.
Wrought Washer Manufacturing Company	Milwaukee, Wis.

Marking

Ackerman-Gould Corporation	New York, N. Y.
Altair Machine Corporation	New York, N. Y.
George Gorton Machine Company	Racine, Wis.
Griffin, Campbell, Hayes, Walsh, Inc.	New York, N. Y.
Markem Machine Company	Keene, N. H.
James H. Matthews & Company	Chicago, Ill.
Pannier Bros. Stamp Company	Pittsburgh, Pa.
Parker Stamp Works, Inc.	Hartford, Conn.
Peerless Roll Leaf Company	Union City, N. J.
H. P. Preis Engraving Machine Company	Newark, N. J.
Simplex Gold Stamping Press Company, Inc.	New York, N. Y.

Testing Machines

Adamson Machine Company	Akron, Ohio
Baker Perkins, Inc.	Saginaw, Mich.
Baldwin Locomotive Works, The	Philadelphia, Pa.
Brown Instrument Company	Philadelphia, Pa.
Cambridge Instrument Company	New York, N. Y.
Falstrom Company	Passaic, N. J.
Gisholt Machine Company	Madison, Wis.
Illinois Testing Laboratories, Inc.	Chicago, Ill.
Indicating Calipers Corporation	New York, N. Y.
Frank M. Martin	Springfield, Mass.
Olsen Testing Machine Company, Tinius	Philadelphia, Pa.
Read Machinery Company, Inc.	York, Pa.

Finishing and Machinery Equipment: ***Continued***

Testing Machines

Henry L. Scott Company	Providence, R. I.
Shallcross Manufacturing Company	Collingdale, Pa.
Tenney Engineering, Inc.	Bloomfield, N. J.
Testing Machines, Inc.	New York, N. Y.
Wm. R. Thropp & Sons Company	Trenton, N. J.
Thwing-Albert Instrument Company	Philadelphia, Pa.

Scrap Grinders:

Ball & Jewell,
Brooklyn, N. Y.

These grinders consist of four stationary and three revolving extra heavy steel knives driven by a self-contained motor and belt drive. Loss of material is eliminated with a special hopper; power required is a 2 hp., and capacity runs to 250 lb. per hr.

Handles both thermosetting and thermoplastic materials. Frequently used for grinding in intermediate stages of resin manufacture.

Plastics Marking:

Markem Machine Co.,
Keene, N. H.

After plastics products have been molded or cast and the various finishing operations have been performed, another operation — marking — is frequently necessary. Numbers, letters, or designs may be made in various ways and in a wide variety of colors by either standard marking machines or in machines especially designed for the plastics industry. The printing methods developed for plastics result in clear, sharp imprints comparable in quality to any other type of good printing.

Some plastics may be indented for marking by the use of machines utilizing engraved brass or hardened steel dies. Where simple impressions on the surface are sufficient, a plain stamping action is used; when more definition is desired, a combination indenting and inking process is used. Inks may be of any color, and are usually in contrast to the piece being marked. In cases where metal leaf is used instead of inking, automatic attachments for the simultaneous laying of the metal leaf are available.

Printing is the common method of marking plastics. The letters or designs are printed directly on the article by use of rubber plates and air-drying chemical compounds. The marked article may be packed a few minutes after marking.

Standard capacities run to 3000 pieces per hour, and imprint areas up to 4 in. by 15 in. Special equipment can be obtained for greater capacities. The machines include manually operated machines for small production, motor driven, and two-color printers.

Ackerman-Gould Corporation,
New York, N. Y.

Machines consist of a bed or slide, a roll of the marking leaf, and dies for making the impression. Although roll leaf marking is generally used, straight indenting may also be done. The pieces to be marked are fed onto the table, the die is brought to the surface of the piece, and pressure is applied by hand lever. Heavy clamp pressure, when needed, is obtained with the use of toggles. The marking leaf is held on a roll attached to the machine and is fed under the die automatically. The die head, in most

Plastics Marking: *Continued*

cases, can be raised or lowered, and is electrically heated. The marking leaf may be of almost any type, gold, imitation gold (usually bronze), and aluminum being most commonly used.

James H. Matthews & Co.,
Chicago, Ill.

Marking plastics with trade names, lot numbers, or ornamental designs is accomplished by a variety of machines. For simple marking of one or more letters or figures, a hand die is used, the marking being done by the blow of a hammer. For light markings, or shallow indenting, a holder may be used for the letters or numbers. This holder costs from $10 to $12. Tool-steel type faces, beveled for wear resistance and to increase legibility, are set in this compact holder which accommodates as many as eight characters in sizes up to 3/16 in. each.

Other holders are available for marking on rods, marking more than one line at a time, and for curved or convex faces. Inspection hammers bearing trade-marks or lot numbers may be obtained for marking rods or stock shapes.

Cutting Machine:

Andrew C. Campbell Div.,
American Chain & Cable Co., Inc.,
Bridgeport, Conn.

A new abrasive wheel machine has been designed for cutting plastics tubes and rods with a smooth, accurate cut. The machine has a capacity of 3½ in. on tubes and 2 in. on rods. The coolant system is designed to eliminate scorching of material and has a special splash shield and non-clogging features. A stop bar with micrometer adjustment speeds up work and ensures uniformity and accuracy of cut. The work clamp is adjustable to pressures from 105 to 315 lb. without changing the clamping thruster, while the clamping action itself is automatic.

Following a cutting job through to completion, the operator presses starter button, lays the bar stock in place and adjusts the bar stop to the measurement required. Then he pulls the operating handle downward, but before the cutting wheel reaches the stock, the automatic hydraulic clamps operate and firmly hold the stock in place. The cutting blade is then brought down to and through the stock. After this operation is completed, the operator cuts off the coolant and easily pokes the bar stock up and out of the way, and pushes the stock through so that it ejects the cut piece. The complete cycle is a matter of seconds.

CHAPTER XVIII

MOLDS

Molding compounds are the raw materials which are used by the molding industry for the manufacture of molded plastics items. As in every other industry the quality of the fabricated piece depends upon the type of tools available and the precision with which these tools are used. The major tool with which the molder works is the mold, used in conjunction with suitable pressing and heating equipment. The mold assumes first place in importance — this because it is that tool with which the raw material comes in contact when producing the desired shape of the final molded piece, and is the medium through which pressure and heat are applied to the molding compound.

The manufacturer of molding compounds sets up in his own mind what is considered to be an ideal plastic. This should be such that the molding would approach a punch press operation, wherein time, temperature, and pressure become insignificant factors.

At present, our modern molding compounds fail to approach this ideal plastic although it must be said that in the past several years research conducted by the various manufacturers of molding compound has greatly improved the moldability of the various types of plastics available. It is also true that the moldings produced today are larger, more complicated, and are molded under conditions involving much shorter cycles, an operation far advanced from that of a few years ago.

Types of Molds. Molds for " hot-molding " fall into two classifications: molds for thermoplastic materials and molds for thermosetting materials. Molds for thermosetting materials are, in turn, divided into four different types:

1. Positive mold, Fig. 18.1.
2. "Landed" positive mold (modified positive type), Fig. 18.2.
3. Flash-type mold, Fig. 18.3.
4. Semi-positive mold, Fig. 18.4.

Each of these types has definite reasons for existence.

The positive-type mold is always most desirable where the casting must be very dense, since all of the molding pressure is applied to the projected area of the molded piece. It is also used for molding high impact plastics.

The landed positive mold is generally used where it is necessary to split the casting horizontally to accommodate either a radius, a bevel, or some necessary projection.

The flash-type mold is being used generally in producing thin pieces and where the preform is used for the charge. This type of mold is generally the least expensive. There must be relief around the cavity either on the lower or upper part of the mold or sometimes on both, so that there is only a comparatively small area in contact when the mold is completely closed. This landing is called the "cutoff." Care must be taken that this land area or cutoff area is not reduced too greatly, since high pressure used during the molding cycle will invariably upset or ruin the mold; on the other hand, if the cutoff area is too great, it will result in heavy flashing which will increase the cost of finishing the parts. Generally, this cutoff area varies from ⅛ to 7/32 in. and should produce molded parts with a fin thickness between 0.003 and 0.005 in. As can be seen in Fig. 18.3, part of the molding pressure is absorbed by the cutoff edge and consequently the molded parts are never so dense as they would be if positive or semi-positive molds were used. Also, this type of mold will consume more material than the other three types. One excuse for its existence is the original cost of the die.

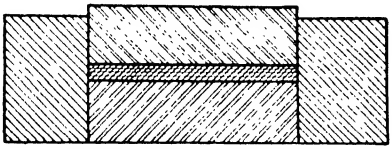


FIG. 18.1 — Positive mold.

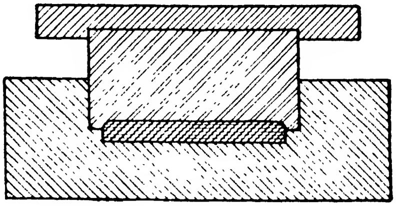


FIG. 18.2 — " Landed " positive mold.

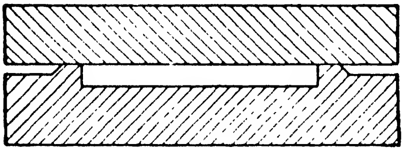


FIG. 18.3 — Simple flash mold.

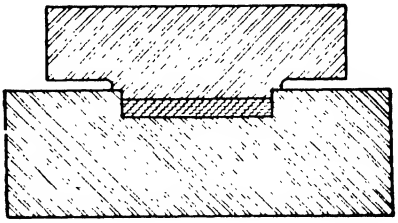


FIG. 18.4 — Semi-positive mold.

The semi-positive mold is generally used in connection with molding urea type material.

Another type of mold for thermosetting material is the " transfer " mold. This type of mold resembles the construction of an injection mold for thermoplastic material, with the exception that the partly heated material is forced through the orifice into a hot mold rather than conversely, as in an injection mold.

Molds for thermoplastic materials are always of the flash type.

Positive mold. Providing that a tight fit between force and cavity is maintained, this type of mold ensures full pressure on the compound. There is then little or no overflow and effective pressure is maintained. However, it is obviously impossible to maintain effective pressure on all cavities of a multi-cavity mold unless two distinct conditions are met: The amount of material in each cavity must be precisely the same and the cavities must be identical in size. This is true also for semi-positive molds.

When the fit between force and cavity of a positive mold is made loose to allow overflow, or sprue grooves are added and external press stops are employed to determine the depth of cavity, maintenance of pressure on a compound becomes impossible. For these reasons multi-cavity positive molds are not recommended.

Full-flash mold. In molds of this type, best results are obtained by some combination of the following practices:

1. Quite heavy overload of material.
2. Dense preforms approximating finished piece in size and shape. These preferably should be preheated.
3. A slow closing of the mold, allowing the compound thoroughly to heat and partially to harden before final closing. As a variation of this method, the press may be held on low pressure for a few seconds when the mold comes together before applying high pressure.

Semi-positive mold. As molded items have increased in size and complexity, and the depth of draw measurably increased, it has become desirable to resort to a combination of the positive and flash-type mold, now commonly referred to as a semi-positive mold. (See Fig. 18.4.) The use of such a mold produces a piece having a maximum density inasmuch as the material is under pressure during its plastic stage and for some few seconds after the mold has seated on the cutoff edge.

With this type of mold construction (Fig. 18.4), effective pressure on the compound is assured during the last of the closing cycle, because of the short distance of vertical positive fit between force and cavity. Slow uniform closing, however, allowing the material to fuse completely before the mold is closed, will increase the effective pressure on the compound with optimum results.

The term " semi-positive " is applied rather loosely in the molding field and many so-called semi-positive molds are really only flash molds. Figure 18.4 illustrates what might be considered an ideal semi-positive mold. In this mold it will be observed that any excess material must first escape through the narrow vertical opening followed by further escapement through a tight horizontal area. A true semi-positive mold may be built in two ways:

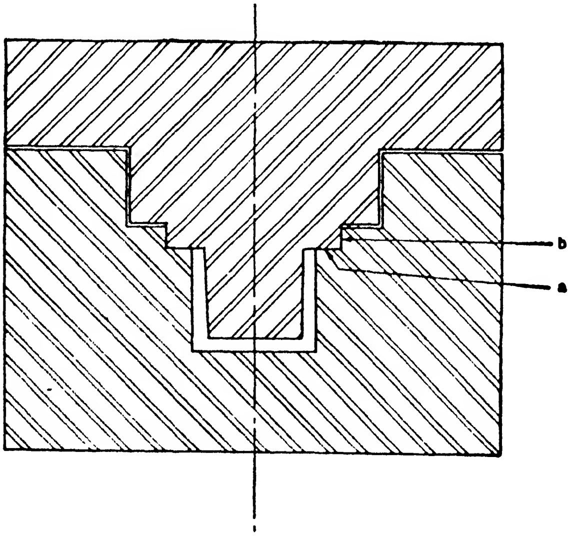


FIG. 18.5 — Semi-positive type mold with horizontal flash, *a*, followed by vertical **flash**, *b*.

1. The first flash may protrude horizontally and then through a vertical rise (see

Fig. 18.5); or a reverse condition may exist, namely, escapement vertically followed by further horizontal escapement. (See Fig. 18.6.)

2. Some molds are built with a horizontal cutoff followed by an overflow well of such large capacity that no back pressure is exerted on the escaping material. (See Fig. 18.7.) The fallacy in classifying this type of mold as semi-positive exists in the fact that the vertical portion of the mold, following the overflow well into which the excess material flashes, becomes a guide for the punch rather than a cutoff for material, unless, of course, excessive material is used to fill completely the overflow well, making such a mold truly semi-positive. Either the overflow well should be eliminated, or a portion of the punch should enter the cavity at least 1/16 in., as shown in Fig. 18.8.

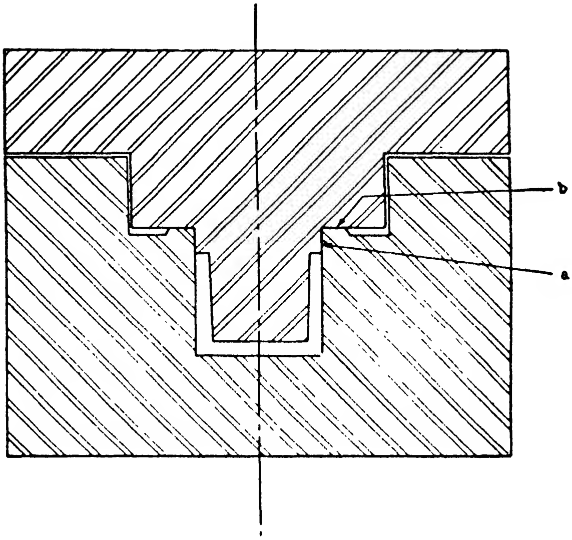


Fig. 18.6 — Semi-positive type mold with vertical flash, *a*, followed by horizontal flash, *b*.

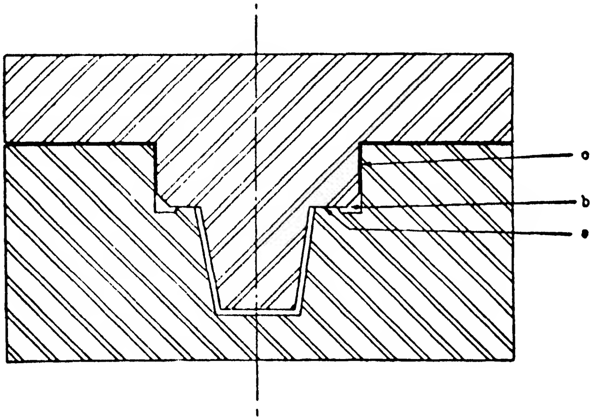


Fig. 18.7 — Full flash type mold, often misnamed semi-positive. Flash appears only at cutoff, *a*, unless overflow well, *b*, becomes completely filled with excess material. Vertical guide, *c*, acts only as guide for punch.

Design of Molds. The most essential part in the designing of molds is to see that the mold is adequate for the material to be used in the molding of parts. Due to large variations in the properties of materials, the designer must investigate and determine definitely the type of material to be used. The bulk factors of these materials vary a great deal, from 1.5 to 1 to 12 to 1. Consequently, a mold designed for the use of material with a bulk factor of 1.5 to 1 could never be used to mold material with a bulk factor of 10 to 1 or 12 to 1. Also, the mold shrinkage is variable as well for different types of materials. Next, the designer must know the size of the equipment where the mold will operate. The mold designer must also be guided by the estimate form showing how the part is to be furnished to the customer, with respect to the finish and other characteristics which are taken care of in the mold. One of the essential points of mold designing is the simplicity of the mold and simplicity of operation. Any unnecessary side cores or excessive handling of loose pieces retards production and consequently increases the cost of the molded part. The designer also should study very carefully the customer's requirements and the part drawing or sample to determine the most economical mold consistent with monthly and yearly production.

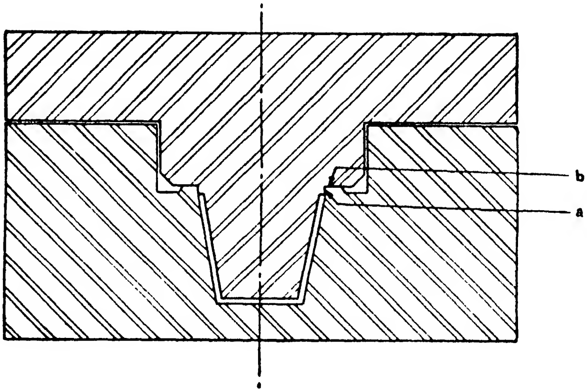


FIG. 18.8 — True semi-positive mold vertical flash appears at cutoff, *a*, followed by a horizontal flash at cutoff, *b*.

Molds constructed by the hobbing process very often have to be replaced due to the damage done by continuous operation of the mold.

While it has been indicated that semi-positive molds are desirable for the molding of urea plastics, it is not always feasible to use this type of mold exclusively. For certain applications, a flash-type mold is suitable and, in some cases desirable, particularly in the molding of small objects where multi-cavities are used. Each manufacturer of molding compounds has his own pet theories with respect to the type of mold suitable for his particular type of material, and in general, the molder himself must decide what type of mold to use, particularly as the molds must be available for more than one type of molding compound. In general, urea plastics will mold satisfactorily in molds designed to run the phenolics. However, in some instances it may be advisable to change the tolerances existing at the vertical flash line. While such a change will allow greater ease in molding ureas, it does not adversely affect the molding of phenolics.

The effect of mold types on the physical properties of molded urea plastics has been shown by data produced in the laboratories of the Plaskon Company, Inc. Three types of die, as referred to above, were built to produce a test bar in order to illustrate the importance of the principle of maintaining effective pressure on the compound throughout the molding cycle. Figures 18.9, 18.10 and 18.11 illustrate the type molds used.

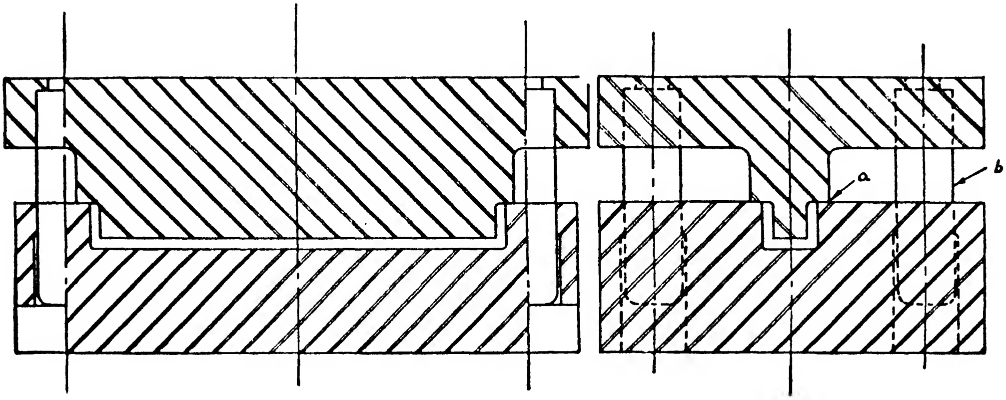


FIG. 18.9 — Flash type mold: *a*, horizontal cutoff; *b*, guide pin.

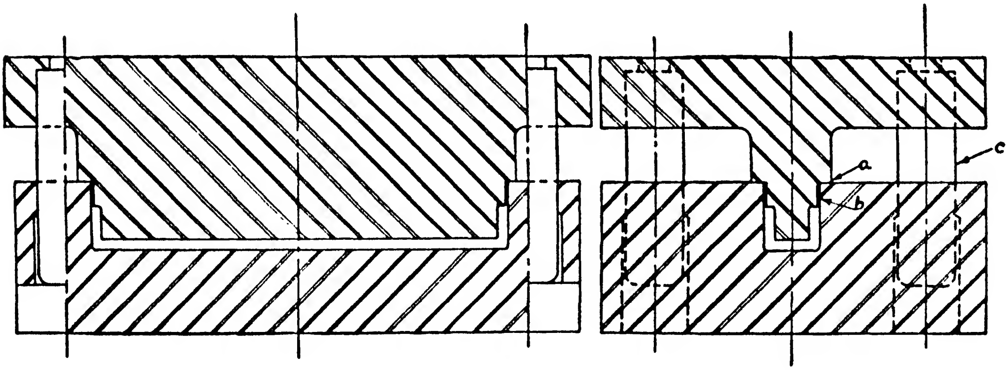


FIG. 18.10 — Semi-positive type mold: *a*, horizontal cutoff; *b*, vertical flash; *c*, guide pin.

The piece produced measured 4½ in. long, ½ in. deep and ½ in. wide. The piece was channeled to give a uniform cross section of ⅛ in.

The pieces produced were tested for impact and flexural strength. Table 99, page 690, shows the results obtained.

In molding large housings, or similar castings of deep draw, the best results are obtained by employing not only semi-positive dies, but the principle of decreasing taper of the side-wall sections as well. The principle involved is, that during the closing of the mold, the compound becomes increasingly confined, through a wedging action as it flows vertically up the side wall. Hence, the effective pressure so important in molding urea plastics is maintained throughout the flow of the material.

It has been pointed out that for the proper curing of urea plastics they must be subjected to elevated temperatures for definite periods of time. Naturally, this means that the molds must be properly heated. There are several ways by which this may be

TABLE 99. TESTS FOR IMPACT AND FLEXURAL STRENGTH

Mold Type	Flexural strength as molded from preforms	Flexural strength as molded from powder	Impact strength as molded from preforms	Specific gravity of moldings
Simple Flash (Fig. 18.9)	15,000†	Molding impossible	0.70*	1.4928
Semi-positive (Fig. 18.10)	16,500†	17,000†	0.70*	1.4939
Positive (Fig. 18.11) (Sprue grooves and stop blocks)	10,500†	13,000†	0.45*	1.4900

* Foot pounds.

† Pounds per square inch.

accomplished. The mold may be cored and piped to receive superheated steam, or superheated water or hot oil may be circulated. The mold may also be cored to receive electrical heating units. Other than this, molds may be heated by simply allowing them to sit upon hot plates. In some instances, molds are heated by the use of gas flames. The various portions of the mold should be uniformly heated and at the same time provisions must be made for varying the degree of heat.

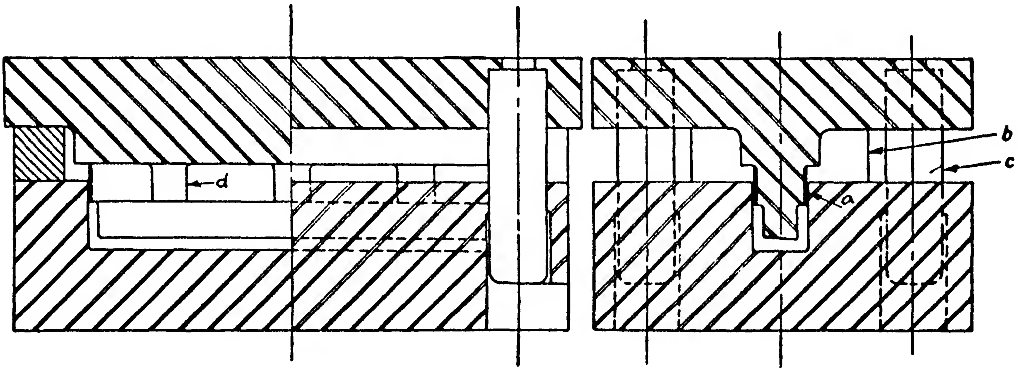


FIG. 18.11 — Positive type mold with stop blocks and sprue grooves: *a*, vertical flash; *b*, stop blocks; *c*, guide pin; *d*, sprue grooves.

Experience has shown that these ideal molding conditions are best achieved by proper coring and the use of superheated steam. Reducing valves may be used to regulate the steam pressure. Molds which produce thin, flat pieces may be heated by transfer of heat from hot plates. Molds for other pieces should be cored; if not, sufficient steel must be used to distribute the heat adequately. (See Figs. 18.12 and 18.13.)

In building molds to be heated by direct channeling, sufficient steel should be provided so the channels are not too close to the mold surface. Placing the channels near the outside of the mold, rather than near the cavity, ensures a more uniform temperature on the cavity surface. Broadly speaking, the shortest distance from a channel to the cavity should not be less than one-half the greatest distance. Figures 18.14 and 18.15 show proper and improper design for a mold heated by direct steam channeling.

In certain localities, electricity is preferred as the heating medium. The difficulty encountered with this type of heating is that an inadequate number of heating units is frequently used and the cartridges necessarily run at very high temperatures, which makes it difficult to obtain a uniform mold temperature. If electricity is used, better heating is obtained by using numerous heating cartridges so placed that the heat radiated therefrom will closely correspond with the results that would be obtained if the mold were cored for steam.

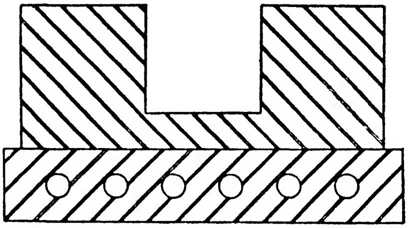


FIG. 18.12 — Proper method of steam plate heating.

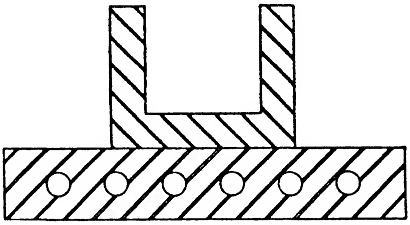


FIG. 18.13 — Improper method of steam plate heating.

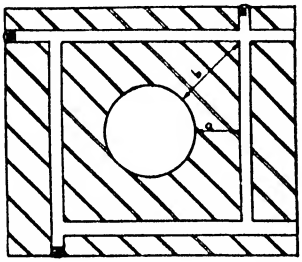


FIG. 18.14 — Proper steam channeling: *a* is greater than ½*b*; *a* represents shortest distance from channel to cavity; *b* represents greatest distance from channel to cavity.

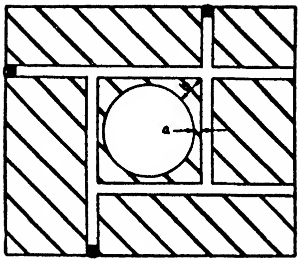


FIG. 18.15 — Improper steam channeling: *a* is less than ½*b*; *a* represents shortest distance from channel to cavity; *b* represents greatest distance from channel to cavity.

While hot oil may be used for the transfer of heat to molds it represents a possible hazard and the practice is not looked upon with much favor.

Superheated water has been tried but generally is not so satisfactory as steam.

While the use of gas-heated molds may be satisfactory for certain plastics, the manufacturers of urea plastics discourage this method of heating, primarily because it is not possible to heat a mold uniformly. If economical to use gas as a fuel, it is desirable to use the gas to generate steam, and if the molder is not in a position to have a large central heating plant, he may well resort to the use of individual gas-fired boilers of one- or two-horsepower capacity. The use of such individual steam boilers represents certain economies and added convenience due to the fact that expensive reducing valves are not necessary.

Material Used for Molds. Material used to construct molds must be selected very carefully, due to the high pressure exerted on the walls of the molds during the molding cycle. Over a number of years, there has been a difference of opinion as to the best steel to use. Tool steel, such as oil hardening grade, is employed to good advantage in many places while in some, mild machine steel, properly heat treated, gives excellent service. While tool steel possesses minimum distortion during heat treating as well as under the molding pressure, it has a distinct disadvantage in machining and also in its higher cost per pound. Machine steel is much easier to machine and it can be used for hobbing; it also costs less per pound. It is known to distort under heat treatment and also to crack under molding pressure due to the hard surface and comparatively soft core.

Mold Construction. The metal to be used must have certain properties to make it suitable for mold construction.

1. It must take a hard surface to withstand high pressures and long operation. It must not wear unduly at places where the molding material has a tendency to flow.
2. It must be unaffected by temperatures of 350° to 400° F.
3. The metal just below the hardened surface must be resilient.

The two most common methods of mold building are machining and hobbing. In machining, the mold is carved from a massive block of steel. This is followed by case-hardening and a final polishing operation. Most molders follow this with a chromium plate to protect the mold from undue wear and to give freedom from corrosion. Several types of steel are available.

When a number of cavities are to be built alike, it is usually more economical to hob them. A hob is made of special steel having a contour duplicating the required molded piece. Blanks are cut from a softer steel and the hob is pressed into these blanks under great pressure. Special hobbing presses are required.

The blanks for hobbing usually receive special treatment and certain preliminary machining. To reduce the amount of metal flow, considerable metal is removed from the back of the blank by drilling or milling. It is desirable to sink the hob with a single continuous stroke. This eliminates flow lines and secondary polishing operations. Various steel companies offer a variety of steels for such purposes.

Steel " A."

Application: The hobbing blanks for difficult-shaped molds for short runs only.

Analysis	*Per Cent*
Carbon	0.10
Manganese	0.25
Phosphorus	0.03 max.
Sulfur	0.03 max.

Physical Properties: Soft machinery steel made of low carbon ingot iron with elastic limit of about 30,000 lb. per sq. in. after heat treatment. May be annealed to a Brinell hardness of 90. Machining properties are fair.

Steel " B."

Application: General purpose mold steel.

Analysis	*Per Cent*
Carbon	0.10
Manganese	0.50
Chromium	0.50
Nickel	1.25

Physical Properties: Better resistance to upsetting and greater strength than Steel

" A." Elastic limit after heat treatment 80,000 lb. per sq. in. Casehardens to Rockwell C scale 63. Hardness untreated, 120 Brinell.

Heat Treament: Heat treated by cyaniding or casehardening. The usual procedure is to carburize from a temperature of 1650° F. to depth of case desired, cool in air to 1440° F., and quench in oil of brine and draw at 300° F.

Steel " C."

Application: Large dies where maximum strength and service are required.

Analysis	*Per Cent*
Carbon	0.10
Manganese	0.40
Chromium	1.50
Nickel	3.50

Physical Properties: High ore strength, elastic limit after heat treatment, 135,000 lb. per sq. in. Good wear resistance. When annealed it has a hardness of 180 Brinell. Machines like annealed tool steel.

Heat Treatment: This steel is heat treated by casehardening at 1600° F., reheating at 1425° F., and oil quenching.

Steel " D."

Application: Molds where extreme dimensional accuracy is important.

Analysis	*Per Cent*
Carbon	0.90
Manganese	1.60
Silicon	0.25

Physical Properties: This is an oil-hardening steel, having high strength. Hardens after heat treating to Rockwell C scale 63. It has excellent resistance to wear and machines well.

Heat Treatment: It is heat treated by oil quenching at 1440° F., drawing for one hour at 350° F. The above low temperature quenching reduces scale formation.

Steel " E."

Application: General purpose steel for hobs.

Analysis	*Per Cent*
Carbon	2.10
Manganese	0.25
Silicon	0.25
Chromium	12.50
Nickel	0.50

Physical Properties: Dense structure, great strength, good wear resistance and hardens with minimum of scale. Hardness after treatment, Rockwell C scale 63.

Heat Treatment: Pack in charcoal, heat to 1750° F. Soak, quench in oil, draw for at least 1 hr. at 400° F.

Steel "F."

Application: Excellent universal hob steel.

Analysis	*Per Cent*
Carbon	0.90
Manganese	1.60
Silicon	0.25

Physical Properties: Combination of hardness, toughness, dimensional accuracy, freedom from scale and good machinability. Hardness, Rockwell C scale 62.

Heat Treatment: Heat from 1400° F. to 1440° F. and quench in oil. Draw for 1 hr. or more at 375° F.

TABLE 100. STEELS RECOMMENDED FOR VARIOUS APPLICATIONS

Application	*Qualifications*	*Recommended type*
Cold-hobbed cavity dies to be carburized	Easy hobbing Carburizes readily Clean (electrically melted) Brinell No. — 90 60,000 lb. per sq. in. Carburized surface, Rockwell C-63	Crusca cold Hobbing steel
Cold-hobbed cavity dies to be carburized	Easy hobbing Resists heavy pressures High polish Clean (electrically melted) Brinell No. — 125 Rockwell C-63 after treatment 80,000 lb. per sq. in.	Halcomb's Hoballoy
Machined or cut dies to be carburized	Excellent machinability High surface hardness Dimensional stability Exceptional finish Rockwell C-60-61, 190,000 lb. per sq. in.	Plastic C.S.M. No. 2
Machined or cut dies to be carburized	Fair machinability High hardness Non-deforming Tough	Ketos Oil Hardening

Mold economy depends upon several factors: (1) production cost, (2) upkeep cost, (3) life, and (4) quality of molded parts.

The steel used controls to a large extent the cost-performance figure. Steels cost from 3 to 15 cents a pound, the lower figure representing so-called boiler plate steel. This material has been successfully used for small molds, such as button cavities. The better type steels are those electrically melted. For carburizing, a low chrome- or nickel-molybdenum steel is recommended; and for a minimum of deformation after heat-treating, a high-carbon manganese alloy is used.

Ketos steel referred to above has an approximate chemical composition:

Analysis	*Per Cent*
Carbon	0.90
Chromium	0.50
Manganese	1.15
Tungsten	0.50

The effect of heat treatment gives rise to a variation in the corresponding hardness. The following gives some idea of the effect of draw temperature after quenching at 1475° F.

Draw temperature, ° F.	*Rockwell Hardness,* C *scale*
300	63
350	62
400	61
450	59
500	58
600	55
700	51
800	45
900	44
1000	40

Steel Hardness. Some companies standardize on one type of steel, usually a chrome-nickel alloy, and by suitable heat treatment bring the surface hardness up to approximately the same level. Hobs in such cases are usually made from a very tough steel, the Brinell hardness being 627. Mold blanks in such cases usually have a hardness of 578. In the soft stage, such a steel would have a hardness of 125 Brinell.

Other Mold Materials. It is no secret that mold costs are a distinct disadvantage to the molding industry. Search for cheaper methods of mold construction is constantly being made.

New materials have been produced, but to date none have been commercially successful. Beryllium-copper alloys have unusual strength and may be cast, but so far its disadvantages have ruled it out for construction of even medium-sized molds. Cast steel has been tried with little success. Molds built up by a metal spraying process are under consideration, but as yet are limited to small pieces. In this case only the cavity member may be made.

A process has been developed for the manufacture of molds by electrodeposition of pure iron, but this is limited to shallow pieces. However, for reproducing complicated designs this method has merit, particularly if the molder builds an assembled mold, using electrodeposited pieces for inserts.

STANDARD AMERICAN IRON AND STEEL INSTITUTE SPECIFICATIONS[1]

The ever-growing variety of chemical compositions and quality requirements of steel specifications has been a matter of concern in the steel industry for years. That condition prompted the General Technical Committee of the American Iron and Steel Institute to make a study of it with a view to simplifying the problems of both consumer and producer. Having in mind the potential benefits of simplification and standardiza-

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[1] This section by courtesy of Joseph T. Ryerson Co., Inc.

tion, their survey was first directed to determining which of the many grades being specified were the ones in most common demand; also, the feasibility of combining specifications having like requirements.

That survey showed that, exclusive of stainless steels and tool steels, steels with several thousand different combinations of chemical elements were being manufactured to meet the individual demands of purchasers of the primary rolled and forged steel products used in American industry.

The facts thus developed have convinced steel producers that if their efforts could be concentrated upon a limited number of standardized grades, deliveries could be expedited and service improved. Moreover, there would be a better opportunity to achieve advances in manufacturing practices and quality and to study more fully the possibilities of applications inherent in those grades.

The General Technical Committee selected the grades of steel listed herein as representing compositions of proved merit and in extensive use for a wide variety of purposes. Such steels are called "standard steels."

When the many other grades of steel now being used are critically compared with the equivalent standard grades listed, it is believed that in most cases the standard grades can be used successfully to replace them without detriment to fabricating method or impairment of quality of the article manufactured.

Inasmuch as both SAE and AISI specifications are now in use, it frequently becomes necessary to compare the ranges of these two systems and interpret one in terms of the other. Such a comparison is often troublesome when it necessitates references to two separate lists. For general convenience we have combined the comparable SAE and AISI bar steels and listed them in their proper relationship.

As the difference in composition ranges between the AISI steels are much less than between SAE steels, a single SAE specification is likely to include several AISI specifications. In almost every case there is an AISI steel that meets the SAE specifications and there are also a number of other AISI compositions which come very close to the SAE limits but do not exactly meet them. From the wide selection of AISI standard compositions there should be no difficulty in choosing a steel to fit almost any requirement.

In order to make this comparison chart as helpful as possible, we have governed our selection of representative AISI steels in each grouping by physical performance as well as composition similarity.

SAE System of Identification. A numeral index system is used to identify the compositions of the SAE steels, which makes it possible to use numerals on shop drawings and blueprints that are partially descriptive of the composition of material covered by such numbers. The first digit indicates the type to which the steel belongs; thus "1 – " indicates a carbon steel; "2 – " a nickel steel, and "3 – " a nickel chromium steel. In the case of the simple alloy steels the second digit generally indicates the approximate percentage of the predominant alloying element. Usually the last two or three digits indicate the average carbon content in "points," or hundredths of 1 per cent. Thus "2340" indicates a nickel steel of approximately 3 per cent nickel (3.25 to 3.75) and 0.40 per cent carbon (0.35 to 0.45).

In some instances, in order to avoid confusion it has been found necessary to depart from this system of identifying the approximate alloy composition of a steel by varying the second and third digits of the number. An instance of such departure is the steel numbers selected for several of the corrosion and heat resisting alloys.

The basic numerals for the various types of SAE steel are

Type of Steel	*Numerals (and Digits)*
Carbon Steels	1xxx
Plain Carbon	10xx
Free Cutting (Screw Stock)	11xx
Free Cutting, Manganese	X13xx
Manganese	13xx
Nickel Steels	2xxx
3.50% Nickel	23xx
5.00% Nickel	25xx
Nickel Chromium Steels	3xxx
1.25% Nickel, 0.60% Chromium	31xx
1.75% Nickel, 1.00% Chromium	32xx
3.50% Nickel, 1.50% Chromium	33xx
3.00% Nickel, 0.80% Chromium	34xx
Corrosion and Heat Resisting Steels	30xxx
Molybdenum Steels	4xxx
Chromium	41xx
Chromium Nickel	43xx
Nickel	46xx and 48xx
Chromium Steels	5xxx
Low Chromium	51xx
Medium Chromium	52xxx
Corrosion and Heat Resisting	51xxx
Chromium Vanadium Steels	6xxx
Silicon Manganese Steels	9xxx

Prefixes. The prefix "X" is used in numerous instances to denote variations in the range of elements.

AISI System of Identification. For convenience of classification herein, a system of symbols is used to identify the grade classifications of standard steels. In those symbols capital letter prefixes are used to indicate types of steel by process of manufacture. Numbers are used to indicate grades of steel by chemical composition. Lower case letters are used as suffixes to indicate various special requirements affecting quality. The application and meaning of the letters and numbers are explained below.

Letter Prefixes

A designates basic open-hearth alloy steels.
B denotes acid bessemer carbon steel.
C denotes basic open-hearth carbon steel.
CB denotes either acid bessemer, or basic open-hearth, carbon steel at the option of the manufacturer.
D denotes acid open-hearth carbon steel.
E designates electric furnace alloy steel.

Letter Suffixes

a. Restricted chemical compositions closer than standard ranges.
b. Bearing steel quality.
c. Guaranteed segregation limits affected by methods of sampling.
d. Specified discard.
e. Homogeneity tests. (Macro-etch tests.)
f. Rifle barrel quality.
g. Limited austenitic grain size.
h. Guaranteed hardenability.
i. Guaranteed conformity to non-metallic inclusions standards.
j. Fracture test.
t. Extensometer test.
v. Aircraft quality or Magnaflux testing requirements.

Numerical Designations of Grades. The use of numbers to designate different chemical compositions, that is, *grades,* in the classification of standard steels is explained below. A four-number series designates carbon and alloy steels specified to chemical composition ranges. The series is similar to but not identical with the system used originally by the Society of Automotive Engineers, Inc., and is extended to include other grades of steel.

The basic numbers for the four-numeral series of the various grades of both carbon and alloy steel and their meanings are as follows:

Series Designation	*Types and Classes*
10xx	Basic open-hearth and acid bessemer carbon steel grades, nonsulfurized and nonphosphorized.
11xx	Basic open-hearth and acid bessemer carbon steel grades, sulfurized but not phosphorized.
12xx	Basic open-hearth carbon steel grades, phosphorized.
13xx	Manganese 1.60 to 1.90%.
23xx	Nickel 3.50%.
25xx	Nickel 5.00%.
30xx	Nickel 0.50% — Chromium 0.50%.
31xx	Nickel 1.25% — Chromium 0.60%.

Series Designation	*Types and Classes*
32xx	Nickel 1.75% — Chromium 1.00%.
33xx	Nickel 3.50% — Chromium 1.50%.
40xx	Molybdenum.
41xx	Chromium-molybdenum.
43xx	Nickel-chromium-molybdenum.
46xx	Nickel 1.65% — Molybdenum 0.25%.
48xx	Nickel 3.25% — Molybdenum 0.25%.
50xx	Low chromium.
51xx	Medium chromium.
52xxx	Chromium, high-carbon.
61xx	Chromium-vanadium.
92xx	Silicon-manganese.

The last two digits of the four-numeral series are intended, as far as feasible, to indicate the approximate middle of the carbon range, i.e., 21 represents a range of 0.18 to 0.23 per cent. It is necessary, however, to deviate from this rule and to interpolate numbers in the case of some carbon ranges, and for variations in manganese, sulfur, phosphorus, and chromium.

Comparison of SAE and AISI Specifications. This comparison shows the SAE (Society of Automotive Engineers, Inc.) numbers and the corresponding AISI (The American Iron and Steel Institute) number, or number for bar steels only. The bold face numbers are the AISI steels whose ranges are exactly equivalent or represent a more narrow range within the SAE specification. The other AISI listings may be considered as substitutes, comparable in chemical and physical properties, though certain of their element ranges are slightly over or under the SAE specification limits.

When no equivalent steel is given, it means that there is no comparable analysis. In all cases, when an AISI steel is selected by number it is recommended that the analysis be checked and compared with the other steels of the same type as shown in the tables of standard composition ranges.

Prefix Letters

A	**Indicates basic open-hearth alloy steel.**
B	**Indicates acid bessemer carbon steel.**
C	**Indicates basic open-hearth carbon steel.**
CB	**Indicates either acid bessemer or basic open-hearth carbon steels at the option of the manufacturer.**
D	**Indicates acid open-hearth carbon steel.**
E	**Indicates electric furnace steel.**

The various AISI analyses shown herein are considered standard for *bars only.*

Because of trade requirements a bar standard may, or may not be, considered standard for *semi-finished products* or for *wire rod.* Due to this condition, separate tables are published by the American Iron and Steel Institute to cover steel for these other products.

TABLE 101. CARBON STEELS

S.A.E.	A.I.S.I.	S.A.E.	A.I.S.I.	S.A.E.	A.I.S.I.
1010	C1006 C1008 CB1008 **C1010** **C1012** CB1012	**1035**	C1030 CB1032 **C1033** **C1035** C1038 C1040	**1080**	C1080 C1085
1015	C1010 **C1012** CB1012 **C1014** **C1015** C1017 CB1017	**1040**	C1035 **C1038** **C1040** C1042 C1043	**1085**	C1080 **C1085**
X1015	C1016 C1018 **C1019**	**1045**	C1040 **C1042** C1043 **C1045** C1046 C1050	**1090**	C1085 C1095
1020	C1014 C1015 CB1017 **C1017** **C1020** **C1021** **C1023**	**1050**	C1045 C1046 **C1050** C1055	**1095**	C1085 **C1095**
X1020	C1016 **C1019** **C1022**	**1055**	C1050 **C1055** C1059 C1060 C1061	—	B1008 B1011 B1110
1025	C1020 C1021 **C1023** **C1025** **C1026**	**1060**	C1055 C1059 **C1060** C1064	**1112**	**B1111** B1112
X1025	C1022 C1029	—	C1068	**X1112**	B1112 B1113
1030	C1029 **C1030** CB1032 C1033 C1035	**1065**	C1060 C1064 C1073 C1074 C1078	**1115**	**C1115** **C1116** C1121
		1070	C1074 C1080	—	C1109 C1110 C1113 C1120
		1075	**C1080** C1083	**X1314**	**C1112** **C1117**
				X1315	**C1118** C1122
				X1330	**C1132** C1137
				X1335	C1132 **C1137**
				X1340	C1137
				—	C1140 C1145

TABLE 102. ALLOY STEELS

S.A.E.	A.I.S.I.
—	A1320 A1321
1330	**A1330**
1335	**A1335**
1340	**A1340**
1350	—
2315	**A2317**
2330	**A2330**
2340	A2335 **A2340**
2345	A2340
2515	E2512 **A2514** **E2517**
—	A3045
3115	**A3115** A3120
3120	A3115 **A3120**
3130	**A3130**
3135	A3130 **A3135** A3140
3140	A3135 **A3140**
X3140	A3140 **A3141** A3145
3145	A3140 A3145
3150	A3145 A3150
3215	—
3220	—
3240	**A3240**
3245	A3240
3250	—
3312	**E3310** E3316
3415	—
—	A4023 A4024 A4032 A4037 A4047 A4063 A4065
—	A4119 A4120
X4130	**A4130** **E4132** A4134
4140	E4135 E4137
—	A4142 A4143
4150	E4150
4320	**A4317** **A4320**
X4340	A4337 **E4337** **E4340**
—	A4608
4615	**A4615** **E4617** A4620 E4620
4620	A4615 **E4617** **A4620** **E4620**
—	A4621
4640	**E4640**
4815	**A4815** A4821
4820	A4815 A4821
—	**A5045**
5120	**A5120**
—	A5130
5140	—
5150	A5145 A5150 A5152
—	E52095
52100	E52098 E52099 **E52100** E52101 E52107
—	A6120
6135	—
6150	**E6150** **A6152**
9250	A9255
9260	A9255 **A9260**
—	A9262 A9263

Average Physical Properties Table. This table of figures represents *average* results compiled from many tests. It is offered as a general guide to the *probable* physical expectancy of the steels listed. We cannot guarantee the accuracy of the figures for steels which have not been heat treated. *It must be understood that in individual tests, these steels may develop results differing widely from the averages shown.* It is evident these figures cannot be used as a basis of acceptance or rejection of material in any of the grades listed.

The size of the section, rolling temperature, permissible variation within analysis limits, and the atmospheric temperature at time of rolling, all influence the final physical properties of any steel in normal state. In any given analysis, the change from hot rolled to cold drawn physicals is governed largely by the amount of size reduction during cold drawing. Dependable physical properties can only be secured through carefully controlled heat treatment.

Special Steels:

Hawkridge Brothers Co., 303 Congress St., Boston, Mass.

Description. Special steels have been developed for various uses in the plastics industry. Increased use of hobbing has resulted in special carburized steel for deep hobbing. Polishing plates for use in sheet polishing may be obtained with a mirror finish which gives high luster to flat plastics sheets. Die steels which have been pre-ground and pre-tested, drill rods, rounds and flats and squares, and coated sheets are all available for various purposes. This company offers the following steels for special uses:

Hawk 3312–B. For dies in which the impression is machined, and which must stand maximum pressures.

Hawk 3310. For machined or cold-hobbed dies which must stand medium to high pressures. (Only moderate flow of metal feasible in hobbing.)

Hawk Magnetic Iron (Electric melted). For dies requiring severe flow of metal in hobbing and in which long wear is not of primary importance.

Yellow End. For dies in which the impression is machined and in which it is not necessary to withstand very high pressures. Advantages are easy machinability, and freedom from seams and internal hairlines.

Yellow End Machinery Steel. For cold-hobbed dies which are not required to withstand much pressure in use. (Moderate metal flow.)

For hobbing by cold pressure the following are recommended:

Hawk 777 — for severe work.

Hawk Special — for moderate work.

Hawk Brand or *Standard Tool* — for light work.

Mirror Steel. Plynik mirror steel is rolled nickel-surfaced steel sheet. The mirrored surfaces are on both sides and give a clear surface with perfect reflectivity. Stock gauges are 0.16 and 0.20 in. thick, maximum sheet size being 22 × 50 in.

Lustro Coated Sheets. For use where pre-coated or pre-finished steel is desired. Available with one or two sides finished in chrome, nickel, copper, or brass. Various gauges and sizes up to 36 × 96 in. are in stock.

Enduros Stainless Steel Sheets. These sheets are used in polishing presses and are available with only one side mirrored.

Machining of Molds. Machining of molds is greatly different from the average tool and die making. It requires more patience since almost all production molds have multiple cavities. They may have 24 or 36 cavities and each cavity must be

TABLE 103. AVERAGE PHYSICAL PROPERTIES

A.I.S.I.	S.A.E.	Condition of the Steel	Tensile Strength Lb. per sq. in.	Yield Point Lb. per sq. in.	% Elong. in 2"	% Red. of Area	Hardness		Machinability Rating
							Bri-nell	Rock-well "C"	
C 1006 C 1008 CB 1008 C **1010** C **1012** CB 1012	1010	Natural Hot Rolled	51,000	29,000	38	70	101	—	40%
		Cold Drawn	56,000	33,000	35	65	113	—	45%
	Mild Steel	Natural Hot Rolled	57,000	32,000	37	66	113	—	
		Cold Drawn	67,000	42,000	30	60	149	—	50%
C 1010 C **1012** CB 1012 C **1014** C **1016** C 1017 CB 1017	1015	Natural Hot Rolled	65,000	40,000	32	65	137	—	50%
		Cold Drawn	67,000	43,000	30	62	143	—	50%
C 1016 C 1018 C **1019**	X1015	Natural Hot Rolled	68,000	45,000	32	60	143	—	53%
		Cold Drawn	72,000	50,000	29	62	149	—	65%
C 1014 C 1015 CB 1017 C **1017** C **1020** C **1021** C **1023**	1020	Natural Hot Rolled	67,000	45,000	32	65	137	—	52%
		Cold Drawn	69,000	48,000	30	63	143	—	60%
C 1016 C **1019** C **1022**	X1020	Natural Hot Rolled	69,000	47,000	30	58	143	—	62%
		Cold Drawn	78,000	53,000	23	54	163	—	70%
		1" Rd. carburized 8 hr. at 1700° F., cooled in box, reheated to 1625° F., water quenched — core properties:	109,000	85,000	7	23	225	20	
C 1020 C 1021 C **1023** C **1025** C **1026**	1025	Natural Hot Rolled	70,000	41,000	31	58	130	—	58%
		Cold Drawn	80,000	67,000	18	48	162	—	65%
C 1022 C 1029	X1025	Natural Hot Rolled	79,000	46,000	29	58	156	—	65%
		Cold Drawn	85,000	71,000	20	52	170	—	70%
C 1029 C **1030** CB 1032 C 1033 C 1035	1030	Natural Hot Rolled	75,000	46,000	30	56	137	—	60%
		Cold Drawn	85,000	72,000	20	47	179	8	70%
		1" Rd. Water Quenched 1575°F.—Drawn 1000°F.	98,000	73,000	27	64	212	14	60%
C 1030 CB 1032 C **1033** C **1035** C 1038 C 1040	1035	Natural Hot Rolled	88,000	55,000	30	56	179	10	60%
		Cold Drawn	92,000	59,000	25	50	200	12	62%
		1" Rd. Water Quenched 1525°F.—Drawn 1000°F.	103,000	78,000	24	62	230	20	55%

TABLE 103. AVERAGE PHYSICAL PROPERTIES (*Continued*)

A.I.S.I.	S.A.E.	Condition the Steel	Tensile Strength Lb. per sq. in.	Yield Point Lb. per sq. in.	% Elong. in 2"	% Red. of Area	Hardness		Machinability Rating
							Brinell	Rockwell "C"	
C 1035 **C 1038** **C 1040** C 1042 C 1043	1040	Natural Hot Rolled	93,000	58,000	27	52	190	9	60%
		Cold Drawn	100,000	64,000	22	46	221	19	62%
		1" Rd. Water Quenched 1525°F.—Drawn 1000°F.	110,000	84,000	21	58	235	21	
C 1040 **C 1042** C 1043 **C 1045** C 1046 C 1050	1045	Natural Hot Rolled	99,000	60,000	24	47	200	12	55%
		Cold Drawn	110,000	69,000	19	41	235	21	58%
C 1045 C 1046 **C 1050** C 1055	1050	1" Rd. Water Quenched 1500°F.—Drawn 1000°F.	120,000	93,000	20	52	277	28	48%
C 1050 **C 1055** C 1059 C 1060 C 1061	1055	Hot Rolled, Ann'led.	95,000	59,000	25	52	197	14	53%
C 1055 C 1059 **C 1060** C 1064	1060	1" Rd. Oil Quenched 1550° F.—Drawn 1000°F.	122,000	90,000	19	53	255	25	
C 1060 C 1064 C 1073 C 1074 C 1078	1065	Hot Rolled, Ann'led.	100,000	60,000	22	50	212	17	45%
C 1074 C 1080	1070	1" Rd. Oil Quenched 1525°F.—Drawn 1000°F.	133,000	96,000	18	51	285	29	
C 1080 C 1083	1075								
C 1080 C 1085	1080	Hot Rolled, Ann'led.	103,000	62,000	22	48	217	18	44%
C 1080 **C 1085**	1085	1" Rd. Oil Quenched 1500°F.—Drawn 1000°F.	143,000	102,000	17	50	293	30	
C 1085 C 1095	1090	Hot Rolled, Ann'led.	106,000	60,000	23	47	201	12	45%
C 1085 **C 1095**	1095	1" Rd. Oil Quenched 1450°F.—Drawn 1000°F.	178,000	122,000	12	37	363	39	
B 1111 B 1112	B's'mr. 1112	Natural Hot Rolled	67,000	40,000	27	47	140	—	
		Cold Drawn	80.000	62,000	16	43	170	6	100%
B 1112 B 1113	B's'mr. X1112	Cold Drawn	83,000	73,000	15	45	180	8	120-140%

TABLE 103. AVERAGE PHYSICAL PROPERTIES (*Continued*)

A.I.S.I.	S.A.E.	Condition of the Steel	Tensile Strength Lb. per sq. in.	Yield Point Lb. per sq. in.	% Elong. in 2"	% Red. of Area	Hardness		Machinability Rating
							Brinell	Rockwell "C"	
C 1115 **C 1116** C 1121	1115	Cold Drawn	91,000	77,000	13	40	187	9	90%
	1120	Natural Hot Rolled	69,000	36,000	32	55	117	—	
		Cold Drawn	80,000	62,000	20	50	170	4	80%
C 1112 **C 1117**	X1314	Natural Hot Rolled	71,000	45,000	28	52	135	—	
		Cold Drawn	82,000	63,000	18	44	162	—	94%
C 1118 C 1122	X1315	Natural Hot Rolled	76,000	49,000	24	50	153	—	
		Cold Drawn	89,000	69,000	16	40	179	8	90%
C 1132 C 1137	X1330	Natural Hot Rolled	90,000	56,000	22	40	179	8	75%
		Cold Drawn	100,000	75,000	16	35	207	16	57%
C 1132 **C 1137**	X1335	Natural Hot Rolled	92,000	60,000	20	35	185	9	70%
		Cold Drawn	105,000	80,000	15	30	212	15	
C 1137	X1340	1" Rd. Oil Quenched 1500°F.—Drawn 1000°F.	123,000	96,000	20	53	245	24	55%
Ryerson	Rycase	Natural Hot Rolled	73,000	47,000	33	63	149	—	
		Cold Drawn	80,000	60,000	20	47	160	—	95%
		1" Rd. carburized 8 hr. at 1700° F., cooled in box, reheated to 1600° F., water quenched—core properties:	140,000	104,000	6	27	302	31	
A **2317**	2315	Natural Hot Rolled	85,000	56,000	29	60	163	—	50%
		Cold Drawn	95,000	75,000	25	58	197	12	
		1" Rd. carburized 8 hr. at 1700° F., cooled in box, reheated to 1500° F., oil quenched—core properties:	168,000	122,000	14	40	363	38	
A **2330**	2330	Natural Hot Rolled	98,000	65,000	25	50	207	16	45%
		Cold Drawn	110,000	90,000	17	47	235	22	
		1" Rd. Oil Quenched 1500°F.—Drawn 1000°F.	125,000	104,000	22	61	270	22	40%
A 2335 A **2340**	2340	Natural Hot Rolled	110,000	80,000	22	47	225	19	40%
		Annealed and Cold Dr.	115,000	90,000	21	48	235	21	
		1" Rd. Oil Quenched 1475°F.—Drawn 1000°F.	137,000	119,000	21	59	302	31	35%
A 2340	2345	Hot Rolled, Ann'led.	108,000	75,000	23	46	235	22	50%
		Annealed and Cold Dr.	119,000	92,000	17	40	255	25	
		1" Rd. Oil Quenched 1475°F.—Drawn 1000°F.	140,000	130,000	19	58	311	32	30%
E 2512 A **2514** E **2517**	2515	Natural Hot Rolled	92,000	69,000	27	67	179	8	40%
		Cold Drawn	103,000	75,000	24	62	207	16	

TABLE 103. AVERAGE PHYSICAL PROPERTIES (*Continued*)

A.I S.I.	S.A.E.	Condition of the Steel	Tensile Strength Lb. per sq. in.	Yield Point Lb. per sq. in.	% Elong. in 2″	% Red. of Area	Hardness		Machinability Rating
							Brinell	Rockwell "C"	
A **3115** A 3120	3115	Natural Hot Rolled	75,000	60,000	30	65	151	—	50%
		Cold Drawn	95,000	70,000	20	53	201	12	
A 3115 A **3120**	3120	1″ Rd. carburized 8 hr. at 1700°F., cooled in box, reheated to 1500° F., oil quenched—core properties:	132,000	101,000	17	45	280	28	
A **3130**	3130	Natural Hot Rolled	100,000	72,000	24	55	212	15	45%
		Cold Drawn	105,000	85,000	18	48	223	19	
		1″ Rd. Oil Quenched 1550°F.—Drawn 1000°F.	130,000	105,000	20	61	285	29	35%
A 3130 A **3135** A 3140	3135	Hot Rolled Ann'led.	96,000	64,000	26	56	195	12	57%
		Annealed and Cold Dr.	115,000	98,000	17	45	248	24	
A 3135 A **3140**	3140	1″ Rd. Oil Quenched 1525°F.—Drawn 1000°F.	147,000	123,000	18	57	302	31	38%
A 3140 A **3141** A 3145	X3140	Hot Rolled, Ann'led.	100,000	68,000	24	54	207	16	48%
		Annealed and Cold Dr.	118,000	100,000	17	44	248	24	
		1″ Rd. Oil Quenched 1525°F.—Drawn 1000°F.	150,000	127,000	17	52	311	33	36%
A 3140 A 3145	3145	Hot Rolled, Ann'led.	104,000	73,000	19	51	229	21	50%
		Annealed and Cold Dr.	123,000	95,000	14	33	269	27	
A 3145 A 3150	3150	1″ Rd. Oil Quenched 1475°F.—Drawn 1000°F.	156,000	131,000	16	53	321	34	35%
A 3240	3240	Hot Rolled, Ann'led.	107,000	75,000	23	57	197	13	46%
A 3240	3245	1″ Rd. Oil Quenched 1500°F.—Drawn 1000°F.	155,000	134,000	19	55	311	32	
A 4119	—	Natural Hot Rolled	91,000	52,000	28	62	179	—	60%
		Cold Drawn	97,000	63,000	21	51	207	—	
		1″ Rd. carburized 8 hr. at 1700°F., cooled in box, reheated to 1475° F., oil quenched—core properties:	137,000	112,000	16	42	302	31	
A **4130** E **4132** A 4134	X4130	Hot Rolled, Ann'led.	89,000	60,000	32	65	179	7	58%
		Annealed and Cold Dr.	112,000	78,000	18	47	241	23	
		1″ Rd. Oil Quenched 1550°F.—Drawn 1000°F.	145,000	118,000	22	61	302	31	40%
E 4135 E 4137	4140	Hot Rolled, Ann'led.	90,000	63,000	27	58	187	12	56%
		Annealed and Cold Dr.	114,000	90,000	18	50	241	23	
		1″ Rd. Oil Quenched 1575°F.—Drawn 1000°F.	156,000	131,000	17	57	352	37	

TABLE 103. AVERAGE PHYSICAL PROPERTIES (*Continued*)

A.I.S.I.	S.A.E.	Condition of the Steel	Tensile Strength Lb. per sq. in.	Yield Point Lb. per sq. in.	% Elong. in 2″	% Red. of Area	Hardness		Machinability Rating
							Brinell	Rockwell "C"	
E 4150	4150	Hot Rolled, Ann'led.	105,000	71,000	21	54	220	20	54%
		Annealed and Cold Dr.	124,000	100,000	16	48	269	27	
		1″ Rd. Oil Quenched 1550°F.—Drawn 1000°F.	175,000	153,000	15	50	375	40	
A 4317 A 4320	4320	Natural Hot Rolled	87,000	59,000	30	60	179	10	55%
		Cold Drawn	99,000	65,000	23	54	207	16	
		1″ Rd. Carburized 8 hr. at 1700°F., cooled in box, reheated to 1475° F., oil quenched—core properties:	185,000	151,000	16	54	415	43	
A 4337 E 4337 E 4340	X4340	Hot Rolled, Ann'led.	115,000	95,000	18	45	235	21	58%
		1″ Rd. Oil Quenched 1550°F.—Drawn 1000°F.	187,000	160,000	15	55	388	41	
A 4615 E 4617 A 4620 E 4620	4615	Natural Hot Rolled	82,000	55,000	30	61	167	4	58%
		Cold Drawn	98,000	70,000	18	55	203	14	
A 4615 E 4617 A 4620 E 4620	4620	1″ Rd. carburized 8 hr. at 1700°F., cooled in box, reheated to 1475° F., oil quenched—core properties:	151,000	125,000	15	44	321	34	
E 4640	4640	Hot Rolled, Ann'led.	100,000	87,000	21	50	201	12	60%
		Annealed and Cold Dr.	126,000	97,000	14	39	269	27	
		1″ Rd. Oil Quenched 1500°F.—Drawn 1000°F.	161,000	145,000	17	54	341	36	
A 4815 A 4821	4815	Natural Hot Rolled	105,000	73,000	24	58	212	15	55%
		Cold Drawn	110,000	78,000	23	55	217	17	
A 4815 A 4821	4820	1″ Rd. carburized 8 hr. at 1700°F., cooled in box, reheated to 1450° F., oil quenched—core properties:	203,000	170,000	16	52	415	43	
A 5120	5120	Natural Hot Rolled	73,000	55,000	32	67	143	—	50%
		Cold Drawn	82,000	60,000	25	58	163	6	
		1″ Rd. Carburized 8 hr. at 1700°F., cooled in box, reheated to 1475° F., oil quenched—core properties:	112,000	78,000	18	40	241	23	
A 5145 A 5150 A 5152	5150	Hot Rolled, Ann'led.	103,000	68,000	22	57	201	12	50%
		Cold Drawn	115,000	77,000	18	52	248	24	
		1″ Rd. Oil Quenched 1525°F.—Drawn 1000°F.	167,000	147,000	15	47	347	38	

TABLE 103. AVERAGE PHYSICAL PROPERTIES (*Continued*)

A.I.S.I.	S.A.E.	Condition of the Steel	Tensile Strength Lb. per sq. in.	Yield Point Lb. per sq. in.	% Elong. in 2″	% Red. of Area	Hardness		Machinability Rating
							Bri-nell	Rock-well "C"	
E 52098 E 52099 **E 52100** E 52101 E 52107	52100	Hot Rolled, Ann'led.	109,000	80,000	25	57	235	22	45%
		1″ Rd. Oil Quenched 1550°F.—Drawn 1000°F.	185,000	170,000	9	34	415	43	
E 6150 **A 6152**	6150	Hot Rolled, Ann'led.	103,000	70,00	27	51	217	18	50%
		Annealed and Cold Dr.	118,000	94,000	20	43	255	25	
		1″ Rd. Oil Quenched 1575°F.—Drawn 1000°F.	179,000	160,000	15	49	388	41	
A 9255	9250	Hot Rolled	135,000	90,000	19	40	269	27	
		1″ Rd. Oil Quenched 1650°F.—Drawn 1000°F.	182,000	160,000	15	32	363	39	
A 9255 **A 9260**	9260	Hot Rolled, Ann'led	142,000	92,000	18	38	302	31	
		1″ Rd. Oil Quenched 1650°F.—Drawn 1000°F.	188,000	165,000	14	29	388	41	
Ryerson	*H.T.M	Hot Rolled, Ann'led.	130,000	100,000	18	45	260	26	60%
		1″ Rd. Oil Quenched 1550°F.—Drawn 1000°F.	197,000	185,000	15	51	415	43	
Ryerson	*Ry-tense A.A.	Natural Hot Rolled	98,000	65,000	18	34	187	12	80%
		Cold Drawn	111,000	95,000	16	38	223	20	
		1″ Rd. Oil Quenched 1525°F.—Drawn 1000°F.	136,000	99,000	20	47	293	30	
*Ry-Arm Heat Treated		These Special Steels are sold only in the heat-treated condition on the basis of these typical minimum physical properties.	90,000	64,000	20	50	215	17-23	60%
*Ry-Ax Heat Treated			95,000	67,000	20	50	220	17-23	60%
*Ryco Heat Treated			100,000	70,000	20	50	200	17-23	60%
*Rycrome Heat Treated			125,000	105,000	16	50	269-325	27-34	55%
*Nikrome Heat Treated			125,000	105,000	16	50	250-280	24-28	55%
*Nikrome "M" Heat Treated			110,000	90,000	16	47	240-265	23-26	65%

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*Typical Minimum Physicals. Trade Name Steel.

identical. Rough machining is generally done by die-sinking machines with small cutters specially prepared for each job. The final finishing, however, is done by hand filing. A number of molds are produced by the hobbing process which consists in forming relatively soft steel blanks by forcing a hardened steel master or hob into the blanks. This blank is then a cavity of the mold or die. In this process, the hob or master is first machined to the exact size of the molded part plus the shrinkage. The best grade of steel must be used since hobs are very expensive, and if made of poor steel, are apt to break, resulting in a substantial loss. Very often, chrome-vanadium or other special alloy steels are used to obtain a hob comparatively soft but of extremely tough structure, as the hob must stand pressure of from 100 to 125 tons per square inch. Polish on such hobs must be of the highest type and very often these hobs are chromium-plated to add to the ease of the hobbing operation.

Production of Molds. It is almost impossible to determine the production of molds because very rarely are they duplicated. It is a special job for every molded part, with some rare exceptions. Perhaps the best method to illustrate the production of molds is to refer to Figs. 18.16, 18.17, and 18.18. Construction of this mold, consisting of two cavities of a case and two cavities of a cover (combination mold producing parts for an electric clipper) represents labor of 960 hr. Figure 18.19, a two-cavity hand mold, represents 255 hr. of labor. Figure 18.20, a four-cavity injection mold, 110 hr.

Mold Plating. Many molds in current use are chromium plated. While almost all modern plastics are free from substances injurious to steel, it has been found true that when different types of materials are molded alternately, there is evidence of pitting. More frequently troublesome sticking is encountered. These conditions may be eliminated by surfacing the mold with chrome plate.

Molds which are too tight may be ground and polished to fit. To build up a loose mold, either it must be heavily plated with chrome or welded in an atmosphere of hydrogen, a new art recently making its appearance in the tool room.

The reasons for plating are: (1) reduced surface wear, (2) reduced tendencies to sticking and surface poisoning, (3) reduction of surface friction, (4) increase in surface brightness of molded piece, and (5) ease of fin removal.

There are two types of chromium plate.

1. Flash plating, usually thickness not exceeding 0.0005 in.
2. Hard plating, the thickness varying from 0.0005 to 0.030 in.

Chromium plating is always applied to the hardened, polished surface. In no case should chrome plate be used to cover over pits or blemishes. Inevitably, the plating will sink into the pit.

The first step in plating is to remove foreign matter, particularly grease, from the steel surface. Usually the mold is set up first, always as the cathode; then the anodes are placed in position, an operation requiring special treatment. To ensure uniform plating, the distance from the anode to every portion of the surface must be equal so that equal amounts of chromium will be thrown onto the surface. Usually the " Octopus " anode is used. This consists of a lead-in wire to which are attached dozens of smaller lead wires. These may be bent to take care of intricate mold shapes. The lead-in wire may be lead-coated copper bar. The mold must be so placed that the hydrogen bubbles which always accompany the plating operation may escape freely, otherwise they will cling to the mold surface and form pits.

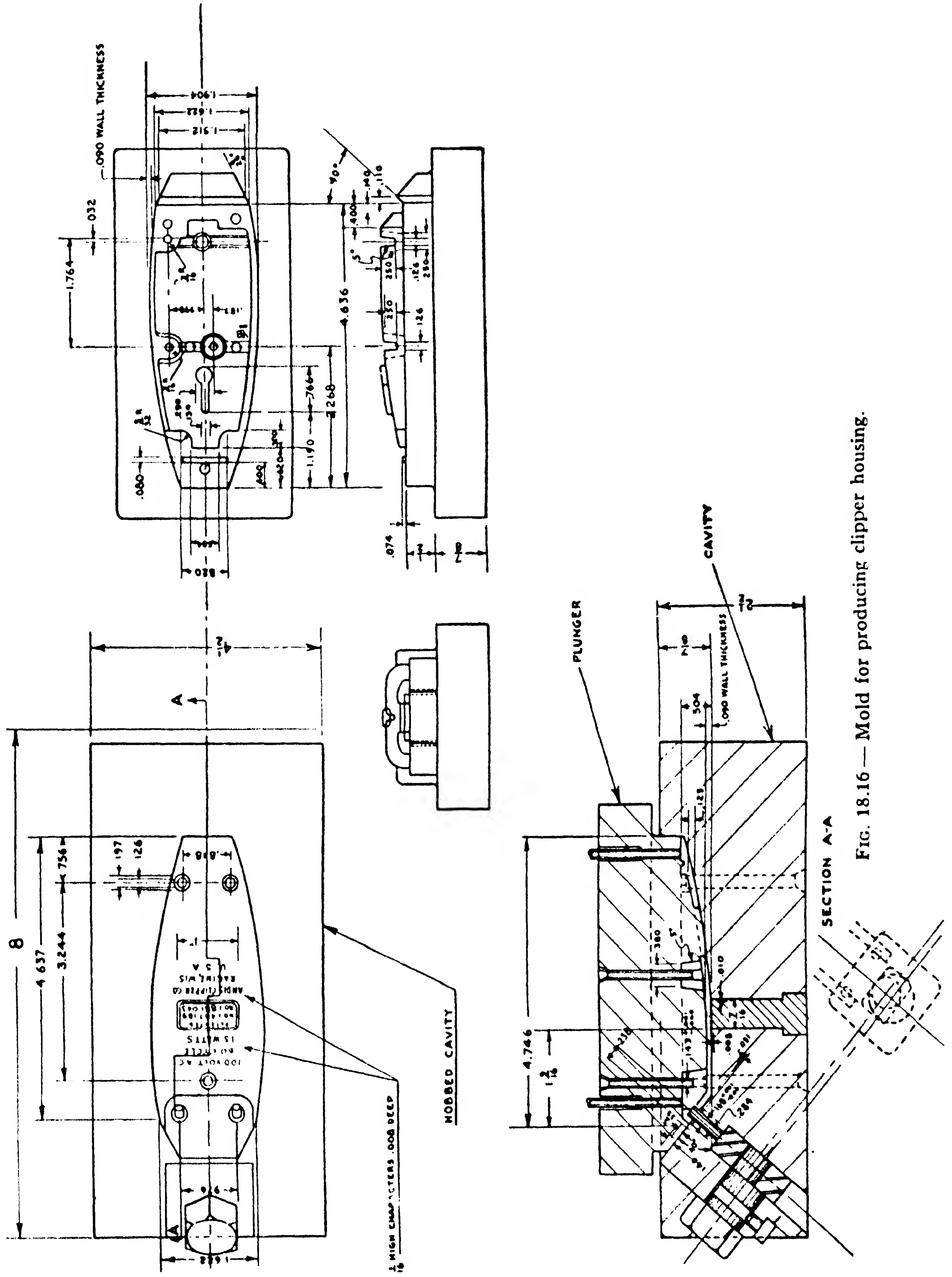


Fig. 18.16 — Mold for producing clipper housing.

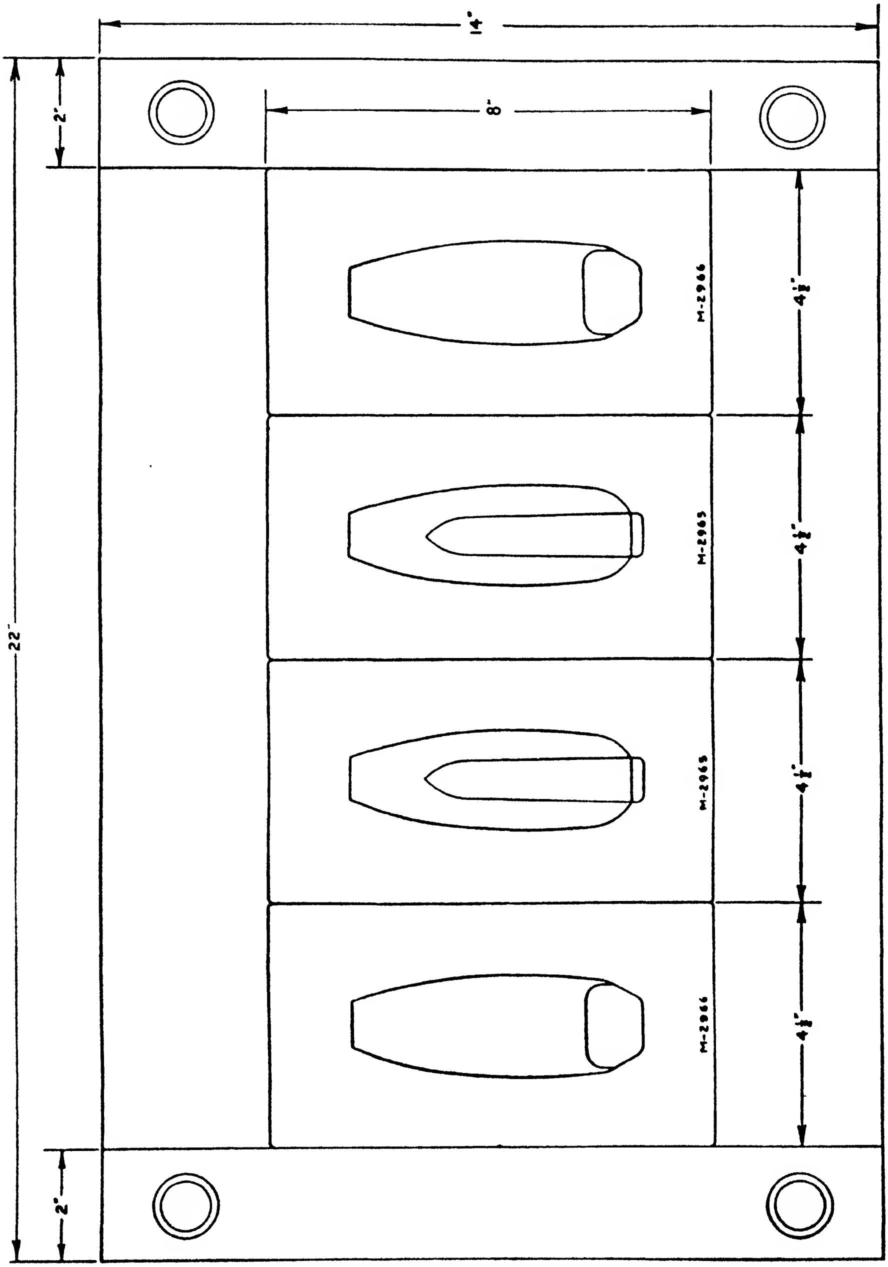


FIG. 18.17 — Yoke or mounting plate for four-cavity top and bottom halves of clipper housing.

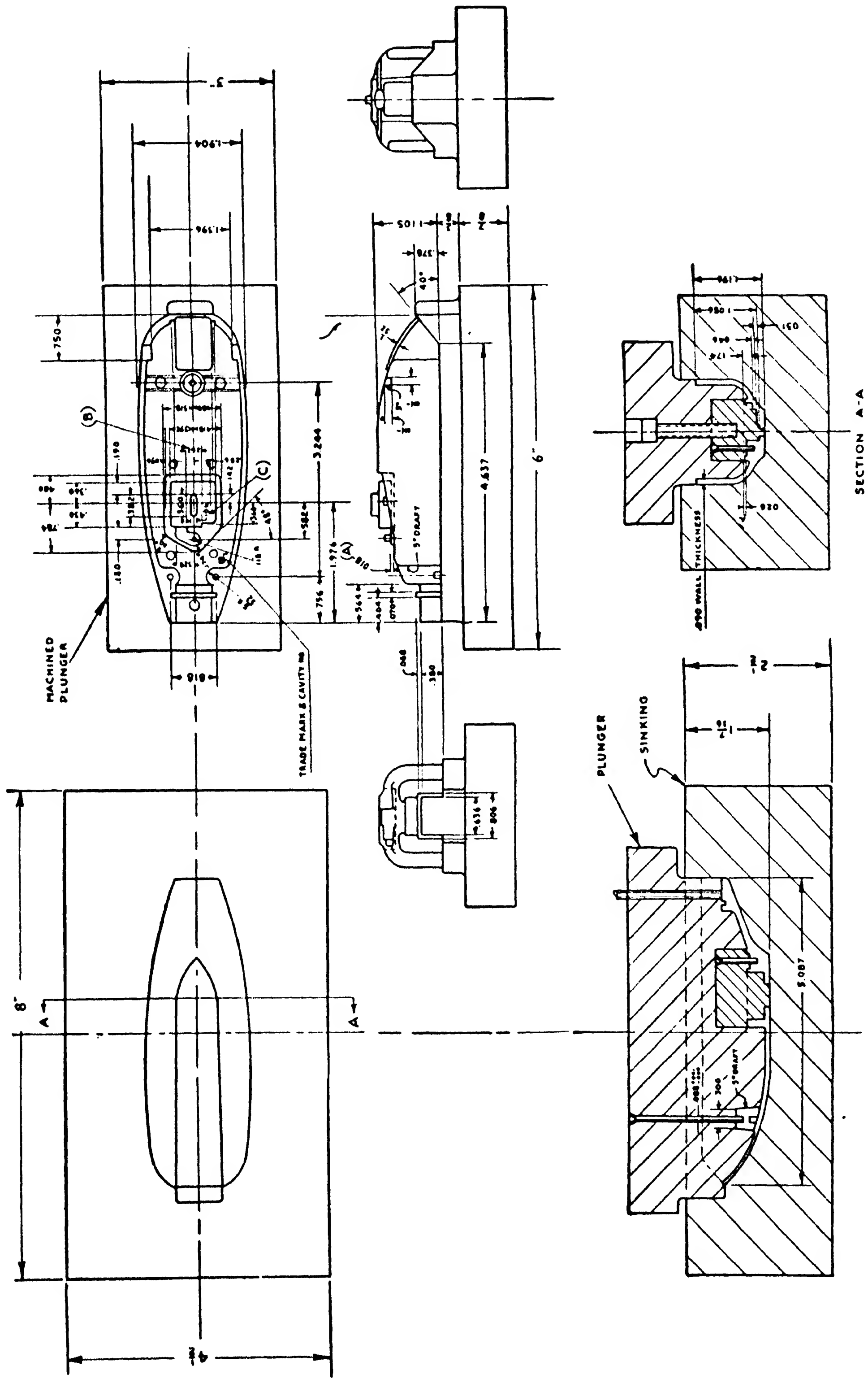


Fig. 18.18 — Mold for producing clipper housing.

The degreasing operation consists in treating the surface with an alkaline solution. Caustic soda to the extent of 8 oz. per gallon is used with a cathode current of 40 to 50 amp. per sq. ft. The mold is rinsed well in running cold water. It is then treated anodically in chromic acid solution, 28 oz. per gallon, with a current density of 90 to 100 amp. per sq. ft., and at a temperature of 140° F.

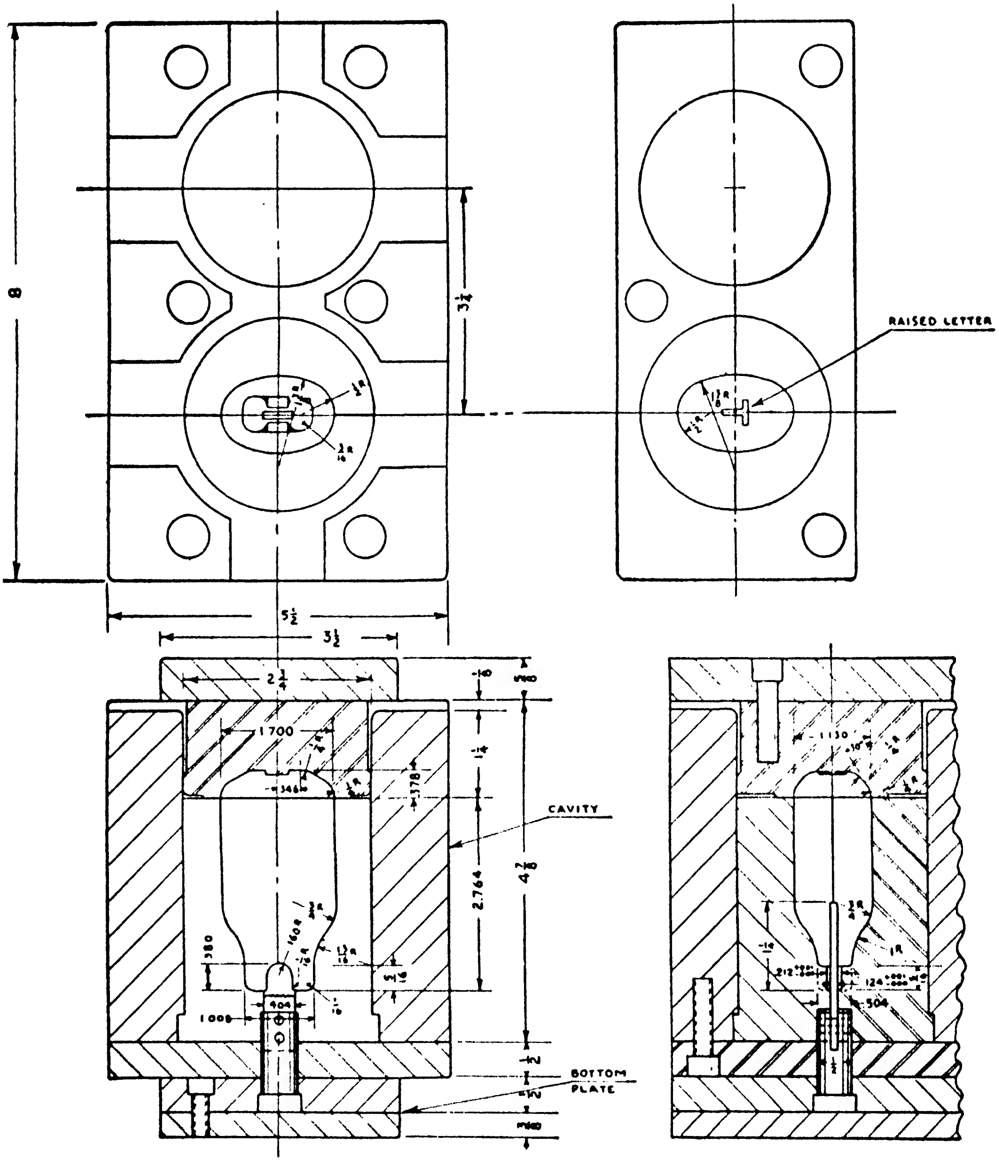


Fig. 18.19 — Two-cavity hand mold for producing a handle.

This treatment produces a very fine etch, ensuring subsequent bonding of the chrome plate. Without rinsing, the mold is subjected to the plating bath.

There are two solution strengths employed industrially. One contains 250 gm. per liter, the other 400 gm. per liter with sulfate ratios 1 to 100 in proportion to Cr_2O_3 in both cases. The 400 gm. per liter solution is generally favored. The temperature of the bath is 110° to 115° F.

In plating, the current density must be maintained so that a file-hard surface is obtained. This requires a controlled temperature. When removed from the bath the surface, if properly thrown, should be bright or slightly frosty; in no case should it appear milky. After plating, the mold is rinsed in an alkaline bath, followed by cold running water.

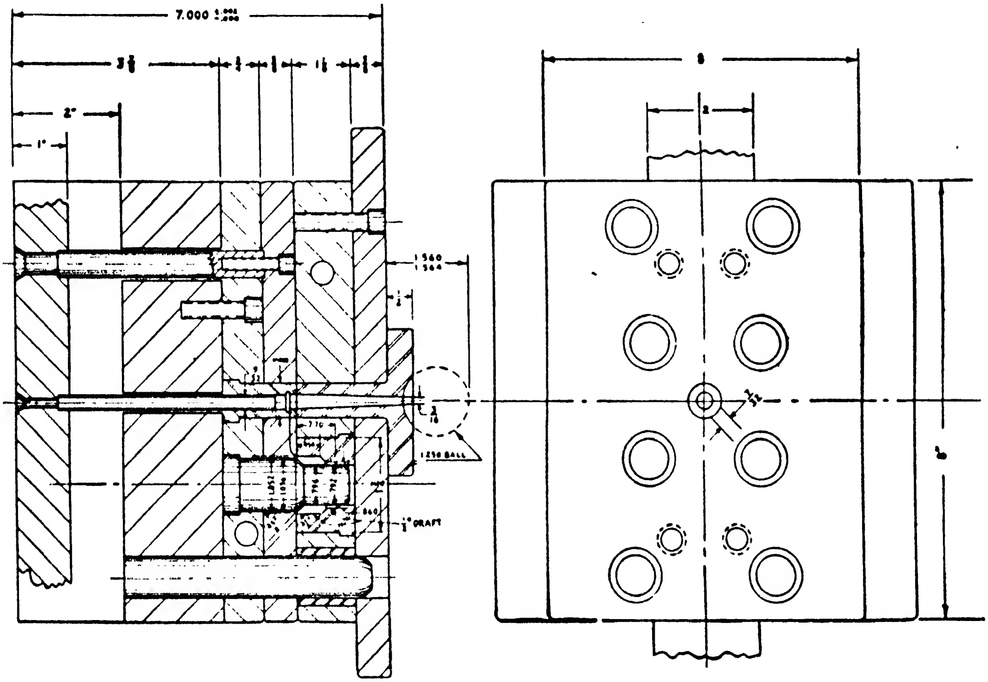


FIG. 18.20 — Four-cavity injection mold for producing a bushing.

TABLE 104. PLATING TIME VS. CURRENT DENSITY

(To produce 0.001-in. thickness)

Hours	*Amp. per Sq. In.*
0.5	3.25
1	2.25
1.5	1.6
2	1.3
3	1.06
4	0.90

PART VI

Chemistry of Plastics

●

CHAPTER XIX
Chemistry of Plastics

CHAPTER XX
Analysis of Plastics

CHAPTER XIX

CHEMISTRY OF PLASTICS

SYNTHETIC RESIN PLASTICS — CONDENSATION TYPE

Phenol-Formaldehyde. A statement of the chemical nature of phenol-formaldehyde resins is difficult in that their resinous state is due to a mixture of many complex isomers and to the variety of large and complex molecules present. A variety of reactions is even possible according to the acid, alkaline or neutral character of the catalysts used.

Various types of phenol-formaldehyde compounds may be defined as follows:

1. A resol or Type A or A-stage resin is a resin in the form of a thick liquid hardenable by heat to a final infusible and insoluble condition. It is an intermediate product, reacted to the stage where it is soluble in acetone and becomes thinner when heated.
2. A resitol or B-stage resin is one which is reacted to the point where it softens but does not melt on heating, and swells but does not dissolve in acetone.
3. A resite is the final or C-stage resin, insoluble in acetone, infusible and showing no softening on heating.
4. A Novolak is a different type of product, which remains fusible and soluble, and does not harden upon heating.

Numerous complicated formulas for these have been devised, but none has proved completely satisfactory. The chemical structures of some of these materials have not been determined.

An older suggestion by Raschig set forth the steps in the resinification as shown in Fig. 19.1. The final stage, No. IV, is Raschig's representation of Bakelite C. It has been found to disagree with actual analyses of the resin. Baekeland and Bender, on the other hand, suggested an ether formation. The A-stage resin was believed to be chiefly *p*-hydroxyphenyl phenoxy-methane, formed as in Fig. 19.2.

Baekeland and Bender believed the B-stage resin to be formed by the condensation of this ether with another molecule of formaldehyde, as in Fig. 19.3. The C-stage was then believed to be formed by polymerization of the intermediate compound.

The product of the alkaline condensation of formaldehyde was represented as in Fig. 19.4. Baekeland and Bender's idea of a C-stage resin of the ether type, polymerized (see Fig. 19.5) can be objected to on the grounds that the rate of resinification is so largely governed by the nature and positions of the substituents in the phenyl groups. Megson has suggested that poly-alcohols and branched chain structures may be involved.

Amann and Fonrobert thought the resin to consist of a long chain of hydroxy benzyl groups and suggested the following structure, assuming that di- and trihydric alcohols are formed. See Fig. 19.6. Blumfeldt proposed a still different arrangement, but one which cannot be accepted because of certain serious objections. Bakelite C has not been found to have marked crystalline properties with a cleavage plane, as this formula would suggest, and analytical results do not agree with so small an oxygen content. See Fig. 19.7.

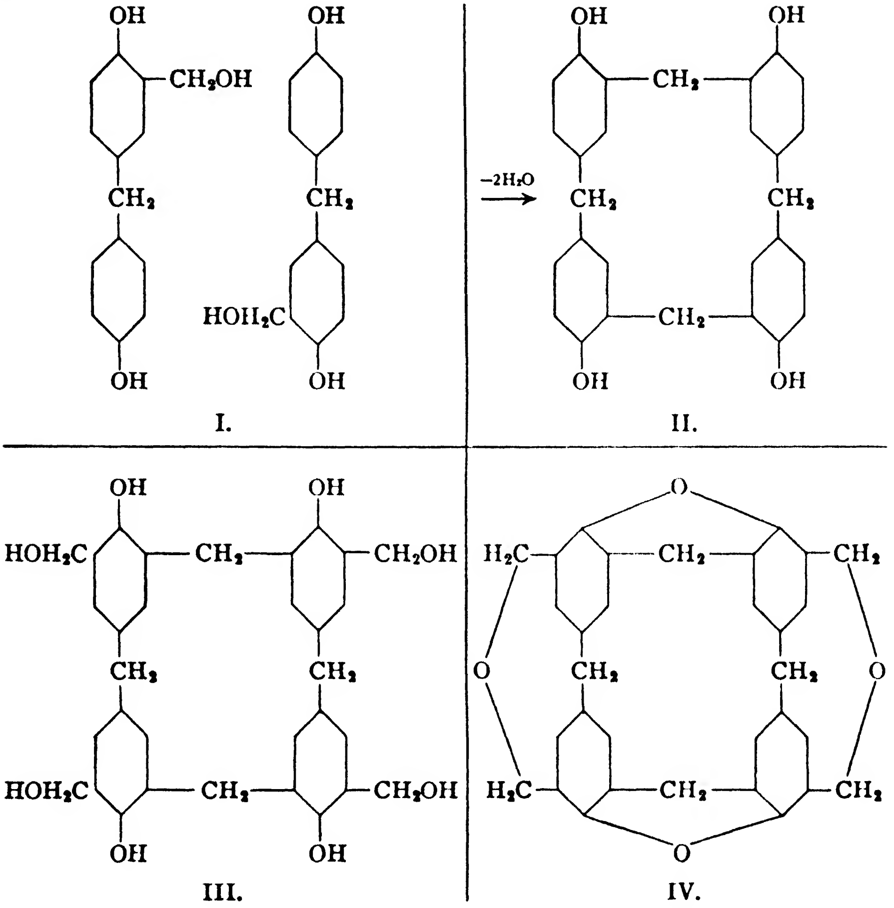


FIG. 19.1 — Resinification of phenol formaldehyde by Raschig.

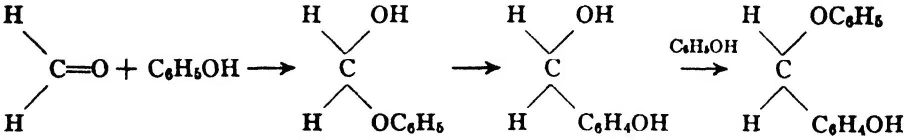


FIG. 19.2 — Formation of A stage resin.

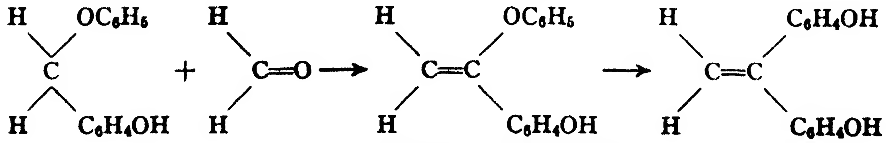


FIG. 19.3 — Formation of B stage resin.

Cross-linkages of long chains in Fig. 19.8 have been suggested by Megson.

A suggested formula for a Novolak and one most frequently agreed upon among chemists, (Figs. 19.9 and 19.10) is offered to explain the structure of Novolaks.

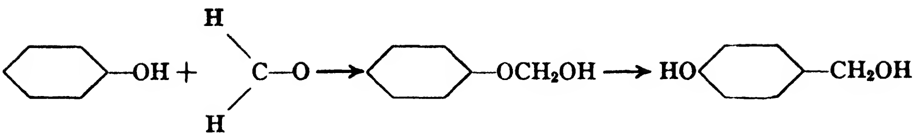


FIG. 19.4 — Condensation of formaldehyde.

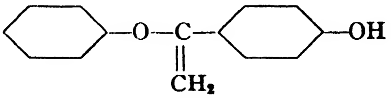


FIG. 19.5 — Modification of C stage resin.

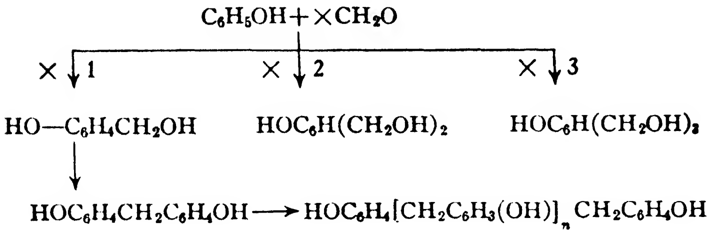


FIG. 19.6 — Hydroxy benzyl group.

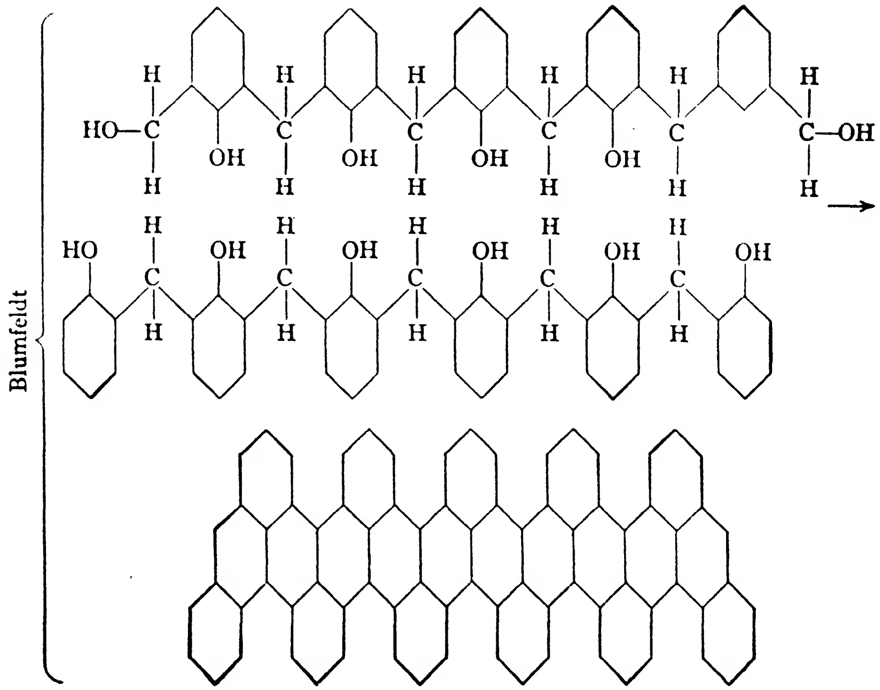


FIG. 19.7 — A further Blumfeldt arrangement.

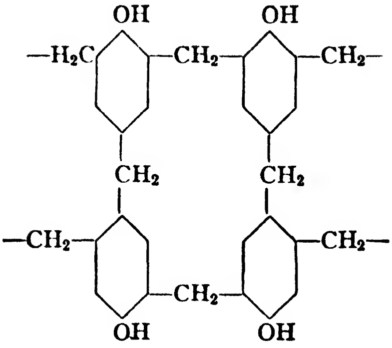


Fig. 19.8 — Megson's suggestion.

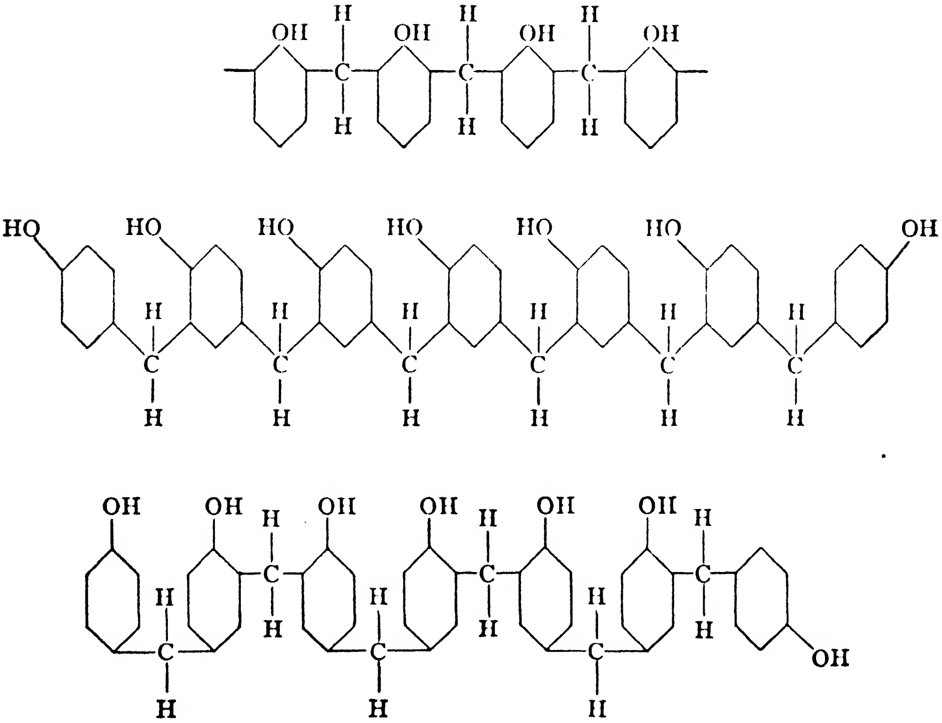
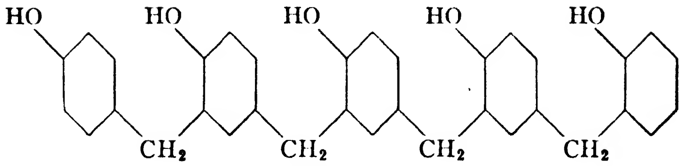
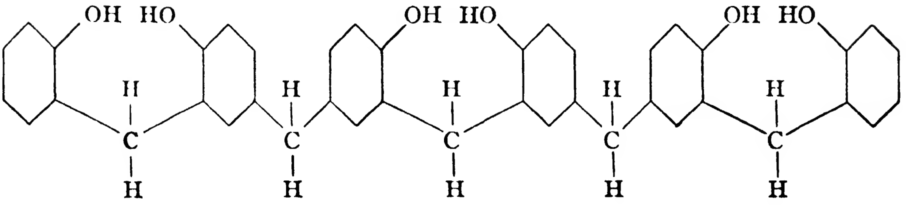


Fig. 19.9 — Novolak structure.

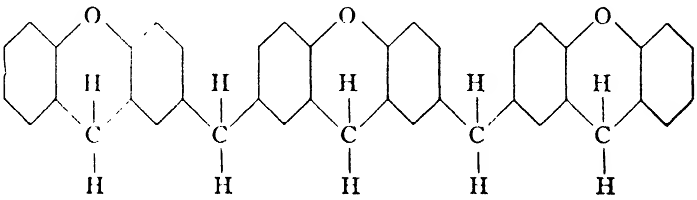
Urea-Formaldehyde. It has been fairly well established that the polymerized urea resins have a ring structure, giving them great chemical stability. The urea resin itself is a definite compound.



Novolak 1



Novolak 2



Novolak 3

FIG. 19.10 — Novolak structure.

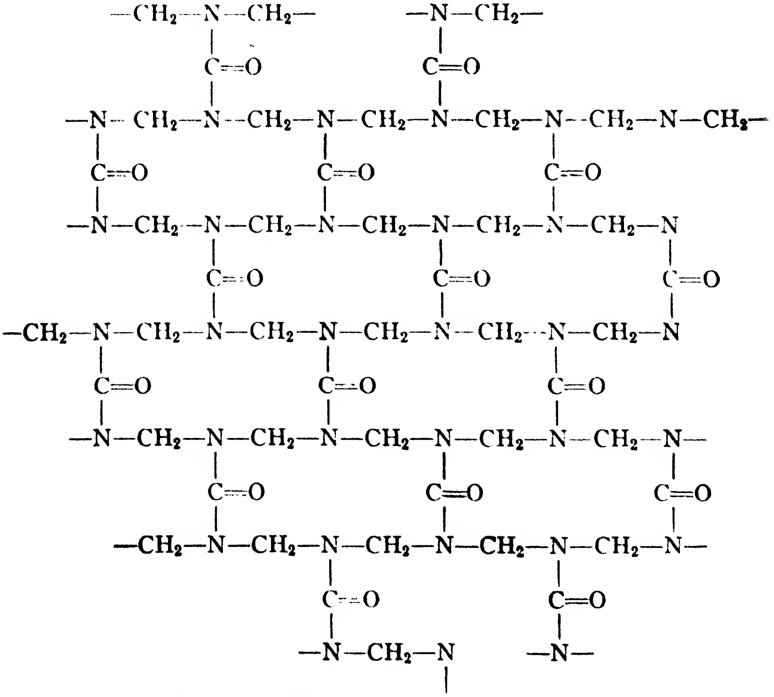


FIG. 19.11 — Molecular Structure of Phenolics.

A perfectly oriented molecular structure of the simplest form of compound most generally used in molding plastics would probably be somewhat like that in Fig. 19.11. The end valences may be taken up by hydrogen atoms attached to the unsaturated nitrogen valences, and by hydroxyl groups attached to the methylene groups; or they may be taken up by combined acid or basic radicals from the catalysts, fillers, or other modifying agents that happen to be present.

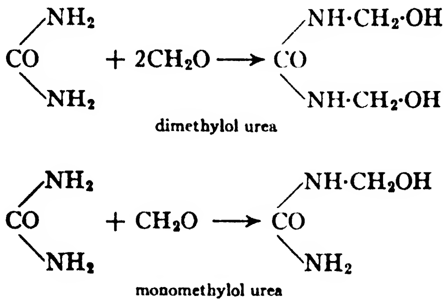


Fig. 19.12 — Formation of monomethylol urea and dimethylol urea.

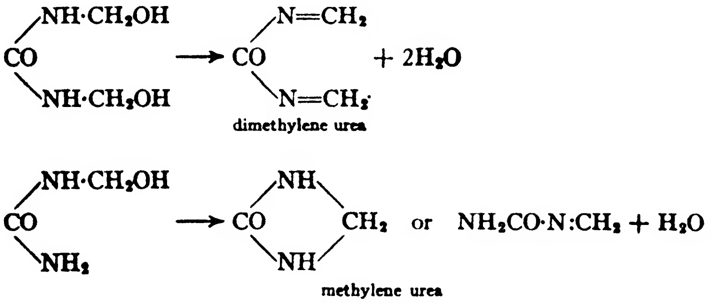


Fig. 19.13 — Formation of methylene urea.

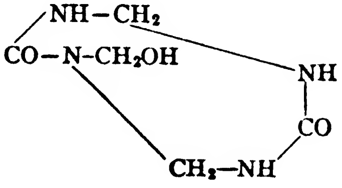


Fig. 19.14 — Goldschmidt's compound.

The first stage in the reaction is probably the formation of monomethylol urea and dimethylol urea; this is illustrated in Fig. 19.12. The next stage is the formation of methylene urea or dimethylene urea, taking place in an acid condensation medium. (See Fig. 19.13.)

Successful preparation of urea resins depends on control of the pH to avoid formation of insoluble compounds which are useless for moldings. The best known of these compounds is Goldschmidt's compound (Fig. 19.14).

Aniline Formaldehyde. Aniline condenses with formaldehyde to form anhydroformaldehydeaniline $(C_6H_5N{=}CH_2)_3$. This has a ring structure like Fig. 19.15. Higher polymers, of the same empirical formula $(C_6H_5N{=}CH_2)_n$, are also found.

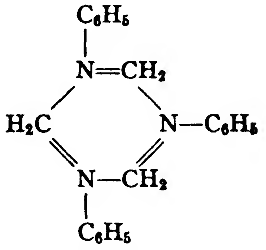


FIG. 19.15 — Anhydroformaldehydeaniline.

The structure in Fig. 19.16 is considered possible.

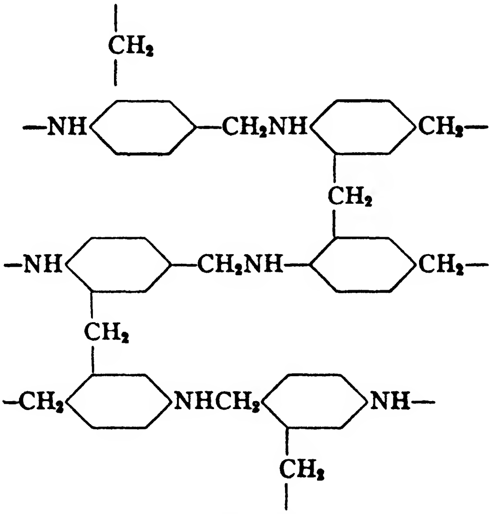
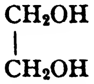


FIG. 19.16 — Modified structure.

Alkyds (Glyptals). Alkyd resins consist of groups of high molecular weight formed by the condensation of a polyhydric alcohol and a polybasic acid. The reaction may be symbolized by the use of HO—X—OH to represent a dihydric alcohol such as glycol and H—Y—H to represent a dibasic acid such as phthalic acid (or phthalic anhydride). In this case the intermediate product is HO—X—Y—H and the finished resin is HO—X—Y—(X—Y—)$_n$—XY—H.

Accordingly, the resin produced from glycol



$$\begin{array}{c} CH_2OH \\ | \\ CH_2OH \end{array}$$

and phthalic anhydride (Fig. 19.17) probably has a structure like that indicated below.

$$HO{-}CH_2{-}CH_2{-}O(CO{-}C_6H_4{-}CO{-}CH_2{-}CH_2{-}O)_n{-}CO{=}C_6H_4{-}COOH$$

The above is an example of one of the non-heat convertible alkyds, those alkyd resins formed by the condensation of a dihydric alcohol or dibasic acids which do not gel on heating.

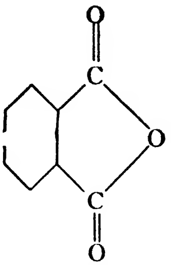


FIG. 19.17 — Phthalic anhydride.

An example of a heat-convertible resin, one produced from a trihydric alcohol and a dibasic acid or by dihydric alcohols and acids with at least three carboxyl groups, would be the resin formed by glycerol and phthalic anhydride.

This resin is believed to have a branched chain structure somewhat like Fig. 19.18.

A different and interesting type of alkyd resin is the ethylene succinate type which forms long-chain molecules which lend themselves to the formation of flexible fibers. These are not heat-convertible except by the introduction of a small proportion of heat-convertible glycerol phthalate.

Polyamides (Nylon). Higher amino acids lose water on heating and polymerize to form resins. These polyamides consist of long-chain molecules of the general structure in Fig. 19.19.

The alkyd groups represented by *R* may be most complicated, and complex alkyd groups may be substituted for the hydrogens. Mixed polyester polyamides are used for the preparation of filaments similar to those of silk.

Commercial nylons are generally prepared by condensing diamines, dibasic acids, and amino acids. Although certain of these substances can be synthesized from coal, air, and water, and a type of polyamide resin prepared from these materials, the commercially useful synthetic fibers are not usually prepared in this way.

Polymerization Type

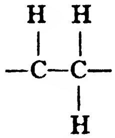
Aliphatic Vinyl Type. *Polyvinyl Alcohol.* On the basis of evidence from other linear polymers of similar structure, polyvinyl alcohol probably has the structure shown in Fig. 19.20. The straight chain is of indefinite length, but in polyvinyl alcohol for use in plastics most of the molecules may be assumed to contain from 35 to 300 units.

The unsatisfied end valences could be accounted for by a possible cyclic formation as in Fig. 19.21. Again the number of units is indefinite.

A variation might be the formation of small rings along the straight chain structure, by etherification. See Fig. 19.22.

Smaller rings might also be formed by dehydration followed by cyclization resulting from unsaturation as in Fig. 19.23.

Polyvinyl esters. Vinyl esters have a long-chain linear polymer structure based on substitution in the vinyl unit:



$$\begin{array}{cc} \mathrm{H} & \mathrm{H} \\ | & | \\ -\mathrm{C}- & \mathrm{C}- \\ & | \\ & \mathrm{H} \end{array}$$

Polyvinyl acetate has the structure shown in Fig. 19.24.

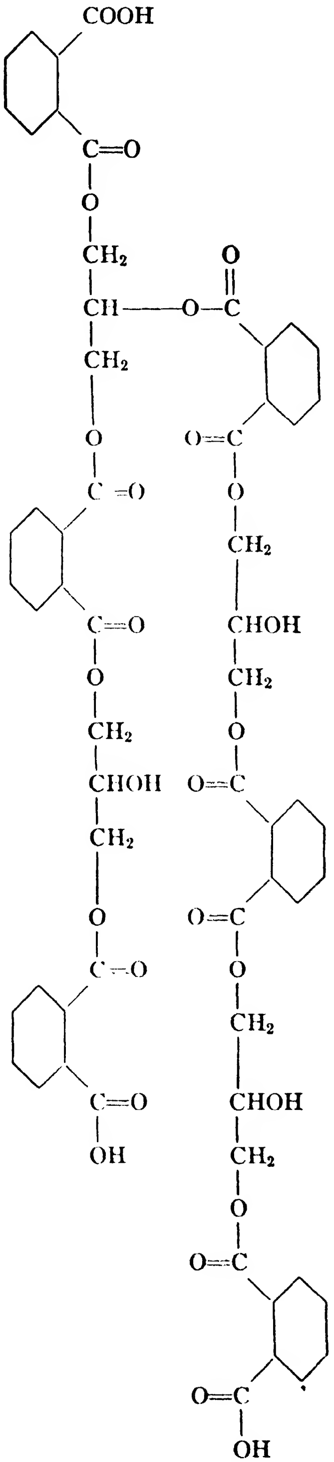


Fig. 19.18 — Alkyd resin structure.

Materials of various degrees of esterification may be prepared. There are usually 17 to 900 units in a molecule of polyvinyl acetate to be used in plastics.

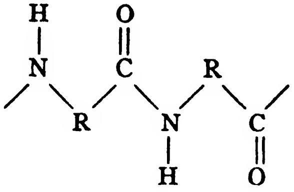
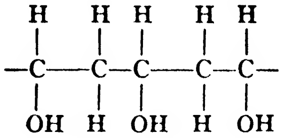


FIG. 19.19 — Nylon structure.



$$\begin{array}{ccccccccccc} & H & & H & & H & & H & & H & \\ & \mid & & \mid & & \mid & & \mid & & \mid & \\ - & C & - & C & - & C & - & C & - & C & - \\ & \mid & & \mid & & \mid & & \mid & & \mid & \\ & OH & & H & & OH & & H & & OH & \end{array}$$

FIG. 19.20 — Polyvinyl alcohol.

Similarly, polyvinyl chloride has the conformation as in Fig. 19.25.

A copolymer of vinyl chloride and vinyl acetate often is prepared. This may be regarded as a long chain with alternate links of vinyl chloride and vinyl acetate units.

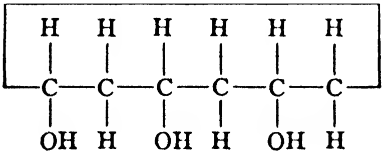


FIG. 19.21 — Modification of Polyvinyl alcohol.

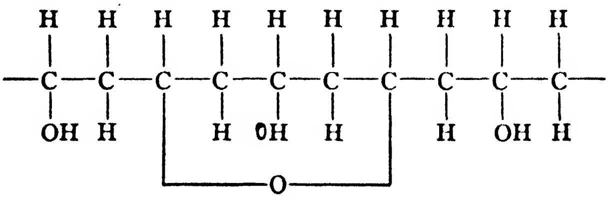


FIG. 19.22 — Further modification.

The proportion of chloride to acetate may be varied widely, and even in a one to one proportion the actual distribution of the chloride and acetate units is determined by chance and is therefore not a regular alternate distribution. The theoretical structure is shown in Fig. 19.26.

Polyvinyl aldehydes, prepared by the hydrolysis of polyvinyl acetate to the alcohol and treatment of the alcohol with any of various aldehydes, have a chain structure similar to that of the substance from which they are derived. Acetaldehyde, formaldehyde, or butyraldehyde may be used with good results. (See Fig. 19.27.)

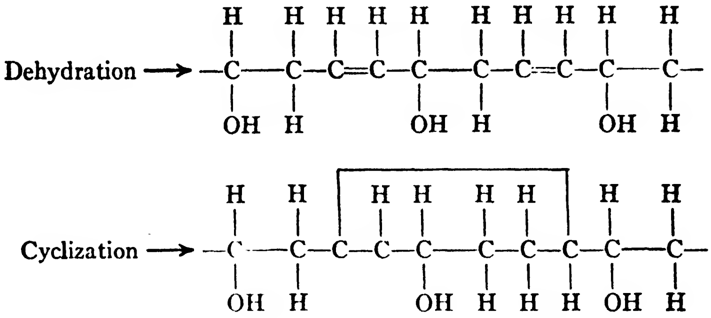
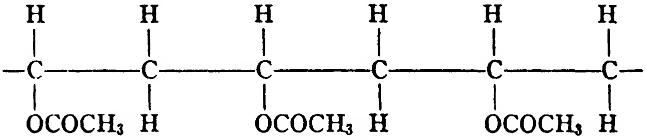


FIG. 19.23 — Dehydration of polyvinyl alcohol.

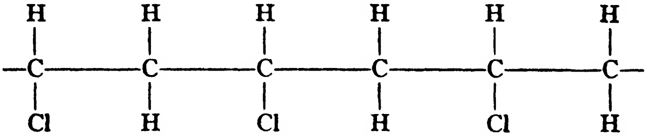
Vinylidene-chloride resin, like the other vinyl polymers, is believed to have a long-chain linear structure consisting of monomeric units linked at the double bond as in Fig. 19.28. The similarity of this formula to that of polyvinyl chloride is obvious.



$$-\underset{OCOCH_3}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{OCOCH_3}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{OCOCH_3}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-$$

FIG. 19.24 — Polyvinyl acetate.

Vinylidene chloride can be made to polymerize with vinyl chloride to give a product like Fig. 19.29.



$$-\underset{Cl}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{Cl}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{Cl}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-$$

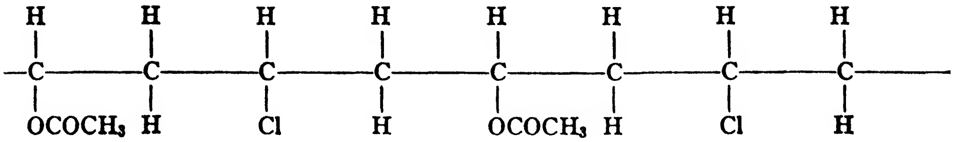
FIG. 19.25 — Polyvinyl chloride.

Acrylic resins include polymerized acrylic and methacrylic acids and their polymerized esters and salts. The esters, notably the methyl ester of methacrylic acid, are the most important.

Polymerized methyl methacrylate is believed to have somewhat the molecular configuration shown in Fig. 19.30.

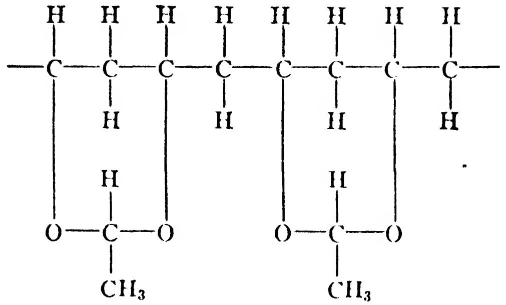
Accordingly, ethyl acrylate would be represented by Fig. 19.31. Mixed esters (copolymers) may be prepared.

Polymerized acrylic and methacrylic acids are of course similarly formed as in Fig. 19.32. All these acrylic ester molecules have free end valences while they are still growing in length, but these are eventually stablized by ring formation or by

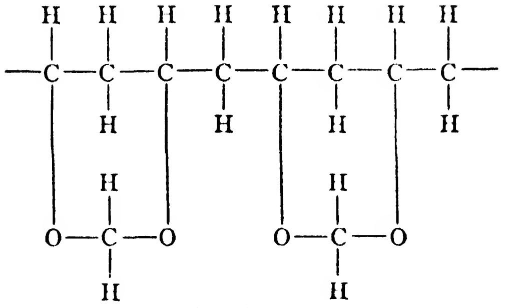


$$-\underset{\mathrm{OCOCH_3}}{\overset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{Cl}}{\overset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{OCOCH_3}}{\overset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{Cl}}{\overset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-$$

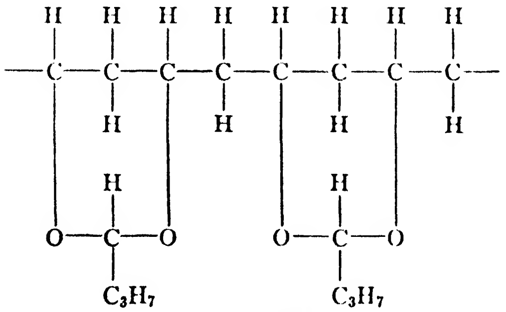
FIG. 19.26 — Copolymer of vinyl chloride and vinyl acetate.



Acetaldehyde



Formaldehyde

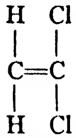


Butyraldehyde

FIG. 19.27 — Chain structure of acetaldehyde, formaldehyde, and butyraldehyde.

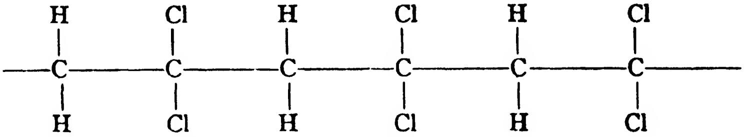
combination with catalysts, solvent molecules, or various impurities that may be present.

Aromatic Vinyl Type. *Polystyrene* has a long-chain structure consisting of a series of styrene groups connected end to end at the double bond. Thus the main structure of the resin is like Fig. 19.33. The end valences may be satisfied by the sort of structure shown in Fig. 19.34, or by migration of a hydrogen atom from one molecule to another or from one end of a chain to the other as in Fig. 19.35.



$$\begin{array}{ccc} \mathrm{H} & & \mathrm{Cl} \\ | & & | \\ \mathrm{C} & = & \mathrm{C} \\ | & & | \\ \mathrm{H} & & \mathrm{Cl} \end{array}$$

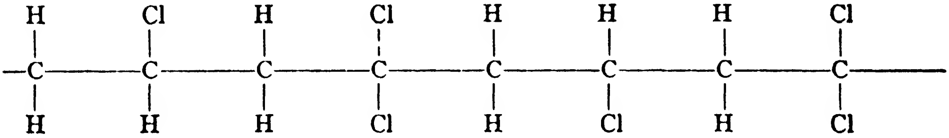
Vinylidene chloride (monomer)



$$\begin{array}{ccccccccccccc} & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & \\ & | & & | & & | & & | & & | & & | & \\ - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - \\ & | & & | & & | & & | & & | & & | & \\ & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & \end{array}$$

FIG. 19.28 — Vinylidene chloride (polymer).

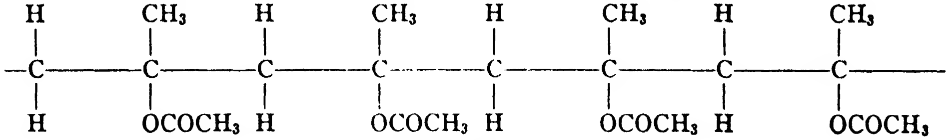
Another possibility is the entrance of some catalyst, A–B, into the reaction. (See Fig. 19.36.)



$$\begin{array}{ccccccccccccccccc} & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{Cl} & \\ & | & & | & & | & & | & & | & & | & & | & & | & \\ - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - \\ & | & & | & & | & & | & & | & & | & & | & & | & \\ & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & \end{array}$$

FIG. 19.29 — Vinylidene chloride polymerized with vinyl chloride.

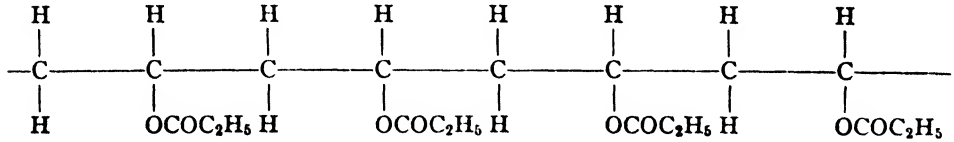
Cyclization is also possible, and is not out of keeping with the known properties of the resin. Development of such a ring formation causes the resin to become a flattened ring or double chain rather than a single chain. (See Fig. 19.37.)



$$\begin{array}{ccccccccccccccccc} & \mathrm{H} & & \mathrm{CH_3} & & \mathrm{H} & & \mathrm{CH_3} & & \mathrm{H} & & \mathrm{CH_3} & & \mathrm{H} & & \mathrm{CH_3} & \\ & | & & | & & | & & | & & | & & | & & | & & | & \\ - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - \\ & | & & | & & | & & | & & | & & | & & | & & | & \\ & \mathrm{H} & & \mathrm{OCOCH_3} & & \mathrm{H} & & \mathrm{OCOCH_3} & & \mathrm{H} & & \mathrm{OCOCH_3} & & \mathrm{H} & & \mathrm{OCOCH_3} & \end{array}$$

FIG. 19.30 — Methyl methacrylate.

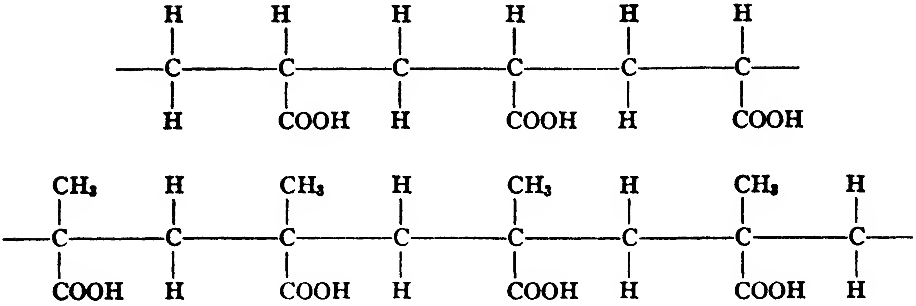
Other Types. *Cumarone* and *indene* are two similar compounds found in a fraction of coal tar naphtha boiling between about 165° and 185° C. If isolated, each may be polymerized separately to form polycumarone and polyindene, but in practice it is most difficult to separate them, so they are polymerized together to form cumarone-indene resin as in Fig. 19.38.



$$\begin{array}{ccccccccccccccccc} & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & \\ & | & & | & & | & & | & & | & & | & & | & & | & \\ - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - \\ & | & & | & & | & & | & & | & & | & & | & & | & \\ & \mathrm{H} & & \mathrm{OCOC_2H_5} & & \mathrm{H} & & \mathrm{OCOC_2H_5} & & \mathrm{H} & & \mathrm{OCOC_2H_5} & & \mathrm{H} & & \mathrm{OCOC_2H_5} & \end{array}$$

FIG. 19.31 — Ethyl acrylate.

It is believed that the catalytic polymerization of cumarone and indene is an



$$\begin{array}{cccccc} H & H & H & H & H & H \\ | & | & | & | & | & | \\ -C- & -C- & -C- & -C- & -C- & -C- \\ | & | & | & | & | & | \\ H & COOH & H & COOH & H & COOH \end{array}$$

$$\begin{array}{cccccccc} CH_3 & H & CH_3 & H & CH_3 & H & CH_3 & H \\ | & | & | & | & | & | & | & | \\ -C- & -C- & -C- & -C- & -C- & -C- & -C- & -C- \\ | & | & | & | & | & | & | & | \\ COOH & H & COOH & H & COOH & H & COOH & H \end{array}$$

FIG. 19.32 — Polymerized acrylic and methacrylic acids.

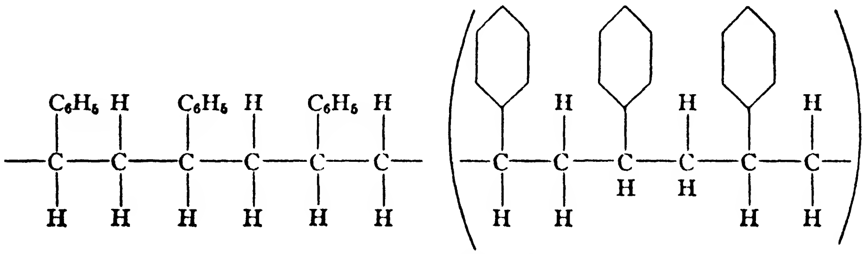


FIG. 19.33 — Polystyrene.

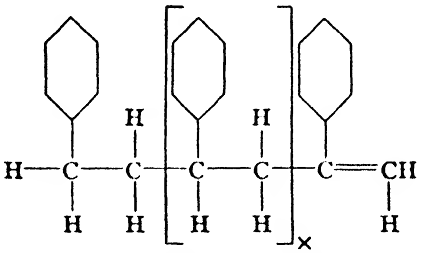


FIG. 19.34 — Polystyrene end valences.

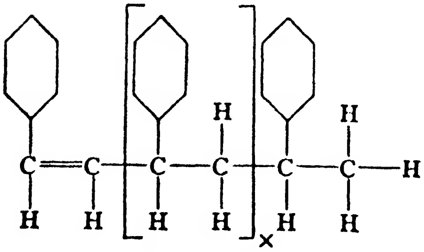


FIG. 19.35 — Modified form.

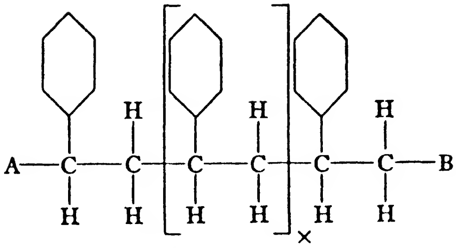


FIG. 19.36 — Catalyst A–B.

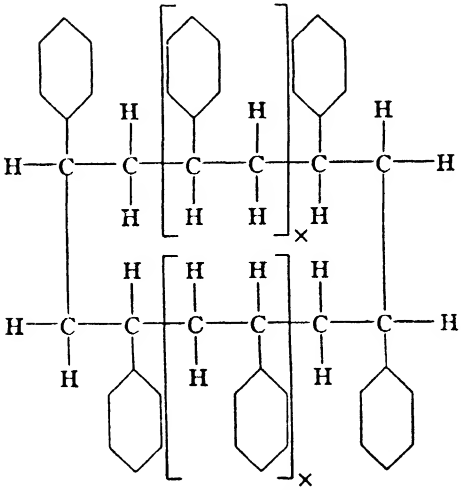


FIG. 19.37 — Double chain structure.

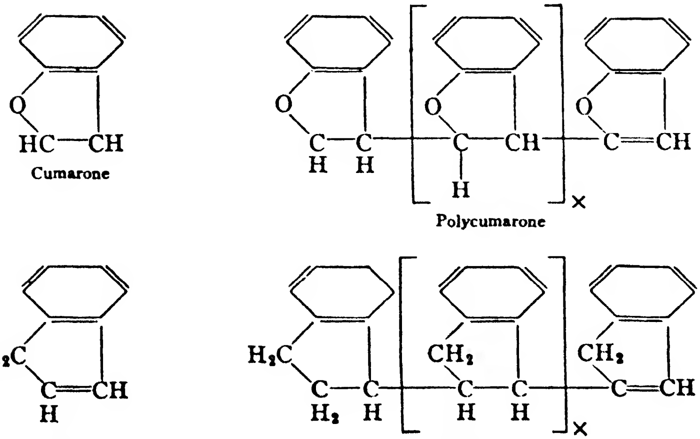


FIG. 19.38 — Cumarone-indene.

additive reaction, forming a long-chain molecule. (See Fig. 19.39.) The proportion of cumarone to indene units is dependent on the proportions of cumarone and indene present in the reaction mixture and the arrangement of these in series is by chance.

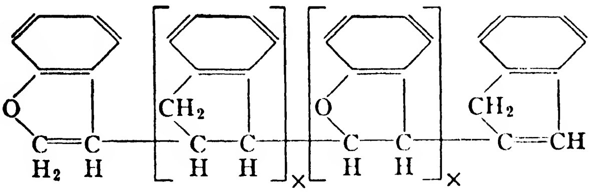


FIG. 19.39 — Cumarone-indene resin.

Furfural has the structure shown in Fig. 19.40. It is similar to that of cumarone, and the resin formed by the polymerization of furfural itself might be expected to have a structure similar to that of polycumarone, as in Fig. 19.41.

Furfural also reacts as an aldehyde in condensing with various other substances, notably phenol, and aniline. In these cases the aldehyde groups take part in a linkage similar to that found in the case of the simpler formaldehyde.

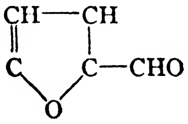


FIG. 19.40 — Furfural.

CELLULOSE PLASTICS

Regenerated Cellulose. Cellulose molecules are believed to be composed of long chains of cellobiose units joined together in groups of fifty to one hundred. These groups are arranged in bundles of about fifty. Each bundle is called a micelle, many of which are required to make up a cellulose fiber.

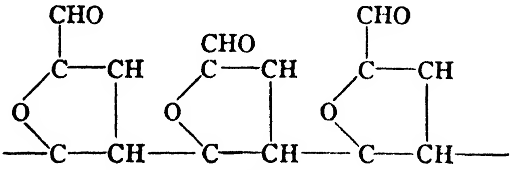


FIG. 19.41 — Cellulose molecule.

Cellobiose, the cellobiose unit, is a disaccharide which can be hydrolyzed to form a simple sugar, glucose. The glucosidic unit of cellulose has a structural formula something like that shown in Fig. 19.42.

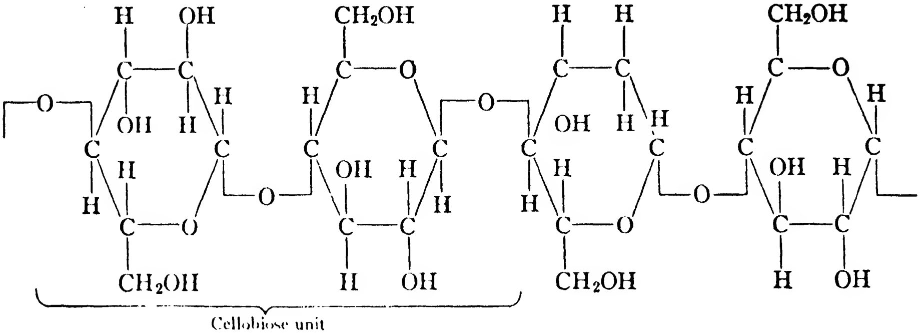


FIG. 19.42 — Cellulose sugar.

Regenerated cellulose, or hydrocellulose, such as is prepared from cellulose xanthate solution, is represented by the conventional cellulose formula given in Fig. 19.42. It

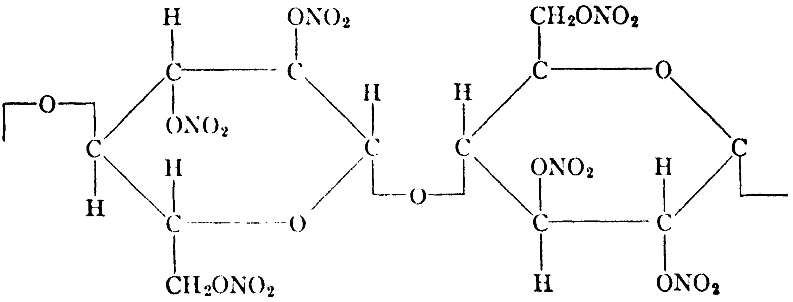


FIG. 19.43 — Cellulose nitrate unit.

is spun as viscose rayon, in which the molecules are oriented along the axis of each fiber, and it is produced in transparent thin sheets such as cellophane.

Cellulose Ester Plastics. *Cellulose Nitrate.* Cellulose esters are formed by substituting nitrate, acetate or other suitable groups for the hydroxyl groups in the molecule. Cellulose may be esterified to a greater or less degree. In the case of cellulose nitrate, partially nitrated material is used for plastics. The completely nitrated material, of formula $[C_{12}H_{14}O_4(ONO_2)_6]_x$ is known as gun cotton and is unsuitable for the production of plastics. The cellulose nitrate unit is illustrated in Fig. 19.43.

Cellulose Acetate. Again in the case of cellulose acetate, the partially esterified material is used for plastics. The "tri-acetate" $[C_6H_7O_2(OCOCH_3)_3]_x$ or completely esterified material is prepared first and then hydrolyzed or de-acetylated to the desired degree. (See Fig. 19.44.)

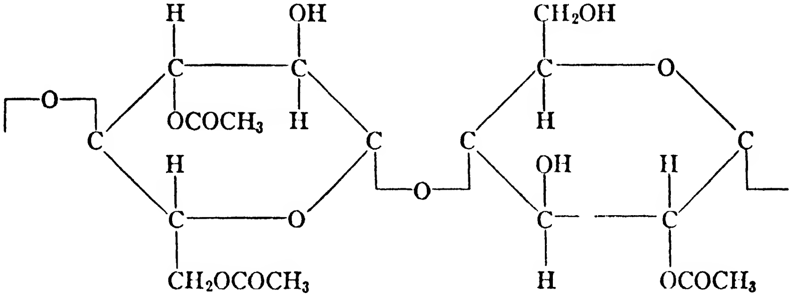


FIG. 19.44 — Cellulose acetate unit.

Cellulose Acetate-Butyrate. Other cellulose esters used in the plastics industry are mixed esters such as cellulose acetate-butyrate and cellulose acetate propionate. An empirical formula for a completely esterified material in the preparation of which two acetate equivalents for each butyrate equivalent were used might be $[C_{12}H_{14}O_4(OCOCH_3)_4(OCOC_3H_7)_2]_x$. In practice, of course, the material used for plastics is not completely esterified, and the composition of the material may be varied by varying the relative proportions of the two acids and anhydrides employed.

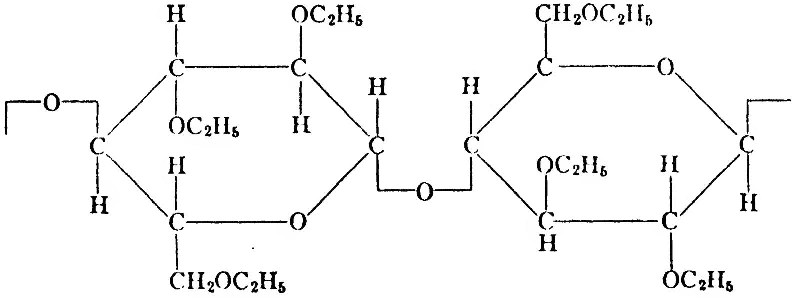


FIG. 19.45 — Ethylated cellobiose unit.

Ethyl Cellulose. Cellulose ethers consist of cellulose molecules in which the six available hydroxyl groups in each cellobiose unit have been replaced by ethyl, benzyl, methyl, or similar groups instead of by acetate nitrate groups as in the case of cellulose ester plastics.

A completely ethylated cellobiose unit might be represented as in Fig. 19.45.

In practice, standard ethyl cellulose for plastics is ethylated to the extent of an average of 2.4 to 2.5 ethoxyl groups per glucose residue, or 4.8 to 5.0 ethoxyl groups per cellobiose unit (as against six in the completely ethylated material).

Benzyl Cellulose. In the case of benzyl cellulose, —OC_6H_5 groups are substituted instead of ethoxyl groups. Again the partially substituted material is used for plastics. The benzyl cellulose unit is given in Fig. 19.46.

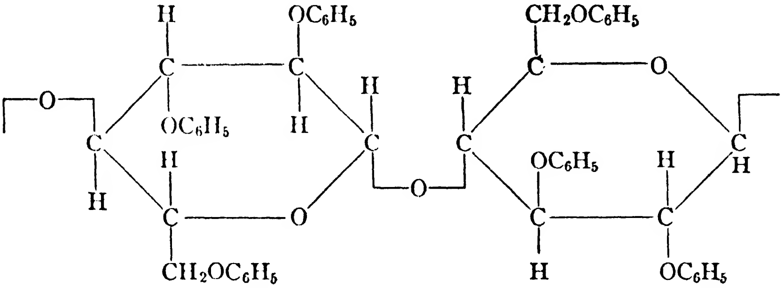


FIG. 19.46 — Benzyl cellulose unit.

Other Types. *Casein.* The chemistry of casein plastics is somewhat obscure because of the complex nature of the casein itself. However, explanations have been offered for the resin-forming reaction with formaldehyde.

There are two types of casein: (1) that prepared by the *rennet method,* which is a double salt of calcium paracaseinate and calcium phosphate and is called "paracasein"; and (2) casein prepared by the acid method, which is simply the basic material known as casein. Representing the complex structure of the casein molecule by *R*, the explanations presented in Fig. 19.47 have been offered to explain the effect of formaldehyde on casein, as a condensation reaction.

Lignin Plastics. Wood consists principally of cellulose, lignin, hemicellulose, and sap, the sap containing resins and water-soluble substance. The average lignin content of wood is about 26 per cent.

The lignin content of wood is believed to consist of *a*-lignin about 64 per cent (suggested formula $C_{10}H_{12}O_4$), and *b*-lignin about 36 per cent [suggested formula $C_{10}H_{12}O_4(C_9H_9O_4COCH_3)_2$].

More recently a structural unit of lignin has been suggested, somewhat like Figs. 19.48 and 19.49.

Lignin itself polymerizes to form a chain-like structure as indicated by the suggested formula above. Usually, however, the lignin serves as a binder as it occurs naturally in wood. The lignin bonds in woody raw material are broken and the lignin reactivated so that the disintegrated wood can again be bonded into a new form by the lignin present in the woody material.

Shellac. Natural shellac is obtained from a secretion of the lac insect, and is a mixture of various complex chemical compounds of similar structures. The shellac can be separated into two parts: hard lac and soft lac. The soft lac is semi-liquid and acts as a plasticizer for the hard lac. It consists chiefly of a mixture of aleuritic and shellolic acids, with certain other uncondensed hydroxy acids, and also some simple condensates of aleuritic acid and an isomer, and of shellolic acid. The hard lac may be separated into four fractions, of which the largest, representing 40 per cent of the whole, consists of monobasic inter-ester acids from which aleuritic and shellolic acids have been isolated. The next largest fraction, 20 per cent, contains monobasic inter-ester lactone acid, of composition $C_{15}H_{24}O_5$, from which aleuritic, shellolic, and kerrolic acids and their isomers have been separated. The remainder of the hard lac consists of similar enter-esters, with molecular weights up to 1500.

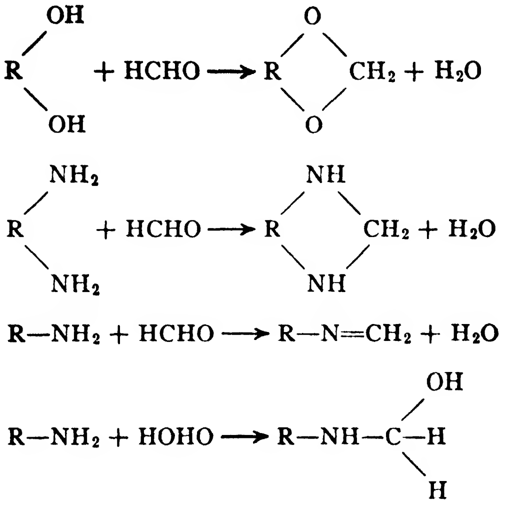


FIG. 19.47 — Effect of formaldehyde on casein (R represents casein).

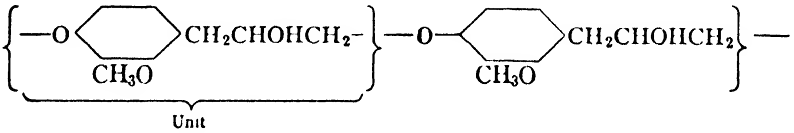


FIG. 19.48 — Lignin.

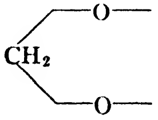
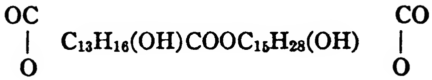


FIG. 19.49 — Modification of lignin.

Although the exact composition of natural shellac is still in doubt, it is believed to be a mixture of substances obtained by the lactide condensation of various hydroxy-carboxylic acids, notably aleuritic acid — $C_{15}H_{28}(OH)_3COOH$ — and shellolic acid — $C_{13}H_{16}(OH)_2(COOH)_2$. Kerrolic acid, $C_{15}H_{27}(OH)_4COOH$, and other similar hydroxy acids also play a part.

A possible formula for one of the simpler components of shellac is



$$\begin{array}{ccc} OC & & CO \\ | & C_{13}H_{16}(OH)COOC_{15}H_{28}(OH) & | \\ O & & O \end{array}$$

A somewhat different structure suggested as one of the chief components of lac resin is given in Fig. 19.50.

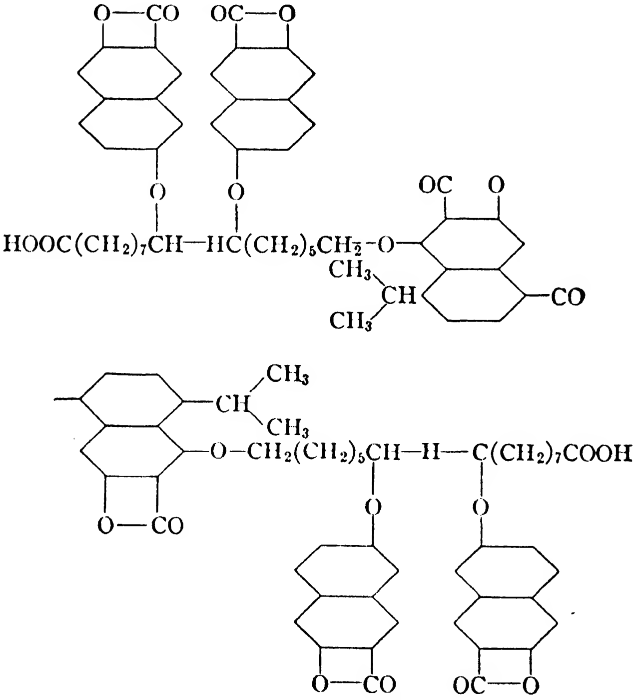


Fig. 19.50 — Shellac.

CHAPTER XX

ANALYSIS OF PLASTICS

The chief aim in the qualitative analysis of a plastics molded or cast article, coating, or other derivative is the identification of the resin or base present. These materials are often very inert, and virtually insoluble, but to one familiar with the characteristics of the various types of plastics an observation of their physical properties such as color, specific gravity, refractive index, and behavior upon heating may be sufficient to identify a resin or base as belonging in one of several groups. When the nature of the material has been tentatively decided upon, the findings may be verified by running a parallel series of tests on the unknown sample and on a sample of material known to contain the same base. A knowledge of the principal applications of each resin or of the bases commonly used together in various applications will often allow the analyst to limit the possibilities to three or four materials for which he can then make tests.

The analytical tests necessary for the routine identification of the bases, such as resins, in a plastic are fairly simple, requiring mainly familiarity with the types of resins which may be expected to be present. In some instances it may also be desirable to make quantitative tests, which are difficult because it is usually necessary to decompose the resin in order to make the tests.

The nature and amount of filler present may be determined separately if desired, for example, by microscopic analysis, but its presence will not usually affect the analysis. The filler may make the physical properties of the composition different from those of the resin binder, but the filler should not interfere with the identification of the resin.

OUTLINE FOR THE IDENTIFICATION OF THE PRINCIPAL BASE OR RESINS PRESENT IN A PLASTIC

GENERAL OBSERVATIONS AND TESTS

Applications. Determination of which types of synthetic resins can be successfully adapted to the production of the article which is to be analyzed. (See section on Applications, page 787.)

Color. Determination of which of the synthetic resins can be obtained in the color or degree of transparency or opacity, or special design or mottle displayed by the unknown, and those which are most frequently produced with this appearance.

Some resins are naturally clear and colorless, and are seldom used with fillers; others are very difficult to obtain in very light colors or in certain tints; some are almost never produced without fillers; some are usually produced in brown or black. (See tables of Physical Properties, page 31, and section on Materials, page 225.)

Specific Gravity. This may be determined by any standard method, usually by water displacement in the case of solids, and by the pycnometer in the case of liquids. The specific gravity is often greatly altered by the presence of plasticizers and fillers, and its determination may be of little assistance unless the resins can be separated from these interfering materials.

For determining certain properties such as the density and refractive index it is desirable to remove fillers and pigments. These can often be removed from a solution of the plastic by centrifuging. In addition, it is often desirable to eliminate plasticizers. This may be done by extracting a portion of the plastic with petroleum ether.

When the exact nature of the filler and resin present is known, the amount of each component may be roughly approximated by comparison with a sample of known material.

For small samples, and for rapid work in routine analysis, the specific gravity of a solid may be determined by immersion in salt solutions of known density. (See table on Specific Gravity of Synthetic Resins and Plastics, page 744 and also Chap. II on physical properties.)

Refractive Index. This value can be obtained only for transparent materials. It is also affected to some extent by the presence of plasticizers, and obscured by fillers and pigments.

It may be determined by the use of the Abbé refractometer or for small samples, the microscope, with Becke or oblique illumination methods. (See table on the refractive indices of synthetic resins, and natural resins, page 744.)

When several different types of resins are present, they may often be separated by differential solubility in various solvents, and their individual properties then determined.

In certain analyses it may be desirable to treat the plastic in the following way (for qualitative testing):

Dissolve the plastic in suitable solvent, remove the pigments and fillers by centrifuging.

Precipitate cellulose esters from the solution with benzene or toluene, and analyze these separately. Wash the precipitate, redissolve it in acetone, reprecipitate it with benzene or toluene.

The remainder of the solution should be evaporated to dryness, and freed of plasticizers such as diethyl, dibutyl or diamyl phthalates, tricresyl phosphate, rosin and the like, by extracting with petroleum ether. The petroleum ether insolubles should be dried and subjected to analysis.

Thermosetting phenolic resins may be isolated from the filler by extraction with acetone.

Fluorescence Tests. Many natural and synthetic resins fluoresce with characteristic colors when exposed to filtered ultra-violet light. Although of some value, fluorescence tests as applied to the analysis of plastics are still undergoing investigation and hence are not to be considered as thoroughly reliable as yet.

Behavior upon Heating. The behavior of a sample of a plastic upon heating will often quickly reveal the nature of the resin present. Thermosetting resins will either remain infusible or will fuse and set to an infusible mass. Thermoplastic substances will melt at temperatures characteristic of each resin, except as modifying agents may alter the melting point.

Strong heating of a small sample in a flask or test tube allows observation of the following: (1) odor, (2) melting point or softening point (if any), (3) formation of

TABLE 105. A SCHEME FOR THE QUALITATIVE ANALYSIS OF

I. OPAQUE, HOMOGENEOUS OR LAMINATED

A. Treat a large sample of the finely

<table>
<tr><th colspan="3">Residue Insoluble in Toluene</th></tr>
<tr><td colspan="3">Phenolics, casein and other protein plastics, urea and other amine plastics, cellulose hydrate, cellulose nitrate, cellulose acetate, polyvinyl chloride. Also inorganic and organic fillers and coloring matters, and glyptals and other alkyds.</td></tr>
<tr><td colspan="3">Drive off the toluene from the above mixture by warming over a water bath, and treat the residue with methyl formate, refluxing the mixture.</td></tr>
<tr><th>Insoluble in methyl formate</th><th colspan="2">Soluble in methyl formate</th></tr>
<tr><td>Phenolics, casein, urea, glyptals, cellulose hydrate, polyvinyl chloride, fillers and coloring matters.</td><td colspan="2">Cellulose nitrate, and cellulose acetate.</td></tr>
<tr><td rowspan="3">Other tests to be applied to above residue:
1. Phenol: Heat with NaOH. Odor of phenol and characteristic color reactions identify it.
2. Amine plastics (urea, thiourea, etc.). Heat with NaOH. Odor of ammonia identifies them. Test for S to see if thiourea is present.
3. Protein plastics (casein, etc.) Destructive distillation gives odor of burning hair or feathers. Heating with NaOH gives odor of ammonia.
4. Glyptals: Test for phthalic acid.
5. Cellulose hydrate: Smell of burning paper on charring.
6. Polyvinyl: Test for Cl.
7. Fillers: Inorganic: Reduce plastic to ash and test qualitatively. Examine microscopically. Use phloroglucinol test for lignin to determine presence of wood.</td><td colspan="2">Distill off the solvent and treat the remainder with amyl formate (boiling point 116°C.)</td></tr>
<tr><th>Residue</th><th>Solution</th></tr>
<tr><td>Cellulose Acetate. Test for acetic acid by saponification.</td><td>Cellulose nitrate. After distilling off the solvent, test the flammability and make the diphenylamine test.</td></tr>
</table>

any sublimate, (4) volatilization of compounds with characteristic odors, (5) acid or basic nature of the vapors given off, and (6) depolymerization or charring upon strong heating.

Destructive distillation of a large portion, with absorption of the volatile constituents in water, permits further analysis. If strong heating causes depolymerization of the resin the boiling points of the resulting monomers may be determined. See Table III.

Saponification. A separation based upon saponification may be used, but its value is limited because many synthetic resins are themselves unsaponifiable, though in plastic compositions they may be modified by rosin, fats, or other saponifiable material.

Half normal or normal solutions of aqueous NaOH, or alcoholic NaOH, or a mixture of equal parts of benzene and normal alcoholic caustic may be used for saponification. For example, a weighed sample of the resin may be heated with an excess of 0.5 N or 1 N NaOH in methanol and the excess alkali determined with a corresponding strength

THE MORE COMMON PLASTICS. BASED ON SOLUBILITIES

PLASTICS, MOLDED OR EXTRUDED

pulverized plastic with toluene, and reflux

<table>
<tr><td colspan="6">Solution of Matter Soluble in Toluene ✓</td></tr>
<tr><td colspan="6">Ethyl cellulose, benzyl cellulose, polystyrene, polyacrylic acid-methyl ester, methyl methacrylate, mixed polymers of methyl acrylate and polyvinyl chloride, cumarone resin, bituminous material, chlorinated rubber and plasticizers.</td></tr>
<tr><td colspan="6">Distill off the toluene by slow heating over a water bath until the mixture is toluene-free. Then treat with methanol and reflux.</td></tr>
<tr><td colspan="4">Residue insoluble in methanol</td><td colspan="2">Soluble in methanol</td></tr>
<tr><td colspan="4">Benzyl cellulose, polystyrene, polyacrylic acid, methyl methacrylate, mixed polymers, cumarone resin, bituminous material, chlorinated rubber.</td><td colspan="2">Ethyl cellulose and plasticizers.</td></tr>
<tr><td colspan="4">Treat with ether</td><td colspan="2">Add petroleum ether in excess.</td></tr>
<tr><td colspan="2">Residue</td><td colspan="2">Ether solution</td><td>Precipitate</td><td>Solution</td></tr>
<tr><td colspan="2">Benzyl cellulose, mixed polymerization product as above, chlorinated rubber, bituminous materials in part.</td><td colspan="2">Polystyrene, cumarone resin, mixed polymers in part, bituminous materials in part.</td><td rowspan="4">Ethyl cellulose. Further identified by tests for the ethyl group, and tests of solubility.</td><td rowspan="4">Plasticizers. After distilling off the solvent, make tests for the more common plasticizers. Camphor (Palatinole), chlorinated diphenyl, tricresyl phosphate.</td></tr>
<tr><td colspan="2">Treat with methyl formate.</td><td colspan="2">Distill off the ether and extract the residue.</td></tr>
<tr><td>Residue</td><td>Solution</td><td>Residue</td><td>Solution</td></tr>
<tr><td>Chlorinated rubber and polyvinyl chloride (mixed polymerization). Give test for chlorine. Bituminous materials give residue a dark brown color.</td><td>Benzyl cellulose and part of mixed polymers. Test for benzyl cellulose by distilling off solvent, treating with dilute H_2SO_4 and heating. Odor of benzaldehyde, disappearing on neutralizing with NaOH identifies it.</td><td>Polystyrene (Test to identify). Part of mixed polymers.</td><td>Cumarone resin. Distill off the solvent, saponify with alcoholic KOH. Test the unsaponifiable matter by Storch-Morowsky test.</td></tr>
</table>

acid. Phenolphthalein is the usual indicator. If sodium phthalate crystals appear during saponification in the presence of alcohol they may be removed for analysis.

If a high saponification number is found, it may be desirable to saponify a large portion of the resin for the purpose of separating and identifying the acids present. A saponification number of over 200 is a strong indication of the presence of polybasic esters.

Crystals which separate out during saponification in alcohol may be obtained by filtration and dissolved in water. The aqueous solution may then be acidified with a mineral acid, precipitating the polybasic acids. These acids may then be filtered, washed and examined microscopically. They may be further identified by color tests, by determinination of the melting points, and by neutralization equivalents of the purified samples, or by preparation of their p-nitrobenzyl, or p-phenylphenacyl esters, or by other derivatives such as anilides. Other specific tests may also be made. (See analysis of alkyd resins.)

TABLE 105. A SCHEME FOR THE QUALITATIVE ANALYSIS

II. CLEAR, COLORLESS OR COLORED, FREE OF

A. Reflux a large sample of the finely

Undissolved residue
Phenolics, urea and other amine plastics, glyptals and other alkyds, polystyrene, polyvinyl chloride, polymethyl methacrylate, benzyl cellulose, cellulose nitrate, cellulose acetate.
Treat with benzene, and reflux

Residue	Solution in benzene
Phenolics, ureas, glyptals and other alkyds, polyvinyl chloride, cellulose nitrate, cellulose acetate.	Polystyrene, polymethyl methacrylate, benzyl cellulose, and mixed polymers of esters of polyacrylic acid with polyvinyl chloride.

Apply the seven tests listed under Part I to be applied to residue insoluble in toluene and in methyl formate.
Also treat with methyl formate and reflux.

Residue	Solution
Phenolics, ureas, glyptals, polyvinyl chloride.	Cellulose nitrate, cellulose acetate, part of the polyvinyl chloride and part of the glyptals.

Distill off the solvent and treat the residue with amyl formate (boiling point 116°C.)

Residue	Solution
Cellulose acetate (saponify and test for acetic acid.)	Cellulose nitrate. Distill off the solvent. The residue is highly flammable and gives the characteristic diphenyl amine test.

This table was taken from " Laboratoriumsbuch für die organischen plastischen

The polyhydric alcohols and soaps remain in the initial filtrate. The former may be recovered by evaporating to dryness and extracting with a 1 to 1 mixture of absolute ether and ethanol, or other suitable solvent.

The fatty acids may be freed by acidification of the water solution and extracted by suitable solvents such as ether. After removal of the extraction medium, they may be washed and dried, and their densities, refractive indices, acid numbers, saponification numbers, iodine values, and thiocyanate and hexabromide values determined. Wolff's modification of Twitchell's method for the separation of oxidized fatty acids and resin acids by means of diethyl sulfate may be employed. (See also Mulliken's identification of pure organic compounds.)

Acid Number. The acid number equals the number of milligrams of KOH which must be added to 1 gm. of resin to neutralize it, using a phenolphthalein indicator. It is useful in identifying certain resins which are more commonly used as admixtures or diluents in plastics than as principal ingredients.

Method. One gram (or a lesser weighed amount) of resin is placed in each of two 250-cc. Erlenmeyer flasks which contain 25 cc. of benzene and 25 cc. of 95 per cent alcohol, with a few drops of phenolphthalein. The mixture should be warmed and agitated for some time. The resulting solution after cooling to room temperature should be titrated with aqueous 0.1 N KOH until the phenolphthalein endpoint is reached.

OF THE MORE COMMON PLASTICS. BASED ON SOLUBILITIES (*Continued*)

FILLER, SOLID PLASTICS, MOLDED OR EXTRUDED

powdered plastic with methanol

Solution in methanol
Ethyl cellulose, plasticizers. Add an excess of benzene (petroleum ether).

Precipitate	Solution
Ethyl cellulose (identified by the presence of the C_2H_5O group).	Plasticizers

Treat with ethyl alcohol and reflux.

Residue	Solution
Polystyrene, benzyl cellulose (and portions of mixed polymers). Treat with ether	Polymethyl methacrylate (and portions of mixed polymers). Test by observing the low sp. gr. (1.18) and after depolymerizing the substance by saponifying the distillate at from 95 to 105°C. and reducing the liberated methacrylic acid to isobutyric acid.

Residue	Solution
Benzyl cellulose (test to identify).	Polystyrene. Sp. gr. about 1.05. Test solubility, and test by heating.

Kunstmassen" by E. J. Fischer. Details of tests are given separately.

The endpoint may be indefinite in the presence of much phenolic material or in dark-colored solutions. (See "Analysis of Alkyd Resins," by Frederick Kavanagh, *Ind. and Eng. Chem., Anal. Ed.*, **8**, 397–8, 1936.)

Acid Number of Dark-colored Resins. The usual acid number determination of synthetic or natural resins by titration of an alcohol or benzene-alcohol solution with standard alkali, using phenolphthalein as an indicator, is unsatisfactory for use with dark-colored resins because the endpoint of the titration is masked. Hence the Albert method of titration in a two-phase medium should be used: an upper benzene-alcohol layer, in which the color bodies remain, and a lower aqueous layer, saturated with NaCl for sharper separation between the layers, and containing the phenolphthalein or other indicator, the color change of which is clearly defined. (See " Acid Numbers of Dark Colored Resins," by Hayward H. Cobwin, *Ind. and Eng. Chem., Anal. Ed.*, **2**, 181, 1930; and " Chemische Fabriken," by Dr. Kurt Albert, *Albertschrift,* No. 15, p. 55.)

Method. One to 5 gm. of dark-colored resins are dissolved in 25 cc. of a neutral mixture of two parts of benzene and one of alcohol. Twenty-five cc. of a neutral, saturated sodium chloride solution, and several grams of crystalline sodium chloride are added after solution of the resin is complete. (The solid sodium chloride keeps the solution saturated during titration.) After the addition of phenolphthalein the solution

TABLE 106. SPECIFIC GRAVITY AND REFRACTIVE INDICES

Plastic	Specific Gravity	Refractive Index
SYNTHETIC RESINS		
Aniline-Formaldehyde	1.25–1.22	—
Benzyl Cellulose	1.22	—
Casein-Formaldehyde	1.35–1.33	—
Cellulose Acetate	1.37–1.27	—
Cellulose Acetate Butyrate	1.22–1.14	1.48–1.47
Cellulose Hydrate (Vulcanized Fiber)	1.25	—
Cellulose Nitrate	1.60–1.35	1.50
Chlorinated Diphenyl	1.80–1.157	1.70–1.61
Chlorinated Rubber	1.64	1.56
Cold Molded Non-Refractory	2.15–1.87	—
Cold Molded Refractory	1.85–1.63	—
Cresylic Acid-Formaldehyde	1.20	1.645–1.57
Cumarone-Indene	1.15–1.05	1.645–1.617
Cyclohexanone-Formaldehyde	1.207	1.544
Ethyl Cellulose	1.14	1.47
Ethylene Glycol-Phthalate	1.352	1.57–1.56
Glycerol Phthalate	1.389	1.58–1.56
Hard Rubber	1.80–1.12	—
Isomerized Rubber	1.06	—
Lignin	1.45	—
Methyl Methacrylate	1.19–1.18	1.49
Organic Polysulfide	1.55–1.54	—
Pentaerythritol-Phthalate	1.39	1.584
Phenol-Formaldehyde (spirit-soluble resin)	1.27–1.21	—
Phenol-Formaldehyde (molded)	2.0–1.3	1.70–1.47
Phenol-Formaldehyde (oil-soluble resin)	1.23–1.05	—
Phenol-Furfural	1.4–1.3	—
Polyamide (Nylon)	1.14	—
Polystyrene	1.07–1.05	1.60–1.59
Polyvinyl Acetate	1.19–1.15	1.473
Polyvinyl Chloride-Acetate	1.36–1.34	1.53
Polyvinyl Chloride	1.6–1.2	—
Toluene-Sulfonamide-Formaldehyde	1.35–1.21	1.596
Urea-Formaldehyde	1.50–1.45	1.90–1.54
Urea-Thiourea-Formaldehyde	1.477	1.66
Vinylidene Chloride	1.75–1.6	1.63–1.60
NATURAL RESINS		
Amber	—	1.548–1.538
Canada Balsam	1.00	1.530
Congo (fused to 30% loss in weight)	1.050	1.545
Congo (hard, amber)	1.059	1.545
Congo Copal No. 1, Pale	1.066	1.54
Congo Ester	1.076	1.506
Copal	—	1.528
Dammar, No. 1, Singapore	1.062	1.515
East India Gum	1.087	1.537
Gum Mastic	1.070	1.536–1.535
Gum Sandarac	1.078	1.545
Kauri (Grade 303)	1.043	1.565–1.540
Linseed Oil, Dry	—	1.50–1.48
Manila Copal (hard)	1.072	1.544
Manila Ester	1.090	1.506
Natural Rubber	—	1.535
Pontianac	1.068	1.545
Rosin	—	1.548
Rosin Ester	1.095	1.496
Rosin M	1.069	1.525
Shellac	—	1.54
Shellac (bleached dry)	1.11	1.534
Shellac (orange)	1.152	1.516
Varnish, Dry	—	1.54–1.51

NOTE. If the specific gravity of a resin is above 1.15, the resin is usually of synthetic origin, but may contain rosin, oils, or fatty acid modifying agents. If the specific gravity lies between 1.10 and 1.15, the resin may comprise a cumarone-indene polymer, shellac, or synthetic resin of modified type. If the specific gravity is less than 1.10 the resin is probably of natural origin, although polystyrene has a specific gravity of 1.05. These statements of course do not apply to filled or highly plasticized resins. Chlorine-containing resins generally exhibit high specific gravities. (See Table of Physical Properties for differences in specific gravity of a resin with different fillers.)

TABLE 107. FLUORESCENCE OF COMMON PLASTICS IN FILTERED ULTRA-VIOLET LIGHT

Substance	Color	Substance	Color	Substance	Color
Cyclohexanone — formaldehyde	Pale greenish yellow	Cumarone	Intense dark violet by reflected light, brown by transmitted light	Polyvinyl acetate	Brilliant white-blue
Phenol-formaldehyde	Intense blue-violet similar to color from rosin, but stronger	Polyacrylic acid	Intense blue with rosy tinge	Polyvinyl alcohol	White
Phenolic resins (uncured)	Dark olive green	Polyacrylic acid, methyl ester	Dull bluish white, dull grayish white	Polyvinyl chloride	Faint blue-green, greenish white
Urea-thiourea formaldehyde	Bluish white	Polyacrylic nitriles	Intense bright yellow	Polyvinyl chloride—chlorinated further	Dull blue-gray
Glyptals	Pale blue	Polybutadiene	Bright violet	Polyvinyl methyl ether	Pale yellow
Sulfonamide — aldehyde	Pale blue, similar to that of gyptals	Polystyrene	Strong blue-violet, but weaker than polyvinyl acetate	Mixed polymerization product of vinyl chloride and methyl ester of acrylic acid	Very weak, colorless
Cellulose acetate	Very faint, bluish white	Chlorinated rubber	Very pale, light blue	Rosin, glycerin ester	Bright blue-violet
Cellulose nitrate	Yellow-brown	Rosin	Brilliant	Rosin, phenol-aldehyde ester	Bright blue-violet

is titrated with 0.5 N NaOH with vigorous shaking until the lower layer has turned a permanent red which will not fade on further agitation. An excess of reagent may be added. The solution is then titrated with 0.5 N H_2SO_4 until the phenolphthalein has just lost its red color. During titration a swirling rotary motion should be kept up in the flask, but the separation between the layers should preferably not be broken. If the NaOH causes a loss of sharpness between the layers due to emulsification, a small amount of neutral alcohol may be added.

With this method and phenolphthalein as an indicator, erroneous results are given with some resins, particularly shellac. An electrometric method of determination is possible, but has some inherent difficulties and there is no standard procedure for all resins.

TABLE 108. BEHAVIOR OF PLASTICS ON STRONG HEATING OF SAMPLE IN TEST TUBE

Indication	Alkyl polysulfide	Aniline formaldehyde	Casein or other protein resins	Cellulose acetate	Cellulose acetate-butyrate	Nitrocellulose	Cellulose ethers: ethyl and benzyl cellulose
Odor	Odor of hydrogen sulfide	Odor of aniline	Smell of burning hair or feathers. May be accompanied by odor of formaldehyde	Sharp acrid odor	Odor of butyric acid	Odor of camphor, steamy vapors	When heated with acid, such as acetic, characteristic odor of ester formed
Melting or softening point	Infusible	About 260° F.	Softens at 200° F.	Softens at 140°–260° F.	Softens at 140°–250° F.	Melts 160°–195° F. Decomposes at high temp. Burns swiftly	Ethyl cellulose 210°–265° F. Benzyl cellulose 200°–260° F.
Decomposition products etc.	Vapors give hydrogen sulfide test with lead acetate paper	Aniline largely, some tar	Char easily, sometimes formaldehyde driven off. Vapors give alkaline reaction	Softens and carbonizes on strong heating. Vapors are acid to litmus		May explode if heated over 140° C. Vapors give reactions for nitric acid	Char on strong heating

TABLE 108. BEHAVIOR OF PLASTICS ON STRONG HEATING OF SAMPLE IN TEST TUBE (*Continued*)

Indication	Cellulose hydrates. Hydrocellulose	Chlorinated rubber, chlorine fillers	Furfural-Phenol	Phenolic resins	Phenolic with paper filler	Phenolic with mineral filler	Phenolic with wood-flour filler
Odor	Odor of burning paper	Acrid odor of hydrochloric acid, odor of scorching rubber	Characteristic odor of furfural	Odor of phenol, cresol, or xylenol, sometimes slight odor of formaldehyde	Odor of burning paper and of phenol	Odor of phenol plus any peculiar odor of filler	Odor of scorching wood and of phenol
Melting or softening point	Do not melt	Chlorinated rubber softens at 175°–230° F.	About 500° F.	Infusible when cured	Infusible	Infusible	Infusible
Decomposition products etc.	Char on strong heating	Vapors give reactions of chlorine	Phenol furfural	Phenols, sometimes ammonia and formaldehyde	Chars on strong heating		

TABLE 108. BEHAVIOR OF PLASTICS ON STRONG HEATING OF SAMPLE IN TEST TUBE (*Continued*)

Indication	Phthalic esters (alkyds)	Polyacrylic acid esters	Polymethacrylic acid esters	Polyvinyl chloride Copolymer	Polyvinyl Esters	Polystyrene	Thiourea
Odor	Acrolein or phthalic anhydride	Sweetish	Sweetish	Acrid odor of HCl	Polyvinyl acetate gives odor of acetic acid when heated. Odor of acetaldehyde sometimes given off, or odor of acrolein	Odor of blooming hyacinths mingled with odor of benzol (characteristic of artificial gas)	Ammonium sulfide
Melting or softening point	Infusible	Soften	Soften at 151°-231° F.	Softens over wide range depending on plasticizer	Softens at 130°-160° F.	Melts at 190°-250° F.	Does not soften or melt. Chars above 175° C.
Decomposition products etc.	Give white crystalline sublimate of phthalic anhydride	Depolymerized by heat	Depolymerized by heating above 250°-300° C to a liquid boiling at lower temperatures	Chars readily on strong heating. Vapors give acid reaction		Destructive distillation breaks it down into the monomeric styrene, a colorless liquid boiling at 146° C.	

TABLE 108. BEHAVIOR OF PLASTICS ON STRONG HEATING OF SAMPLE IN TEST TUBE (*Continued*)

Indication	Urea or other amine resin	Cumarone	Cyclohexanone-formaldehyde	Sulfonamide-aldehyde	Chlorinated diphenyl	Polymerized acetaldehyde	Chlorinated Naphthalene
Odor	Odor of ammonia or musty odor	Characteristic odor of coal tars, indene, etc.	Odor of peppermint and/or formaldehyde	Marked odor of formaldehyde on heating	Chlorine	Odor of acetaldehyde or acrolein	Aromatic chlorine
Melting or softening point	Chars above 150° C.	Melts at 100°–110° C.		See Monsanto literature	Melts readily to liquid of low viscosity	Softens above 200° C.	Liquid at 136° C.
Decomposition products etc.	Vapors give alkaline reaction. Nitrogenous	Decomposes to cumarone (B.P. 172° C.) and indene (B.P. 182° C.)			Vapors give acid reaction	Heating with soda-lime yields acetaldehyde or its condensation products giving a red color with Schiff's reagent	Distills. May be detected by sublimation

Filler. *Microscopic Examination.* By microscopic examination of ground and polished cross sections of plastics, the exact nature of any filler used in its manufacture can usually be determined. Since the filler often makes up a large part of the bulk of the plastic, identification of the filler is important in the analysis of some plastics.

Microscopic examination, in connection with organic qualitative tests and observations of the behavior of the substance in certain reagents while under the microscope, often serves to identify the particular type of plastic being investigated.

An especially useful microscopic test for fillers is the phloroglucinol test for lignin. It may be performed on a powdered sample or on a polished section. Macerate the resin in HCl, cover it with a drop or two of phoroglucinol-HCl mixture (1 gm. phloroglucinol in 50 cc. conc. HCl), and examine it under the microscope. In a few minutes a bright red color will appear in any lignin-containing material, making wood flour, wood shavings, cork, etc., clearly visible. Textiles such as linen and cotton (freed of lignin) do not give this reaction.

Determination and Analysis of Ash. Fusing a weighed sample of the resin in a crucible and then charring it and further subjecting it to a direct flame until all the black of the carbon disappears leaves a mineral ash (mostly filler material). This ash should be subjected to the routine analytical procedures, and in addition, should be examined microscopically. Asbestos, and to a lesser extent, siliceous fillers can be identified by microscopic analysis of the ash; the asbestos retains its fibrous structure under prolonged, intense heating. The percentage of ash by weight should be determined.

Action with Strong Caustic Soda. A pulverized sample is boiled with 20 per cent NaOH. An odor of phenol or cresol indicates phenolic resins, while an odor of ammonia indicates urea and casein (or other protein) plastics.

Fusion with 50 per cent solid NaOH giving off the strong odor of capryl alcohol usually indicates the presence of castor oil.

Miscellaneous General Tests. Other physical and chemical properties, such as softening point, hardness, effects of solvents and chemicals, electrical properties, etc., are also other useful tests to make. (See tables of Physical and Chemical Properties, Chap. II, page 31.)

SPECIFIC TESTS

Specific tests for compounds or elements commonly occurring in plastics may also be made, and are of special value when the substances are present in small quantities, or when it is desired to determine which of two similar compounds is present, or whether both are present.

Tests for Chlorine, Nitrogen, Sulfur, and Phosphorus. Tests may be made by sodium fusion or alternative methods.

Sodium Fusion. A portion of the substance may be decomposed by fusion with metallic sodium (or potassium), and the resulting melt extracted with water.

The presence of combined chlorine may be determined by adding silver nitrate solution to a small portion of the extract. A white precipitate of silver chloride, blackening on exposure to light, indicates the presence of chlorine.

Nitrogen or sulfur may be detected by mixing a portion of the extract with ferrous sulfate solution containing iron oxide, and warming the mixture with an excess of nitric acid. An undissolved dark blue residue consisting of Prussian blue, or a blue-green coloration, shows the presence of nitrogen.

The presence of sulfur will be indicated by the appearance of a blood-red color, a characteristic reaction of potassium thiocyanate in the presence of iron salts.

The presence of sulfur may be confirmed by placing a drop of the extract of sodium fusion on a bright silver coin, which will tarnish in contact with the solution if sulfur is present. Also, a lead acetate solution will give a black precipitate with a portion of the sulfur-containing solution.

Phosphorus may be tested for by the molybdate reaction.

Alternative Tests. An alternative method of preparing an extract for the silver nitrate test for chlorine is to heat a powdered sample of the resin with two parts of powdered calcium hydroxide, free from chlorine, and heat until all the volatile matter is driven off. After cooling, a few cc. of water are added, and the mixture is boiled for a short time and mixed with nitric acid and silver nitrate solution. A precipitate of silver chloride will result if the sample tested contains combined chlorine.

TABLE 109. COMMON PLASTICS, ARRANGED ACCORDING TO THE PRESENCE OF NITROGEN, SULFUR, PHOSPHORUS, AND OXYGEN

Plastics in which nitrogen, sulfur, phosphorus, and oxygen are not normally combined:

- Polystyrene
- Phenol-formaldehyde
- Hydrocellulose
- Polyvinyl alcohol
- Cellulose ethers
- Polyvinyl ether
- Cumarone
- Acetates
  - Polyvinyl acetate
  - Cellulose acetate
  - Cellulose acetate butyrate
- Cyclohexanone formaldehyde
- Rosin
- Ester gum
- Polyacrylic acid ester
- Polymethacrylic acid ester
- Glyptals

Plastic substances containing nitrogen in addition to carbon, hydrogen, and oxygen:

- Cellulose nitrate
- Urea formaldehyde
- Polyacrylic acid nitrile and mixed polymers
- Aniline formaldehyde resin
- Nitrogen-containing polyvinyl compounds
- Polyamides (nylon)

Substances containing sulfur in addition to carbon, hydrogen, and oxygen:

- Alkyd polysulfides
- Vulcanized and hard rubber

Substances containing nitrogen and sulfur in addition to carbon, hydrogen, and oxygen:

- Thiourea formaldehyde
- Sulfonamide-formaldehyde

Substances containing nitrogen, sulfur, and phosphorus in addition to carbon, hydrogen, and oxygen:

- Casein and other proteins

Substances containing chlorine in addition to carbon, hydrogen, and oxygen:

- Polyvinyl chloride and mixed polymers
- Vinylidene chloride
- Chlorinated rubber

An alternative test for sulfur is to convert the sulfur present to a sulfate. The powdered sample is mixed with double the amount of anhydrous sodium carbonate and sodium nitrate, and melted in a porcelain crucible. After cooling, the melt is extracted with distilled water, and the extract filtered and acidified with HCl. After warming, it is treated with barium chloride solution. A white precipitate of barium sulfate indicates the presence of sulfur.

These tests are useful in the identification of resins, provided that the resins are not modified with substances containing nitrogen, sulfur, chlorine, or phosphorus.

Tests for Phenol. A number of tests can be made to determine the presence of phenol.

Boiling the pulverized sample with water may be sufficient to extract the phenol, or it may be necessary to boil the resin with alkali or to fuse it with NaOH and extract it with boiling water, acidify and boil further. The odor of phenol or cresol can usually be detected.

If the solution containing phenol is acidified with H_2SO_4, boiled, and treated with Millon's reagent at room temperature, or with slight warming, a red color will appear. Proteins also give a similar red color.

If the alkaline extract containing phenol is acidified with H_2SO_4, then made alkaline with ammonia and mixed with calcium or sodium hypochlorite and warmed, a blue to violet color will appear.

If the alkaline extract is warmed with chloroform a yellow to red color will appear if phenol is present.

When the extract is neutralized with sulfuric acid and carefully mixed with a solution of H_2SO_4 containing 1 per cent formaldehyde, a red ring will appear at the zone of contact of the two liquids, and shaking the mixture will produce a red precipitate and red-colored liquid.

Phenol may also be detected by the indo-phenol test of Gibbs. (*J. Biol. Chem.*, 72, 649, 1927.) A suspension of 2, 6 dibromoquinone chloroimide (Eastman) is prepared by agitation of a lump the size of a small pea with 10 to 50 cc. of water. When two or three drops of this reagent are added to from 10 to 50 cc. of the aqueous extract of the resin, and the solution rendered slightly alkaline (about pH 9.4) with 0.1 N NaOH, a deep bright blue coloration develops when phenols are present. The muddy pale violet color often produced by the reagent in alkaline solution should not be confused with the true phenol test yielded by this reagent.

Test for Aniline. A finely ground sample should be boiled for some time with strong aqueous sodium hydroxide, and the liberated aniline extracted with ether. The ether solution is then extracted with HCl. The acid layer is drawn off and warmed to drive off the dissolved ether and then tested with a drop of a hypochlorite such as Zonite. Aniline gives a red-violet color.

Test for Furfural. Aniline dissolved in pure glacial acetic acid and added to an acetic acid extract of the powdered resin will produce a red color in the presence of furfural. Quantitative values may be established on a comparative basis.

Tests for Phthalates. If strong heating of a sample of the resin produces a white crystalline sublimate, the presence of phthalic anhydride may be detected by the following tests, which are, however, also positive for several common dicarboxylic acids.

Phenolphthalein Test. In a test tube, mix 1 gm. of the resin with two or three times this weight of phenol and two or three drops of concentrated H_2SO_4. Heat the mixture over an open flame until an orange or brownish melt has formed. Undue charring should be avoided. After cooling, the melt should be extracted with boiling water and the solution diluted to 100 cc. and made alkaline with aqueous NaOH. The appearance of the characteristic pink color of phenolphthalein is a positive test for phthalates.

Fluorescein Test. Heat a gram of the resin with two or three times its weight of pure resorcinol and boil for 5 min. After cooling, extract the residue with water, using agitation. Dilute to 50 to 100 cc. with distilled water and render the solution slightly alkaline with dilute aqueous sodium hydroxide. The appearance in the solution of the characteristic greenish yellow fluorescence of fluorescein indicates the presence of phthalates. This test may be applied to the crystalline sublimate obtained by heating the resin.

The above tests are also given by simple non-resinous phthalate esters used as plasticizers. These may be removed from the plastic by continuous extraction and refluxing of a pulverized sample with petroleum ether or some other suitable solvent which will remove these plasticizers and leave the phthalate resins completely or almost completely undissolved.

Test for Rosin. Shake vigorously 1 gm. of powdered resin with 10 cc. of petroleum ether and treat the solution with the same quantity of 1 per cent copper acetate. The two solutions are separated, and the presence of rosin or turpentine is shown by a blue-green coloration due to formation of salts of copper, soluble in abietic or pimaric acids. See also Liebermann-Storch (Storch-Morawski) and the Halphen-Hicks tests for rosin described below.

Test for Cumarone. A method of determining the presence of cumarone is by observing the characteristic permanent red color produced when cumarone is treated with bromine in the presence of glacial acetic acid.

One cc. of a 10 per cent solution of the resin in chloroform is mixed with 6 cc. of chloroform, and one cc. of 10 per cent chloroform solution of bromine is added with further agitation, and the mixture is allowed to stand in a stoppered container for some time. Cumarone gives a red color, deepening to dark red after several days. Pontianac resin gives a yellow orange color, gradually fading to yellow. (See C. Ellis, *Synthetic Resins and Their Plastics*, 1923, p. 53.)

Color Readings (Liebermann-Storch, Halphen-Hicks). A powdered sample of the resin or plastic is boiled with acetic anhydride and the solution filtered into a shallow porcelain dish. Some H_2SO_4 of specific gravity 1.53 is then carefully dropped in at the edge and mixed slowly with the solution. A blue-violet color, fading at once, indicates the presence of rosin or ester gum.

Boiling a sample with acetone and treating the solution as described above may give an intense, bright red color after the transient violet has disappeared. A bluish green fading into green indicates the presence of vinyl resins. Cumarone gives a permanent cherry-red. Cyclohexanone gives an intense rose-red, soon turning to dirty orange. A variety of colors is given with other natural resins, but none with shellac.

The Halphen-Hicks color reaction may be used to verify the results of the above test. The sample to be examined is extracted with a solution of phenol in carbon tetrachloride (1 in 2), and bromine vapor is wafted across the surface. Rosin gives an intense violet color, fish oil a carmine color, and mineral oil a brownish coloration.

TABLE 110. METHOD OF SEPARATING CELLULOSE DERIVATIVES

Tables to aid in distinguishing cellulose derivatives present in plastics, after the presence of one or more cellulose derivatives has been established.

A. Table of solubilities of cellulose ethers and esters in twenty solvents

Solvent	Ethyl cellulose	Benzyl cellulose	Cellulose nitrate	Cellulose acetate
Petroleum ether	I	I	I	I
Benzene	S	S	I	I
Mesitylene	S	I	I	I
Monochlorobenzene	S	S	I	I
Chloroform	S	S	I	S (in presence of some alcohol)
Carbon tetrachloride	S	I	I	I
Ethane pentachloride	S	S	I	I
Isoamyl chloride	S	I	I	I
Ethylene dichloride	S	S	I	S (in presence of some alcohol)
Ethylene trichloride	S	Sl(Sw)	I	I
Epichlorohydrin	S	S	S	S
Methanol	S	I	Sl	Sl
n-Propyl alcohol	S	I	I	I
Benzyl alcohol	S	S	I	S
Ether (Ethyl)	Sl(Sw)	I	Sl(Sw)	I
Isopropyl ether	S	I	—	—
Dioxane	S	S	S	S
Methyl formate	S	S	S	S
Amyl formate	S	S	S	I
Glacial acetic acid	S	I	S	S

I = Insoluble; S = Soluble; Sl = Slightly soluble; Sw = Swells

B. Colorless or white cellulose derived plastics should be treated with aqueous iodine-potassium iodide solution. The plastic, freed of plasticizer by extraction with ether, is examined after immersing it in 10 per cent iodine-potassium iodide solution, and rinsing off the excess reagent with water.

TABLE OF COLOR REACTIONS

Cellulose derivative	*Color*
Cellulose nitrate	Yellow
Ethyl cellulose	Pale yellow
Cellulose nitrate acetate	Deep yellow
Cellulose butyrate	Deep brown
Cellulose acetate	Red brown
Benzyl cellulose	Brown

Tests for Cellulose Acetate, Nitrate, and Butyrate. A small amount of the finely ground material should first be boiled for some time in a solution of KOH in methyl alcohol. The alcohol is then evaporated, and the mixture neutralized with HCl. At this point phenol may be detected by its odor and color reactions. The phenol may be separated by extracting with ether, and the ether washed acid-free with water.

Some of the residue left by evaporation of the methyl alcohol is warmed with dilute H_2SO_4. If the odor of acetic acid (fumes acid to litmus) is given off, cellulose acetate is indicated. A further odor of butyric acid indicates cellulose acetate butyrate.

Another portion of the residue should be dissolved in water, and some concentrated H_2SO_4 in which a few milligrams of the diphenylamine have been dissolved should be carefully poured into a test tube containing the solution of the residue. A dark blue ring at the zone of contact of the liquids indicates a nitrate and hence probably cellulose nitrate.

General Characteristics of Rubber, Synthetic and Natural. Natural rubber is not affected by acetone, but chloroprene is somewhat swelled; Thiokol may be slightly affected, and Buna rubber may be swelled considerably. Gasoline and other petroleum products have much less marked effects on chloroprene and on Buna rubber than on natural rubber, and have practically no effect on Thiokol.

Chloroprene. Chloroprene polymers undergo a permanent change like the vulcanizing of rubber when they are heated without any vulcanizing agents. Metallic oxides such as magnesium oxide, zinc oxide, and litharge are often added to serve as vulcanizing agents, rather than sulfur which acts as an accelerator. The addition of carbon black yields a stiffer compound, but does not increase the tensile strength as with natural rubber. A product similar to hard rubber (but usually without sulfur) can be produced.

A sodium fusion test for chlorine and its rubber-like physical properties are characteristic.

Butadiene Polymers. These compounds usually contain only carbon, hydrogen, and oxygen. Sulfur is ordinarily used as a vulcanizing agent with zinc oxide and organic accelerators. Heating Buna S at 130° to 150° C. for one or two hours in the air produces a temporary change known as thermal oxidative softening. Ebonites made from Buna rubber are said to soften at a higher temperature than those made from natural rubber.

Organic Polysulfides (*Thiokol*). These contain a very large amount of sulfur, have a strong, unpleasant odor, are opaque and dark in color, have a tendency to cold flow, and have other mechanical deficiencies. They are by far the most resistant of the synthetic rubbers to the effects of solvents.

Isobutene Polymers (*Vistanex, Oppanole*). Polymerization of isobutene, a hydrocarbon, proceeds rapidly at low temperatures with boron fluoride or aluminum chloride as catalyst, producing a rubber-like product of very high molecular weight. Isobutene polymers cannot be vulcanized.

Plasticized Vinyl Chloride Polymers. These are transparent, colorless vinyl resins with the characteristics of other vinyl resins except for a certain extensibility of the material when mixed with a plasticizer, usually tricresyl phosphate. The product can not be vulcanized.

Polyvinyl alcohol is used in Germany as a rubber substitute. It is affected by water.

ANALYSIS OF PHENOLIC PLASTICS

General Characteristics of Phenolic Plastics. Phenolic plastics may be light colored to water-white and transparent if cast resin, but usually are darker colored and opaque.

TABLE 111. RESISTANCE TO CHEMICALS SHOWN BY VARIOUS PLASTICS, RUBBER DERIVATIVES, AND SYNTHETIC RUBBERS

Legend:

R — Resistant
R–1 — Some grades resistant, others not.
A — Attacked
R–2 — Most grades resistant, others not.
S — Soluble
Sf — Softens
Sw — Swells
F — Fair

Chemical	Phenolics	Ureas	Vinyl resins	Polystyrene	Cellulose acetate	Cellulose nitrate	Plioform	Neoprene	Thiokol	Hard rubber A	Hard rubber B	Hard rubber C	Soft rubber	Soft rubber, fabricated
Acetic acid, very dilute	R	—	R	R	—	R	R	R	R	R	R	R	—	—
Acetic acid, moderately dilute	R	—	—	R	—	R	R	R	R	R	R	R	—	—
Acetic acid, concentrated	R	—	—	R	S	—	R	R	R	R	R	—	—	—
Acetic anhydride	R–1	—	—	—	—	—	—	R	—	R	R	—	—	—
Acetone	R	R	—	R	S	S	—	R	R	R	R	R	—	—
Alcohols	R–2	R	R	R	Sf	S	R	R	—	—	—	—	—	—
Aliphatic hydrocarbons	R	R	—	S	R	R	A	R	R	—	—	—	—	—
Aluminum chloride	R	—	R	—	—	R	—	R	—	R	R	R	R	—
Aluminum sulfate	R	—	R	—	—	R	—	R	—	R	R	R	R	R
Ammonia, anhydrous	R–2	—	R	R	—	—	—	R	—	—	R	R	—	R
Ammonium chloride	R–1	—	—	R	R	R	—	R	—	R	R	R	R	R
Ammonium hydroxide	A	—	—	R	—	—	R	R	—	—	R	R	—	R
Ammonium nitrate	R–1	—	—	—	—	R	R	R	—	R	R	R	R	—
Ammonium sulfate	R	—	—	—	—	R	R	R	—	R	R	R	R	R
Amyl acetate	R	—	—	—	—	—	—	R	—	—	—	—	—	—
Amyl chloride	R	—	—	—	—	—	—	R	—	—	—	—	—	—
Aniline	R	R	—	—	—	—	—	R	—	—	—	—	—	—
Animal oils	R	R	R	Sw	R	R	A	R	R	—	—	—	—	—
Aromatic hydrocarbons	R–2*	R	Sw*	S	R	R	A	—	F	—	—	—	—	—
Benzaldehyde	R	R	—	—	—	—	—	R	—	—	—	—	—	—
Bromine	—	—	—	—	—	—	—	R	—	—	—	—	—	—
Butyl acetate	R	—	—	—	—	S	—	R	—	R	—	—	—	—
Calcium chloride	R–2*	—	—	R	—	R	R	R	—	R	R	R	R	—
Calcium hypochlorite	R–1	—	—	—	—	—	—	R	—	R	R	R	R	R
Carbon disulfide	R	—	R	—	—	R	—	R	—	—	—	—	—	—
Carbon tetrachloride	R	—	R	—	—	R	—	—	R	—	—	—	—	—
Carbonic acid	R	—	R	—	R	R	—	R	—	R	R	R	—	—
Chloroacetic acid	R	—	—	—	—	—	R	R	—	R	—	—	—	—
Chlorine water	—	—	R	—	—	—	R	R	—	R	R	R	—	—
Chromic acid	—	—	R	—	—	—	—	—	—	—	—	—	—	—
Citric acid	R	—	R	—	—	—	R	R	—	R	R	R	—	R
Copper sulfate	R	—	R	—	—	R	—	R	—	R	R	R	R	R
Esters	R	—	S	S	Sf/S	S	—	R	—	R	—	—	—	—
Ethyl acetate	R	—	—	—	—	S	—	R	—	R	—	—	—	—
Fatty acids	R	R	R	—	R	R	—	R	—	—	—	—	—	—
Ferric chloride	R	—	R	—	—	R	R	R	—	R	R	R	R	R
Ferric sulfate	R	—	R	—	—	R	R	R	—	R	R	R	R	R
Ferrous chloride	R	—	R	—	—	R	R	R	—	R	R	R	R	—
Ferrous sulfate	R	—	—	—	—	R	R	R	—	R	R	R	R	—
Formaldehyde	R	—	R	—	—	—	R	R	—	R	R	—	R	—
Formic acid	R	—	—	R	—	—	R	R	—	R	R	—	—	R
Hydrobromic acid	—	—	R	—	—	—	—	R	—	R	R	R	R	—
Hydrochloric acid (very dilute)	R	—	R	R	—	R	R	R	R	R	R	R	R	R
Hydrochloric acid (moderately dilute)	R	—	R	R	—	—	R	R	R	R	R	R	R	R
Hydrochloric acid (concentrated)	—	—	R	R	—	—	R	R	R	R	R	R	R	R
H_2O_2 — 3%	R	—	R	—	—	R	R	R	—	—	—	R	—	—
Iodine	—	—	R	—	—	—	—	R	—	—	—	—	—	—
Ketones	R–2*	R	S	—	S	S	—	—	—	—	—	—	—	—
Lactic acid	R	—	R	—	—	—	R	R	—	R	R	R	—	—

* In many.

TABLE 111 (*Continued*)

Chemical	Phenolics	Ureas	Vinyl resins	Polystyrene	Cellulose acetate	Cellulose nitrate	Plioform	Neoprene	Thiokol	Hard rubber A	Hard rubber B	Hard rubber C	Soft rubber	Soft rubber, fabricated
Magnesium chloride	R	—	R	—	R	R	R	R	—	R	R	R	R	R
Magnesium sulfate	R		R	—	R	R	R	R	—	R	R	—	R	R
Mineral oils	R	—	R	Sw	R	R	A	F	R	—	—	—	—	R
Mixed acids	—	—	R	R	—	—	—	R	R	—	—	—	—	—
HNO_3 (very dilute)	R–1	—	R	—	—	R	—	R	R	R	R	R	—	—
HNO_3 (moderately dilute)	—	—	R	—	—	—	—	—	—	—	—	R	—	—
HNO_3 (concentrated)	—	—	R	—	—	—	—	—	—	—	—	—	—	—
Nitrous acid	R	—	R	—	—	R	—	R	R	R	—	—	—	—
Oxalic acid	—	—	R	—	—	—	R	R	—	R	R	—	—	—
Phenol	R–1			R	—	—	—	R	—	—	—	—	—	—
Phosphoric acid	R–2*		R	—	—	—	R	R	—	R	R	—	R	—
Sea water and brine	R	—	R	—	R	R	R	R	R	R	R	R	R	R
Sodium bisulfate	R	—	R	R	—	—	R	R	—	R	R	R	R	R
Sodium bisulfite	R		R	R	—	—	R	R	—	R	R	R	—	—
Sodium carbonate	R		R	R		—	R	R	—	R	R	R	R	R
Sodium ferricyanide	R		R	—		—	R	R	—	R	R	R	R	—
NaOH (very dilute)	—	R	R	R	—	—	R	R	R	R	R	R	R	R
NaOH (moderately dilute)	—		R	R	—	—	R	R	—	R	R	R	R	R
NaOH (concentrated)	—	—	R	R	A	A	R	R	—	R	R	R	—	—
Sodium hydrosulfite	R	—	R	—	—	—	—	R	—	R	R	—	—	—
Sodium hypochlorite	—	—	R	—	—	—	R	R	—	R	R	R	R	—
Sodium nitrate	R	—	R	—	R	R	R	R	—	R	R	R	R	—
Sodium phosphate	R	—	R	—	—	—	R	R	—	R	R	R	R	R
Sodium sulfide	—		R	—	—	—	R	R	—	R	R	—	R	—
Sodium sulfite	R	—	R	—	—	—	R	R	—	R	R	R	—	—
H_2SO_4 (very dilute)	R	—	R	R	—	R	R	R	R	R	R	R	R	R
H_2SO_4 (moderately dilute)	R	—	R	R	—	—	R	R	R	R	R	R	R	R
H_2SO_4 (concentrated)	—	—	R	R	—	—	R	—	—	—	—	—	—	R
Sulfurous acid	R	—	R	—	—	R	—	R	—	—	R	—	—	—
Tannic acid	R	—	R	—	—	R	R	R	—	R	R	R	R	—

*In many

They may have an odor of phenol (especially if cold molded), and usually give off an odor of phenol when heated. They have good insulating properties, varying with humidity, are thermosetting, are decomposed by strong alkalies and oxidizing agents, have a low burning rate, and are not very saponifiable unless modified by large amounts of rosin or fatty acids.

Phenol-furfural resins often develop chromophore groups, with resulting permanency of colors, especially in black and brown moldings. They are stable, free from scorching, heat- and water-resistant, and chemically inert.

The refractive indices range generally from 1.62 to 1.69 unless the resins are modified by much rosin or oils.

Distinguishing Tests. The constituents to look for are phenols, cresols, xylenols, formaldehyde, rosin, glycerin, higher fatty acids, Congo or other natural acid resins, high boiling tar-acids, polyhydric phenols, furfural, acetaldehyde, ortho and para hydroxy diphenyls, *p*-tertiary amyl and *p*-tertiary butyl phenols. Phenolic plastics are recognized by tests for phenol as given under General Tests, and also under Tests for Phenol.

A test for phenol can also be obtained by heating the finely divided resin with soda lime, producing sodium and calcium phenolate. A solution of this fused product yields phenol when treated with CO_2. The phenol can be extracted with ether and identified by its characteristic color reactions. A sodium fusion may be used to detect the presence of nitrogen due to the use of hexamine in the manufacture of the resin.

TABLE 112. SYNTHETIC RUBBERS

Properties which aid in recognizing and distinguishing them

A. Swelling of unvulcanized compounds in liquids

(Per cent volume increase after immersion for 8 weeks at room temperature.)

Liquids	Natural Rubber	Neoprene	Perbunan	Perbunan Extra	Thiokol A	Thiokol D	Thiokol DX, F
Light gasoline (benzene)	160	—	20	20	0	—	—
Gasoline	230	8	40	—	0	3	3
Kerosene	—	60	—	—	0	2	2
Diesel oil	120	—	15	15	—	—	—
Fuel oil	—	—	—	—	0	10	10
Lubricating oil	—	40	−4	—	0	1	1
Paraffin oil	140	—	3	—	—	—	—
Transformer oil	150	—	5	—	—	—	—
Acetone	—	25	110	100	—	—	9
Benzene	370	160	210	140	7	150	90
Carbon tetrachloride	670	160	220	120	0	40	30
Ethyl ether	130	50	50	—	—	—	—
Linseed oil	100	—	20	—	—	1	1
Turpentine	300	90	50	30	0	—	—

B. Specific gravities and refractive indices of unvulcanized materials

	Specific gravity	Refractive index
Natural rubber	0.911	1.5190
polymer of chloroprene	1.23	1.551
Chloroprene (Neoprene)	1.25	1.558
Perbunan	0.96	1.52
Methyl rubber	0.9292	1.525
Thiokol A	1.60	—
Thiokol D	1.34	—
Thiokol DX	1.39	—
Thiokol F	1.38	—
Vistanex HM	0.9125	1.51
Polyvinyl chloride (no plasticizer)	1.42	1.565
Polyvinyl chloride (30% plasticizer)	1.33	—
Polyvinyl chloride (60% plasticizer)	1.25	—
(tricresyl phosphate, polyvinyl chloride plasticizer)	—	1.549

Ordinary phenol gives o and p-nitrophenol when mixed with dilute nitric acid. On dilution and steam distillation, the o-nitrophenol distills over as a yellow solid (melting point 450° C.) while the residue upon cooling deposits crystals of p-nitrophenol (melting point 115° C.). Picric acid (melting point 123° C.), not volatile in steam, is formed in some cases. Cresols and xylenols may also be nitrated. Nitrophenols as a class are characterized by giving an intense orange color with alkali. Phenolic resins are not saponifiable but, if modified by large amounts of rosin or fatty acids, saponification products of the added materials may be obtained.

Estimation of Free Phenol in Phenolic Plastics. *Free Phenol Determination (Method of W. F. Koppeschaar).* The liquid or finely powdered plastic is extracted with 300-cc. portions of water until bromine tests of the washings no longer show a precipitate. The washings are combined and filtered into a volumetric flask, which is then filled up to the mark with distilled water. The procedure to be used depends upon the fact that when phenol is treated with an excess of bromine the phenol is converted quantitatively into tribromophenol:

$$C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$$

Potassium iodide is then added and iodine is liberated corresponding to the excess of bromine; by titrating with sodium thiosulfate solution the amount of phenol may be determined.

The reactions involved:

$$5KBr + KBrO_3 + 6HCl \rightarrow 6KCl + 3H_2O + 3Br_2$$

$$Br_2 + 2KI = 2KBr + I_2$$

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

Necessary reagents:

1. A tenth normal solution of bromine, made by dissolving exactly 2.784 gm. of potassium bromate and about 10 gm. potassium bromide in water and diluting to 1 liter.
2. A tenth normal solution of sodium thiosulfate, made by dissolving 24.83 gm. of the salt in water and diluting to 1 liter.
3. A solution of 125 gm. of potassium iodide in a liter of water.
4. Freshly prepared starch solution.
5. Concentrated HCl.

Procedure. To an aliquot of the aqueous extract containing about 0.1 gm. of phenol contained in a glass-stoppered flask with a flared neck, add 100 cc. of the solution of mixed bromine salts, pour in 5 cc. of conc. HCl, stopper and shake. After 15 min. add 10 cc. of potassium iodide solution and titrate the iodine liberated with the thiosulfate solution. Near the completion of the titration add a little of the starch solution. The percentage of phenol present is found by the equation:

$$\frac{(100 - t) \times 0.001568 \times f}{a}$$

where t = cc. 0.1 N thiosulfate
a = weight of sample
f = a factor for converting the aliquot to the original dilution.

Estimation of the Water-soluble Portion of the Phenol. To the extract obtained by repeatedly boiling the very finely powdered sample with water, bromine water is added dropwise until the pale yellow color disappears. The precipitate is washed with water, dried first in the air at room temperature and then in a desiccator over calcium chloride. It is dissolved in ether, and this ether solution evaporated in a Petri dish. The residue is dried in a desiccator and weighed. Three hundred and thirty-one parts of $C_6H_2Br_3OH$ are equivalent to 94 parts of phenol.

Estimation of the Amount of Phenol Obtained by Destructive Distillation (*Method of W. Herzog*). The finely powdered sample is placed in a Jena fractionating flask with a long side-arm. A destructive distillation is carried out in an atmosphere of nitrogen. Treated in this way, resins usually give up from one-quarter to one-fifth of their weight of phenol, with some water. The distillate is collected in an Erlenmeyer flask fitted with an air condenser and is poured from there into a graduate. The amount of phenol is then determined by gravimetric or volumetric methods.

In this way about 15 per cent of the combined phenol can be split off.

Cold molded phenolic plastics are usually very dark brown in color and have a pronounced odor of phenol even at room temperature. There remains behind in the fractionating column (in the case of filler-free plastic) a brown to black charred residue consisting of from 40 to 50 per cent of the original material.

The cresols can be separated from the phenols by fractional distillation.

Tests for Formaldehyde. Only traces of phenol, formaldehyde, and other salts can be recognized from a water extract of phenolic resins, except when the resins have not been properly cured.

Aldehydes can be detected in aqueous solution by a red coloration appearing when the aldehydes are mixed with Schiff's reagent.

Formaldehyde can be detected by adding a dilute solution of resorcinol, and carefully pouring in some concentrated H_2SO_4, which forms a red ring where it touches the other solution if formaldehyde is present.

A delicate test for formaldehyde is Schryver's, in which phenylhydrazine hydrochloride, potassium ferricyanide, and conc. HCl give a red color in the presence of formaldehyde.

Free formaldehyde can be determined by the peroxide method adopted by the British and Italian Pharmacopoeias. (*J. Amer. Chem. Soc.*, 27, 1183, 1905.)

Fifty cubic centimeters of 1 N NaOH, 50 cc. of pure 3 per cent H_2O_2 solution, and 3 cc. of the formaldehyde solution (phenolics, urea, casein, etc., plastics are insoluble, so the water extract or pulverized sample must be used) to be examined are placed in a 500-cc. Erlenmeyer flask, and the mixture refluxed over a steam bath with occasional shaking. The steam bath is then removed, the condenser and walls of the flask washed down with distilled water and the contents of the flask cooled. The excess of NaOH is then titrated with normal acid using litmus as an indicator. Cooling is necessary before titration to obtain a sharp endpoint with litmus. From the volume of formaldehyre solution used and the specific gravity, the percentage by weight of formaldehyde in the sample can be determined.

Heating on a hotplate is advisable to prevent the absorption of CO_2. The mixture should be shaken during heating until no more gas is evolved.

To determine whether a phenolic resin was produced in an acid or basic condensation medium, test whether the vacuum distillation of the product yields p,p′-Dioxydiphenylmethane or o,p′-Dioxydiphenylmethane. The finely divided sample is vacuum distilled, and yields at about 20 to 25 mm. and 230° to 250° C. a distillate which congeals in crystalline form. The product is crystallized after fractioning with much hot water. In this way, if the resin was formed in an acid condensation, the leaves of the p, p′ compound (melting point 160° C.) will appear first, and later the needle-like crystals of the o, p′ compound (melting point 115° to 116° C.). In the case of the basic condensation, only the needle-like crystals of the o, p′ compound will appear.

Estimation of Water Content. A 100-gram sample of finely divided plastic is suspended in 200 cc. of xylol which has just been distilled over quicklime to remove every trace of moisture. The mixture is distilled, collecting the distillate in a graduate. When the distillate appears clear the number of cubic centimeters of water distilled is then read off. The percentage of water which was present in the sample is then calculated.

Miscellaneous Substances Present. All kinds of additional substances are found in phenolic resins including plasticizers, acids, salts, fillers, and other modifying agents.
Acids: sulfuric, hydrochloric, formic, acetic, oxalic, succinic, and others.
Acid salts: ammonium chloride, aluminum chloride, zinc chloride, and others.
Neutral salts: ammonium acetate, calcium chloride.
Basic substances: ammonia, sodium hydroxide, calcium hydroxide, hexamethylenetetramine, and others.
Basic salts: sodium carbonate, calcium carbonate, borates, thiosulfates, aluminates, sulphates, and zincates.

Substances like the above, soluble in water, can be extracted from the pulverized sample with warming, and subjected to routine analysis.
Inorganic fillers: sulfides, oxides of heavy metals, hydroxides of heavy metals, emery, carborundum, graphite, asbestos, talc, mica, clay, chalk, gypsum, barytes, white lead, lead sulfate, various kinds of rock flour, inorganic colored minerals and earth colors, and occasionally aluminum, iron, or steel.

The inert fillers can be isolated by ashing for qualitative and quantitative analysis. Fillers may often be identified by microscopic examination of polished samples.
Organic fillers: wood flour (most common), paper, cork, textiles, fish scales, wood pulp and wood shavings, jute, cotton linters, natural resins, and others.
Modifying agents: Many natural and synthetic resins are often added: rosin, copals, cellulose esters, urea resins, aniline resins, rubber (natural or synthetic), shellac, etc. Resorcinol or chlorinated phenol may be used, or acetaldehyde, furfural, benzaldehyde or other aldehydes, oils (castor oil, tung oil) and waxes (make resin opaque), blood, and other proteins, aniline, pyridine, sulfonated derivatives are often added. Stearine pitch, aluminum stearate, and aluminum palmitate are used as lubricants.

Glycerin or its chemical equivalent added in the manufacture of the resin acts as a common solvent for the water and the resin base, and translucency to transparency results. Transparency or opacity is related to the size of the water droplets in the emulsion, in the absence of pigment.

A concentrated aqueous extract of the plastic, subjected to the usual Kjeldahl analysis for nitrogen content, may reveal the probable presence of one of the following: urea, ammonium salts, hexamethylenetetramine, aniline, and other cyclic bases.

Aluminum stearate or palmitate soaps used as lubricants may be identified as follows: The powdered sample should be boiled with diluted HCl. filtered, and the filtrate tested for aluminum by any standard analytical test. The residue on the filter paper, containing the fatty acids, should be warmed with 90 per cent alcohol, filtered hot and mixed with water. The fatty acids, obtained as a flocculent precipitate, may be purified by redissolving in alcohol, reprecipitating with water, drying, and crystallizing from alcohol or ether. Palmitic acid melts at 63° to 64° C., stearic acid at 69° C.

The resistance of the resin to chemicals and to various solvents should be tested. The solubility varies with the composition and the extent of the condensation. Usually these resins are poorly soluble in petroleum hydrocarbons unless they are modified by much rosin or fatty acids. They may be compatible with oils if modified by large amounts of oil.

The percentage of solids present should be determined if the sample is a liquid.

ANALYSIS OF AMINO PLASTICS

General Characteristics of Amino Plastics, Especially Urea Formaldehyde. *Amino* plastics are hard, tough, colorless, odorless. They do not melt or burn, but they char at 300° C. or above. They are insoluble in water and many organic solvents and oils. They are wear resistant, and have superior resistance to arcing. They have a very low water absorption.

Urea plastics (often modified with thiourea) come in pastel colors and can be molded into drinking cups, etc., since they do not absorb water and colors are non-bleeding in alcohol. They are usually translucent to opaque but Pollopas is transparent. They are used in coating resins; the intermediate condensates are used as cements or adhesives (in aqueous solution). They are attacked by strong acids, alkalies and weak acids; density is 1.48 and refractive index 1.66.

Aniline formaldehyde resins usually come in translucent light brown, and may have the odor of formaldehyde, especially when heated. Density 1.22 to 1.25.

Distinguishing Tests. Urea plastics have a typical odor on burning.

Thiourea is readily identified, as described in the preliminary tests. The fluorescence under ultra-violet light should be noted.

Estimation of Urea Content (by Nitrogen Determination). The nitrogen is readily determined by the Kjeldahl method, and the urea calculated from this. However, any ammonium salts present in the condensation medium are not accounted for in this way.

Procedure. One gram or less of the powdered sample is boiled with 30 cc. of concentrated H_2SO_4, 10 gm. potassium sulfate, and 1 gm. of anhydrous copper sulfate, until the solution is perfectly clear. After cooling, dilute the solution with 150 cc. of water, cool again and cautiously add 50 cc. of a 30 per cent solution of NaOH, and a small grain of zinc. Immediately distill the ammonia into a measured excess of 0.1 N sulfuric acid. Titrate back the excess acid with 0.1 N NaOH, using methyl orange as indicator.

Calculate the per cent urea content as follows:

$$\frac{(T - T') \times 0.30}{\text{wt. sample}}$$

where T = 0.1 N acid
T' = 0.1 N alkali

Thiourea Content Determination. Thiourea resins give nitrogen and sulfur indications on sodium fusion.

The presence of sulfur often indicates the presence of thiourea which is frequently added to improve the water resistance and molding properties of the plastic or to increase its transparency.

To test for combined sulfur, prepare an alcoholic extract of a pulverized sample and, after evaporating the alcohol, mix the residue with double the amount of pulverized potassium nitrate and anhydrous sodium carbonate (1:1 mixture). Heat this mixture in a covered porcelain crucible until it glows red, cool, extract the residue with water, filter, acidify the filtrate with HCl and test for sulfate with barium chloride. See also the preliminary test for sulfur.

For the quantitative determination of thiourea, proceed as follows: Melt 0.3 to 0.5 gm. of the finely powdered substance with a mixture of 10 gm. of calcined sodium carbonate and 2 gm. of potassium chloride in a porcelain crucible. Extract the cooled melt with water, filter out the undissolved material, and after acidifying with acetic acid, heat the filtrate and treat with barium chloride solution. From the amount of barium sulfate precipitated, the amount of thiourea present can be determined. One gram $BaSO_4$ represents 0.326 gm. thiourea.

A test for thiourea has been devised, based on a reaction between copper salts and thiourea. Sometimes the plastic must be decomposed in order to employ the test. The limit of identification is fairly high, and one can determine whether the thiourea is present as an admixture or as an impurity.

Procedure. An aqueous extract of the test sample, or the filtrate containing decomposition products of the plastic, is gently boiled for from 2 to 4 min. with a few grains of copper chloride (Cu_2Cl_2). A drop of the clear solution (allowing the precipitate to settle suffices as a rule; turbidity from sulfur makes no difference) is brought in contact with a spot test paper saturated with potassium ferricyanide solution in the cold. If a blue or violet color appears at the center of the drop, thiourea is present. The color is not always pure (brownish) but in the absence of thiourea no trace of a blue or violet color can be found.

NOTE. If one wishes to detect thiourea in a plastic in which it is suspected that thiourea makes up only a small part of the whole, it is desirable to decompose a sample by heating it for a long time with a strong aqueous solution of sodium or potassium hydroxide containing alcohol or acetone. In this way the combined aldehyde (from the breaking down of the methylol or methylene group) is set free. The solution so obtained must be carefully neutralized, since in alkaline solution the trithiourea-cuprous chloride to be formed is decomposed to copper-sulfur compounds.

The resulting solution may now be tested for thiourea as described above.

Content of Additional Substances. (Casein, gelatin, or glue is sometimes incorporated to improve the working properties). Urea-formaldehyde plastics are not often modified with plasticizers except occasionally with o- and p-toluene sulfonamides. Thiourea formaldehyde improves the properties of the resin. In pure form, urea-formaldehyde plastics are clear, colorless, and glossy but warp, crack, and deteriorate with age. The addition of fillers greatly improves their properties and allows for translucence in their sections.

Common fillers used are:

Organic: paper pulp, wood pulp, textile fibers, macerated cloth, wood flour, cork flour.

Inorganic: asbestos fiber, chalk, plaster of Paris, carborundum, sand, barium sulfate, oxides of heavy metals, etc.

The plastic may contain traces of the catalyst used in its production. Usually these are alkaline: ammonia, hexamethylenetetramine, pyridine, or urea itself, sodium acetate, borax, caustic alkali. Occasionally they are neutral salts or acids (HCl, H_2SO_4, HNO_3).

The resin produced without the aid of a condensing agent is generally soluble in water and used as an adhesive.

The fillers can best be identified by microscopic examination and analysis of the ash.

Analysis of the Ash. If the analysis of the ash of a urea plastic shows the presence of $BaSO_4$ and zinc sulfide (both from lithopone), the zinc content of the ash must be determined, and hence the amount of ZnS. The $BaSO_4$ corresponding to the ZnS is then subtracted from the above determined quantity of barium sulfate.

ANALYSIS OF ALKYD RESINS

General Characteristics of Alkyd Resins, especially Phthalic and Maleic Acid Resins. *Phthalic* resins are easily saponifiable, give a pale blue fluorescence with ultraviolet light, yield a sublimate of phthalic anhydride when heated, and give acrolein and acetaldehyde when heated with potassium bisulfate.

They are made with glycerin and organic acids, are transparent and colorless to yellowish, have a density of 1.10 to 1.42 and a refractive index of 1.54 to 1.59. They give fluorescein and phenolphthalein color reactions as described in the preliminary tests and have a wide range of solubilities, usually soluble with difficulty in petroleum hydrocarbons and ethanol, requiring benzenoid hydrocarbons, ketones, esters, or ether alcohols. Some modifications are soluble in petroleum hydrocarbons.

The resins are thermosetting, non-flammable, and give a white crystalline sublimate of phthalic anhydride upon strong fusion. They occur most commonly in resinous coatings and lacquers, enamels, and varnishes (often in conjunction with aromatic hydrocarbons, but are also used as plastics). The flexible resins have a remarkable sound absorbency and ability to dampen vibrations and are used as gaskets. The remarkable electrical properties make glyptals valuable for cements and insulators in radio work. Their compatibility is high.

Finely divided iron is sometimes used as a catalyst in the condensation of glyptals.

Alkyd resins containing phthalic acid or phthalates give a white crystalline precipitate of phthalic anhydride when strongly heated, and give characteristic color reactions (phenolphthalein, fluorescein) as described in the preliminary tests.

The color reactions referred to above can also occur with an entirely different plastic having somewhat similar physical properties and made with the addition of a plasticizer or lubricant which contains phthalic acid. This is especially likely to be confusing if a mixture of resins, cellulose esters, or cellulose ethers is present. Treatment of the plastic with ether will separate out the phthalic resins, and the residue after distilling off the ether can be tested for these substances.

Determining the Amount of Phthalic Acid Resin Present in a Plastic. ***Cannegieter's Method.*** One-half to one gram of the substance is weighed out on fat-free paper, placed in a Pyrex test tube and heated over a small flame. The phthalic anhydride sublimes, and heating is continued until yellow vapors form. The tube is then cooled, and the anhydride carefully removed from the outer surface of the inner tube by hot water. The mixture is reheated several times until no more phthalic anhydride is deposited. The water containing the phthalic anhydride is then boiled to convert the anhydride into acid, and is filtered if necessary.

If the anhydride is dissolved in alcohol and titrated, only 60 per cent of the phthalic acid present will be found. Resins of this class are easily saponified, and in any saponification of the resin, the phthalic anhydride will be found in the soluble portion.

Kavanagh's Method.[1] This analysis is based on the fact that acid added in proper amount to the saponified resin will free all the fatty acid without liberating any phthalic acid. The fatty acids are then removed by extraction with ether, and the phthalic acid freed by the addition of more acid, and extracted with ether. The method is especially recommended for use with alkyd-resin varnishes, but may also be applied to plastics.

Acid Number Determination. The acid number of the resin in solution must first be determined (see preliminary tests). The acid number of glyptals lies between 85 and 130. Those formed in acid condensation (yellow to brown in color) contain unsaturated fatty acids. They are 85 to 99 per cent esterified, and give an acid number of from 4 to 60.

If the acid value of the resin is higher than 15, the resin must be dissolved in acetone, not in alcohol and benzene.

Separation of Solids. The resin is dissolved either in acetone or alcohol-benzene as described above, and the pigments, etc., separated out by centrifuging.

The metals present are determined by ashing and qualitative examination of the ash.

The percentage of solids (especially applicable to varnishes includes resin and pigment) is determined by heating two shallow pans, each containing 1.0 to 1.5 gm. of the substance at 150° C. for 2 hr., weighing, and continuing heating and weighing until a constant weight is reached or until the weights begin to rise because of oxidation of the oils.

Estimation of Oils Present. Saponify a small sample (about 1 gm.) dissolved in acetone or a mixture of alcohol-benzene (1 to 1) with 10 cc. of 6 per cent aqueous KOH. Boil off solvents. Repeat after adding alcohol if the odor of hydrocarbons is still present.

The soap obtained in this way should be dissolved in about 10 cc. of water, and 10 per cent HCl added until a clouded precipitate just begins to form, a few drops of methyl red indicator being present. Add ether, about 10 to 20 cc. and a more dilute solution of HCl until the aqueous phase turns faintly pink. This is the difficult part of the procedure because the ether extracts the fatty acids from the aqueous phase, and because all the fatty acids and any other monobasic acids present must be liberated, without freeing any phthalic acid.

Important: Any phenols present will also be extracted by the ether and will interfere with the results.

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[1] Kavanagh, Frederick, "An Analysis of Alkyd Resins," *Ind. and Eng. Chem. Anal. Ed.*, 8, 397–8 (1936).

The ether solution should be removed, and the aqueous phase extracted several times with portions of ether to extract all the fatty acids, these extracts being added to the first. The ether solution is then evaporated almost to dryness over a hotplate, and the residue of fatty acids dried at 55° to 60° C. in an oven. They are then dissolved in 5 cc. of ether and filtered into a flask, whose sides are carefully washed down with more ether. After evaporation of the ether without boiling, the acids are dried again in an oven as before, until a constant weight is reached.

An aqueous 0.1 N solution of KOH is then used to titrate the solution of the residue of acids in 50 cc. of neutralized alcohol, phenolphthalein being used as an indicator. The acid number of the acids present may then be determined. In the presence of rosin, fossil-resin acids, and phenols, the number will appear raised, and it will be lowered in the presence of benzoic acid. A rosin test should be made on the extracted fatty acids rather than on the resin itself.

Estimation of Phthalic Anhydride. To the aqueous solution remaining after the extraction of the fatty acids, add concentrated HCl, and extract the liberated phthalic acid with small portions of ether, which are combined in a flask and evaporated. If maleic anhydride is present in the resin the acid number of the acid liberated must be determined.

The remainder of the aqueous solution should be concentrated by heat until the KCl begins to crystallize. Add just enough water to redissolve the salt. Extract this solution with ether, add the extract to the phthalic acid residue, evaporate again almost to dryness, and mix with 50 cc. of water, a few drops of phenolphthalein, and a slight excess of 0.1 N KOH. This mixture should be heated until all the phthalic acid is dissolved, and the hot solution titrated with 0.1 N HCl until the color just disappears. After careful standardizing of the KOH and HCl with phthalic acid or phthalic anhydride under the same conditions, the following calculations may be made (1 cc. of 0.1 N KOH = 0.004 gm. phthalic anhydride).

Analysis of Alkyd Resins Containing Maleic Acid.[2] This method is based on solubility in faintly acid aqueous solutions. This property differentiates maleic-abietic acid resins from rosin and phenol-formaldehyde resins. Phthalic acid may be removed in advance. A quantitative determination of maleic-abietic acid is obtained in this way. (During production of the resin the quantity present is reduced from about 100 per cent to 60 or 70 per cent.) This method of testing may be used as a control during manufacture of the resin or as an analytical test for maleic-abietic acid.

Procedure. A solution of a one-fifth gram sample of the resin in 0.5 cc. of benzene is saponified by refluxing for an hour in a 100-cc. Erlenmeyer flask with 20 cc. of a solution of N KOH in 90 per cent ethyl alcohol, followed by heating over a steam bath for an hour without a condenser. The residue so obtained is mixed with 50 cc. of water, and the flask heated over the steam bath for one-half hour longer. The material is then mixed with enough water to make 200 cc. (transferred to a 300-cc. Erlenmeyer flask) and 6 to 7 cc. of 4 N acetic acid are added until the methyl red indicator approaches red. Since the rosin itself is set, the precipitate must settle before the color can be clearly observed (pH about 4.5). The material is then filtered and washed twice, boiled for 10 min. and precipitated with 5 cc. of 1 to 10 lead acetate solution. A flocculent colloidal precipitate results, which will require about 24 hr. to filter (after cooling)

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[2] Sadolin, Erik, *Ind. and Eng. Chem., Anal. Ed.*, **11**, 608–10 (1939).

through a Jena glass filtering crucible (16 G 4). The filtering requires a long time because the precipitate is sticky and clogs the pores of the filter. After filtration the precipitate is dried in an oven at 80° to 90° C. for 45 min. and weighed. The factor for the maleic acid-lead precipitate is approximately 0.30, assuming that 60 per cent of the maleic acid used in the resin is found by this procedure.

Heating the precipitate with dilute hydrochloric acid will cause the maleic-abietic acid to separate as a resinous lump, while phthalic and other similar acids will dissolve.

CAUTION: If the operations are not all performed with the utmost care, the results will be strongly affected.

Other Constituents. Modified alkyd resins consist of mixed esters of rosin, vegetable oil, fatty acids, and plasticizing oils such as castor oil, inter-esterified with polyhydric alcohols and polybasic acids. Sometimes they are modified with phenol-aldehyde or urea-aldehyde to improve their properties. They are not often molded, and fillers are not usually used.

Alkyd resins are often prepared from the following substances: phthalic anhydride, glycerol, rosin, higher fatty acids, ethylene or diethylene glycol, pentaerythritol, other polyhydric alcohols or ether alcohols, monohydric alcohols, benzoic, succinic, malic, maleic, citric, and tartaric acids, Congo or natural acidic resins, adipic acid or its higher homologues.

The following plasticizers are sometimes used: tricresyl phosphate, glycol diacetate, triacetin, dibutyl phthalate, ethyl benzoate, acetanilide and m-dinitrobenzene.

The following modifiers are also used: zinc oxide, calcium oxide, metallic soaps, finely divided iron or zinc, naphthalene, anthracene, boric acid, rosin, pitch, asphalt, polymerized vinyl chloride, Portland cement, indene polymer, nitrocellulose (with alkyd resin having excess of glycerol).

Fillers used for special purposes: lampblack, asbestos, mica dust, mica sheets, alpha cellulose, cork dust (for floor tiles, etc.) and abrasives such as sand and carborundum.

ANALYSIS OF PROTEIN PLASTICS

General Characteristics of Protein Plastics, especially Casein. *Casein* plastics are insoluble in all organic solvents, nonflammable, easily charred by strong heat, giving off the odor of burning hair or feathers, sometimes mixed with the odor of formaldehyde. They give a blue fluorescence in ultra-violet light, while urea plastics give none. They come in light colors and are opaque. They are hygroscopic, warp, and are affected by atmospheric changes. They can be softened in hot water and are attacked by acids and alkalies.

Casein plastics are given an inexpensive " dip polish " by being placed in a hypochlorite bath and heated to a maximum of 150° F. for from 2 to 5 min., removed, rinsed, and dried. The softened surface sets to a glaze. Specific gravity is from 1.35 to 1.33.

They can be distinguished from natural horn by a sour casein-like characteristic odor given off when they are heated for 10 min. in a pulverized condition, with 5 cc. of normal sulfuric acid. Horn and other keratin-containing materials have a characteristic odor of their own.

Nitrogen (Casein) Content. The nitrogen content should be determined by the Kjeldahl method. By multiplying the percentage of nitrogen found with the protein factor, 6.25, the amount of casein present can be determined approximately.

Casein Content. Casein comprises a double salt of calcium caseinate combined with a calcium phosphate. A typical analysis is the following: 53.13 per cent carbon; 7.06 per cent hydrogen; 15.78 per cent nitrogen; 0.86 per cent phosphorus; 22.4 per cent oxygen; 0.77 per cent sulfur. (Rennin acts on calcium caseinogenate of milk, forming a jelly-like curd: calcium paracaseinate, altered by formaldehyde.)

Water Content. The only plasticizer used in casein plastics is commonly water. The water content can be determined by drying a weighed sample to constant weight and determining the weight loss. The water content will vary with the conditions of moisture to which the plastic has been exposed.

Additional Organic Substances. *Cellulose nitrate* can be separated from the powdered sample by treatment with acetone and filtering. After distilling off the solvent, the cellulose nitrate can be identified by its inflammability, burning rate, and the diphenylamine test.

Asphalt or *tar* can be removed from the powdered substance and their nature determined.

Phenol formaldehyde may be detected by cooking the test powder with NaOH, decomposing the solution with hydrochloric acid, and extracting the free phenol with ether. It can then be identified by suitable tests.

Aluminum Salts.[3] In 1929, Christensen patented the incorporation of water-soluble aluminum salt in soft plastics to give materials hard enough to be worked by automatic machine. Buttons are turned from rods of alum casein and hardened in formaldehyde for 3 to 5 days.

The aluminum salts may be extracted from the powdered sample with water, and the usual qualitative and quantitative tests for aluminum employed.

Blood Plastics. The brown and black protein plastics prepared from the blood of slaughtered animals, otherwise similar to the casein plastics, can often be recognized by the fact that cold water will extract hemoglobin from their powder. The filtered, colored solution is evaporated in a porcelain evaporating dish and the residue moistened with nitric acid, evaporated to dryness, reduced to an ash, and the ash taken up in a little dilute HCl. The addition of ammonium sulfocyanate solution gives a blood-red color in the presence of iron, which constitutes 0.3 to 0.4 per cent of the hemoglobin.

ANALYSIS OF VINYL RESINS[4]

General Characteristics of Vinyl Resins. Vinyl resins are thermoplastic, transparent, water-white to pale straw-colored solids, rubbery and elastic to hard and tough, unaffected by acids or most solvents. They are resistant to alcohol (slightly soluble), alkalies, grease, water and most corrosive agents, and insoluble in petroleum hydrocarbons and isopropyl ether. They are generally soluble in acetone, ethyl acetate,

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[3] Dodd, Robert, "Casein Materials as Applied to Plastics," *Chem. and Ind.*, 273–6 (1937).

[4] Polyvinyl, polystyrene, and polyacrylic resins are related, and all contain the vinyl group CH_2-CH. They are all produced by the polymerization of monomers by the action of light and heat, often with the aid of a catalyst. They are all thermoplastic, softening between 70° and 150° C. A sharp analytical separation of these is not known at present.

benzene, and toluene. In some cases they are partly saponifiable. They have a specific gravity of 1.15 to 1.45 and a refractive index of 1.47 to 1.48. They are usually associated with lacquers, with or without nitrocellulose, but seldom with oils or varnishes. They give a characteristic odor upon strong heating and char easily.

Vinyl resins are usually combined with a halogen or an acid ester.

Constituents: vinyl-chloride polymers, vinyl-acetate polymers, polystyrene, formaldehyde, cyclohexanone-formaldehyde.

Chlorine Content. A sodium fusion and chlorine content test will show the amount of chlorine in polyvinyl chloride or polyvinyl chloride acetates.

Refluxing the finely powdered sample with ether and following this with a chlorine test (see preliminary tests) will also give the amount of chlorine in polyvinyl chloride, and will detect chlorine-containing plasticizers, such as chlorinated diphenyl which may be recovered by distilling off the ether. Chlorinated rubber, if present, gives off an odor of burning rubber on heating. Pure polyvinyl chloride gives up no chlorine when boiled with aqueous or alcoholic KOH.

Distilling vinyl resins with soda-lime gives acetaldehyde, uncontaminated with acids. Sodium and calcium salts formed at the same time may be examined for acetic acid.

Vinyl polymers saponified by alkalies and alkaline solutions may be tested for chlorides and acetates.

Vinyl acetate in acetic anhydride gives a blue-green color slowly changing to green when it is mixed with two drops of concentrated H_2SO_4.

Separation of Chloride and Acetate. Mixed polymers (vinyl chloro-acetate) are easily separated by boiling the pulverized plastic with alcoholic KOH, polyvinyl acetate being easily saponifiable, and the undissolved polyvinyl chloride remaining behind.

Removal of Plasticizers. The soluble plasticizers are extracted from the finely pulverized plastic by refluxing with ether. (Chlorinated rubber is only slightly soluble in this.)

Polyvinyl Alcohol Test. After the plasticizers have been removed, the plastic may be saponified by boiling it over a water bath with methyl alcoholic KOH, in a flask fitted with a reflux condenser. The solution which results is then filtered and concentrated by evaporation. A flocculent precipitate of polyvinyl alcohol may separate out, especially with the addition of a suitable alcohol. In acidified aqueous solution this gives a blue color. In the first filtrate from the separation, any acetic acid present may be detected.

Maleic Acid Tests. A test for maleic acid, specifically for polyvinyl maleate, which is often used for making tubes, is carried out on the remainder of the filtrate from the above test. In the absence of acetic acid the filtrate is concentrated and neutralized with hydrochloric acid and then mixed with calcium chloride solution, which precipitates calcium maleate as a white substance, soluble in alcohol and insoluble in water.

For a further test for maleic acid, the remainder of the filtrate from another sample (extracted with ether, saponified with alcoholic KOH and filtered) is just neutralized with dilute nitric acid and then mixed with lead acetate solution, precipitating the maleic acid, if present, as lead maleate. The precipitate should be washed with alcohol, and mixed with warm water with the addition of H_2S solution. The lead sulfide which separates should be filtered out and the filtrate evaporated over a water bath. A portion of the residue is dissolved in water, and exactly neutralized with dilute sodium hydroxide using phenolphthalein indicator, after any free sulfur has been removed by filtration. The solution is then heated with the addition of some ferric chloride solution, which produces a red-brown precipitate of ferric maleate in the presence of maleic acid.

Another small weighed sample of the residue (first dried in a desiccator) to be tested for maleic acid is dissolved in some water and titrated with 0.1 N potassium hydroxide. One-tenth gram of pure maleic acid requires 17.2 cc. of this solution for neutralization. By this method a quantitative test for the amount of maleic acid in a given sample can be determined.

Additional Constituents. Vinyl resins are commonly modified with plasticizers, but are usually unfilled, transparent plastics.

Catalysts used in the polymerization of vinyl resins are: benzoyl peroxide, acetyl benzoyl peroxide, sodium borate, boric acid, lactic, hydrochloric and acetic acids, and the chlorides of zinc and aluminum.

Plasticizers commonly added are: tung oil or other natural drying oils, waxes, dialkyl phthalates, triphenyl phosphate, the Aroclors, Halowax, fatty oils.

Stabilizers for vinyl resins are alkaline earth-metal soaps, resinates, oxides or carbonates, aromatic amines, epichlorohydrin, phenoxypropene oxide.

Fillers: silica, mica, and any of the other common fillers.

Modifying Agents: dispersions of rubber, amorphous silica, rosin, acetaldehyde, resins, phenolic resins.

ANALYSIS OF POLYSTYRENE

General Characteristics of Polystyrene. Polystyrene is naturally a clear, transparent, colorless plastic which transmits ultra-violet light, burns less easily than hard rubber and is very stable.

On heating it gives off the odor of blooming hyacinths and of benzene. Above 110° C. it assumes a rubbery form and at 300° C. it can be decomposed into styrene and distyrene. It is completely unsaponifiable into alcoholic alkalies and very resistant to chemicals, even hydrofluoric acid. It has excellent dielectric properties. It is soluble in aromatic and chlorinated hydrocarbons.

Distinguishing Tests. The finely powdered plastic is extracted with methanol to remove plasticizers, and then distilled with a mixture of powdered potassium bichromate and dilute sulfuric acid from a retort or fractionating column. A large amount of undecomposed styrene distills over with water vapor. This distillate is separated from the materials which will distill over next, because after some time certain complicated reactions will begin to take place in the retort. Masses of benzoic acid crystals will be found floating in the distillate, some of the acid being dissolved in the distillate. The whole should be shaken with warm sodium bicarbonate solution, and the resulting mixture (now containing dissolved sodium benzoate) should be mixed with dilute hydrochloric acid and the benzoic acid extracted with ether. After the evaporation of the ether from the decanted ether layer, the benzoic acid remains. Part of it may be sublimed by heating in a test tube and part reduced to benzaldehyde by the use of zinc and dilute sulfuric acid. These tests serve to identify it.

Recently it has been found that the addition of diphenyl chloride to polystyrene resins increases their hardness and strength and decreases their flammability and burning rate.

Polyvinyl Chloride. Mixed polymers of polystyrene and polyvinyl chloride may be recognized by an elevation of the specific gravity to about 1.3, and by giving a test for chlorine after the chlorine-containing plasticizers have been removed by extraction with methanol, and the diphenyl chloride has been removed by extraction with a suitable solvent, for example, petroleum ether. If these conditions are found, the possible presence of chlorinated rubber should be considered.

Polyvinyl Acetate. The presence of polyvinyl acetate is shown by evidence of acetic acid in the saponification product of a test sample saponified with alcoholic potassium hydroxide.

Polyalkylacrylate. Polyalkylacrylates in mixed polymers with polystyrene raise the specific gravity to 1.10 or 1.15 and give saponification products and clear saponification solutions without separation.

Estimation of Volatile Matter. The finely divided resin is heated in a high vacuum to 180° C. and the gaseous products passed through strong carbonic acid. In this way about 4 per cent of the gaseous products are found; about half consisting of monomeric styrene, and about 40 per cent of ethylbenzene. A greater content of gaseous products is the cause of surface cracking, and growing haziness and discoloration of the finished transparent plastics on exposure to light and air.

Additional Constituents. Polystyrene is not generally made with fillers. Plasticizers used with it are various phthalates such as diphenyl phthalate or butyl phthalyl butyl glycolate. Polystyrene may be modified with the related vinyl or acrylic compounds.

Analysis of Polyacrylic Acid Resins

General Characteristics of Polyacrylic Acid Resins. Polyacrylic resins may be prepared without the use of plasticizers or fillers and usually are. They are produced in colorless form or dyed in a wide range of colors.

Acrylic resins may consist of acrylic and methacrylic acids, their esters, amides, salts, halides, and nitriles. The esters are of most importance.

The compatibility of the resins is limited. Many of the acrylic polymers are unexpectedly incompatible with each other; mixed polymers, likwise, are unexpectedly incompatible with each other. Mixed polymers with polyvinyl chloride are often used. One commercial plastic is a mixture of butadiene and polyacrylic acid.

Distinguishing Tests. Acrylic resins are colorless, hard (hardness 2–3 on Mohs' scale), weather and light resistant, with a refractive index of 1.49 and a light transmission of about 95 per cent in the visible range and 50 to 70 per cent in the ultraviolet range (1800 to 3000 Å).

They are soluble in ketones, esters, and aromatic hydrocarbons. Little is known of their chemical nature and their analysis is difficult.

Removal of Plasticizers. The plasticizers should first be removed by refluxing a powdered sample with methanol. The percentage of placticizers and their nature may then be determined.

Saponification. Saponification is accomplished by prolonged boiling of the pulverized sample (from which the plasticizers have been removed) with alcoholic KOH. The potassium salt of polyacrylic acid or polymethacrylic acid is obtained in this way.

Methanol Test. To test for methanol, distill the saponified solution, and collect separately the portion which distills over between 60° and 70° C. Into this solution (about 3 cc.) dip a copper spiral whose surface has been oxidized, add a drop of 0.5 per cent resorcinol solution after removing the copper, and carefully pour in concentrated sulfuric acid to make a separate lower layer. If methanol is present, a rose-red zone will appear where the two solutions meet.

In contrast to the methyl ester of polyacrylic acid, the methyl ester of polymethacrylic acid is not saponifiable with alcoholic KOH.

Distinction between Methyl Esters of Polyacrylic and Polymethacrylic Acids.

Methyl Acrylate	*Methyl Methacrylate*
Saponifiable with alcoholic KOH.	Unsaponifiable with alcoholic KOH.
Gives test for CH_3OH after saponification in the alcoholic solution.	After depolymerization by heating at 250 to 300° C. the distillate collected is saponifiable.
	The alcoholic solution from saponification gives a positive test for CH_3OH.

Heating the unsaponifiable part of the resin to depolymerize it and then saponifying the distillate allows the separation of these resins.

To carry out a further investigation, distill a large portion (20 to 30 gm.) of the finely powdered sample in intimate mixture with an equal weight of fine sand or quartz-meal which had previously been heated to glowing. Place the mixture in a distilling column made of glass difficult to melt, heat to a temperature of 250° to 300° C., and collect the distillate.

By means of another distillation, separate the fraction distilling between 96° and 104° C., which contains the monomeric methyl methacrylate (boiling point of the pure product 100° C.). This fraction should then be saponified with potassium hydroxide in ethyl alcohol, and the alcohol distilled off over a water bath. The alcoholic distillate (methanol) should then be investigated as well as the residue which consists of potassium methacrylate.

From the former, separate by fractionation the portion distilling between 60° and 70° C., which probably contains the methanol formed during saponification. Test the liquid for methanol by the test previously described.

The residue from the distillation should then be dissolved in water and a portion of the solution slowly mixed with a small amount of sodium amalgam at room temperature, and later poured off from the liberated mercury. The free alkali should be neutralized with dilute sulfuric acid. This solution is then distilled until the distillate no longer gives an acid reaction. The distillate indicates the presence of polymethacrylic acid ester if it is not saponifiable, and gives an odor of isobutyric acid, which is like the odor of rancid butter.

More simply, one can test a portion of the aqueous solution of the residue of the distillate from the alcoholic saponification of the plastic, acidify it with dilute sulfuric acid, add zinc dust, and warm. The characteristic odor of isobutyric acid reveals the presence of polymethacrylic acid in the plastic.

The free methacrylic acid liberated by dilute hydrochloric acid from another portion of the residue solidifies at 10° C. (melting point 16° C.). It dissolves easily in warm water, and readily in alcohol and ether. The copper salt is a light blue precipitate, insoluble in water, while the zinc and cadmium salts are readily water soluble.

According to Mjoen the polymethacrylic acid octopolymer obtained from the methacrylic acid by distillation has the formula $C_{24}H_{40}(COOH)_8$.

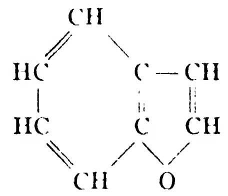
When separated from the potassium salt by treatment with hydrochloric acid it forms a hard white solid of porcelain-like appearance, which is slowly but entirely soluble in ammonia. This solution gives a gummy precipitate with calcium or barium chloride. The polymethacrylic acid decomposes above 200° C. and volatilizes at 300° C. without melting. It is soluble in absolute alcohol, from which it is precipitated by anhydrous ether as a light flocculent powder. It is slowly soluble in water, first absorbing the water and swelling, and is also slightly soluble in acetone and soluble in chloroform, benzol, and acetic acid. It resists acids, both dilute and concentrated.

If, after saponifying with alcoholic KOH, there still remains in the plasticizer-freed sample any residue in which chlorine can be detected, it may be assumed that the substance under investigation is a mixed polymer of polyvinyl chloride and acrylic or methacrylic acid. Chlorinated acrylic resins or chlorinated rubber may also be present. If acetic acid is detected in the alkali salts obtained by saponification, it may indicate polyvinyl acetate. In this case a flocculent precipitate of polyvinyl alcohol separates out when the saponified solution is cooled down.

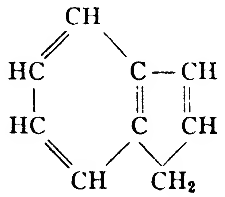
Analysis of Cumarone–Indene Polymers

General Characteristics of Cumarone-indene Polymers. The structural formulas are:

Cumarone



Indene



Cumarone-indene polymers are light-colored, transparent resins, of specific gravity 1.10 to 1.15 (may be as low as 1.05), and with a refractive index of 1.60 to 1.66 unless modified by rosin or oils. They are not saponifiable unless modified with saponifiable materials (rosin or fatty acids).

When strongly heated, these resins give off a characteristic unmistakable odor of melting cumarone. The resins are slightly soluble in 90 per cent ethanol and very soluble to completely soluble in benzol, acetone, and carbon tetrachloride.

Since cumarone-indene resin is used almost exclusively as a minor ingredient in plastics, the tests are planned accordingly.

The characteristic bromine-acetic acid color reaction of cumarone is described in the preliminary tests.

Identification of Cumarone Resins when Mixed with Other Resins. Cumarone resin dissolves in acetone and is partially soluble in petroleum ether, in both of which most types of phenolic resins are insoluble. Natural resins melt at higher temperatures, and with the exception of Pontianac, have higher acid numbers, saponification and iodine values.

Separation of cumarone-indene from fatty acids can be done with esterification, the esters being removed by distillation or extraction with alcohol, though oxidized oils may interfere and make saponification desirable.

Free sulfuric and sulfonic acids can be separated from cumarone resin by treating a solution of the resin in neutral benzene with successive portions of warm water and precipitating the acids with barium chloride.

Final identification of cumarone resin is accomplished by destructive distillation which yields decomposition products at 300° to 400° C. with the formation of cumarone, indene, hydrindene, and small quantities of phenols and cresols. Separation can be accomplished by fractional distillation, the largest fraction obtained boiling at 160° to 180° C. Cumarone and indene can be identified in the distillate by means of their picrates and bromides:

	Cumarone	*Indene*
Picrate	m.p. 102° to 103° C.	m.p. 98° C. b.p. 179.5° to 180.5° C.
Monobromide	m.p. 39° C.	————
Dibromide	m.p. 86° C.	b.p. 43° to 45° C.

Test for Cumarone. Cumarone resin may be tested for in the unsaponifiable portion of a test sample in the following way:

Heat a small portion of the substance in a test tube over an open flame. Cumarone melts with the odor of coal-tar oils. The test tube should be plugged with a wad of glass wool in which the distillate collects. The glass wool is then removed, and covered with 5 cc. of acetic anhydride. The liquid is then poured off into a mixture of 5 cc. of acetate anhydride and 3 or 4 drops of H_2SO_4 (sp. gr. 1.53). The appearance of a red-gold to orange color indicates cumarone resin.

Cumarone resin can be separated in the following way from a plastic mixture containing gutta percha, colophony, wax, asphalt and tar, mineral fillers, wood flour and other cellulose-containing mixtures:

Cumarone resin together with natural asphalt, petroleum, and gutta percha can be removed by treatment with hot allyl alcohol. The remainder after evaporation of the alcohol can then be treated with hot acetone, in which the other three substances are insoluble or nearly so, and the cumarone is left upon distilling off the acetone.

Constituents. Cumarone-indene resins consist of cumarone polymers, indene polymers, and other unsaturated fatty acids from coal tar, rosin or rosin ester, higher fatty acids. They are often mixed with tung oil to increase their resistance to alkali.

ANALYSIS OF CELLULOSE ACETATE PLASTICS

General Characteristics of Cellulose Acetate Plastics. Cellulose acetate plastics are essentially clear and transparent and can be made in any color. They contain plasticizers and are thermoplastic, softening at 140° to 260° F. They have good electrical properties. They are attacked by strong acids and alkalies, and are soluble in ketones and esters, softened or slightly soluble in alcohol, and little affected by hydrocarbons. They have a specific gravity of 1.37 to 1.27. Cellulose acetate occurs in several forms, all of which are soluble in acetone, but only one of which (the triacetate) is soluble in chloroform.

Test for Hydrocellulose. Cellulose acetate is easily saponified by boiling for about 10 min. with 50 cc. of 5 per cent sodium hydroxide, after extracting the plasticizers from the finely powdered sample (2 to 3 gm.) with ether or methanol. After cooling, add 2 cc. of 95 per cent alcohol and slowly pour in 5 cc. of concentrated H_2SO_4. When the mixture is heated just to boiling, the fresh fruity smell of ethyl acetate esters can be noticed. The residue after saponification contains the hydrocellulose (insoluble in water and organic solvents) and the mineral fillers.

Estimation of Acetic Acid Content. A rapid method of acetyl determination suitable for plant control is one in which the cellulose acetate is saponified while in a highly dispersed phase. When the cellulose acetate is dissolved in acetone, and then saponified, the acetyl value can be determined with reasonable accuracy at the end of one-half hour. A solvent which will show a greater solubility and also be unaffected by alkali is pyridine.

In the pyridine method, as with acetone, the sample is placed in 20 cc. of the pyridine, kept at 53° C. for 15 min., and then for one-half hour longer after the addition of 20 cc. of 0.5 N NaOH. The sides of the flask are washed down with 25 cc. of distilled water, 2 drops of phenolphthalein are added, and the excess alkali titrated back with standard acid until the solution is just colorless. There is no tendency for the cellulose to retain alkali as in the other method.

The sample must first be treated so as to be readily soluble in warm pyridine. The acetylation solution of the sample is diluted with 2 to 4 volumes of acetone and poured in a small stream into 6 to 8 volumes of hot water (85° to 95° C.). This gives a finely divided precipitate which dissolves in the pyridine readily, even in the case of triacetate acetylation solution. If the precipitate consists of large horny nodules the pyridine does not dissolve them and the results are low.

Upon long contact at fairly high temperatures, especially in the presence of NaOH, pyridine appears to react with the cellulose acetate.

Acid Value of Cellulose Fatty Acid Esters.[5] Preliminary treatment of the ester to be saponified by soaking in alcohol-water or alcohol-acetone causes it to swell and become porous and greatly decreases the saponification time.

Procedure. The sample to be tested is dried to constant weight at 105° C., and a 0.5 gm. sample is immersed in 20 cc. of 75 per cent ethyl alcohol at 50° to 60° C. for one-half hour. A double-walled flask in which acetone is kept refluxing maintains a constant temperature of 53° C. within 1° C. variation.

The treated sample is then saponified by heating it for 15 min. with 20 cc. of 0.5 N NaOH and allowing it to stand for 24 to 48 hr. with occasional shaking. After washing down the walls of the flask with 50 to 75 cc. of distilled water, add 2 drops of 1 per cent phenolphthalein and back titrate the excess alkali.

Estimation of Free Acid — Sulfuric and Acetic. Ten grams of powdered cellulose acetate are digested for 24 hr. with frequent agitation in a stoppered flask with

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[5] Murray, T. F., Jr., Staud, C. J., and Gray, H. LeB., "Acid Value of Cellulose Fatty Acid Esters and Rapid Analysis of Certain Cellulose Acetates," *Ind. and Eng. Chem., Anal. Ed.*, **3**, 269–73 (1931).

100 cc. of carbon dioxide-free water. The mixture is then filtered and the water titrated with 0.1 N alkali, using phenolphthalein as an indicator.

Estimation of Combined Sulfuric Acid. A weighed amount of the powdered sample is melted with double the amount of a mixture of equal parts of sulfate-free potassium carbonate and sodium carbonate. The white melt is extracted with water, and the SO_4 ion in the solution is determined with barium chloride in the usual manner.

Water Content. The water content should be determined by the xylol method as described in the test for water content of phenolic plastics.

Plasticizers and Other Constituents. Plastics of the cellulose acetate type are colloidal solutions of cellulose acetate in plasticizers. The cellulose acetate is mixed with plasticizers and a volatile solvent such as alcohol or acetone until a jell-like colloidal mass is obtained. The volatile solvents are later removed in manufacture. Some of the common plasticizers used are: dimethyl phthalate, dibutyl tartrate, triacetin, para toluene ethylsulfonamide, and sometimes triphenyl phosphate as a fire retardant.

Tests for Plasticizers. Ten grams or more of finely powdered cellulose acetate are extracted by refluxing with ether or methanol or a mixture of both solvents for about an hour. The resulting solution is filtered and all the solvent distilled off. The residue is tested for phthalates by the characteristic color reactions, for castor oil by fusion with sodium hydroxide, and for chlorinated diphenyl by a test for chlorine. Any residue should be saved and its saponification number determined.

A simpler, more rapid, method is the following:

Five hundred grams of the plastic are cut into small strips and vacuum distilled from a 2-liter distilling flask which is immersed in an oil bath almost to the side arm. The distillate is collected in a receiving flask attached to the side arm and kept cool by immersion in a freezing mixture if desired. A vacuum of 0.1 mm. Hg is applied to the system, and the oil bath rapidly heated to about 250° to 260° C. which results in slight charring with some substances, but does not produce volatile decomposition of the cellulosic material, though it is high enough to distill the high boiling plasticizers commonly used. Lower temperatures may be satisfactory except in lengthening the time of separation, whereas higher temperatures produce objectionable volatile cellulosic decomposition products (which can, however, be removed with relative ease if necessary). At the temperature described above, it requires only a few hours to complete the separation. Quantitatively this method is satisfactory for plant control tests. It has been tried successfully with ethyl and benzyl cellulose acetate, and other kinds of cellulose derivatives containing several different plasticizers and from different kinds of cellulosic material.

The purity of the plasticizer may be determined by measurements of the refractive index, and by determination of the saponification number.

Fillers. Any of the usual fillers may be incorporated with cellulose acetate, but often it is unfilled.

ANALYSIS OF CELLULOSE NITRATE PLASTICS

General Characteristics of Cellulose Nitrate (Pyroxylin) Plastics. Cellulose nitrate is the cheapest plastic for most decorative purposes. It is naturally transparent and colorless but discolors with age. It is available in all colors. The plastic smells of camphor, especially when rubbed vigorously with a cloth, since camphor is the plasticizer ordinarily used. On exposure to an open flame the plastic burns swiftly, giving off camphor vapors. It is thermoplastic and decomposes at high temperatures (140° C.), often explosively. It is very susceptible to high temperatures and is easily saponified.

The plastic is highly water resistant but may dissolve in warm sulfuric acid. Good solvents for nitrocellulose are acetone, amyl acetate, acetic acid, formic acid, alcohol-ether mixtures, pyridine, epichlorohydrin, dioxane, Cellosolve, and cyclohexanone.

The plastic softens and swells in absolute alcohol. It is insoluble in water, benzene, carbon tetrachloride and other chlorinated hydrocarbons, petroleum ether and glycerin.

The plastic can be heated, stretched and quickly cooled in the distorted shape only to return to its orginal shape on reheating. The cellulose nitrate base is usually defined by its nitrogen content and viscosity. The plastic burns swiftly with an acrid odor of camphor and oxides of nitrogen.

Nitrate Test. The plastic gives a dark blue color when dipped into a diphenylamine sulfuric acid solution (3 gm. of pure diphenylamine in 50 cc. of nitrate-free concentrated H_2SO_4 — see preliminary test for nitrates).

Treatment of the readily saponified plastic with alcoholic KOH yields insoluble cellulose and potassium nitrate solution in which the nitrate ion can be detected by the usual test with ferrous sulfate and concentrated H_2SO_4.

Fluorescence. Cellulose nitrate films have a characteristic yellow-brown fluorescence when exposed to ultra-violet light, and the color of this fluorescence is altered by the presence of certain plasticizers. With castor oil it is yellow-green and with p-toluenesulfonamide it is reduced almost to nothing.

Distinguishing Cellulose Acetate from Cellulose Nitrate. Cellulose acetate is insoluble (or only very slightly soluble in amyl formate, but cellulose nitrate is soluble in this solvent.

Analysis of Cellulose Nitrate Plastics. Cellulose nitrate should be analyzed for camphor content, nitrogen, hydrocellulose, ash, plasticizers, and soluble coloring matters.

Test A. Two or three grams of the finely divided plastic are refluxed with 150 cc. of carbon tetrachloride to extract camphor and related compounds, other plasticizers, and some soluble coloring matters. The residue, consisting of nitrocellulose and mineral fillers, should be dried at about 60° C., and the total weight of the mixture determined.

Most of the carbon tetrachloride should be distilled off over a water bath, and the remainder removed by a steam distillation, which also carries away the camphor. The dry weight of any residue remaining from this steam distillation is determined after removal of water (by distillation) and washing with acetone and drying. The camphor content (mixed with other substances such as certain plasticizers) is given by the formula $c = a - (b + d)$, where a = the weight of the original plastic sample, b = the weight of the nitrocellulose + organic fillers and d = the mixture that remained behind from the steam distillation. The camphor content usually varies from 5 to 30 per cent.

The mineral content can be analyzed further by the standard methods of qualitative analysis, and the residue from the steam distillation investigated to identify the plasticizers.

If the color reactions for phthalates (preliminary tests) are given by the sample, proceed in the following way:

Saponify a sample of the plastic by refluxing for an hour with 0.5 N aqueous or alcoholic KOH. If necessary, filter, since the potassium phthalate is soluble with difficulty in alcohol. Evaporate the filtrate and dissolve the residue in a little water (solution A). To a small portion of solution A, add dilute hydrochloric acid, and warm. Separation of an oil may indicate castor oil, the presence of which can be recognized by heating a small portion of the oil separately and noting its characteristic odor, which can be compared with that of a sample of pure warmed castor oil.

The remainder of solution A should be tested in the usual way for acetic acid. The presence of this acid may indicate that triacetin (glycerol triacetate) was present and has been decomposed. To make certain of the presence of this plasticizer, run a test for glycerin on the solution which distilled over during the steam distillation of camphor, after the camphor has been distilled off. Add potassium sulfate to the solution, and evaporate the mixture to dryness over a water bath. Heat the residue in a test tube of potash glass. Collect the acrid fumes in water and add a little fuchsine solution decolorized with sulfurous acid. The appearance of a red color indicates the presence of glycerin.

Test B. Two grams of finely powdered plastic are extracted by shaking with acetone until only the mineral content remains undissolved. An 8 per cent ammonium chloride solution is then added to about 50 cc. of the acetone solution, and the resulting precipitate washed in a Gooch crucible with a mixture of acetone and 8 per cent NH_4Cl solution. The remainder is washed with absolute alcohol and dried to constant weight at 60° C. The percentage of camphor present can then be determined.

The precipitate should be melted with some paraffin, then charred and burned completely, and the weight of the ash determined on cooling.

Nitrogen Content. The nitrogen content may be determined by means of the du Pont nitrometer. The plastic is first freed of camphor by extraction with methanol or carbon tetrachloride, then dissolved in 60° Bé. sulfuric acid and decomposed in the nitrometer.

A newer method is the "Nitron" method. Saponify 1 gm. of the cellulose nitrate with 10 cc. of 30 per cent sodium hydroxide mixed with 1 cc. of 30 per cent H_2O_2. Heat the mixture over a water bath to 50° or 60° C., and then filter and wash carefully the precipitated hydrocellulose (mercerized cellulose). Boil away any excess hydrogen peroxide from the filtrate, render the solution mildly acid with dilute acetic acid, place the resulting mixture in a flask, and add water to bring the volume up to 50 cc. To a fraction of this solution in which there may be 0.01 to 0.05 gm. of NO_3 present (in about 5 cc.), add a few drops of acetic acid, heat to 60° to 70° C., pour in 10 cc. of 10 per cent nitron acetate solution and let the mixture stand at room temperature for 24 hr. After decanting as much of the solution as possible, the thin needles of the nitron-nitrate compound ($C_{20}H_{16}N_4 \cdot HNO_3$, mol. wt. 375.17) should be filtered out into a filtering crucible which has previously been dried at about 105° C. The precipitate should then be washed with 50 cc. of saturated nitron-nitrate solution, then taken up with 10 to 12 cc. of ice water and the precipitate dried at 100° C. for 2 or 3 hr.

$$\text{Per cent } HNO_3 = \frac{16.798 \times G}{a}$$

where G = the determined amount of nitron-nitrate in grams
a = the weighed amount of substance used

The exact determination of camphor is best made upon natural camphor by the polarimetric method of Foerster in which is used a benzene extract of Celluloid or an alcoholic solution of the camphor isolated by a steam distillation in the presence of sodium hydroxide. Or, in the case of synthetic camphor, the refractometer method of Utz may be employed, with the aid of the Zeiss immersion refractometer.

Estimation of Hydrocellulose (Regenerated Cellulose). This substance is left behind as a structureless form of cellulose by the denitration of cellulose, as by saponification. It may be determined by treating Celluloid with concentrated ferrous chloride solution at 100° C. and adding hydrochloric acid. After the evolution of oxides of nitrogen has ceased, the hydrocellulose that remains behind should be washed, first with water until completely neutral, then several times with alcohol, and should then be dried and weighed.

Soluble Colors (Coal Tar). These are subjected to tests of solubility, resistance to light and to dilute acids, and other similar tests, which are not strictly analytical.

Modifying Agents. Nitrocellulose is sometimes used without camphor in connection with casein, metal caseinates, glue, gelatin, lime, and natural resins like shellac, and sometimes with acetone or ester-soluble polymerization products.

Plasticizers. Camphor is still the most commonly used plasticizer. Special plasticizers containing chlorine and phosphates act as fire retardants. In addition to camphor, triacetin and phthalates and tricresyl and other phosphates, and various glycolates may also be used.

ANALYSIS OF MIXED CELLULOSE ESTERS

Cellulose Nitrate Acetate. These plastics are very similar to cellulose acetate, and are rather difficult to analyze.

Identification of Acetic Acid in Mixed Esters. The only way in which acetic acid can be identified in these mixed esters is microscopically, in the following manner:

A gram of the pulverized plastic is placed in a 500-cc. fractionating flask with 25 cc. of 75 per cent sulfuric acid and allowed to stand for one-quarter hour with occasional agitation. Then 150 cc. of water is introduced into the fractionating column by means of a dropping funnel. A Liebig condenser is connected to the flask, which is then slowly heated to boiling. The distillation should be regulated to yield about 50 cc. in 30 min. and at 30-min. intervals distilled water is added in sufficient amount to keep the contents of the flask at their original volume. The condenser must be kept well cooled.

The acid distillate obtained is just neutralized with 0.1 N NaOH, using litmus. An excess of NaOH is not to be used. The solution is then heated to dryness in an evaporating dish over a water bath. The residue is carefully mixed with 10 cc. of absolute alcohol and allowed to stand for a time. The mixture is filtered, the alcohol driven off, and a little water added to make a total volume of about 0.3 cc. From this solution a drop is transferred to a microscope slide, steamed to dryness over a small flame, and allowed to cool. The cooled residue is mixed with a drop of uranyl formate solution, and the slide placed under the microscope (magnified 200 to 300 times) without a cover glass. At first CO_2 is evolved, but unless it is very copiously and vigorously evolved it has no effect on the crystallization of the acetate. After a short time, if acetic acid is present in the sample, the characteristic glistening tetrahedral crystals of sodium uranyl acetate appear. These stand out clearly in spite of the admixture of various other decomposition products, so that the test is distinct and unmistakable.

Estimation of Nitric Acid. Nitric acid can be detected with ferrous sulfate and sulfuric acid or by the diphenylamine test as previously described, and can be determined quantitatively by the " Nitron " method.

Estimation of Regenerated Cellulose. Regenerated cellulose can be isolated by saponification with alcoholic KOH.

Cellulose Acetate Butyrate. Cellulose acetate butyrate is a mixed ester (butyryl and acetyl groups substituted at the hydroxyl groups of the cellulose).

This substance has a specific gravity similar to cellulose but absorbs only half as much water. It is made with a low percentage of plasticizer, and the plasticizers used have a greater water resistance and lower vapor pressure than those of cellulose acetate.

The mixed ester is compatible with plasticizers and other resins. When heated, the flow increases uniformly up to a certain temperature and then the material flows considerably faster. Harder flows can be molded and these have an increased resistance to heat. (See test for butyric acid by method described in preliminary tests.)

Cellulose acetate butyrate and other mixed esters, after having been freed of plasticizers by extraction with carbon tetrachloride or methanol, should be saponified with N or 0.5 N KOH (5 gm. of ester to 100 cc. of 0.1 N alkali) by refluxing for about 2 hr. over a water bath. The alcohol should then be distilled off, the residue taken up in a little water, the remaining hydrocellulose filtered out, and the filtrate evaporated to dryness over a water bath. The residue should be dissolved in a little water and placed in a fractionating flask (150- to 200-cc. capacity) with a long arm. Ten cubic centimeters of absolute alcohol and 10 cc. of concentrated H_2SO_4 are then added, and the mixture fractionated in a sand bath. Ethyl acetate distills at 77° C., and ethyl butyrate at 120° C., each recognizable by a characteristic odor. The ethyl acetate can be saponified, and the acetic acid identified microscopically.

ANALYSIS OF CELLULOSE ETHERS

Ethyl Cellulose. Ethyl cellulose plus a plasticizer gives a colorless, transparent plastic, thermoplastic and stable to heat, not discolored by ultra-violet light or heat. The plastic burns like cellulose acetate, producing harmless gases. Its moisture absorption is about 2 per cent.

It may be used pure or in combination with other plastics or resins, or with various plasticizers. It is compatible with many resins of the phenolic, glyptal, and ring hydrocarbon types, and its solubility in rosin is complete. It is compatible with a wide range of solvents, resins, waxes, oils, and plasticizers.

Its films have a great resistance to alkalies, dilute acids, and many solvents. In contrast to the cellulose esters it is soluble in benzene and its homologues, methanol, ethanol and the next higher alcohols, monochlorobenzene, chloroform, and chlorinated hydrocarbons. It is only softened in ether.

The plastic is unsaponifiable.

Ethyl cellulose is difficult to identify because it has few distinctive properties. The best test of whether a product is, or contains, ethyl cellulose is to identify the ethoxy group: C_2H_5O—. Compounds containing this group form ethyl iodide when heated with hydriodic acid. Ethyl iodide with silver nitrate gives a precipitate of silver iodide.

Test for Ethoxy Group, C_2H_5O—. Ten cubic centimeters of pure hydriodic acid (specific gravity 1.68) are placed in a 30- to 35-cc. flask with 0.2 to 0.3 gm. of the finely powdered sample. The mixture is boiled in a stream of CO_2 and the evolved vapors are conducted through a reflux condenser (filled with water at 40° to 50° C.) and then through a Geissler tube in which water and 0.2 to 0.5 gm. of red phosphorous have been placed. This apparatus is immersed in water at 50° to 60° C. The vapors coming from the apparatus are passed into an Erlenmeyer flask containing a mixture of aqueous silver nitrate solution and alcohol. The ethyl iodide in the distillate causes a yellow precipitate of silver iodide to form as the vapors pass through the silver nitrate solution.

The free alkali, free acids, and water content should be determined as before.

Extent of Etherification of Ethyl Cellulose. To determine exactly the extent of etherification of ethyl cellulose the Zeisel method for determining the number of ethoxy groups present serves very well, especially for control of manufacture. It requires a large and rather costly apparatus, but has been worked out as a micro-method by Pregl. An ethoxyl content of 54.87 per cent indicates a triethyl compound, according to Berl and Schupp, and a content of 23.68 per cent, a single ethyl group for each $C_6H_{10}O_5$.

Plasticizers. Plasticizers commonly used with ethyl cellulose are: chlorinated diphenyl (Clophen), tributyl phosphate, tricresyl phosphate, various phthalate plasticizers, butyl stearate, and isoborneol.

Benzyl Cellulose. As in the case of ethyl cellulose, some hydrogen atoms of the hydroxyl groups of the cellulose can be replaced by benzyl groups ($C_6H_5CH_2$).

The benzyl cellulose is a white or pale yellowish, friable, odorless, powdery, thermoplastic substance. The yellowish color often appearing is due to side reactions of related compounds such as benzyl alcohol, which are eliminated from the reaction mixture only with the greatest difficulty.

The molding temperature lies between 200° and 260° C. The plastic remains practically unchanged up to 180° C. The plastic has a specific gravity of 1.22 and may be formed into various shapes by compression or extrusion molding. It is almost nonflammable, though it will burn quietly when held in an open flame and will char during or after melting. Clear films of the plastic are greatly resistant to water, strong acids and alkalies, ozone, mineral oils, petroleum ether, and fatty oils. The plastic has good dielectric properties, high elasticity, and good working properties.

Benzyl cellulose has the advantage over ethyl cellulose in greater resistance to oils and to alcohol. Resistance to heat — 120° to 150° C.

Boiling the plastic for a long time with dilute H_2SO_4 produces the odor of benzaldehyde (odor of oil of bitter almonds). The odor disappears upon neutralizing the solution with alkali.

Saponification. Benzyl cellulose is highly resistant to alkalies, and cannot be saponified.

Estimation of Water Solubles. Boil a 10-gm. pulverized sample of the resin with a portion of freshly distilled water. Test the extract, and if free hydrochloric acid is found to be present, evaporate the extract to dryness and weigh the residue.

Benzyl Content. The plastic should be treated with acetic anhydride in the presence of an equal amount of sulfuric acid. The reaction products of acetic acid and benzyl acetate are driven off with superheated steam, and collected. The acetic acid in the cooled distillate is exactly neutralized with NaOH, and the benzyl acetate is saponified with an accurately measured excess of 0.5 N NaOH. The excess alkali is then titrated back with 0.5 N HCl.

$$1.0 \text{ cc. of } 0.5 \text{ N NaOH} = 0.05355 \text{ gm. of } C_6H_6CH_2O$$

Plasticizers. To determine the kind and amount of plasticizers, reflux a finely powdered sample of the plastic with acid-free ether. Test for phosphoric acid (tricresyl phosphate) and chlorine (chlorinated diphenyl, etc.) in a portion of the weighed residue left by evaporation of the ether. Saponify a large second portion with alcoholic caustic alkali, and analyze it.

Plasticizers commonly used with benzyl cellulose: tricresyl phosphate, tributyl phosphate, butyl stearate, chlorinated diphenyl, triacetin, camphor, isoborneol, amyl tartrate, benzyl benzoate, benzyl abietate, and glycerin dicresyl acetate.

ANALYSIS OF CELLULOSE HYDRATE AND HYDROCELLULOSE

These substances are insoluble in all organic solvents and unsaponifiable by any alkalies.

Determination of Water-soluble Substances (Free Acids and Salts). The aqueous extract should be tested in the usual way for free acids — sulfuric, hydrochloric; and for zinc coming from zinc chloride.

Determination of Water Content. Dry to constant weight at 100° C.

Determination of the Presence of a Lacquer Coat or Waterproof Impregnation. The pulverized sample is extracted with petroleum ether. Paraffin, ceresin, wax, asphalt, and the like, go into solution, and may be recovered when the solvent is distilled off. Paraffin, ceresin, and asphalt are unsaponifiable; wax gives a soap solution from which, after evaporating the alcohol, the unsaponifiable portion of wax can be dissolved out with petroleum ether.

Hydrocellulose. Transparent sheets (Cellophane) of hydrocellulose respond to organic solvents as does vulcanized fiber. Hydrocellulose, however, in contrast to cellulose hydrate, will reduce Fehling's solution, causing the formation of cuprous oxide.

A test to distinguish Cellophane from cellulose acetate was devised by G. Sandov. The sheets to be tested are immersed for 30 sec. in a 1 per cent extract of spruce bark, then rinsed with water and exposed to filtered ultra-violet light. Cellophane fluoresces a strong violet, while cellulose acetate may be recognized by its characteristically weak fluorescence.

Cellulose hydrate and hydrocellulose are commonly prepared without the use of plasticizers and modifiers.

Vulcanized Fiber. These plastics are made from hydrated cellulose, produced by treating cellulose, cotton, or paper with concentrated H_2SO_4 or zinc chloride. Vulcanized fiber has high strength, resistance and toughness, leather-like working properties and low specific gravity, raised by mineral filler to 1.4 to 1.5. It is highly hygroscopic and can absorb up to 10 per cent of water, though normally the water content of the commercial product is about 8 per cent, which is not excessive. It withstands strong mineral acids, free chlorine, and caustic alkali and is not dissolved or attacked by organic solvents.

It is used as a coating to protect from abrasion, water, and the like. The heat resistance of vulcanized fiber lies between 70° and 90° C. according to Martens. The mineral and earth colors are often used as pigments, and silicate powder and other mineral powders as fillers.

It is almost non-flammable, burning slowly while held in a flame and giving off the odor of burning paper.

Its specific gravity is about 1.25.

Lignin Plastics. These consist of sawdust and other lignocellulosic material reacted with phenols, aldehydes, aniline, and other materials.

The lignin reaction may be used to detect the lignin, and the plastic subjected to analytical tests for the other substances. Celluiose may be identified. These plastics are of little commercial importance as yet. They are used for paneling and as diluents in other plastics which have better qualities, to reduce costs of more expensive chemicals.

ANALYSIS OF MISCELLANEOUS SYNTHETIC RESINS

Polymerized Acetaldehyde Resins. These resins are sometimes used as modifiers in plastics.

Behavior on Fusion. Heating with soda lime results in the evolution of acetaldehyde or its condensation products, giving a red color with Schiff's reagent. These resins are saponifiable.

Chloro Diphenyl Resins. These are used as plasticizers and modifiers in plastics.

Saponification. Chloro diphenyl resins are unsaponifiable.

The resins give qualitative tests for chlorine. They distill readily in vacuo. Dry distillation yields chlorinated diphenyl (boiling point 250° to 400° C.).

The resins vary from thin liquids to hard, brittle solids or semi-crystalline substances. The solids melt readily to a liquid. The specific gravity of these resins varies from 1.37 to 1.96 and the refractive index is 1.62 to 1.67.

Chloro diphenyls have a wider range of solubility in organic solvents than any other synthetic resin with the possible exception of cyclohexanone formaldehyde. They are soluble in most alcohols, ketones, esters, and hydrocarbons. They occur in lacquers and varnishes and in many plastics.

Constituents. Chlorinated diphenyl, rosin or rosin ester, higher fatty acids.

Cyclohexanone Formaldehyde. Cyclohexanone formaldehyde resins are used as modifiers in other plastics and in resinous coatings.

Strong heating of these resins, especially with soda lime, produces the characteristic peppermint-like odor of cyclohexanone, often accompanied by the odor of formaldehyde. Under ultra-violet light, cyclohexanone resins give a strong greenish-yellow fluorescence. The Liebermann-Storch test with acetic anhydride and sulfuric acid produces an intense rose-red color, soon changing to dirty orange.

The resins generally consist of cyclohexanone and formaldehyde reaction products, sometimes modified by other aldehydes, vinyl esters, etc. The resins have a specific gravity of about 1.207 and a refractive index of 1.544, are usually of a pale lemon color and hard and brittle, and have a wide range of solubilities in organic solvents, including ethanol, hydrocarbons, and oils.

Constituents. Cyclohexanone or methyl cyclohexanone and formaldehyde, other aldehydes, vinyl esters.

Sulfonamide Aldehyde Resins. Sulfonamide aldehyde resins are usually used as modifiers when they appear in plastics at all. Qualitative tests by sodium fusion show the presence of sulfur and nitrogen in these resins. Strong heating produces a marked odor of formaldehyde. Exposure to ultra-violet light produces a pale blue fluorescence similar to that of glyptals.

Sulfonamide-aldehyde resins are saponifiable. They are usually transparent, water-white to pale straw colored, viscous liquids to hard brittle resins or semi-crystalline solids. The specific gravity of these resins is about 1.35 and the refractive index 1.596.

The resins are generally soluble in esters, ketones, and aromatic hydrocarbons and insoluble in ethanol and petroleum hydrocarbons. They are used in nitrocellulose and cellulose acetate lacquers, not at present in oil varnishes.

Constituents. Toluene sulfonamide, aldehydes and other sulfonamides.

ANALYSIS OF BITUMINOUS PLASTICS

Bituminous plastics are opaque, usually dark brown to black plastics, used for special purposes. Some are hot molded and some are cold molded.

The heat resistance is only about 45° C. for the hot molded and about 150° C. for the cold molded. The strength of these plastics is also far less than that of the synthetic resin plastics.

The specific gravity is usually somewhat more than 2, and is greatly affected by the mineral fillers used. The plastics are fairly resistant to cold water, dilute acids and alkalies, and salt solutions. They are more or less attacked by many organic solvents, especially aromatic hydrocarbons, chlorinated hydrocarbons, petroleum ether, petroleum and other mineral oils, coal tar oils, and fatty oils.

Distinguishing Tests. Refluxing the pulverized sample with benzene gives a dark brown solution of bituminous material. The undissolved mineral fillers are filtered out from this solution, washed with benzene until the washings are colorless, and subjected to qualitative analysis. The benzene should be distilled off from the filtrate by the use of a fractionating column, and this residue can be further investigated as to the kinds of bituminous materials present.

Heating a finely powdered sample in a test tube produces a characteristic odor of melting asphalt, or a phenolic odor from the presence of coal tar.

Ash Fillers, Organic and Inorganic. A small portion of finely powdered plastic is ashed in the usual way, and the percentage by weight of the residue compared with the percentage of the undissolved residue left from the benzene extraction. If the latter percentage is larger, the plastic must have contained organic fillers such as lignin or cellulose, wood flour, cork meal, etc. Lignin can be identified by the characteristic lignin reaction. Microscopic examination may serve to identify the fillers further.

The resistance of the plastic to acids, alkalies, solvents, etc., should be tested.

Ingredients. Bituminous plastics are formulated with various percentages of oils (linseed, tung, oiticica, fish, etc.), natural and synthetic resins (cumarone, indene copal, dammar, ester gum, etc.), and asphalts (gilsonite, steam-reduced and blown petroleum), together with stearine pitch or vegetable pitch.

Their chief constituents are a mixture of plastic bituminous products such as asphalt and tar, natural asphalt, petroleum asphalt, hard coal, soft coal, shale tar, montan wax, naphthol pitch, cumarone resin.

A thinner or solvent is added to give the desired viscosity, and a plasticizer such as tricresyl phosphate, butyl stearate, dibutyl stearate or chlorinated diphenyl may be added. This is mixed with the filler (usually in finely pulverized form) consisting of fibrous talc, clay, soapstone, slate-flour, diatomaceous earth, asbestos, or shale, mica, feldspar-, quartz-, granite-, or basalt-flour, or porcelain meal, or iron oxide.

Vulcanizing or oxidizing agents such as sulfur, selenium, litharge, and driers may be added. After the mixture has aged, a lubricant such as a metallic stearate or a neutral soap is often added.

ANALYSIS OF NATURAL RESIN PLASTICS (SHELLAC)

Shellac plastics are fast being replaced by those made from synthetic resins. The plastics are distinguished from the bituminous plastics by their greater resistance to acids and their very great resistance to heat, since they resist fire and sparks. They have a very low water absorption and are among the foremost insulators. The specific gravity for these plastics is usually well above 2. The plastics are more or less attacked by the usual common organic solvents and by mineral oils and fatty oils, and are dissolved by some. They are not resistant to strong caustic alkali solutions.

Distinguishing Tests. On strong heating, a finely powdered sample will give a characteristic odor, resembling the sealing wax odor of molten copal.

Saponification. Upon prolonged boiling with strong alcoholic KOH these resins are saponified. The resulting solution should be filtered, the alcohol driven off by heat and the residue dried first over a water bath and then in a vacuum desiccator.

The saponification number, solubility in various solvents, melting point, softening point (Kraemer-Sarnow), and density of the resin acids should be determined and the values compared with those for copal, amber, colophony, dammar, shellac, and other resin acids, so that the exact nature of the resins present may be determined.

Test for Certain Bituminous Materials. If treatment of a powdered sample with cold carbon disulfide yields a deep brown to brownish black solution which, after filtration, gives a dark brown tarry mass when treated with methyl or ethyl alcohol, the presence of bituminous asphalt, tarry pitch, or montan wax pitch in the plastic is indicated. The tables showing an analytical scheme for the analysis of wax-, resin-, or pitch-like insulators for electrical purposes may be consulted.

Water Content. Dry a weighed amount of the powdered mass to constant weight at 100° C.

Mineral Content (Filler). A weighed amount of the finely powdered plastic should be refluxed with benzene over a water bath for about an hour, and the solution filtered through a dried, weighed filter. The filter paper with its contents is then washed repeatedly with benzene until the washings are colorless, and then washed several times with alcohol and dried. The filter paper is weighed after drying at 90° C.

Phenol. An admixture of phenolic resin may be recognized by boiling the powdered sample with 20 per cent NaOH. The odor of phenol will be observed if phenol is present. Any test for phenol may be used.

Constituents. The usual constituents are hard, fossil and resinous natural materials such as copal, dammar, shellac, amber, acaroid resin, etc., asbestos powder, mica and talcum powder, clay, diatomaceous earth, various kinds of rock flour, quartz and feldspar flour, with small amounts of natural asphalt and pitch-like substances.

PART VII

Applications of Plastics

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CHAPTER XXI
Plastics in Industry
CHAPTER XXII
Designing Molded Plastics Parts

CHAPTER XXI

PLASTICS IN INDUSTRY

In this section no attempt has been made to list and describe every use of plastics. It is, rather, a catalogue of typical applications. The following industries are discussed:

Abrasives
Architecture, Building, and Furnishings
Arts: Music, Handicrafts, and Sculpture Printing and Lithography
Automotive
Aviation
Business: Office Machines, Store Equipment and Displays
Electrical
Household Appliances
Industry: Textile, Ion Exchange Resins, Leather
Packaging: Rigid Transparent, Molded Containers, Closures
Paper and Publishing
Personal
Photography
Recreational: Sports, Games, Toys
Scientific: Laboratory, Medical, Dental, Optical
Transportation

ABRASIVES

Grinding Wheels.[1] Rapid fabrication of parts has become increasingly important in modern industry. High in this list of important production machine tools is the modern grinder, many of the uses of which are made possible by the development of the resinoid or synthetic bonded grinding wheels. The early examples of this type of wheel were of dense structure and therefore of relatively low grinding efficiency. However, research and development work soon brought forth the modern resinoid bonded wheel with an open or porous structure which has enabled rapid cutting. Simultaneously, the development of high-speed grinding equipment has in turn further increased the efficiency of these new open-structure resinoid bonded wheels. The modern resinoid bonded wheels can be made in any size and shape with any grain size, and in a variety of grades of hardness as well as character of porosity.

Although many types of resins have been used as bonding agents, the phenol-formaldehyde type resins are most widely used in the bonding of abrasive articles. However, the alkyd resins are used as bonds in those structures where toughness and thermal yielding characteristics are of importance.

The processing of resinoid bonded abrasive articles is somewhat complicated and requires careful control of the various steps in manufacture. The usual type of abrasive wheel contains 7 to 20 per cent resinoid binder by weight, depending upon the grade of wheel that is desired. They are prepared by thoroughly mixing the abrasive grains, the resinoid binder, and a plasticizer, the latter being commonly furfural or a liquid resin. Proportions for individual wheels are weighed and uniformly distributed in steel molds. The mixture is pressed at about 2000 lb. per sq. in. and the molded wheel is then removed from the mold and baked under controlled tem-

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[1] Prepared in co-operation with Bakelite Corporation.

perature conditions. The heat first melts the resinoid, causing it to flow in and around the individual abrasive particles. With continued additional heat, the bond hardens and becomes strong, and these properties are retained permanently after the wheel has cooled. Finally, the wheel is trued to finished size and shape, graded, balanced, speed tested, and inspected. The grade of hardness of the wheel is controlled largely by varying the proportions of resinoid to abrasive.

The resinoid bonded abrasive wheels have been developed for a large number of uses, and today these wheels find applications in practically all lines of grinding. One of the most important uses for this class of abrasive wheel is in the snagging of steel castings and in the grinding of steel billets, where rapid and sturdy operation is necessary. To a large extent the rate at which this class of grinding wheel cuts or removes material is in direct proportion to its peripheral speed. The early synthetic resin bonded wheels, like vitrified wheels, were limited to operative speeds below 6500 surface ft. per min. The present-day modern resinoid bonded snagging wheels operate at 9000 to 9500 surface ft. per min. — an increase of 45 per cent over the earlier wheels. Another field in which resinoid bonded abrasive wheels have particular merit is in the production of thin cutting-off wheels which are made as thin as 1/32 in. and are operated at 16,000 surface ft. per min. In preparing wheels for these uses, phenol-formaldehyde resinoids have been used almost exclusively as the bonding agents.

During recent years there has been a development of the diamond abrasive wheel bonded with phenol-formaldehyde resinoid that has revolutionized the practice of grinding and sharpening of cemented carbide-tipped cutting tools by performing the grinding operation in a fraction of the time previously required. This new wheel, although expensive, is finding many special uses where its quick cutting characteristics make it outstanding in performance.

Alkyd resins are also used in the production of wheels for special purposes, such as stone cutting, sharpening cutlery, and the development of very fine finishes such as the honing of razor blades.

There are many other grinding applications where resinoid bonded abrasives have been found to have advantages over other shaping operations. Among these uses are saw, surfacing, and smoothing wheels, roughing and finishing cams, springs, edging of tools, shaping castings, roughing crankshafts, cutting and finishing gears, threads, and many other applications.

Progressive research and development work in resinoid materials as bonds for abrasives have resulted in an ever widening field of applications. This rapid expansion in the efficiency of resinoid bonded abrasive articles has in turn forced an improvement in other methods of forming materials into finished articles. It has, through improvement in strengths of the wheels, brought about a distinct advance in the machines employed for operating the grinding units.

Plastics in Architecture, Building, and Furnishings

In the architectural field, plastics are finding specialized uses for finishing and accessory type applications rather than for structural purposes.

Plastics plywood and laminates are providing architects with a medium which combines beauty with wear and water resistance. They are being used for interiors of hotels, restaurants, offices, libraries, theaters, hospitals, stores, and banks.

Resins are used in paints, lacquers, enamels, and varnishes, adhesives and coating or impregnating materials, and binders for mastic floor tile. (Indicated in Table 113.)

Plastics for furniture are still not widely accepted, although the transparents have been used experimentally. Sheet materials and extruded strips have been woven and braided to achieve interesting effects, but their use is limited to special fields—hotel lobbies, public buildings, shops, and night clubs. This limitation is due in some cases to high price, and in others to poor design.

For decorative illumination, plastics seem to be better than some of the materials previously used, particularly since the advent of low-temperature fluorescent lamps. They have good light transmission qualities and may be tinted, embossed, or louvered.

Molded plastics have been found to be practical for certain decorative accessories such as curtain rings, clock housings and closet fittings.

Extravagant predictions have been made for the future of plastics in this field. One architect suggests that all horizontal surfaces should be fabricated from plastics — window sills, table tops, built-in counters and benches. Another has designed an unconventional bathtub, wood coated with a synthetic resin for waterproofing. Plans for " The House of the Future " include all-plastics furniture.

Reports from Europe indicate that the substitution-for-metal program of the Nazi government has introduced plastics plumbing there. This may be a molded or laminated tube or merely a plastics shell replacing chrome around a metal pipe.

Laminates. Phenolic and urea laminates are probably the most widely used plastics in this field. They cover wall surfaces, showers and bathrooms, bar fronts and cafe interiors. They surface table tops which receive hard ware in commercial use. They line shelves, telephone booths, swinging doors in public buildings. Wherever a surface which must be resistant to dirt and scratches is needed, a laminate may be used. A list of applications is as follows:

Air ducts
Airplanes
Bar fronts
Barrels
Baseboards
Book cases
Cabinets
Ceiling
Columns
Counter tops
Desk tops
Door surfaces
Drawer fronts
Elevator cabs
Light sheaths (translucent urea)
Name plates
Paneling
Partitions
Protective sheet
Push plates
Shelves
Skiis
Sleds
Table tops
Telephone booths
Toilet seats (laminated core)
Tray
Venetian blinds
Wainscoting
Wall panels
Wall covering

Grades of laminates range from canvas base phenolic, such as core for toilet seats, to paper base translucent ureas used for fluorescent light tube shields. One grade for table tops employs a thin layer of aluminum to make the laminate resistant to cigarette burns. Unlimited colors and color combinations are available. One process photographs a design or picture on the top layer of the laminated sheets, thereby simulating wood grains, marble or landscape scenes.

Plywood. Synthetic resin bonded plywood has made practical exterior applications of plywood in building. By the same processes as are used for aircraft, plywood also may be molded in special shapes for use in the building field, i.e., cylindrical air ducts, columns, bar fronts. A furniture manufacturing process bends the plywood parts over heated molds.

All-plywood houses for the prefabricated housing field have been built but the high cost of synthetic resin bonded plywood as compared with other building materials limits their use at the present time.

The English have found plastics plywood construction to be practical in the tropics where a sheet of aluminum between plywood or laminate and air spaces is used as heat insulation.

Hardwood plywood, cured by fairly high heat and pressure, makes a fine grain type of paneling for interior finishing. It has been used recently in the National Art Gallery in Washington.

Cumarone-indene Resin. Cumarone-indene is used in the coating and adhesive industry. Its principal uses in this field are in the compounding of mastic floor tiles and for impregnating materials for water resistance. It makes possible a light-colored floor tile, resistant to alkalies and moisture. It is used also as a binder in linoleum compounding. It is also used in paints and varnishes.

Synthetic Fibers. Synthetic fibers — rayons, nylon, Vinyon — are to be found wherever fabrics are used in home furnishings; for example, upholstery materials, curtains, blankets; even rugs are being made experimentally from staple fiber rayon. Metallic threads are coated with synthetic resins to prevent tarnishing. (See Chap. VII, Synthetic Textile Fibers, page 344.)

PLASTICS IN THE ARTS

Plastics in Musical Instruments. Plastics have had varied acceptance in the field of music. They are used for musical instrument structural parts, trim, and accessories.

For Structural Parts. Children's toy and beginners' instruments are molded from cellulose acetate. They are colorful, nearly unbreakable, light weight and easy for small fingers to manipulate.

Molded phenolics are used in the recorder, a revival of the Elizabethan instrument. Here the plastic is reported to be superior to wood, particularly in moisture resistance, thereby retaining acoustical properties satisfactorily. The construction is rugged and the surface easy to clean.

The ocarina may be molded from phenol-formaldehyde plastics. The use of these plastics ensures precise, accurate dimensions in the mouthpiece, body cavity, and finger holes.

Piano accordion fabric is a closely woven material coated with pyroxylin (cellulose nitrate).

The reed for clarinet and saxophone is made of acrylic. Some musicians believe plastic is superior to bamboo reed. The tonal and vibrating qualities are excellent and it is more durable than bamboo. It has a different construction, tone, and power control. It may be cleaned by washing because it does not absorb water and will not warp or split.

Finger grips on instrument valve shields are molded from cellulose acetate which is highly resistant to body acids.

TABLE 113. PLASTICS IN ARCHITECTURE, BUILDING, AND FURNISHINGS

Key: X indicates molded or laminated plastic. ⊗ indicates resin. E indicates extruded.

	Phenolics	Phenolics — Cast	Ureas	Cellulose Acetate	Cellulose Acetate Butyrate	Cellulose Nitrates	Ethyl Cellulose	Methacrylates	Polystyrenes	Vinyls	Laminates	Plastic Plywood	Cumarone-Indene	Rayon-Nylon Fabrics
Adhesives		⊗	⊗			⊗	⊗	⊗		⊗				
Air ducts											X	X		
Architects' tools	X					X		X						
Bar fronts											X	X		
Baseboards					E						X			
Bonding agent (plywood)		⊗	⊗											
Book cases											X	X		
Bookends		X	X					X						
Building wall tile									X					
Bathroom fixtures	X			X	X	X		X	X					
Cabinets								X			X	X		
Ceiling								X	X		X	X		
Chair, arm rests	X	X	X	X				X				X		X
Frame								X				X		
Seat and back				X	X		X	X		X		X		X
Clock housings	X	X	X	X		X		X						
Coat hangers		X		X				X	X	X				
Coatings for fabrics		⊗	⊗			⊗		⊗		⊗				
Columns											X	X		
Cord pulls				X				X		X				X
Cornices								X	X		X	X		
Counter tops											X	X		
Curtain rods					E			X						
Rings				X				X		X				
Curtains, waterproof				X						X				X
Decorative figures		X		X		X		X						
Decorative illumination			X	X				X	X					
Desks and desk tops	X										X	X		
Door cases					E						X	X		

TABLE 113. PLASTICS IN ARCHITECTURE, BUILDING, AND FURNISHINGS (*Continued*)

	Phenolics	Phenolics — Cast	Ureas	Cellulose Acetate	Cellulose Acetate Butyrate	Cellulose Nitrates	Ethyl Cellulose	Methacrylates	Polystyrenes	Vinyls	Laminates	Plastic Plywood	Cumarone-Indene	Rayon-Nylon Fabrics
Door chimes housing		X	X	X										
Door knobs	X	X	X	X	X	X		X						
Door surfaces											X	X		
Drawer fronts		X		X				X			X	X		
Elevator cabs, interior					E						X	X		
Fabric coatings		⊗	⊗			⊗		⊗		⊗				
Firescreen, decorative	X							X						
Floor tile		⊗			E					X			⊗	
Furniture casters	X		X											
Furniture trim	X	X			X			X	X	X				X
Hampers				X	X	X								
Handles	X	X	X	X				X						
Handrails					E			X	X					
Hatstand		X						X						
Impregnating (fabric)		⊗	⊗					⊗		⊗			⊗	
Kick plates	X	X	X	X						X				
Lamp bases		X	X					X		X				
Shades			X	X							X			X
Sheaths (fluorescent)			X	X				X			X			
Light fixtures		X	X	X				X						X
Mirror frames								X						
Models, architectural		X		X		X		X						
Moldings, wall					E									
Panel moldings					E									
Paneling											X	X		
Paints, lacquers, enamels*		⊗	⊗	⊗		⊗	⊗	⊗		⊗			⊗	
Partitions				X				X	X		X	X		X
Pendants or prisms (light fixtures)								X	X					
Protective sheets (walls)				X			X			X	X			
Push plates	X	X	X	X							X			

TABLE 113. PLASTICS IN ARCHITECTURE, BUILDING, AND FURNISHINGS (*Continued*)

	Phenolics	Phenolics — Cast	Ureas	Cellulose Acetate	Cellulose Acetate Butyrate	Cellulose Nitrates	Ethyl Cellulose	Methacrylates	Polystyrenes	Vinyls	Laminates	Plastic Plywood	Cumarone-Indene	Rayon-Nylon Fabrics
Roofing													X	
Screens				X				X			X	X		
Shelves	X							X			X	X		
Shower nozzle					X									
Spray nozzle	X				X									
Soap dispensers	X			X										
Staircase, balustrades					X			X	X					
Stair nosings					X									
Table, frame								X				X		
Top	X							X			X	X		
Edging					X			X						
Telephone booths											X	X		
Tile, building (wall)									X					
Floor	⊗									X			⊗	
Roofing								X	X				⊗	
Toilet seats	X		X	X		X		X			X			
Flush valves	X													
Tank floats	X													
Towel bars				X		X		X		X				
Trays								X			X	X		
Venetian blinds										X	X	X		
Varnish component	⊗		⊗										⊗	
Vases			X					X						
Wainscoting					X					X	X	X		
Walls, exterior												X		
Panels				X				X			X	X		
Covering				X						X	X			X
Moldings					E		E							
Plates	X	X	X					X						
Window ventilators	X		X									X		

Transparent acrylic plastics are used for instrument mouthpieces. While the material is light weight, tasteless, odorless, and does not become heated, it gives a different tone than wood and therefore has not been generally accepted. Transparency, however, gives the acrylic mouthpiece the advantage of enabling an instructor to see a beginner's lip formation, and has proved valuable in teaching.

Piano manufacturers utilize cellulose nitrate for white keys, molded phenolic for black. Both plastics are moisture and acid resistant.

Harmonica mouthpieces are sometimes molded phenolics.

For Trim. Cellulose nitrate sheeting is used for protective and decorative trim on drums, harmonicas, banjos, guitars, and accordions. It is available in pearled and mottled materials as well as plain colors giving an inexpensive yet durable and attractive finish.

An interesting effect is achieved at night or in dark auditoriums by using edge-lighting acrylics to trim musical instruments. Rods of the plastic are formed in the shape of the instruments and fastened to them with transparent tape. On clarinets and saxophones small superstructures of wood hold the rods in position. The rods are illuminated by tiny flashlights whose light is transmitted through the length of the rod by the property of internal reflection. The plastic increases the weight of the instrument only slightly.

For Accessories. Picks for banjos, guitars, and mandolins are usually cellulose nitrate.

Nylon-coated strings are used for the violin, viola, cello, and double bass viol. Nylon is used as a protective covering for gut string. Gut has the best tone for strings but is not moisture and perspiration proof. Nylon has the same tone quality as the gut string but alone does not have longitudinal resistance. It is too soft and light and vibrates only in the place where it is touched. The method of coating gut with nylon has provided a string which is a boon to musicians whose fingers perspire easily.

Xylophone mallets are molded from acrylic or cellulose nitrate. They are more satisfactory than hard rubber.

Phenolic, acrylic, and cellulose nitrate are used for batons. They are light weight, easy to handle, and retain an attractive appearance.

Chin rests for violins are molded from phenol-formaldehyde or fabricated from acrylics. They are sanitary, inconspicuous, and do not cause friction or irritation.

Cellulose acetate louvered sheeting is used to diffuse light from fluorescent tubes on music racks.

Cast phenol-formaldehyde may be worked and used as a slide on a saxophone cord.

Plastics and Phonograph Records.[2] The development of phonograph records parallels to a certain extent the development of plastics.

Early phonograph records were molded from hard rubber and were successful from the standpoint of perfection of molding and sonorous qualities. Scratching noises and the expense entailed in the method of fabrication led to the development of shellac records in 1888-89. These contained silica, china, blanc fixe, gas black, shellac, and flock and were pressed in a toggle press.

After Baekeland's discovery of phenol-formaldehyde plastics, Edison tried using a phenolic surfaced record with a core of softer but similar material. Placed on the market

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[2] Prepared in co-operation with H. P. Billings of Radio Corporation of America.

between 1910 and 1916, these were two to three times as thick as the records of today and frequently peeled in the sound grooves. Their molding cycle was longer than that of shellac.

Cellulose nitrate has been used either as a paper coating on which sound grooves were applied or as disks of thin translucent plastic. High flammability limited their sales.

Cellulose acetate compositions have been introduced more recently but have not yet been perfected for widespread commercial use. Demolding faults and a tendency to cause the needle to drag must be corrected before the materials can be considered competitive.

In the early 1930's an excellent material was found in the vinyl resins. These have come into general use for the more expensive disks used in radio broadcasting work. They possess excellent reproduction qualities but owing to high temperature of fusibility their molding cycle exceeds that of shellac. It is not unlikely that developments will bring about advancement in the art to a broader use of this type of resin.

Record manufacturers prefer thermoplastic resins such as shellac rather than thermosetting resins in record compositions for the following reasons:

1. The molding cycles of shellac compounds are short.
2. Resins, like shellac, have a softening point sufficiently above atmospheric temperature to withstand warpage reasonably well.
3. Compounds of thermoplastic resins have scrap value permitting flash from the press and records rejected for minor defects to be easily reclaimed.

Shellac has qualified in almost every requisite for record composition. When used in combination with other proper ingredients, it gives the desired qualities in the record, such as strength, wear resistance, warp and moisture resistance.

In the process of compounding, extreme fineness of particles of the ingredients and the absence of foreign matter are required in addition to proper plasticity.

The properly weighed proportions of the components are mixed mechanically in dry form. The proper weight of the dry mixture is charged into a plastics mill. To effect mixing, the stock is heated until fused and as the shellac softens, the particles of the fillers are wetted with liquid resin. After a sufficient predetermined time interval, all particles of filler become dispersed into a virtually homogeneous mass. Rolls similar to the type used for compounding rubber are used for sheeting. The stock is sheeted and scored into rectangular " biscuits " of appropriate size to give enough stock for the finished record. The " biscuits " are broken from the sheet of stock when it is cold. This preparation provides preform stock ready for the pressing operation.

The pressing or molding of the record is performed on a hydraulic press. Each plate of the press bears a record die (a square block of steel) cored for conveyance of steam and cold water. The matrices are fitted into the two individual dies and held by clamping rings. When the press is closed, matrices and rings (top surface of the latter slightly above grooved surface of matrix) form a cavity for the record. This constitutes a flash-type mold, excess stock being squeezed beyond the ring edges in the pressing operation.

The pressing or molding operation consists of preheating flat rectangular " biscuits " on a steam-heated table until soft. Meanwhile the matrices have been heated to the proper molding temperature by the steam in the dies. Labels of the record are molded into the surface of the composition. One label is placed face down on the lower matrix, the hole fitting over a short pin which forms the record center hole. The other label is held similarly against the upper matrix. After pressure has been applied, the steam is shut off, and cold water is circulated through the die thus setting the composition in the form of the record. The finlike flash at the edge of the record is removed, and polishing is performed on a lathe. The inspected record is inserted in the commercial envelope ready for shipping.

Plastics in Sculpture. The acrylics (methyl methacrylate) are at present the most popular plastics medium for sculpture. Their versatility is striking, their appearance quite original. They demand a special type of expression and have caused widespread interest among various artists.

Acrylics are noted for their flexibility, luminous beauty, and strength, although they give a delicate appearance. They have the unique ability of carrying light around curves and from a source to an outlet without giving off light in transit, the material becoming edge-lit. The extremities of rods show points of light. These properties add a new dimension to sculpture.

Cubes and prisms may be cut from acrylic bars; sheets may be bent by warming to a moderate temperature. Blocks can be hand tooled, machined, and polished and parts can be cemented together.

Used in intaglio plaques, the plastic may be illuminated from any angle and achieve a three-dimensional effect. The plaques are smooth surfaced on three sides with a roughened carved interior and back. Sculptors take advantage of edge-lighting and light diffusing properties to create effects and impressions rather than pictorial features.

It is possible to combine acrylics with glass to give the effect of Gothic stained glass in mosaics.

Cast phenolics are easily worked and are probably the most widely used plastics among amateur sculptors. Available in forms from transparent to opaque and in a wide range of colors, they are used for figures, vases, and shapes of many types.

Cellulose acetate is molded for inexpensive religious and decorative sculpture including human figures, crosses, and altar trim. The shapes are hollow and light weight. The acetate sheet material is used with glass for mural windows. Dry-point etching is simplified by tracing a picture through acetate sheets.

Laminated urea and sheet vinyl are often used in combination with other materials in murals and decorative wall panels.

Plastics in Handicrafts

Cast phenolic resins are suitable for home workshop use because they can be worked with ordinary equipment designed for wood- or metal-working. Other types, such as molding powders, require special dies shaped like the finished product, expensive equipment, and are most suitable for making large quantities of identical objects.

Other plastics are available in rod and sheet form but are not so adaptable for homecraft work as cast resins. Caseins warp in any sheet size over 4 in. square, and absorb water. Cellulose nitrates are flammable and available only in thin sections. Cellulose acetates are slow-burning, slow-curing, have good color, but are expensive in the thicker sections, as well as being affected by various solvents and chemicals. Ureas are not completely acid-resisting and may swell in the presence of moisture. Laminated materials often contain fillers which make machining difficult.

A hobby kit containing cast phenolic shapes is practical for home and workshops because the material can be worked with ordinary wood- or metal-working tools. It has the additional advantage of being odorless, water-, fire-, acid-, alkali- and alcohol-proof and permanent in color. Each kit contains an assortment of sheets, tubes, and rods of varicolored plastics together with necessary tools and supplies. Instruction and pattern sheets are provided for making ash trays, novelty jewelry, boxes, picture frames and decorative articles.

Plastics in the Automotive Industry

In the automotive industry (see Fig. 21.1) the plastic most widely used for decorative purposes is cellulose acetate. It cannot be used in large sections without support and will not withstand excessive heat or cold when molded over large metal inserts. It has a large range of colors and is usually injection molded. Some plasticizers used in the material have a tendency to condense on adjacent painted metal parts; therefore they should not be used nearer than 1 in. from painted sheet metal. The most extensive applications are for dial handles, knobs, radio cover panels, switch plates, and horn buttons.

Cellulose acetate butyrates are more resistant to weather and shrinkage than the acetates, and the plasticizers used have less effect upon paint. They have replaced the cellulose acetates for many parts and have found new applications — instrument panels, steering wheels, hardware trim, emblems, tail lights.

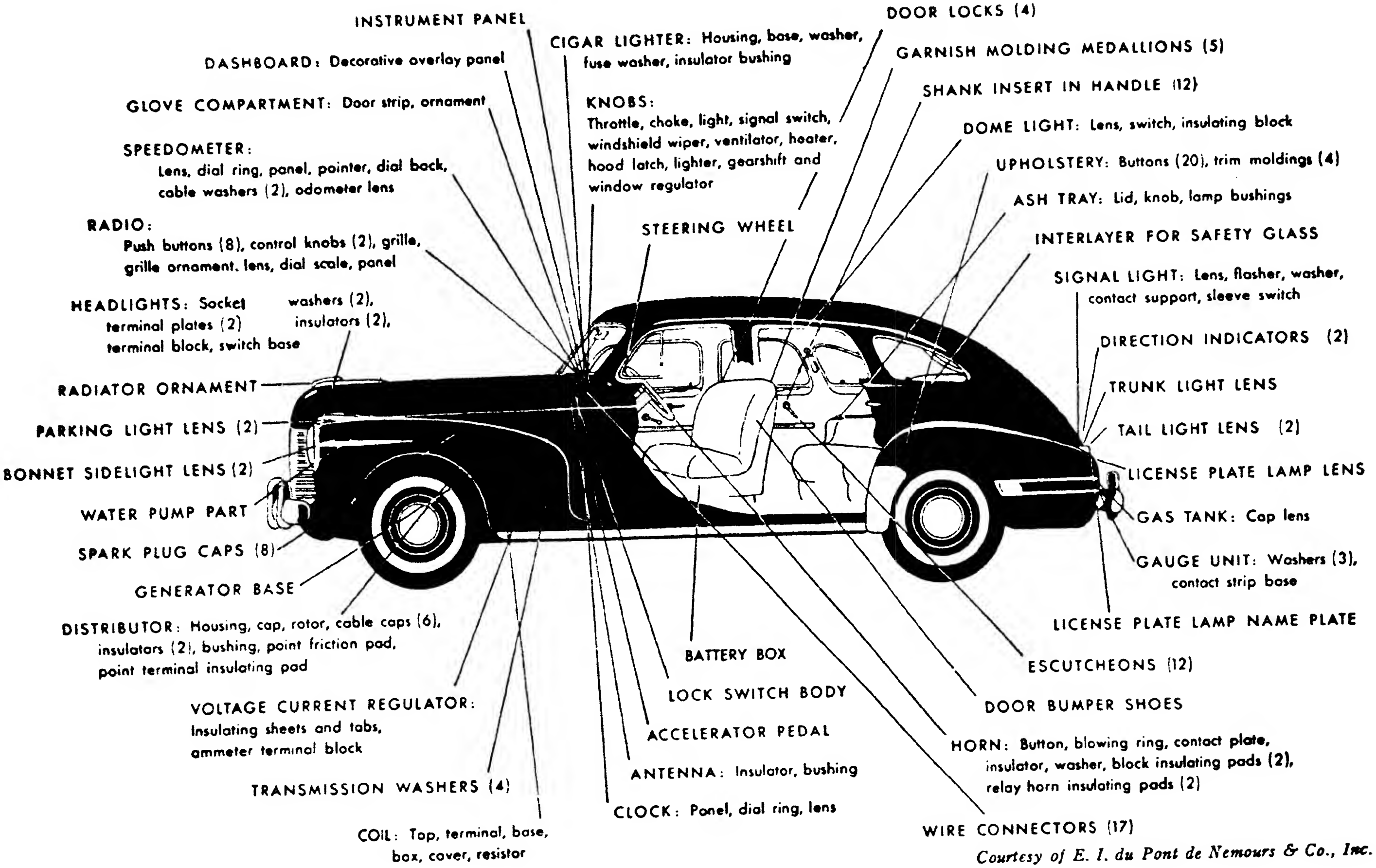
Cellulose nitrate was one of the earliest plastics used in the automotive industry, but because of its flammability, it is used now only in places where it will not come in contact with cigarette ashes or matches, i.e., instrument dials, clock faces.

Methyl methacrylate resins are used particularly where water-white plastic is desired for an edge-lighting effect. Cast methacrylates will withstand any temperatures encountered by the automobile body. Compression molded acrylics have been improved so that they will withstand most conditions. Injection molded methacrylates, however, are somewhat lacking in heat resistance and should be used only with the greatest of care. It can be said, nevertheless, that these two are improving rapidly and within a short time should be satisfactory for many uses in the injection molded form.

Polystyrene has many desirable characteristics in that it is stiff and of higher heat resistance than most of the thermoplastic materials. On the other hand, it is more brittle than thermoplastics in general.

This material is used now only in places where the plastic is shielded from any possible contact with gasoline or cleaning fluids. An example of this is instrument pointers and dials. Safety solvents will change these polymers into a gummy mass on contact. Gasoline attacks them also. There is a good chance that this weakness will be overcome, and if such is the case, they can become a great competitor for the clear or light-colored plastics in automobile furnishings.

Urea-formaldehyde plastics were probably the first light-colored plastics to be used in the automotive industry but were originally discarded because they could not be



Courtesy of E. I. du Pont de Nemours & Co., Inc.

FIG. 21.1 — Plastics parts on an automobile.

injection molded and were not available in the depth of color desired. These resins are now available in a good range of colors and are only awaiting new methods for economically molding thermosetting plastics.

Battery boxes are cold molded from bituminous plastics.

Molded phenolics are used where good dielectric strength is required, as in the electric parts of automobiles including distributor heads, switches, coil parts, magnetos, instrument housings, and molded ignition parts. They may be used as inserts in thermoplastic materials for decorative effects.

Laminated phenolics are used as insulating materials, gears, and instrument board backing, also interior trim in taxis.

Casein was once used for horn buttons but has been replaced by cellulose acetate and cellulose acetate butyrate.

The principal use of vinyl in the automotive industry is for safety glass.

Alkyd resins are used for finishing automobile bodies. (See Coatings, page 437.)

The use of rayon tire cord has greatly increased the mileage and serviceability of automobile tires. This is because: (1) cotton cord, previously used, loses its strength as moisture is removed, while rayon tire cord increases in strength, and (2) cotton tire cord decreases in strength by 30 to 56 per cent at 480° F. against only 12 per cent for rayon.

The cord type of rayon yarn is supplied manufacturers on 800-lb. beams (large spools). (See also Modified Rubber, page 397.)

At the present time, the "all-plastic" automobile is being widely discussed and visioned. Several manufacturers have completed experimental models using various types of plastics. One company made an acrylic demonstration model which showed engine parts and construction through its transparent sides. The Ford Motor Company has a model molded from soybean-filled phenolic. Another manufacturer coats a wire base with ethyl cellulose for an automobile body.

It is difficult to predict which type will come into commercial production first, but it is safe to expect a wider use of plastics in the automobile of the future.

Synthetic Resins in Airplane Construction[3]

From an engineering point of view, plastics as materials in airplane construction fall roughly into three categories:

1. Decorative or utilitarian purposes only, and not considered indispensable.
2. Secondary parts in the structure of the airplane and considered indispensable because of the savings in weight, cost, and efficiency over previous materials.
3. Most important, the primary structure, or parts thereof, upon which depends the structural integrity of the airplane.

Airplane applications of plastics run the entire gamut of thermoplastic and heat-reactive materials and include castings, moldings, and laminated products as well as liquid resins and powdered materials for adhesive purposes. Also, in a separate class, are the resinous bases for paints, varnishes, and lacquers.

The first group, following the example of the automobile industry, includes throttle knobs, buttons, handles, and name plates from cast, molded, and laminated plastics,

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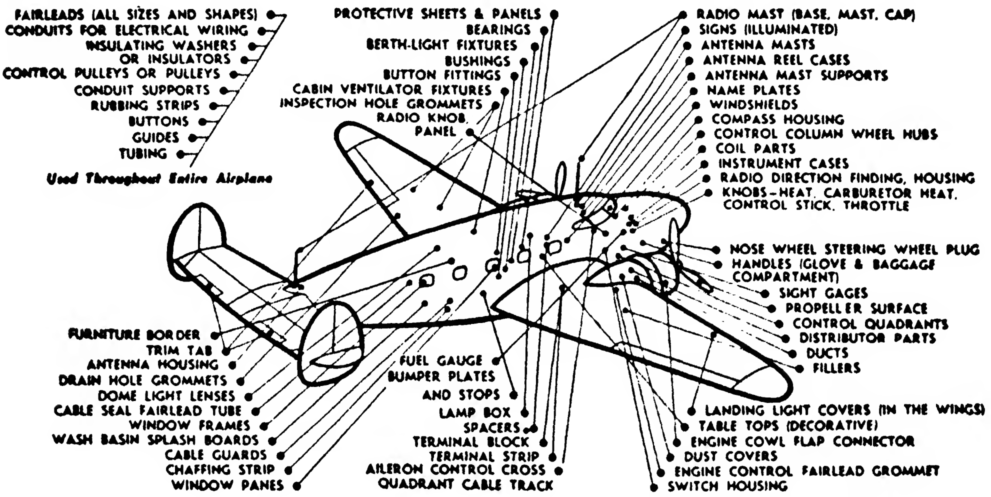
[3] Condensed from report by H. N. Haut, Chief Inspector, Bellanca Aircraft Corporation.

and electrical switch panels and junction boxes from high dielectric strength laminated materials.

Economy, weight saving and interchangeability are found in the fabrication of instruments and magneto parts. Even all-metal propellers have been made with plastics parts in their vital hubs.

With the increase in popularity of the lower priced commercial airplanes, standards of luxury and eye appeal were on the rise before the war and the use of plastics in this field may be expected to increase.



Courtesy of E. I. du Pont de Nemours & Co., Inc.

FIG. 21.2 — Plastics parts on an airplane.

The second group, far more important than the first to the engineer and designer, is represented by the plastics that carry loads of a secondary nature and effect economies in weight or efficiency.

An outstanding example is the thermoplastic, water-clear, sheet resin from which windows, windshields, machine gun turrets, and the like are made. Consider the specific gravity of glass of 2.6 as compared to the 1.18 of a methyl methacrylate resin, keeping in mind that the efficiency of an airplane is measured by its weight, and it is an easy matter to evaluate the contribution of this material.

A high order of workability in the formation of shapes and compound curves so necessary to efficient airplane design makes it a well-nigh indispensable material used as standard equipment on all military and commercial airplanes, with the exception, perhaps, of those in the very low cost brackets where price is the vital consideration. In these we still find the cellulose base transparent sheets of much lower clarity and permanence.

Throughout the control system of the modern airplane, we find control cable pulleys, cable fairleads, and chafing strips of laminated phenolic materials.

Reports of fallen German aircraft indicate the structural use of plastics materials in their design. This is a logical extension of applications already made in this country.

The principal interest of engineers and manufacturers of aircraft today, especially in the light of the present war program, is the *structural* application of plastics. The importance of any developments that will increase production, improve the product, reduce costs or weight, or reduce the percentage of highly skilled labor required, can hardly be overemphasized, and it is undeniable that these advantages go hand in hand with plastics.

Investigations have taken the form of actual construction of component parts, varying in importance from elevator tabs and bomb bay doors to complete wing and fuselage structures. Again the types of resins are unrestricted, covering a variety of both thermoplastic and thermosetting resins, as well as a number of fabricating processes.

At the outset, it was recognized that the pure synthetic resins lack the strength, toughness, and resilience to be applied as structural materials as they are, and it was obvious that a reinforcing medium was needed. Moreover, it was recognized that the reinforcement could not be introduced as a filler of flour or macerated canvas, or as an alloy in metals since the amorphous character of the material could hardly be improved that way.

De Bruyne[4] worked primarily with long reinforcing fibers, such as cotton, silk, flax, and hemp, by packing the fibers tightly together and using just enough phenolic resin to fuse them together. By this method, tensile strengths of well over 100,000 lb. per sq. in. were obtained with specific gravities not exceeding 1.55. He also found that by applying an initial load to the fibers during the molding operation, the modulus of elasticity could be substantially increased. If the ratios of strength over specific gravity and elastic modulus over specific gravity are used as an index of structural efficiency, it is seen that the tensile efficiency far exceeds that of the metals and wood. However, this type of construction has no appreciable effect on the compressive strength, which increases but little over the pure resin. Obviously then, the use of this material was seriously limited. Other investigators, notably Reichers,[5] reported similar results with other vegetable fibers.

The conventional fabric-reinforced laminated material has found a variety of uses in aircraft, but structurally is characterized by a low modulus of elasticity compared with other materials, and this lack of stiffness has been the primary obstacle to its structural use. As early as 1924, propellers molded from tough, strong materials of this nature were actually built and used, but have since faded from the market. It is suspected that the lack of stiffness may have been a contributing cause.

Although the persistently low modulus of elasticity may have impeded its progress structurally, its other virtues of toughness, strength, and water resistance have made it a very desirable product, so much so that it has recently appeared as a completely formed subcontrol surface of approximately 1 sq. ft. area, and by now is probably in production on a well-known airplane.

Probably the most significant of the early developmental work has been in connection with the use of wood as a reinforcement for the plastics. It is a paradox that the bulk of the literature and earlier experimental work comes from Europe, notably England and Germany, where it is necessary to import a large part of the wood requirements.

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[4] De Bruyne. N. A., " Plastic Materials for Aircraft Construction," *Journal of the Royal Aeronautical Society*. Vol. 41, July (1937).

[5] Reichers, K., " Plastics in Aircraft Construction." N.A.C.A. Technical Memorandum No. 841, November (1937).

Kraemer[6] and King[7] have reported on the properties of wood-reinforced resins and subsequent work in this country confirms their findings to a great extent.

The basis of the unusual affinities these materials have for each other lies first in the disparity between the tensile and compressive strength which is a characteristic of wood, and the inverse difference in the resins. Sitka spruce, for example, is much higher in tensile than compressive strength, and a phenolic resin on the other hand is much stronger in compression than tension. Obviously a combination of the two results in vastly improved and more nearly balanced properties. The improvement is further enhanced by the natural adhesive properties of the resin.

The combining of wood and resin to produce the improved product is ordinarily accomplished in one of two ways, either by simply laminating the thin veneers with a resin adhesive of the liquid or film type, under heat and pressure, or by first impregnating the veneers with resin by soaking, vacuum or pressure methods, and then applying the necessary heat and pressure to complete the polymerization cycle of the resin. In either case, the increase in strength is accompanied by an increase in density. It is noteworthy that the increase in density is influenced both by the pressure employed and by the percentage of resin in the construction, the resin having a higher density than the wood. A study of reports[8] on these various constructions indicates that the density increase, which is due primarily to pressure, increases the tensile strength at a greater rate than the compressive strength, whereas the density increase due to the higher resin percentage increases the compressive strength at a greater rate. It is obvious, then, that by suitable manipulation of the variables, a wide variety of physical properties and densities may be had within the limits of the material.

A specific example would be the values reported by Tiltman and Ellison[8] of birch laminations impregnated and compressed to a specific gravity of 1.0. The construction yielded a tensile of 22,000 lb. per sq. in. and a compressive strength of 21,000 lb. per sq. in.

Bernard, Perry, and Stern[9] on the other hand laminated and compressed birch specimens to a specific gravity of 1.05 without impregnation, with a resulting tensile of 19,000 lb. per sq. in. and compression strength of only 11,700.

Another variation of this process is the differential impregnation of wood in which the density of the board is varied from one end to the other by progressively restricting the amount of resin absorbed. The same result may also be accomplished by differential pressure. Visualize a pile of veneers between two parallel planes which are press platens. If the pile is thicker at one end than the other, the pressure will be greater at the thicker end, and the density correspondingly higher.

The advantages of differential impregnation have already been exploited in Europe in the fabrication of propellers, the particular benefit residing in the characteristic stress distribution along the blade. Extremely high stresses are encountered at the hub section, tapering off to zero at the tip and any excess weight especially near the tip is magnified by centrifugal force and translated into higher stresses at the hub.

[6] Kraemer, O., "Synthetic Resins and Their Development for Airplane Structural Materials." *Jahrbuch der Deutschen Versuchsanstalt fur Luftfahrt* (1933).

[7] King, E. P., "Plastics at Hatfield," *de Havilland Gazette*, February (1939).

[8] Tiltman, A. H., and Ellison, A. E., "New Structural Materials." *Aircraft Production*, December (1938).

[9] Bernard, R. K., Perry, Thomas D., and Stern, E. G., "Superpressed Plywood," *Mechanical Engineering*, March (1940).

Efforts to obtain these differential materials from manufacturers in this country have thus far proved fruitless, but some progress has nevertheless been made by using the highly densified wood at the hub section and splicing to it wood of a lower density with heat-reactive synthetic resin adhesives.

Complete descriptions of the working characteristics and physical properties of the laminated and impregnated materials may be found in the literature[4,5] accompanied by comparisons with more conventional structural materials and discussions of their relative merits in airplane structures, but comparatively little of it has actually been used. The average airplane manufacturer has been found very open minded and willing to exploit the new materials, but actually very little can be done with a small block in a glass case, so to speak, and until structural sizes are available, advancement will necessarily lag.

Resin bonded plywood has probably contributed more to the realization of the value of plastics in aircraft than any single factor. Before the advent of resin bonding, plywood had never been a favored material with aircraft designers, principally because of its indeterminate strength, which with the animal adhesives, varied with the vagaries of the weather and delaminated in the humidities of a temperate climate. The introduction of casein glue and its subsequent improvements added to the reliability and water resistance, but not sufficiently to merit the structural confidence of engineers, especially where tropical exposures were to be considered, and casein glued joints of the day were generously reinforced with nails and profusely protected by surface coatings.

The resin bond in plywood, which definitely fixed its reliability, reawakened the interest of the wood-minded engineers, with the subsequent and ever increasing appearance of plywood structures. The long-time exposure tests by Brouse[10] covering a period of four years at the Forest Products Laboratory went far to establish the durability, water resistance, and resistance to parasitic growths of the phenolic bond.

The desirability of using plywood in place of metal in certain applications is best illustrated by examining a typical stressed skin wing or a typical monocoque fuselage of metal. It is seen that even the most ingenious design cannot avail itself of the full compressive strength of the metal, but fails by local buckling before the ultimate metal strength is reached. There are, therefore, a variety of stiffeners, in the form of angles, channels, and corrugations, used to support the unstable skin. They must also be rigidly attached to the skin with closely spaced rivets and with a corresponding increase in the drag of the surface.

Clark[11] has shown that for a given weight, a thicker shell of lower density material without stiffeners will support a greater stress than a metal shell with stiffeners, and upon this thesis is founded one of the plastics airplanes of today. These findings and the research already discussed, accompanied by a continued improvement in the technique of forming compound curves of plastics reinforced wood, and a utilization of the plastic properties of the plastics, i.e., their susceptibility to forming and to remaining formed (thermosetting resins), will result in the plastics airplane.

Three types of plastics airplanes have been developed and described in current literature. Essentially, all three are based on plastics bonded or plastics reinforced

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[10] Brouse, Don, " Exposure Tests on Plywood," Forest Products Laboratory, Madison, Wisconsin.

[11] Clark, V. E., " Low Density Structural Material," *Aero Digest*, July (1939).

wood. True to tradition, one is reported to use a thermoplastic resin of the vinyl butyral type, one a phenolic resin, and the third a urea-formaldehyde resin.

The one using the vinyl butyral resin is constructed by impregnating or soaking thin veneers and by tightly winding them around mandrels or forms, the number of layers determining the strength of that portion of the structure. The mandrels and forms are then assembled and bound together by additional veneers so as to form the skin and bind it to the component parts, in such a way as to make the mandrels removable after the heat treatment.

Upon completion, the entire assembly is encased in a rubber bag from which the air is exhausted and it is then placed in an autoclave and exposed to about 80 or 90 lb. of steam pressure until the impregnated veneers are fused together. The mandrels and the outer surface of the structure must necessarily be treated to prevent the adhesion of the resin.

The second is reportedly constructed by laying carefully fitted veneers, prepared with a liquid phenolic resin, on a male form and by subjecting them to mechanical pressure and simultaneous heat, while the third is prepared on a male form with a urea resin and is then encased in the rubber bag followed by the autoclave treatment.

The conception of plastics and the uses of plastics in airplane structures do not entirely revolve around the molded structures. There is another, more conservative school of thought which bases its design on the utilization of natural wood where efficiency of design, ease of manufacture, and sustained supply indicate, and of prefabricated resin bonded and resin reinforced products, plywood, of course, being the most common.

The use of wood and glue in aircraft manufacture is as old as the industry itself. As a structural material its value is undisputed. High strength-weight ratio, high resilience, corrosion resistance, ease and rapidity of fabrication on high-speed machinery, and the like are all characteristics associated with wood.

In the important matter of joint efficiency, wood again claims an advantage over the other materials. The most perfect weld in a steel structure is apt to reduce the strength of the base metal adjacent to the weld. The rivet demands the sacrifice of rivet holes. Even the spot weld converts its area of wrought base metal to a casting with consequent reduction in strength, while the glued joint does not require such sacrifices.

This optimistic picture, however, is not without its blemishes, since it must be recognized that the many advantages of wood have been offset to a great extent by the lack of permanent dependable joints in component parts. The great majority of failures were observed to be not in the wood itself, but in the joints.

Exposure tests conducted by Brouse[10] at the Forest Products Laboratory have substantiated that joint failures with animal, vegetable, and casein glues could be attributed primarily to a chemical hydrolysis of the glue, a decomposition by parasitic micro-organisms or a mechanical failure due to stresses developed in the wood, the last being particularly serious if the glue is in a softened condition.

Certain resin adhesives could resist water at elevated temperatures indefinitely and are completely immune to the destructive micro-organisms. At the same time, they resisted chemical hydrolysis, and were much stronger than the common glues. But those resin adhesives were used in hot presses at temperatures between about 250° and

325° F. and it was clearly impractical to hot press an assembled wing panel. The apparent need was then a cold-setting resin adhesive.

Months of extensive research led to the development of a cold-setting urea adhesive suitable for this purpose. Through its use the problem of assembling complete airplane structures has been solved.

Its use in production has been approved by the Civil Aeronautics Authority. In addition, military airplanes incorporating these principles are being constructed for the U. S. Air Corps in connection with our war program, but a description of them is not permitted at this time.

With the rapid growth of both the plastics and the airplane industries, it is difficult to foretell their exact future relationship, but we may safely predict that the synthetic resins will increasingly continue to infiltrate the airplane structures and that their use will be associated with wood; as a reinforcement for the new prefabricated structural materials, as a reinforcement, binder, and surfacer in the molded units, and as a bonding agent in the structures of wood and prefabricated materials.

PLASTICS FOR DISPLAYS

Designers of display fixtures, and window dressers, look upon plastics as practical and appropriate materials for their use. A number of different types of plastics have found their way into this field. Among them are: cast phenolics, cellulose acetates, acrylic resins, and various types of vinyl resins, urea and molded phenolics.

Because plastics are attractive, sturdy, easy to clean and maintain, and withstand wear, they are somewhat of a " natural " in this field. Counter displays such as racks for gum and candy, holders for packages of cigarettes, and other such items that can be produced in quantities are finding great favor, not only because they can be turned out inexpensively, but their sales appeal means money. They encourage buying.

Display units must show the merchandise to its best advantage. There must be a focal point of interest, and the advertising message of the product must in some way be related to the display fixture. Because of the easy workability of some plastics, because of their wide color range and the fact that many of them are available in opaque, translucent, and transparent forms, they have lent themselves admirably to this field of displays.

Acrylics. The acrylic resins in cast form are comparatively easy to use. Where sheets, rods, and bars are employed, they can be machined to various shapes. The material may be heated to the temperature of boiling water and can be bent by hand into simple forms. It can be sawed, planed, or drilled with ordinary woodworking tools. The material is readily workable without any great investment in fabricating equipment.

The acrylics are more transparent than glass and less than half as heavy. They are practically unbreakable. Merchandise shown on racks of crystal-clear plastic is not robbed of its appeal by having attention directed toward the display fixture. Although beautiful and brilliant in its own way, the display rack is unobtrusive. Among the items for which acrylic displays have been made are: hosiery, jewelry, gloves, cosmetics, neckwear, handkerchiefs, hats, bathing suits, rings. Many of these fixtures can be used to show more than one type of merchandise.

The light properties of this particular type of plastic make it valuable in this field.

TABLE 114. TYPICAL APPLICATION OF PLASTICS IN AVIATION

	Phenolic, Molded	Phenolic Resin Laminate	Urea, Molded	Urea Resin Laminate	Cellulose Plastics	Methyl Methacrylate	Plastic Plywood	Polystyrenes	Vinyls
Antenna masts	X				X	X		X	
Bearings	X	X							
Bomb bay doors							X		
Cockpit enclosures					X	X			
Cowlings					X	X			
Doors							X		
Distribution and coil parts	X								
Escape hatches						X	X		
Escutcheons	X		X		X	X			
Fairleads	X	X							
Fuselage							X		
Gears	X	X							
Gun turrets					X	X			
Handles	X		X		X	X			
Ignition parts	X	X			X			X	X
Instrument housings	X	X	X	X		X			
Instrument panels	X	X	X	X		X		X	
Interior panels	X	X	X	X			X		
Knobs	X		X		X	X			
Lights and fixtures	X		X		X	X		X	
Plywood parts		X		X					
Propeller blade		X		X			X		
Pulleys	X	X							X
Radio parts	X							X	X
Wind screens					X	X			
Windows					X	X			X
Window frames	X	X	X	X					
Wings							X		
Wing tabs	X	X	X	X			X		
Wiring insulation	X	X			X			X	X

Its ability to " pipe " light even around curves, plus its edge-lighting characteristics, can be used to advantage where lighting effects are important. Because of these qualities in the material, it is possible to light displays made of acrylic resins from concealed sources and direct the light to any desired point. Carved or etched lettering or designs on the surface of the display will also be lighted, while the polished surface will remain almost invisible.

Displays of these transparent plastics seem to follow along the simple, modern lines of design. They make use of the smooth surfaces of the material, combining planes, angles and curves in pleasing shapes appropriate for the merchandise to be displayed. Dealers like fixtures not only because they are sales-attracting, but also because they are easy to maintain, they will not crack or chip, and they withstand hard wear.

Translucents. Translucent plastics of various types (laminates, sheet material) from sheet stock or molded, are frequently used for backgrounds for signs, or for lettering. Three-dimensional letters mounted in a molded plastic frame enclosing lights make a sign that is attractive, permanent, and luminous. One type of sign employs a light box punctured with tiny holes. Colored plastics pegs or plugs are inserted in these holes and these catch the light from the concealed source within and carry it to the outside. The effect simulates myriads of small electric bulbs. Signs of this type can be combined with edge-lighted panels, the panels being slipped into various slots provided for this purpose in the box. A single bulb is sufficient to illuminate all of the various points.

Cellulose acetate is one of the most widely used plastics in the display field. The ease with which this material can be handled is one of the reasons for its popularity in the sheet form. Heavy sheets of this plastic in colors and translucent form can be cut out to make decorative units for windows and combined with spot lights from the side. Certain types of acetate sheets give off a peculiar, luminescent glow at the edges. Letters and numerals for prices are cut from these sheets for shop windows.

Life-sized mannequins as well as leg forms are now made of acetate, the slush molded type. The toughness of this material and its easy fabrication make it worth while in display departments.

One shop that specializes in Southern wear for ladies drew customers in from wintry streets by fixing their windows so that they represented the warm, sultry beaches of Florida. Across each window they had stretched clear thin sheets of cellulose acetate. These sheets were fastened at the top and bottom leaving a space between the window glass and the plastic. Looking at it from the outside one experienced the sensation of seeing heat waves rising from below; a simple trick with the aid of plastics.

Shoe stores find plastics useful to help them display their shoes more attractively. Foot forms in clear and in colors fit inside the shoes and help display merchandise in a practical as well as decorative way. Large rings of the crystal-clear plastics are suspended from the ceiling and shoes are hung by the heels to attract attention.

Colorful and illuminated signs for beer and razors, pedestals for liquor bottles and perfumes, display trays for lipsticks, lighted signs telling directions and identifying buildings — all are made with the assistance of plastics. The story of plastics for displays has only just begun.

PLASTICS IN THE ELECTRICAL INDUSTRY

Modern commercial plastics have certain electrical properties which make them suitable construction materials for the electrical industry. General-purpose phenolic molding compound is used for a variety of electrical parts including radio and telephone parts, coil forms, plugs, switches, magneto parts, meter housings, switchplates and sockets. Phenolics have fair heat resistance and can be used provided temperatures do not exceed 140° to 150° C. (284° to 302° F.).

The urea plastics can be used wherever phenolics are used provided the temperature does not exceed 90° to 95° C. (194° to 203° F.). Ureas have unusual resistance to tracking and arcing and for this reason are being used extensively for circuit breakers, high tension ignition parts, and snubbers.

The cellulose esters are seldom used for electrical switch parts due to poor electrical properties and low heat resistance.

The polystyrene plastics have exceptionally low loss factors and are widely used in high-frequency radio work.

Laminated phenolic and urea materials make excellent electrical parts due to the combined physical and electrical properties. Here again the ureas excel in arc and tracking resistance.

In the lighting industry, particularly for modifying the light distribution of incandescent bulbs, urea plastics hold an enviable position.[12]

Figure 21.3 shows the surface brightness of three plastics units molded in the same mold using low, medium and high density plastic. Figure 21.4 gives the comparative lighting properties of the several plastics with usual lighting materials.

PLASTICS IN HOUSEHOLD APPLIANCES AND GADGETS

Molded Phenolics. Phenolics have excellent electrical resistance and ease of molding, resistance to heat, water, solvents, and cleaning preparations, and excellent appearance in dark colors — a combination of qualities which makes them particularly well suited to applications in the household appliance field.

Principal applications are as follows:

Agitators: compression molded, shock resistant, high surface luster, replace metal.

Ash Trays: available in brown, black, maroon, ease of molding makes for variety of design. Phenolic is resistant to cigarette burns, alcohol and fruit acids, unbreakable and easy to clean. It may be combined with metals or wood for special effects.

Coasters: injection molded in dark colors, inexpensive and practical.

Coffee Makers: vacuum type coffee maker has following parts molded from phenolic: (a) base, trim or electric plate, (b) handle and bottle neck binder, (c) cover, (d) upper bowl (for commercial use), and (e) measuring accessories. The plastic parts are warm to touch but do not unmold as a result of the heat. The upper bowl for commercial use is molded from a specially prepared compound which is not affected by boiling water and imparts no flavor to the coffee. Percolator and drip type coffee pots also have molded phenolic accessories.

Containers: for cans, jars or boxes of cleaning powders to improve appearance in kitchen or bathroom; also, containers for coffee which contains a measuring device, molded in two parts.

Covers: for pots and pans, heat resistant, easily molded, limited use.

Electric Fuse Base: compression molded, light weight, excellent insulation.

Electric Mixer Base: easy to clean, durable, light weight, will not chip or peel.

Filler Cap for Steam Iron: molded of special heat and moisture resistant material.

Flashlight Sheath: light weight, will not corrode, chip, peel, or rust, excellent insulat-

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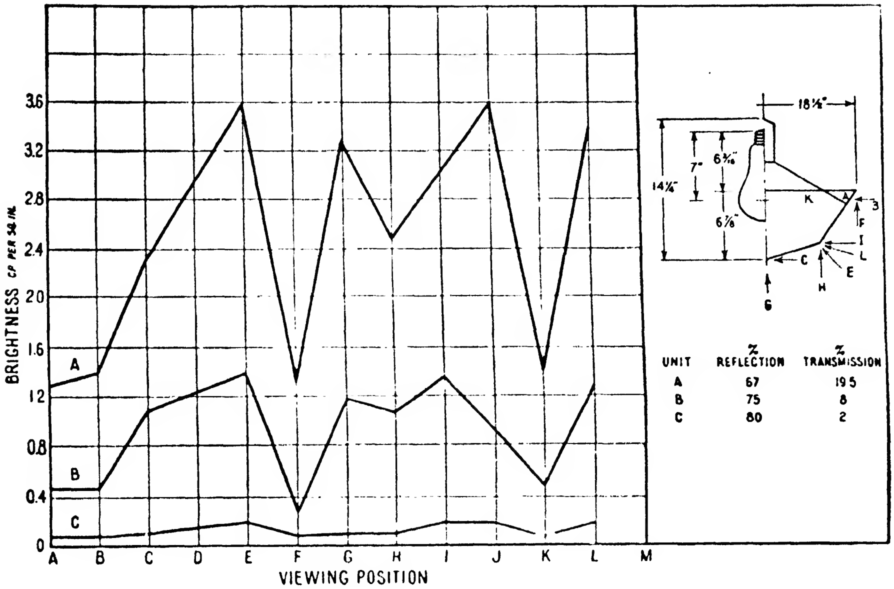
[12] See Architecture, Decorative Lighting, page 793.



UNIT	% REFLECTION	% TRANSMISSION
A	67	19.5
B	75	8
C	80	2

FIG. 21.3 — Comparative brightness: 500-watt, 18-in., semi-direct plastics diffusors. The surface brightness of three plastic units molded in the same mold using low density, medium, and high optical density plastic.

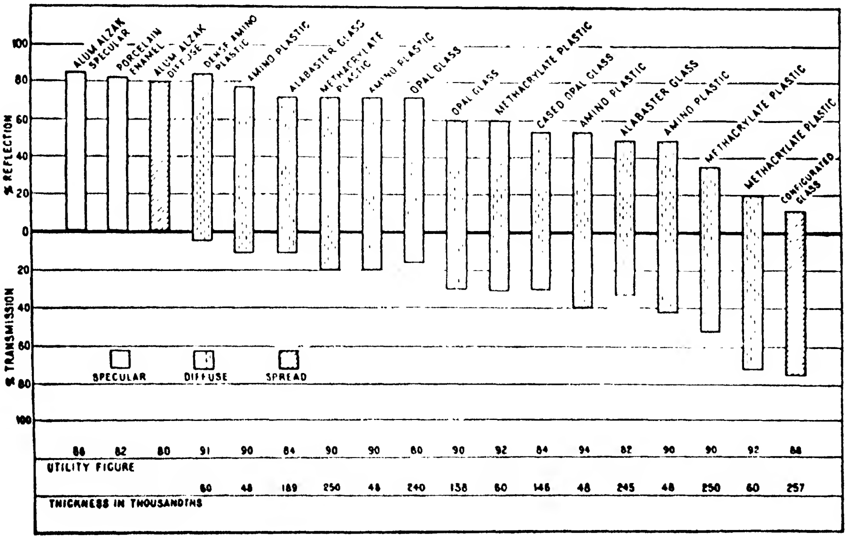


FIG. 21.4 — Optical characteristics of various materials.

TABLE 115. PLASTICS IN THE ELECTRICAL INDUSTRY

	Cast Phenolics	Molded Phenolics	Laminated Phenolics	Molded Urea	Laminated Urea	Cellulose Acetate	Cellulose Nitrate	Cellulose Ethers	Vinyl Polymers	Polystyrenes	Cellulose Acetate Butyrate	Formed Plywood	Methacrylates
Radio													
Fixed condensers		X		X									
Tube bases		X											
Tube sockets		X	X	X	X								
Dials		X		X		X	X	X		X	X		X
Knobs	X	X		X		X	X	X		X	X		X
Cabinets	X	X		X								X	
Terminal blocks		X	X	X	X								
Stand-off insulators		X		X						X			
Condenser bases		X		X									
Coil forms		X		X									
Telephone													
Receiver housing		X				X							
Base		X				X							
Insulators	X	X		X									
Plugs		X		X									
Meters													
Housings		X		X									
Terminal blocks		X	X	X		X							
Circuit breakers													
Commercial		X		X									
Residential		X		X									
Electrical													
Wall plates		X		X									
Switches		X		X		X							

ing properties. One type, without battery, generates electricity by pressure of fingers on case.

Handles, Knobs, and Levers: resistant to water and soap solution, easily molded, good insulating qualities.

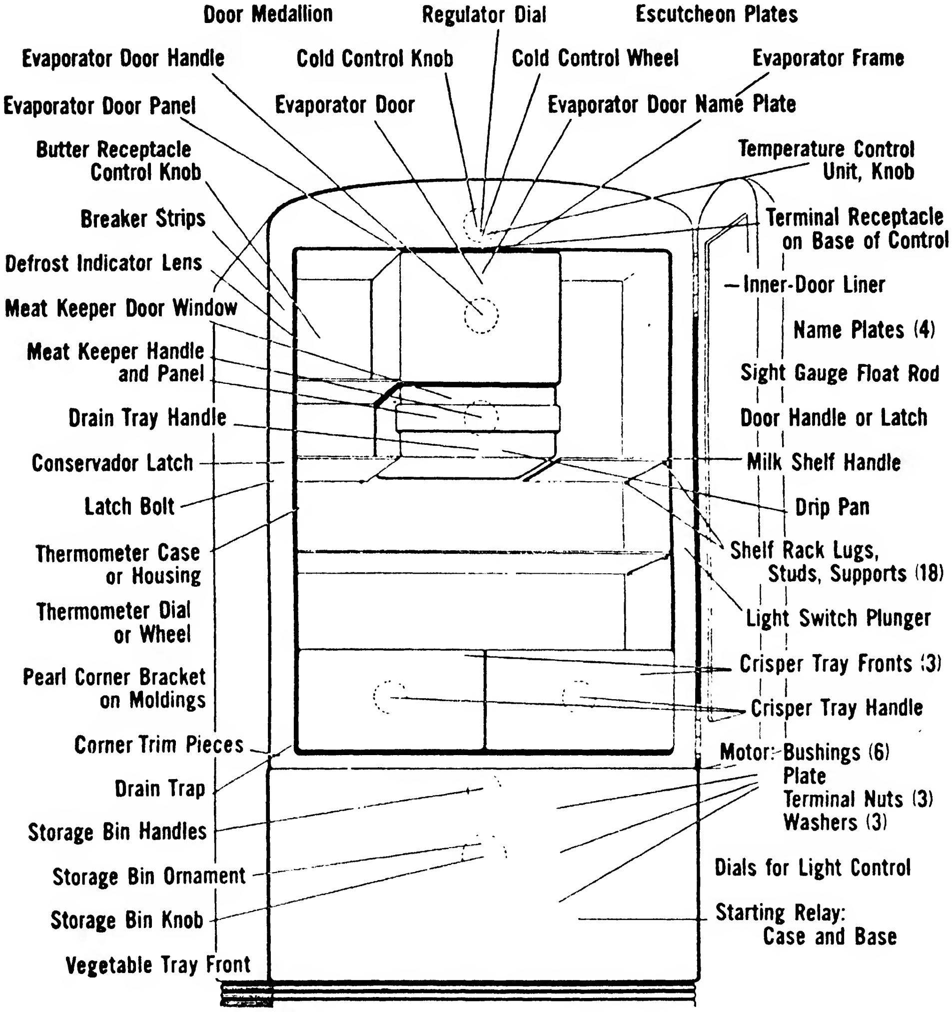
For (a) electric appliances — flat irons, toasters, vacuum cleaners, grills; (b) cooking utensils — pots and pans; (c) kitchen utensils —knives, forks and spoons, gadgets, scoops, shovels, paddles.

Holders: napkin holders.

Housings: good insulating properties, lustrous finish, inexpensive:

For (a) electric equipment — meters, thermostats, kitchen mixers, juice extractors, electric plates, vacuum cleaners; (b) non-electric devices — indicator dials, thermostats, fruit juice reamers.

Plugs for Electrical Appliances: resistant to 450° F., light weight, will not blister, retains original strength. One type is split to adapt it for various size sockets.



Courtesy of E. I. du Pont de Nemours & Co., Inc.

FIG. 21.5 — Plastics on an electric refrigerator. The 48 principal plastics parts on a composite 1942 electric refrigerator are shown on this chart. An estimated 20 per cent increase over 1941 in the number of plastics parts is attributed not only to metal scarcities but to plastics' insulating value, economy, durability, and rust and moisture resistance, which adapt them particularly to electric refrigerators.

Spouts: molded to pouring shape for bottles and cans.

Trays: durable, opaque, light weight.

Trim: easily molded and fastened to other materials.

For (a) electric — refrigerators, vacuum cleaners, washing machines; (b) non-electric.

Cast phenolic is available in a wide range of colors. It is nonflammable, tasteless, and odorless. It is easily machined, carved, and polished.

Ash Trays: combined with metals or other materials, resistant to cigarette burns, alcohol and soap solutions, easily cleaned, decorative.
Cigarette Boxes and Lighters: easily machined for individual designs.
Handles for Non-electric Devices: cutlery, gadgets for kitchen usage.
Humidor: decorative, closes tightly.
Napkin Rings: machined from special shape castings at low cost.
Racks: silverware, smoking pipes, kitchen utensils.

Urea. Although urea has a decided color advantage over phenolics in that it is available in a range from pastels and pure white to the darker colors, it is not so resistant to water and heat and therefore cannot be used successfully for cooking utensils or electric appliances. It has good surface hardness and rigidity.

Broom Shoulders: easily cleaned, good finish and wide color selection.
Closures: odorless and tasteless, molded in variety of sizes and colors.
Coasters: light weight, decorative, fairly resistant to water, resists alcohol and acids.
Fruit Corer: inserted in fruit to remove core or juice.
Electric Fan Grill: available in light colors, easily cleaned.
Handles for Non-electric Devices, i.e., brooms and brushes: good durability, permanent colors where not exposed to high temperatures.
Housing for Gadgets: juice extractors.
Measuring Spoons: molded in exact dimensions, light weight, easily cleaned.
Napkin Rings: wide choice of colors sometimes combined with chrome.
Tableware: almost unbreakable, translucent, easily cleaned, used for all types of dishes, cups, tumblers, salt and pepper shakers.

Cellulose acetate combines moldability with dielectric strength and resistance to alkalies. It has a tendency to shrink upon aging, but its low price, colorability, and toughness make it widely used in this field.

Bar Accessories: beer scrapers, alcohol resistant.
Broom Shoulders: injection molded, will not scratch furniture. One type may be removed and used as a dustpan.
Carpet Sweeper Windows: transparent, makes brush inspection easier.
Closures: molded to fit standard jar and bottle sizes. Some types have pouring spouts.
Clothespins: molded in special three-pronged shape. Will not rip clothes.
Coasters: colorful, easily cleaned, good heat and water resistance.
Cocktail Stirrers: resistant to acids and alcohol. One type is paper core coated with cellulose acetate.
Covers: used over butter dish.
Egg Cups: molded in one piece, inexpensive, colorful, unbreakable.
Fruit Corer: fruit corer; see Ureas.
Funnels: molded in one piece, easily cleaned, unbreakable.
Handles and Knobs: on non-electric devices and on vacuum cleaners.
Housing: vacuum cleaner device.
Juice Extractors: colorful, acid resistant.
Kitchen Utensils: scoops and shovels for flour and sugar, strainer molded in one piece.
Liquid Dispenser: non-tipping design, alcohol resistant.
Measuring Cup: available in colors. One type can be regulated to hold desired amount.
Measuring Spoon: molded to exact measures.

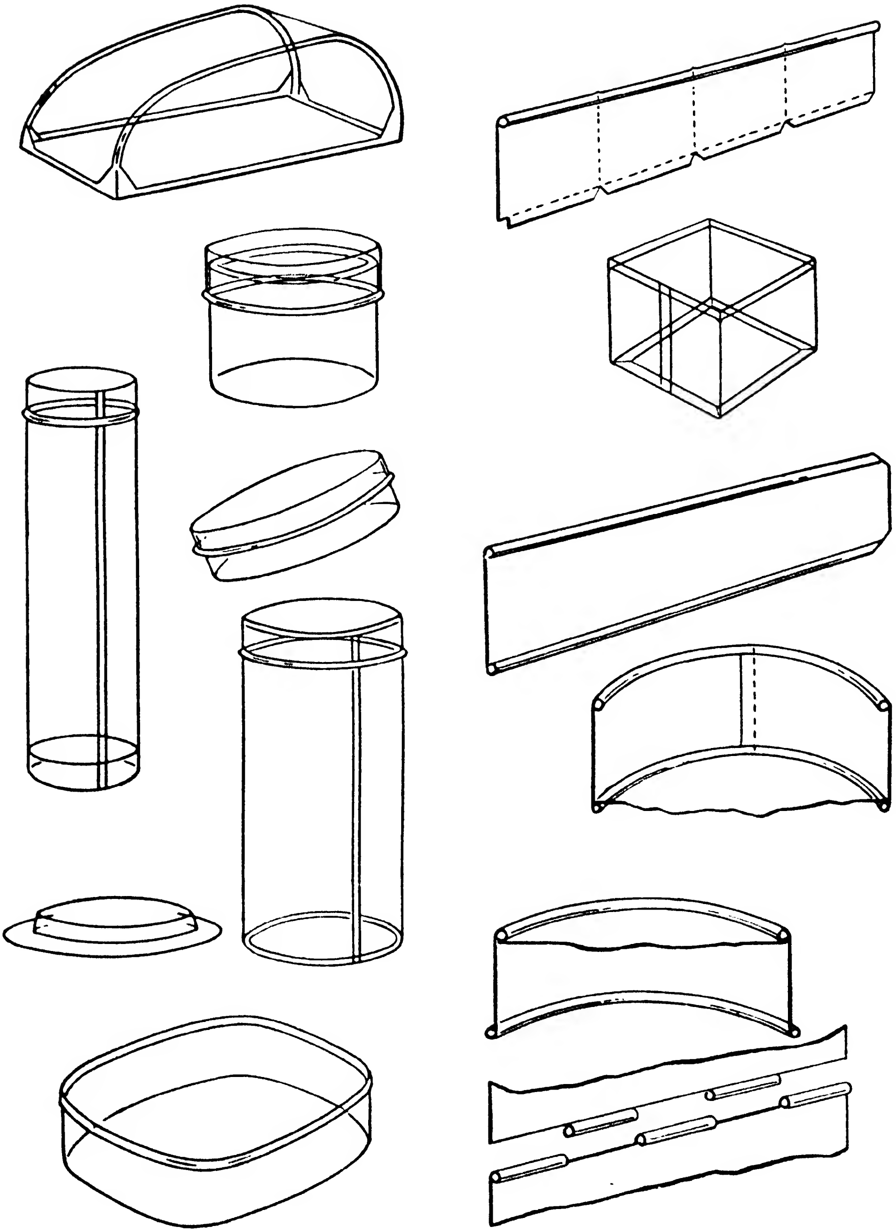


Fig. 21.6 — Beading on rigid transparent containers.

Table Mats: transparent sheets, decorated with designs or monograms, used as place mats under plates.
Tableware: tasteless and odorless, molded in thin pieces, used for dishes, salt and pepper shakers, cups, sugar bowls, creamers.
Trays: strong, acid and alcohol resistant.
Vases: for flowers; decorative, wide color range.

Cellulose acetate butyrate has greater dimensional stability than cellulose acetate, as well as the other properties of the acetate. Its moisture resistance is excellent.

Handles: molded around metal insert, for egg beater.
Kitchen Utensils: strainer, molded around wire mesh.
Refrigerator Parts: molded trim for refrigerator interior.

Cellulose nitrate is tough and wear resistant but highly flammable. It is easily formed, fabricated and cemented.

Covers: for non-electric devices, inexpensive, decorative, used to set over food.
Funnels: easily formed, available in transparent to opaque.
Handles and Knobs: for non-electric equipment, inexpensive, easily cleaned.
Housing: for vacuum cleaner dome, very little abrasive action on wood or fabric.
Picture Frames: decorative, light weight, inexpensive.

Methyl Methacrylate. The extreme beauty of the transparent methyl methacrylate plastic brings about its use for expensive type table settings and decorative accessories. Articles are usually fabricated from sheets, rods, or tubes rather than molded. They have extreme clarity, dimensional stability, and water resistance, but are easily scratched.

Bookends: decorative, unbreakable.
Cigarette Boxes and Lighters: transparent, may be etched or carved, will not break or chip.
Covers: tasteless and odorless, easily cleaned, used over butter.
Handles and Knobs: for non-electric equipment, used for cutlery, brushes, carving sets.
Juice Extractor: acid resistant, used with polystyrene.
Knife: injection molded, with special serrated cutting edge for citrus fruits and holes in center of blade to prevent juice from squirting; good for cake also.
Letter Opener: clear, durable, may be etched; often combined with acrylic lens for reading glass.
Salad Sets: bowls and serving sets fabricated from one piece, available plain, etched, colored, or water-clear.
Table Mats: covering a cork base to protect table from hot dishes.
Tableware: excellent material for crystal clear dishes, easily cleaned, unbreakable, expensive.

Polystyrene is easily molded in intricate shapes. It will resist acids and alkalies, and has extreme dimensional stability.

Canapé Cup and Stand: easily injection molded to the desired shape, available in delicate colors, water-resistant.
Cups: produced with delicate, translucent coloring, resistant to water and soap solutions.
Dishes: have a permanent finish or luster, are easily cleaned and resistant to chipping or breaking.
Ice Cube Trays: molded in one piece, in decorative colors.

Juice Extractor, Non-electric: available transparent and in colors.

Knobs and Handles, mainly for non-electric devices: decorative, strong, durable, easily cleaned and inexpensively injection molded.

Letter Opener: decorative and with a good cutting edge, inexpensively injection molded in one piece, usually clear. One type has a place for a changeable calendar in the handle, visible through a cover of clear polystyrene.

Measuring Cups: in transparent colors, to be used for liquids. Alcohol-resistant and easily cleaned, they are used in bars. One type cannot easily be tipped over.

Salad Bowl: easily molded in good clear colors or mottled; resistant to fruit acids and vinegar.

Salad Sets: available in fine designs and colors, some done in combination with acrylics. They are easily cleaned and will not rust or tarnish.

Spoons: long, thin types in a variety of colors, mostly clear, for iced tea, etc., with a finish easily cleaned and resistant to fruit acids and alcohols.

Table Mats: good colors and painted designs possible in transparent mats, or the polystyrene may be used to cover cork bases. All types are easily washed.

Tableware: see Dishes.

Trays: strong and durable, easily cleaned, alcohol and acid proof, available in a variety of attractive colors.

Vacuum Bottle Parts: decorative, resistant to water and soap solutions, will not corrode metals or cause them to tarnish. Use of fittings of polystyrene which retain their accuracy of dimensions under changes of temperature assures close-fitting parts.

Vinyl plastics can be produced very clear and in a variety of colors. They are non-toxic, tasteless, and odorless and resistant to acids, and have good adhesive properties. They are well adapted to use for a coating on paper, etc., and as a wrapping for sanitary protection of foods.

Bottle Tops: a practical milk-bottle cap has a paper base with a surface coating of vinyl chloride.

Caps and Covers for various types of containers: water and fruit-acid resistant, durable, sanitary, can be flexible or not as desired.

Picture Frames: in one type a clear sheet of the plastic is ribbed by an embossing plate to give the illusion of a third dimension. The ribbed plastics sheet, in the form of a frame, is placed over the picture and the whole is sandwiched in glass, the rear surface being frosted.

Shelf Lining of paper coated with vinyl plastic: durable, easily cleaned, sanitary, with a smooth, water-resistant surface.

Melamine Plastics. These are light in weight, thermosetting, not available in very light colors except amber, resistant to water and many solvents.

Dishes: non-shatterable, easily washed, light in weight, water-resistant and available in a good range of colors (except very light).

Laminated Phenolics. These are low in cost and have great strength and toughness which varies, however, with the type of base used (paper, fabric, asbestos, wood, etc.). They also have good electrical insulating properties and dimensional stability, and are most widely used in electrical parts in machinery (e.g., silent gears).

Refrigerator Parts: door linings, door backs, breaker strips. These parts are sanitary and easily cleaned, tasteless and nearly odorless, strong and durable, attractive in appearance. Paper base laminated can be produced in black, white and many colors.

Nylon Fibers. These are elastic, smooth, easily cleaned, long wearing, and resistant to chemical agents. They do not absorb much moisture as compared with natural fibers.

Nylon Bristles: these are excellent for all brushes because of their durability and their extremely quick drying feature. Principal applications are:

Brushes: (a) bath — quick drying and easily cleaned, do not absorb much moisture; (b) clothes — durable, with hard resilient bristles; (c) bottle washing — resistant to acid and soap solutions, easily cleaned, very durable.

Cold-molded Plastics. The outstanding characteristics of cold-molded plastics are low cost, heat resistance, and adaptability to cheapness of molding. Most cold-molded plastics are bituminous, although phenolic resin or cement binders may be used to produce a cold-molding compound. The colors are usually dark; cold-molded products are used entirely for electrical appliances.

Coffee Maker, cover and base: unaffected by boiling water, tasteless and odorless, easily cleaned.

Knobs and Handles: inexpensive, heat resistant, with a permanent glossy finish which is easily cleaned. Will not corrode metals with which they come in contact, though bituminous materials may cause some tarnishing.

For (a) cooking utensils and other non-electric devices — very inexpensive, durable and heat resistant; (b) electric devices — easily molded, inexpensive and durable, easily cleaned and heat resistant.

INDUSTRIAL APPLICATIONS

Textile Plant. One of the early uses of plastics in the textile industry was the spinning pot in rayon mills. Laminated phenolic, reinforced with steel wire, was the only material that combined highly polished surface and light weight, with strength that could withstand the centrifugal force of 8000 to 10,000 r.p.m. A phenolic laminated reel made possible in 1938 the continuous processing of rayon thread. Intricately molded phenolics are used in rayon mills for washers, gears, jet unions, seal rings, thread guide holders, and brackets.

One of the most interesting applications is the use of laminated phenolic for tenter frames, which hold wet cloth while it passes through a heat chamber. The plastic makes possible a faster process at a higher temperature.

Bobbins and shuttles are made from molded phenolics. Spindles and separators, treadle rolls, cones for wet winding, cone tips, loom fitting, button breaker rolls, and parts of scavenger rolls are made from laminated phenolic. Worktable tops and forms for hosiery examinations are among other applications for plastics.

More recently, nylon brushes have been replacing Tampico fiber and Oriental hog bristle in furnisher brushes which convey dyes from vats to metal rolls in textile mills. One nylon-bristled brush has been in use for more than a year where brushes formerly lasted only one week.

Ion Exchange Resins.[13] In 1935, Adams and Holmes in England discovered that some synthetic resins function as cation or anion exchangers. This discovery has shifted the emphasis on resin properties in some fields from plasticity and chemical inertness to physical rigidity and chemical activity. It has brought a focus of attention on chemical behavior which makes it possible to purify water with synthetic resins and open a flood of new applications in this field.

Previous methods for softening water in the home and in industry had a tendency to create excessive alkalinity in the treated water.

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[13] Prepared from material published by the Resinous Products and Chemical Company.

TABLE 116. SUGGESTIONS FOR USE OF PLASTICS IN DESIGN OF MACHINE TOOLS

Item	*Type of Plastic*	*Advantages*
Cams (on automatic screw machines)	Laminated board	Time saving — 1/6 time in making Economical — long runs
Engine lathe		
End door for feed gear train	Laminated material	Reduced weight
Oil sump	Phenolic resin with reinforcement	Ability to stand vibration and wear and tear
Casing for push-button station for electric motor	Phenolic	Protection of electrical parts Insulation
Levers and Wheels	Laminated phenolic	Quiet operation
Milling machine		
Casings for starting boxes for drive and feed motors	Phenolics	Protection for switch-gear Shock protection for operator
Tool shelf		
Hand wheels	Phenolic molded	
Levels	Phenolic molded	
Speed plates	Phenolic laminated	
Cutting oil discharge and return lines	Vinyl resins Neoprene Thiokol	Resistant to water, alkali, oil, etc.
Oil gauges	Acrylic resin	Stronger More transparent Even, non-glare, shadowless light Cold lighting
Bandsaws		
Pantographs		
Cup grinders		

The ion exchange resins act as carbonaceous exchangers and may be modified to fit particular types of applications. Early discoveries have led to a more recent development — the anion exchanger resins — which make possible the removal of all salts from the water, and by a combination of the two processes result in a solution comparable to distilled water.

The more common uses of the ion exhange resins are as follows:

1. Softening water for:

    - Laundries
    - Textile mills
    - Power plants
    - Chemical manufacturers
    - Hospitals
    - Homes
    - Canneries
    - Dye and pigment manufacturers
    - Breweries
    - Hotels
    - Restaurants
    - Ice plants
    - Railroads
    - Steamships

2. Reduction of alkalinity:

    - Beverage plants
    - Railroads
    - Steamships
    - Municipal supplies
    - Ice plants
    - Powerhouses

They may also be used for:

- Reduction of solids in water
- Purification
- Conversion of salts by double decomposition
- Recovery of elements from aqueous solutions
- Removal of electrolytes
- Acidification or de-acidification

Leather. Up to the present date the uses of synthetic resins in the leather industry have been limited. Certain resins, listed below, have been used with varying degrees of success, as coatings to improve the wearing qualities of leather.

Phenol-formaldehyde Resin — coating — improve resistance to chemical attack.

Urea-formaldehyde Resin — coating — nonflexible, modified with alkyds for patent leather.

Alkyd Resin — coating — flexible, permanent, lacquer-type finish.

Cellulose Nitrate Resin — coating — lacquer type.

Acrylate Resin — coating — finishing material for improved appearance, wear-resistance, artificial leather.

Vinyl Resins — bonding agents — used to bind waste leather to form leather substitutes.

PLASTICS PLYWOOD IN WAR

Aircraft
- Molded Sections
  - Wings
  - Fuselages
  - Nose pieces
  - Aerial housings
  - Control surfaces
  - Bomb bay doors
  - Flooring
  - Leading edges
- Impregnated
  - Molded wings
  - Molded fuselages, etc.
  - Spars and frame members
  - Propellers
- Flat Bonded
  - Wings
  - Fuselages
  - Control surfaces
  - Bulkheads
  - Interior paneling
  - Flooring
  - Gusset plates
- Glued Joints
  - Frame members
  - Frame to skin
  - Propeller laminations

Marine
- Molded sections

Housing
- Impregnated
- Prefabrication — most panel sections
- Cantonments — sheathing
  - siding
  - sub-flooring
  - paneling
  - built-in furniture
  - joint gluing to supplement nailing

Military
- Impregnated
  - Chests
  - Packing cases
  - Cabinets
  - Field kits
  - Assault boats
  - Pontoons
  - Lockers
  - Furniture
- Flat Bonded
  - Small boat hulls
  - Assault boats
  - Motor torpedo boats
  - Bulkheads
  - Superstructures
  - Interior paneling
  - Considered for larger boat hulls
- Joint Gluing
  - Frame members
  - Frame to skin

Plastics in Packaging[14]

Rigid Transparent Packaging. Although regenerated cellulose wrappings (Cellophane) have been on the market for several years, it is only recently that transparent, rigid containers have become an important packaging medium.

Up until the war, about 75 per cent of the business in transparent packages was done during the last half of the year. It was considered luxury packaging for gift merchandise. Almost every operation in the manufacture of transparent containers was done by hand, pushing the cost up to where they were used primarily for packaging toiletries, Christmas gifts, and other relatively high profit margin merchandise.

With the advent of faster and more automatic processes during the past two years, the field of transparent containers has been opened to many manufacturers who previously could not afford them. This has had a stabilizing effect on the industry.

When a manufacturer thinks of shifting from an opaque to a transparent package his most important consideration is: " Will we sell more as the result of the change? " Products which sell better when seen than when concealed by opaque containers, naturally sell better in transparent containers. Department stores estimate that 60 per cent of their sales result from impulse buying. Transparent boxes, displaying their merchandise, lead to impulse buying.

The trend toward permanent reuse of transparent containers has become less and less until at the present time probably not more than 20 per cent of the rigid transparent packages have reuse value. Year round, low-price merchandise cannot stand the cost of heavy gauge materials which are necessary in order to make reusable containers.

Typical applications for rigid, transparent packages are:

Toiletries, cosmetics
Powder puff gift packages
Drugs, not of hygroscopic nature
Food, such as bakery goods, tea-bags, candy
Cigars, pipes
Linen and domestic goods
Liquor gift packages
Silverware, jewelry, watches
Flowers
Wearing apparel
Sporting goods
Hardware

The types of material used for rigid transparent packaging are: (a) cellulose acetate, (b) ethyl cellulose, and (c) vinyl resin.

They are supplied in: (a) standard size sheets, principally 20 in. by 50 in. and 30 in. by 50 in., (b) pieces cut to size, and (c) continuous length rolls. Gauges are 0.003 to 0.020-in. rolls, sheets, and pieces; heavier gauges in 20 in. by 50 in. sheets. The material may be obtained in translucent, transparent, clear, or tinted forms.

Methods of Fabrication. Cylindrical Containers. Rectangular sheets are cut to allow for approximately ⅛ in. overlap and 3/16 to ⅜ in. excess in length to allow for beading. Round or oval shapes are used for bottom and top.

In the hand process, sheets are mounted on a cementing mandrel, cemented at overlap with a camel's hair brush or other applicator, and dipped in acetone or other solvent-cement.

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[14] Prepared with the assistance of the Monsanto Chemical Company and the Norton Laboratories

Edge finishing or beading may be done before or after the cylinder is made. The bottom is cemented into container.

Pressure and heat are used to turn the edge into a permanent round curve. If this is done before the cylinder is made, it is accomplished on a continuous or strip beading machine where the edge is curved by dies and discharged at the end of the machine; if done after the cylinder is made, it is pressed against a grooved, heated metal disk.

Rectangular Containers. Sheets with corners cut, or mitred, are employed.

The sheets are creased by heated bars, and the corners cemented; edges may be plain or beaded.

Drawn Containers. Rectangular, cylindrical, or odd-shaped containers may be drawn. In this process a sheet is formed into the desired shape under heat pressure between male and female dies. It is usually more expensive than ordinary fabrication for small quantities of packages because of the cost of dies, but for a medium or large order it may be more practical, depending upon shape and size.

The depth to which a container may be drawn depends upon the gauge of the material and the diameter of the container. Tall containers can be drawn, but the height usually is not more than one-half the diameter of the base. A new technique, however, makes it possible to draw to considerably greater depths.

Other Type Containers. Certain types of cellulose acetate and cellulose nitrate containers are molded in tube and vial shapes, with threads molded in for screw tops.

Molded or Cast Packages. The plastics used for packaging and typical packages are as follows:

Plastic	*Merchandise Packaged*
Phenolic, molded	Capsules (container base)
	Camera filter (box base)
Phenolic, cast	Powder
Urea	Cosmetics
	Jewelry
Cellulose acetate	Razor
	Camera filter (box top)
Acetate-butyrate	Oil
Acrylic	Cosmetics
	Silverware
Polystyrene	Cosmetics

Molded containers utilize the screw type closure, tight fitting notched cover, or a hinge type closure. The hinged closures may be of the following types:

1. Spring hinge (patented by the Rathbun Manufacturing Company — small, elliptical-shaped, springy steel clips are clamped into undercuts in the moldings; this enables box to be opened to 90 degrees.

2. Pin hinge — metal pin is driven through holes in sides of box and through molded prong inserted between sides. Spring effect may be produced by using bowed metal pin.

3. Piano hinge — hinge of brass or tin attached with rivets or self-tapping screws.

4. General Electric hinge — a roller bearing spring tension type hinge.

5. Other types — combination of hinge and steel spring clips.

Plastics Closures. Plastics have found a large market in the closure field. They are attractive, easily molded, sanitary, and long wearing.

Phenolic is the most widely used plastic for this purpose. Special grades have been developed which will not absorb the odor of the packaged material or release any odors. They are practical for chemicals, drugs, foodstuffs, toiletries, and cosmetics. A variety of shapes are available ranging from closures for tiny bottles to screw tops for widemouthed preserve jars. Threads are molded into the material and special molding methods are used to remove pieces after molding.

Urea is used for cosmetics and elaborate closures where light colors are desired. More important applications are white closures for medicinals, liquors, and foodstuffs. Urea is odorless, tasteless, and bleedproof.

Polystyrene, with its unusual chemical resistance, is widely used for acid closures. One manufacturer has made a different colored closure for each type of acid, thus aiding easy identification of the acids in the laboratory. The material is easily molded and retains the desired resiliency.

TABLE 117. PLASTICS IN CLOTHING AND PERSONAL ARTICLES

	Phenolic, cast	Phenolic, molded	Urea	Cellulose Acetate	Cellulose Acetate Butyrate	Cellulose Nitrate	Casein	Methyl Methacrylate	Polystyrene	Vinyl	Vinyon	Nylon	Rayon
Arch support				X									
Belts				X		X				X			
Belt buckles	X			X	X	X							
Bill folds										X			
Buttons	X	X	X	X		X	X	X		X			
Canes								X					
Clothing:													
Men's suiting													X
Robes													X
Scarves													X
Shirts													X
Shirt fronts										X			
Slacks													X
Cosmetic accessories:													
Compacts	X	X	X	X			X		X				
Makeup capes										X			
Perfume atomizers		X		X						X			
Covers (shoe & bag)						X							
Garters										X			X
Garter fastener				X									
Gloves											X	X	X
Glove fastener		X											
Hair accessories:													
Brush	X	X						X	X				
Bristle												X	
Comb				X				X	X				
Curlers		X		X						X			
Dresser set	X	X		X		X		X					
Hair pins				X									
Wave lotion												X	

TABLE 117. PLASTICS IN CLOTHING AND PERSONAL ARTICLES (*Continued*)

	Phenolic, cast	Phenolic molded	Urea	Cellulose Acetate	Cellulose Acetate Butyrate	Cellulose Nitrate	Casein	Methyl Methacrylate	Polystyrene	Vinyl	Vinyon	Nylon	Rayon
Handbags:													
Clasps				X		X	X	X					
Covering				X	X	X				X	X	X	X
Frames				X		X	X	X					
Handles				X			X	X					X
Jewelry:													
Bracelets	X		X	X		X		X	X				
Brooches	X			X		X		X					
Charms				X									
Clips						X		X					
Gems								X					
Lockets	X			X				X	X				
Necklaces	X	X	X					X					
Laminated and woven fabrics:													
Artificial wool							X						
Dress goods												X	X
Felts							X				X		
Luggage, covers						X				X			
Linings										X			X
Shirt collars										X			
Shirt fronts						X				X			
Millinery				X						X	X		X
Millinery novelties	X					X		X					
Ornaments, dress				X		X	X	X					X
Ornaments, flower				X		X				X			X
Ornaments, hair				X				X					X
Pens	X	X		X		X	X			X			
Sewing thread												X	

TABLE 117. PLASTICS IN CLOTHING AND PERSONAL ARTICLES (*Continued*)

	Phenolic, cast	Phenolic, molded	Urea	Cellulose Acetate	Cellulose Acetate Butyrate	Cellulose Nitrate	Casein	Methyl Methacrylate	Polystyrene	Vinyl	Vinyon	Nylon	Rayon
Shoes and shoe accessories:				X		X				X	X		X
Buttons						X							
Evening slippers					X					X	X		X
Fabrics											X		X
Forms						X							
Heels	X							X		X			
Heel covers				X		X				X			
Heel plates						X							
Hooks				X		X							
Interlinings						X					X	X	
Laces												X	X
Tips	X			X		X				X			
Soles										X			
Skirt marker				X									
Smoking accessories: Cigar holder	X	X						X					
Cigar lighter				X									
Pipe stem		X						X					
Stockings												X	X
Sun glasses				X				X					
Suspenders										X			X
Sweaters							X				X		X
Thimbles				X									
Tie holder				X				X					
Toilet articles: Manicure case	X	X		X									
Shaving brush handle	X			X				X					

TABLE 117. PLASTICS IN CLOTHING AND PERSONAL ARTICLES (*Continued*)

	Phenolic, cast	Phenolic, molded	Urea	Cellulose Acetate	Cellulose Acetate Butyrate	Cellulose Nitrate	Casein	Methyl Methacrylate	Polystyrene	Vinyl	Vinyon	Nylon	**Rayon**
Tissue dispenser				X				X					
Toothbrush bristle												X	
Toothbrush holder				X		X		X		X			
Trimmings, ribbons													X
Umbrella handle	X	X	X	X				X					
Underwear: Brassiere												X	X
Girdles												X	X
Panties													X
Slips													X
Visors				X		X							
Waterproof clothing: Bathing suit											X		
Raincoat	X									X	X	X	
Watch clasp				X				X					
Watch crystal						X		X		X			
Watch straps										X		X	
Zippers				X		X							

TABLE 118. PLASTICS IN PHOTOGRAPHY

	Phenolic, molded	Phenolic, laminated	Cellulose Acetate	Cellulose Nitrate	Methyl Metha-crylate	Vinyl	Shellac Resin Coating
Cameras	X		X				
Knobs	X		X				
Sprockets			X				
Color photographs			X				
Developer	X						
Developing tank	X						
Developing trays	X						X
Exposure meter	X						
Light filters for dark room					X		
Flash synchronizer		X					
Fluorescent powder			X				
Focusing device	X						
Interval timer	X						
Knobs				X			
Micro-file recordak equipment						X	
Movie film, amateur, and educational			X				
Movie film, commercial			X	X			
Photolithography						X	
Fixing spray						X	
Paper cutter and trimming board	X	X					
Print washer	X						
Projector and viewer	X						
Slide viewer	X						
Tongs	X		X				
Tripod head	X						
View-finder lens					X		

TABLE 119. PLASTICS IN RAILROADS AND SHIPPING

	Phenolic, molded	Phenolic and Urea Laminates	Urea, molded	Cellulose Acetate	Vinyls	Plywood
Railroad Light Fixtures	X	X	X	X		
Interior panels		X				X
Interior trim				X		
Furniture		X				X
Insulator	X	X	X			
Rail plates		X				
Electric panels	X	X	X			
Relay Equip.	X	X	X			
Safety glass				X	X	
Marine Light fixtures	X	X	X			
Cabin partitions		X				X
Cabin equip.			X			
Life rafts						X
Signal equip.	X	X	X			
Electric equip.	X	X	X			
Finishes*						

* Synthetic resins used in most coatings.

TABLE 120. PLASTICS IN SCIENCE

Plastics in the Practice of Medicine	Phenolic, molded	Phenolic, cast	Ureas	Cellulose Acetate	Methyl Methacrylate	Vinyl	Nylon	Polystyrene
Bone conductor receiver case	X							
Catheter								X
Contact lenses					X			
Demonstration torso				X	X	X		
Dentures					X			
Earpiece					X			
Foot measuring device	X							
Hearing aid case	X							
Illuminating instruments					X			
Infantometer	X							
Mask				X				
Massage unit handle	X							
Nasal pack			X					
Nipple shield		X						
Oxygen mask and bag				X				
Pessary, supportive					X			
Pocket battery case	X							
Respirator chest piece				X				
Splints					X			
Sterilizer handles and feet	X							
Substage lamp housing for microscope	X							
Surgeons' gloves						X		
Surgical suture							X	
Surgical window			X					
Teaspoon, medicinal								X
Thermometer case	X				X			

TABLE 120. PLASTICS IN SCIENCE (*Continued*)

Plastics in the Laboratory	Phenolic, molded and resin	Phenolic, cast	Cellulose Acetate	Methyl Methacrylate	Polystyrene
Beakers, burettes, etc.	X				
Cover slips, microscopic		X	X		
Closure for acid container					X
Continuous dializer				X	
Filter dispensing cap	X				
Gas analyzer				X	
Graduate and funnels			X		
Ion exchange resins: Purifier	X				
Salt water freshener	X				
Slide comparator	X				
Transparent pump				X	

Plastics in Natural Science	Phenolic, cast	Urea	Cellulose Acetate	Methyl Methacrylate	Vinyl	Polystyrene
Agricultural and biological specimen mounting				X		X
Hose sprayer for insecticide			X			
Teat cups	X					
Trapping snowflake patterns					X	

Plastics in Physics	Phenolics	Methyl Methacrylate
Housings for barometers, compasses, humidity gauges	X	
Radio-meteorgraph base	X	
Thermometer housings	X	X
Thermostat base and housing	X	

TABLE 121. USE OF PLASTICS IN SPORTS, GAMES, AND TOYS

Plastics in Sports	Phenolic, molded	Phenolic, cast	Cellulose Acetate	Cellulose Acetate Butyrate	Methyl Metha-crylate	Plastic Plywood	Nylon
Bicycle frame						X	
Boat windshield			X		X		
Boat hull						X	
Boat trim	X						
Boat paddle						X	
Baseball cap, protective lining			X				
Ear stoppers					X		
Field glasses	X		X				
Fishing equipment	X	X		X			
Artificial bait		X		X			
Fishing leader				X			
Fly boxes				X			
Handles for rods				X			
Needles				X			
Reel ends	X			X			
Reel seats				X			
Golf tees			X				
Golf club ferrules	(Lam.) X						
Shotgun stock	X		X				
Tennis racket strings							X
Underwater air trap for swimmers					X		

Plastics in Games	Phenolic, molded	Phenolic, cast	Urea	Cellulose Acetate	Cellulose Nitrate Lacquer Coating	Methyl Metha-crylate	Casein
Backgammon dice	X	X					
Chess set	X	X					
Chessmen		X		X		X	
Chip racks	X						
Cribbage board	X						
Croupiers rakes	X						
Croquet, wickets, mallets, balls					X		

TABLE 121. USE OF PLASTICS IN SPORTS, GAMES, AND TOYS (*Continued*)

Plastics in Games	Phenolic, Molded	Phenolic, cast	Urea	Cellulose Acetate	Cellulose Nitrate Lacquer Coating	Methyl Metha-crylate	Casein
Dominoes	X	X					
Duplicate bridge board	X		X				
Jackstones				X			
Mah Jong blocks	X		X				
Playing cards				X	X		
Poker chips		X		X			X
Puzzles	X	X		X		X	
Roulette chips		X	X				
Score pad covers				X			
Shuffleboard disks	(Lam.) X						

Plastics in Toys	Phenolic, molded	Phenolic, cast	Urea	Cellulose Acetate	Cellulose Nitrate	Poly-styrene	Vinyl
Airplane (model) propellers				X			
Bank	X			X			
Bathtub boats					X		
Blocks	X	X	X	X			X
Convoy boats				X			
Dishes and cups	X		X				
Doll furnishings	X	X					
Gasoline engine for model airplane	X						
Bridges	X						
Gun handle				X			
Rattles for babies	X		X	X			
Radio buzzer for signal sending	X						
Tail lights for trains						X	
Tea set						X	
Teething rings		X	X	X			
Toy soldiers				X			
Trains				X			
Train marker lights						X	
Tracks	X						

CHAPTER XXII

DESIGNING MOLDED PLASTICS PARTS[1]

A study of procedure in designing products to be made from plastics shows need for close co-operation between the engineer-draftsman and the artist. The former should, of course, indicate all technical details and the various mechanical and functional factors that must be considered in producing any part or product and, at the same time, render the item practical from the standpoint of economical production. On the other hand, the artist lends his talents to the creation of product designs that will sell merchandise.

The type of plastics material to be used may have an important bearing on the design which will be adopted finally, because of different molding techniques involved for the different types of plastics. Furthermore, the phenolics, ureas, acetates, and polystyrenes are produced in a great variety of formulations or modifications. For instance, phenolics alone can be had in several hundred variations and each involves a particular molding technique, because of its individual characteristics.

Consideration must be given to conditions under which the molded part will be used. These include dielectric strength, arcing, opacity to X rays, wear, mechanical stresses, and the like. Creation of the design for a molded plastics part should be in the following sequence:

1. Engineer-draftsman lays out fundamentals of the design, taking into consideration all functional requirements.
2. Artist, using the fundamentals supplied by the engineer-draftsman, designs the piece so as to make it attractive and symbolic of whatever the needs may be, so that the part will meet modern design requirements.
3. Engineer-draftsman interprets the artist's sketches by making accurate mechanical drawings of the designed part. It is essential that the two collaborate in order to accomplish the best results.
4. A perspective drawing is made from the mechanical drawings.
5. After the perspective drawing is found satisfactory, or corrections have been made, a model of the article is then machined or carved from any suitable material, such as cast phenolic plastics, wood, clay, or metal. It is advisable to paint the model to represent the color of the molded part itself. Cellulose nitrate can be used to advantage in constructing models because of good machinability and the ease with which sections can be bonded by simple use of a solvent.
6. Models are studied carefully by the artist, engineer, and production division to make certain that all are satisfied. The production man should not be neglected since his duty may be to assemble the part with others.
7. A single-cavity mold is produced to make the article itself of the plastic to be

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[1] **From *Molding Technic for Bakelite and Vinylite Plastics*, Copyright 1941 by Bakelite Corporation.**

used. This enables such important characteristics as shrinkage, assembly, and serviceability to be determined accurately before production tools are made.

CORRECT DETAILED DESIGN REDUCES MOLD EXPENSE

Precaution should be taken to determine that the product is designed correctly in every detail before the mold is built. Experience has proved that when molds are completed and the designer sees the actual part he often finds that several changes must be made. This involves expensive alterations in the mold and this is why models should be used. With a model or a single-cavity experimental mold, changes can be made at little expense.

Rules and suggestions offered will be helpful to any engineer called upon to design a product in which plastics can be used to advantage. Experience has shown that the firms who are using molded plastics most successfully consult their custom molders while designs are still in the formative stage.

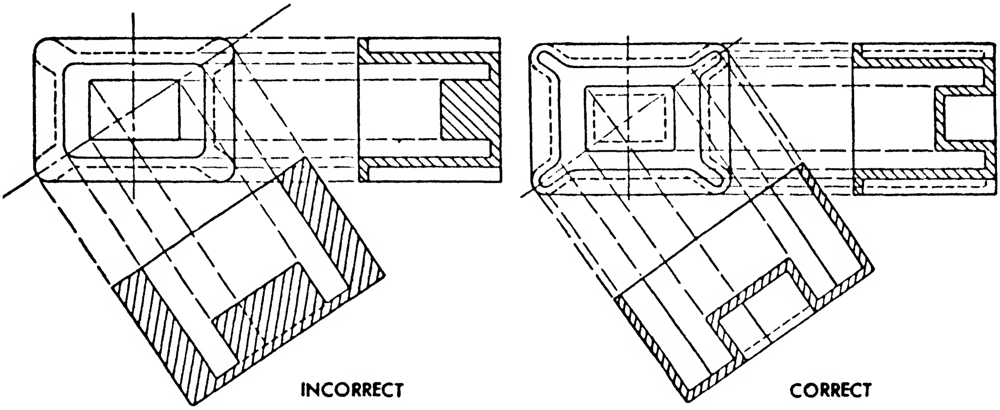
PRINCIPLES OF MOLD DESIGN

In designing products to be fabricated from plastics materials, the first principle to be remembered is to design the part so that it can be removed easily from the mold after molding is completed. Otherwise, a complicated mold is needed and production costs are increased. Proper design and simplicity of construction in the molded piece will result in simplicity in the design of the molds to be produced. The more complicated the molds, the more expensive will be the production costs. It should not, however, be assumed that complicated and intricate pieces cannot be produced. They can be and are being turned out regularly but production and mold costs are commensurate with their complexity.

In designing any molded plastics part, whether simple or intricate in construction, certain basic details or design factors are involved. The more important of these considerations are wall thickness, allowances and tolerances, inserts, fastenings and hinges, threads, fillets, knurling, lettering and engraving, and surface finish.

Wall Thickness. This is a matter for determination in each individual case. Proper thickness of wall construction for the piece in mind is governed by the requirements of mechanical strength and, in the case of electrical applications, that of proper dielectric strength or insulation values. Use the minimum thickness that can be employed to obtain the lowest manufacturing costs, as far as the quantity of material used is concerned, also taking into consideration that the thinner the section, the faster will be the curing time and, therefore, the greater the production from a given number of cavities. Do not, *for the sake of economy,* design parts with walls so thin that the parts will be fragile and their production difficult. Figures 22.1, 22.2, 22.3, and 22.4 illustrate correct and incorrect constructions commonly found in molded parts. A tendency exists, particularly in using thermosetting or hot-set materials, to economize on wall sections. This is false economy, which is evidenced in molding plants by the percentage of rejects. Also, the breakage of molded parts in assembly, during shipping, and under actual service conditions is traceable to this fault.

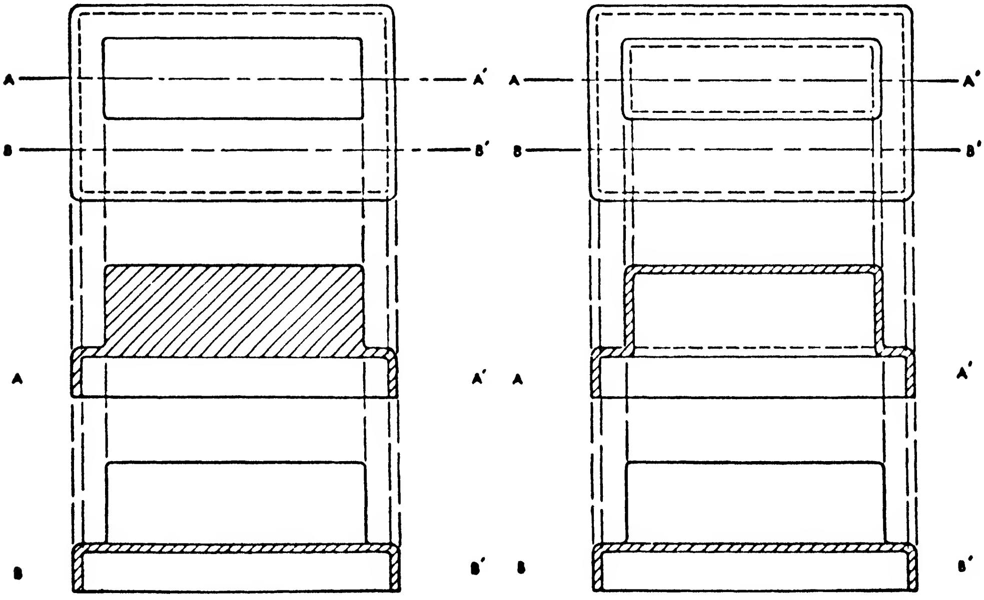
Where injection molding of vinylite materials is involved, do not attempt to mold sections of over 1 in. of length in less than 0.050 in. thickness. This limitation follows from the temperature-plasticity characteristics of these materials and their tendency to set up quickly in thin wall sections and offer prohibitive resistance to further flow. A minimum wall thickness of 3/32 in. for the average box or similar item is generally


INCORRECT

CORRECT

FIG. 22.1 — Wall thickness design.

satisfactory, but on heavier parts, such as radio cabinets, clock and instrument cases, industrial service parts, or office equipment, wall sections of ¼ to ⅜ in. should be used or they should be reinforced with ribbed construction.



INCORRECT

CORRECT

FIG. 22.2 — Cross-section design.

When fabric or impact type materials are used, or where resin board and powder or fabric are combined to give greater strength, thin sections should be avoided, particularly in parts having slots or holes on the side of the molded part parallel to the application of pressure of the mold. Often, proper use of rib construction will permit freer flow of materials as the mold closes. Ribs serve a double purpose, because they act as feeders for the material and also prevent the molded part from being distorted or warped when ejected at minimum molding cycles and while still hot. They provide a further advantage insofar as they economize in material and result in faster production. Also, they eliminate heavy sections, thereby accelerating cooling of the part and improving the appearance, as the molded pieces do not appear bulky.

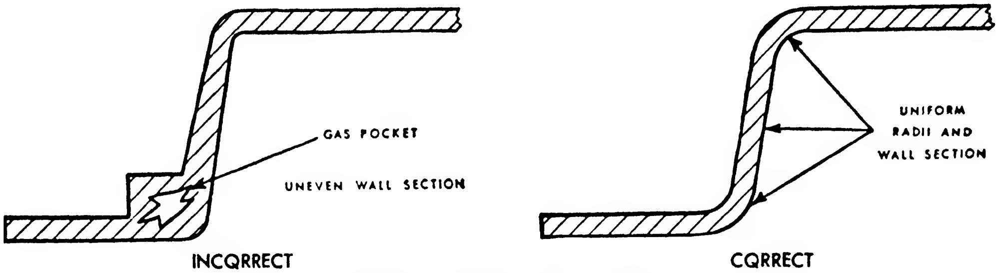


FIG. 22.3 — Cross-section design.

Uniform cross sections in a piece result in more uniform shrinkage and, accordingly, lessen strains during molding and later when the part is placed in service. Figure 22.5 illustrates correct side wall taper and decreased side wall construction or thickness. In this construction the top decreased wall section A is used to assist in molding insofar as the plastic material becomes increasingly dense and more tightly confined as the ram progresses. As the material flows vertically up the side wall the decreased wall thickness assists with a wedging action which greatly assists the effect on molding pressure where and when it is required. Here the proper taper construction does much to aid the production in molding as well as the easy release of the part when it is being ejected. Also, pieces of irregular wall

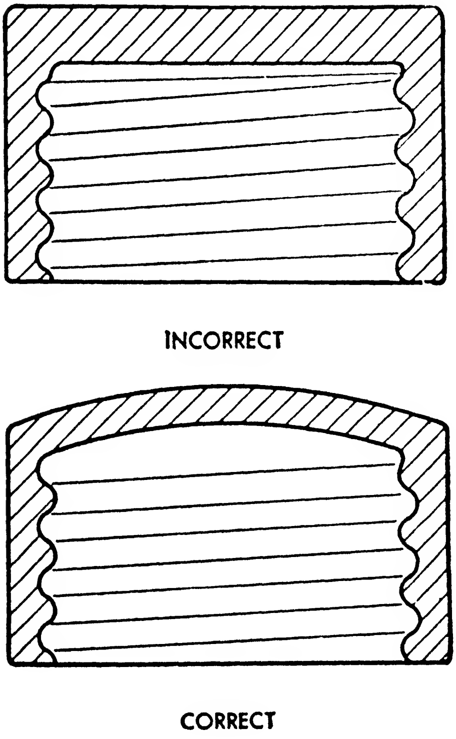


FIG. 22.4 — Bottle and jar cap wall section.

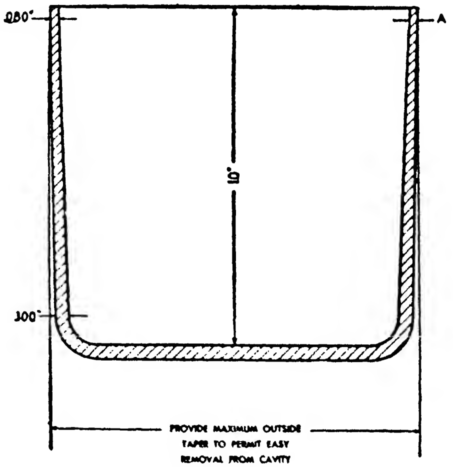
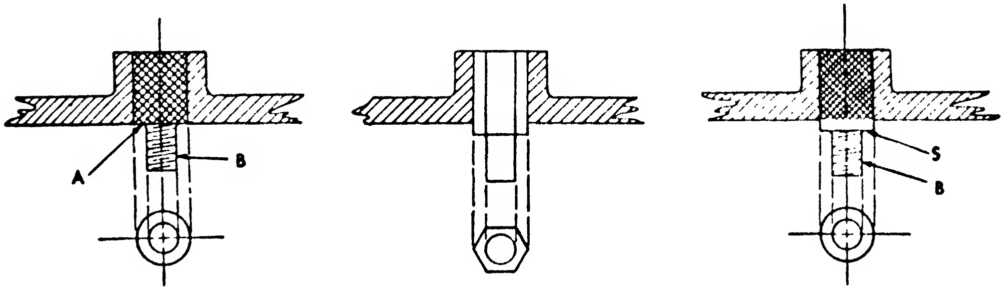


FIG. 22.5 — Correct sidewall taper.

thicknesses will increase molding time in thermosetting materials to that required to polymerize the heaviest section, as well as the cooling time in thermoplastic materials.

Allowances and Tolerances. While parts can be molded with little or no allowance for draft or taper, it is good practice to allow 3 degrees' draft to facilitate ejection of the piece from the mold. Designers have a tendency to demand closer tolerances than are needed. It has been found that, when parts are placed in use, they would have been satisfactory and acceptable with much larger tolerances than originally specified. The designer should remember that when the toolmaker must provide for these exact tolerances in a mold, costs mount rapidly. Do not call for exceptionally close tolerances when they are unnecessary. Tolerances of ± 0.002 in. per inch can be maintained on dimensions perpendicular to the direction of molding pressure on small pieces, but ± 0.005 is considered more practical. On over-all dimensions parallel to the direction of molding pressure, ± 0.005 in. per inch represents about the ultimate, but ± 0.008 or ± 0.010 are more workable. These figures are acceptable for molding both thermoplastic and thermosetting materials.

In designing precision instruments and apparatus, the designer often tends to employ the plastic material so that the instrument's accuracy may depend directly on the molded part. Over a period of time, or aging, slight changes in the molded piece may occur and definitely affect accurate operation of the instrument. Generally, the designer is prompted to do this because of economy or simplicity in assembling, but in most cases this practice has been found to be dangerous. A design problem of this kind might be illustrated by a clock where it is proposed to use plastics for the housing or case. This can be accomplished satisfactorily, however, if the working parts are assembled as a separate unit and simply encased by the molded plastics shell.



Material covers insert at *A* and fills up thread, making cleaning necessary.

INCORRECT

Other than circular inserts protruding from piece makes molds expensive.

INCORRECT

Material will not pass shoulder at *S* and threads *B* will remain clean.

CORRECT

FIG. 22.6 – Embedded metal inserts.

Inserts. Use of inserts is important insofar as they permit inexpensive assemblies and perform valuable functions in molded plastics. They may be of metal, fiber, paper, or pre-molded plastics, and a multitude of other materials that lend themselves readily to the specific problem at hand. By using inserts, simpler assemblies can be made, which are less expensive and equally strong.

The first point to be considered is that metal inserts should be positioned vertically in the part, as this facilitates molding because fundamental motion of the mold is down and up. Care should be used to hold dimensions of inserts to close tolerance so that they can be placed in position by a slight driving fit. This is particularly true when they are placed on top of the piece. Of course, inserts can be molded horizontally, but such inserts should be kept as short as possible. Do not call for blind holes or inserts in the sides of pieces where depth of hole or length of insert is greater than twice the width. Do not try to use long, slender core pins or inserts. They will invariably be sheared off or distorted by the pressure exerted upon them during molding. If using a long insert, preferably of large diameter, it is necessary to support it from two or more positions (Fig. 22.7). This course is necessary when one considers that the working pressure is 1 ton per square inch or more on the molded cross-sectional area. During closing of the mold, pressure at any one point may be much higher. Of course, in molding thermoplastic or thermosetting materials by the extrusion or transfer process (Fig. 22.8) the pressure exerted builds up gradually and uniformly following more nearly the laws of hydraulics, thus simplifying the insert problem and allowing use of delicate inserts.

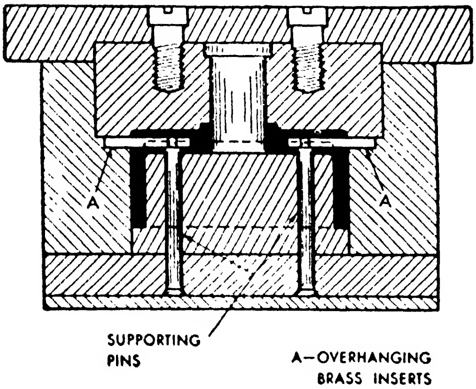


FIG. 22.7 — Supporting long inserts in mold.

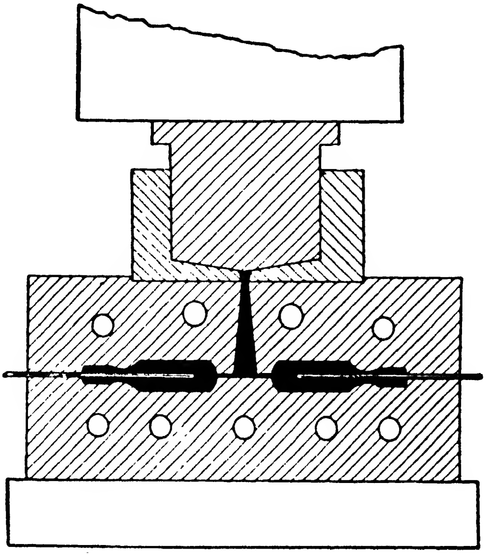
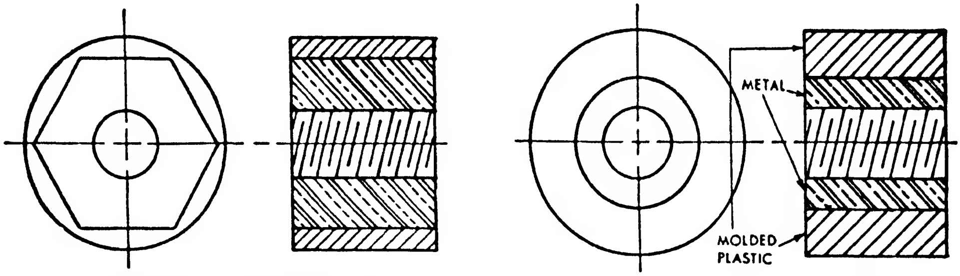


FIG. 22.8 — Extrusion or transfer molding process.

In screw machine production of metal inserts for molded parts, particularly from round rod, proper anchorage, which is easily accomplished by knurling (Fig. 22.6), should be provided. Use a cross or diamond knurl that is fairly coarse and at least 0.010 in. deep on the section of the insert to be embedded in the material. Where square or hexagon rod is used for inserts, grooved undercuts are necessary and these should be of sufficient depth to ensure firm embedding in the molding material. If, however, the hexagonal part is shown protruding from the piece, a hexagonal hole in the mold is required. This increases the expense of building the mold. Do not use square or hexagonal portions above the surface of the molded piece, unless absolutely necessary. Turn down a shoulder on the protruding piece so that it is cylindrical in shape, as a round hole can then be used in the mold.

Metal inserts of large dimensions necessitate taking into consideration differences in the coefficients of expansion of the metal and the plastic in which it is embedded. Cracking may occur immediately after molding, or later in service, when consideration is not given to the fact that shrinkage of the plastic around an insert creates a stress in the former.



THIN WALLS AND SHARP CORNERS AROUND INSERTS CAUSE CRACKING

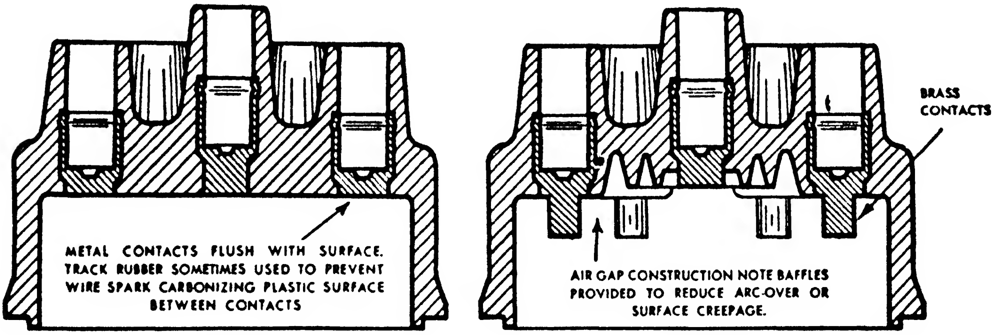
INCORRECT

SUFFICIENT WALL AROUND A CIRCULAR INSERT

CORRECT

Fig. 22.9 — Sufficient wall thickness around inserts prevents cracking.

When using inserts in a molded part, care should be taken that they are not placed too near the edge of the object being molded. Do not use shell-like wall sections around inserts (Fig. 22.9). Provide sufficient wall thickness so that cracking will not result because of differences in the coefficients of expansion of the plastic and the metal.



METAL CONTACTS FLUSH WITH SURFACE. TRACK RUBBER SOMETIMES USED TO PREVENT WIRE SPARK CARBONIZING PLASTIC SURFACE BETWEEN CONTACTS

AIR GAP CONSTRUCTION NOTE BAFFLES PROVIDED TO REDUCE ARC-OVER OR SURFACE CREEPAGE.

INCORRECT

CORRECT

Fig. 22.10 — Air gaps at point of flashing or arcing on electrical parts.

Avoid sharp corners on embedded parts of inserts as mechanical strains will be concentrated at these points.

Appearance of metal inserts can be improved by plating them with nickel, chromium, cadmium, and similar metals.

Metal inserts are frequently used as electrical contacts (Fig. 22.10). Be sure to provide air gaps at the point of flashing or arcing so that there will be no burning, carbonization, or distintegration of the plastic. If an arc occurs on the surface of the molded plastic there is danger of carbonization. Proper selection of the plastic material is, of course, of primary importance in designing equipment that is subject to electric-arcing problems. Frequently there is confusion about the use of plastics for power arcs, as against low amperage arcs, such as magneto or ignition applications. Material suppliers should be consulted on this point. Inserts comprised of hard fiber or track rubber to prevent short circuits at points of contact are desirable, but they should be confined to applications where brush or wipe-spark problems are present. It is better to use a sufficient air gap and baffles. Sharp edges on inserts, between which high voltages may be applied, should be rounded off.

Thermosetting plastics are successfully used in motor commutators. This is accomplished by designing the metal commutator bars so that lugs are provided around which the material is molded. In this way, the metal bars interspaced with mica are firmly embedded in the molded core.

Another method employed in positioning inserts is to place or force them into suitable cavities provided in the molded piece immediately after it is ejected from the mold. In this way, the molding is shrunk around the insert so that, when room temperature is attained, the inserts fit tightly in the molded parts. This method can be successfully used for inlays and for decorative work on molded pieces.

For complicated insert molds, such as multiple-spring relay banks that are used in telephones and other electrical instruments, extrusion or transfer molding is recommended, either in thermosetting or thermoplastic materials. This is necessary to eliminate the distortion which may take place in the compression type of molding.

Fastenings and Hinges. A problem which frequently confronts the designer is that of proper cover construction on boxes, containers, cabinets, and similar parts. Covers often have to be of a different color or another type of plastic than the box or container on which they are used, and trouble arises frequently in designing two pieces that are to fit together, because of the fact that shrinkage varies in different plastics or different colored plastics of one type. In constructing tops and covers, friction fit or the screw type are most economical for phenolics and polystyrenes. A friction fit is less expensive but should be avoided with ureas and cellulose acetates. Fits will be nonuniform with these materials due to dimensional changes.

Where hinge construction is desirable, three types are practical for plastic molding, when considered from the standpoint of simplicity in molding and ease of assembly. They are spring, pin, and piano hinges.

The *Rathbun Spring Hinge* construction (Fig. 22.11) is patented and is made by the Rathbun Molding Corporation. It uses small elliptical-shaped spring-steel clips, for which small undercuts must be provided in both top and bottom of the molded piece. Assembling consists of springing the clips into these undercuts with a special clamping device. Boxes hinged in this way are extremely sturdy and the spring action holds the cover tightly closed or wide open. With this type of hinge, a box can be produced which will open as much as 90 degrees.

Pin hinge construction (Fig. 22.12) is inexpensive from both molding and assembling standpoints. It employs a recess in the side of the box and a molded prong on the cover. A hole is drilled through the side of the box and through the center of the prong and then a hardened pin is driven into the hole.

Piano hinge construction (Fig. 22.13) eliminates the necessity of providing a special design in the mold. Hence, holes for the hinge can be drilled afterward. The hinge, which is made of metal, can be fastened to the molded container with rivets or self-tapping screws. In some instances, holes are molded in the box, but this complicates mold construction.

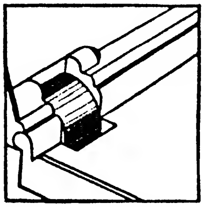


Fig. 22.11 — Rathbun spring hinge.

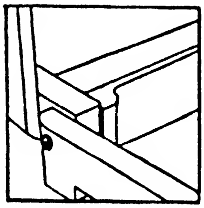


Fig. 22.12 — Pin hinge.

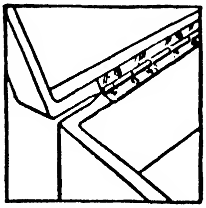


Fig. 22.13 — Piano hinge.

Threads. Strong, accurate threads can be molded in plastic parts. In many applications, threads on molded parts are used so that two molded pieces can be assembled by external and internal molded threads. The standard V-type thread is used extensively for regular mechanical assemblies. However, in bottle and jar caps, a special thread, adopted by the Glass Container Association of America, has been developed to give the greatest ease in screwing the cap on or taking it off the bottle. In this type, a round profile (Fig. 22.14) is used which has been found practical inasmuch as it allows for variations which occur in cast glass threads.

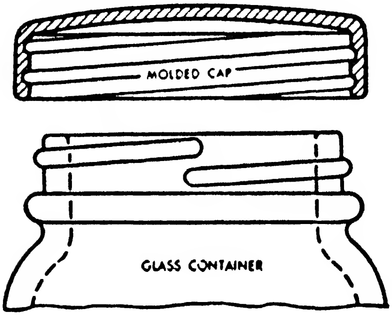


Fig. 22.14 — Standard bottle or jar cap thread with round profile.

Molded threads can be readily unscrewed from the steel cavity, or provision can be made to have separate details or thread plugs which will permit removal of the complete molding from the mold and then unscrewing of threaded portion. On parts having an undercut design where unscrewing the molded piece from the mold is not practical, a conventional parting of the thread may be run along the center line and a sizing die run over the thread later to remove all flash and parting lines. Projecting male threaded inserts should be cut back at the base of the thread to afford a clean joint and to prevent the tendency of the flash to form around the threads of the stud.

Good practice indicates that threads should be started at least 1/32 in. from the end of the face perpendicular to the axis of the thread, as this method produces a more durable molding and eliminates a feather edge on the molded parts (Fig. 22.15).

Not more than 32 threads per inch should be used. A greater number of threads per inch results in slower production in removal of the molded pieces from the mold cavity.

In the molding of small diameter holes, less than 3/16 in. diameter, and which are to be subsequently machine tapped, it is desirable to provide a slight countersink in the molded piece to facilitate easy entrance and withdrawal of the machine tap (Fig. 22.16).

Fillets. Use of fillets (Fig. 22.17) is important on all molded pieces because they overcome structural weaknesses which are inherent in sharp corners. Radii or fillets should be used wherever practicable as this will increase the strength of the molding generally, simplifying mold construction, and consequently reducing cost. They will also tend to strengthen the mold and the molded piece.

Designers should in all cases break sharp corners, particularly on inside construction, and provide a fillet or rib which will permit free flow of material around these sections. This will assist a material that is sluggish in its flow. This is especially necessary for thermosetting materials which undergo continual changes in plasticity characteristics in the short period that the press is closing. Proper radii of corners will do much to help the plastic flow into the proper position for molding. Many times molds that do not fill out the part properly can be made to function properly by adding more generous fillets or ribs in sections which will permit the plastic to flow down or up in greater proportion and thereby fill out long-drawn, or deep moldings, or the upper sections to which flowing the plastic material is necessary.

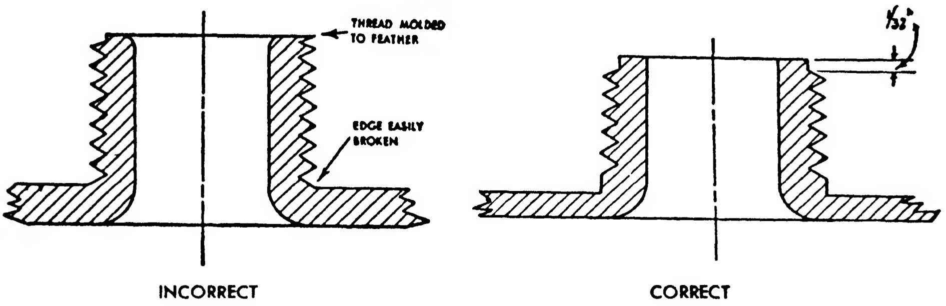


FIG. 22.15 — Start threads at least 1/32 in. from end of face perpendicular to axis of the thread.

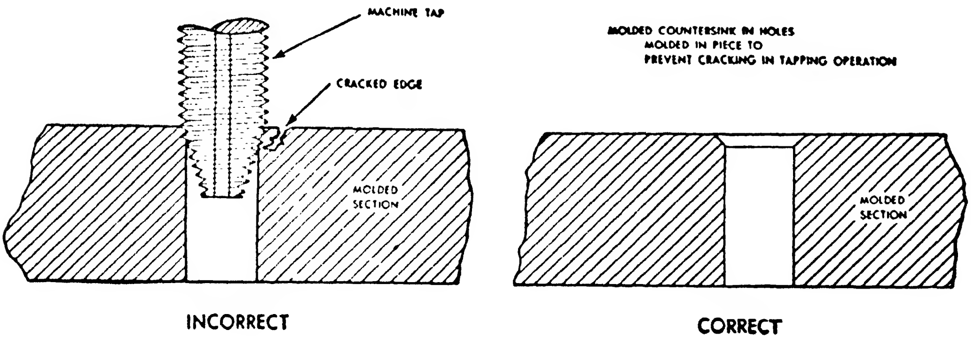
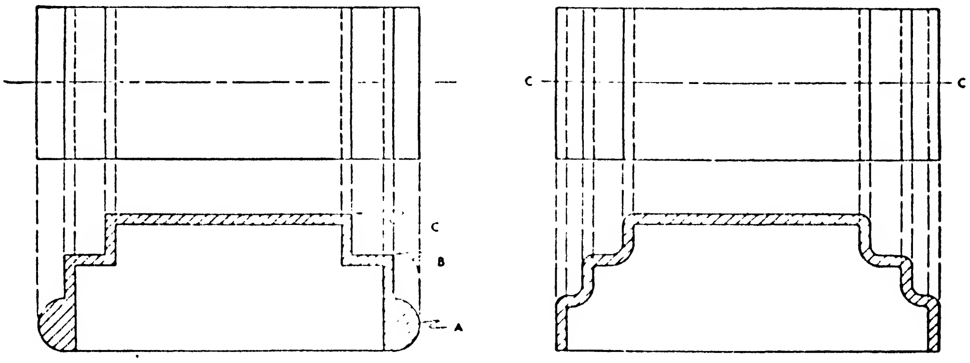


FIG. 22.16 — For machine tapping, provide a slight countersink in the molded piece for holes less than 3/16 in. diameter.

Rules governing fillet construction are those usually adopted in general machine design practice or construction of metal, sand or die castings. Fillets can be produced easily with machine cutters and assist the toolmaker in the ease of polishing the mold surface.

Another important reason for proper and thorough use of fillets is in construction of parts which are to be hobbed (see page 845). Fillets should not be used where the parting line of the molded part is involved. These corners should be left square so that finishing will be simple and the flash or fins can be removed readily by grinding or application to a flat-bed sander. Round corners in this case also necessitate placing parting lines in such a position that extraction of the piece from the mold is difficult.



INCORRECT CORRECT

FIG. 22.17 — Radii or fillets overcome structural weaknesses in sharp corners. *A* should be a sharp corner. As it is the mold must be divided.

More time is required to clean the mold between heats, thus reducing production. Figure 22.18 illustrates correct and incorrect design of hexagonal and elliptical handles.

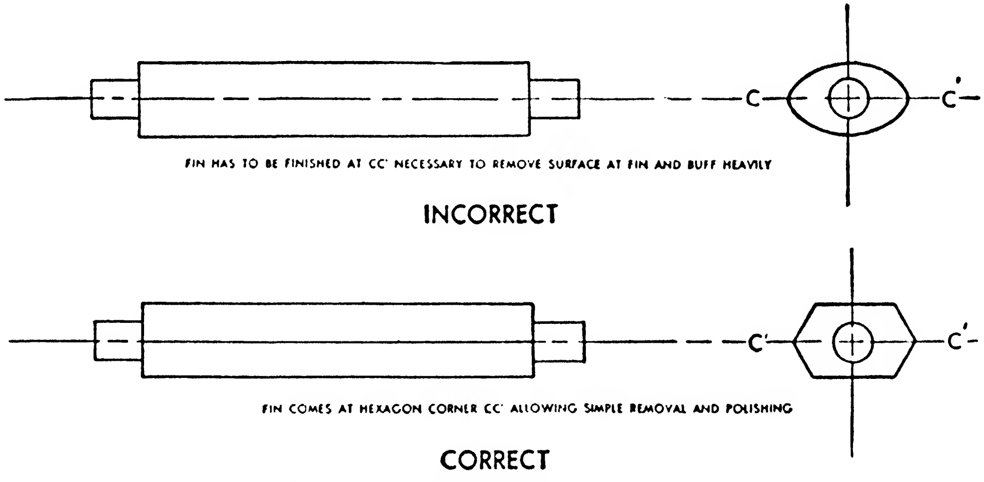


FIG. 22.18 — Design for hexagonal handles.

Knurling. Proper knurling that is consistent with good molding practice will often improve the appearance of the surface or provide a better grip as in the case of handles. In the use of knurling, the fluting should always be placed at right angles to the parting face of the die so that it can be readily withdrawn or ejected. If an intricate design makes this impossible, the use of side cores on which the entire knurl effect is hobbed or machined is practical. Matting or stippling of any desired design or pattern can also be used as a background for engraved characters or letters.

In the use of knurling, shaping or milling, great depth is not necessary. From 0.003

to 0.005 in. will give the necessary effect and light deflection without great expense in tool work or necessity for hobbing.

Knurling can often be used to advantage to assist in removing long thin pieces with inside or outside threads by making the knurl act as a key. This permits using a socket wrench to turn or unscrew the piece from the cavities.

Lettering and Engraving. Little relief is necessary to make surface decoration or lettering stand out. Letters raised 1/64 in. are easily read because they catch sharp highlights; 1/32 or 3/64 in. is almost the maximum to be used on medium-sized molded parts. Fluting or decorative ribs need to be raised only slightly above the surface to catch the light and produce the desired effect.

In injection molding of parts which include large flat areas, it is desirable, where permissible, to break up such areas by the use of engraved or embossed lettering or decorative figures. Such designs serve to hide minute defects, such as shrink marks, which otherwise might be objectionable.

Bas-relief of lettering and engraving (Fig. 22.19) is preferable to reverse intaglio because of saving in tool costs. Raised letters or figures give the desired effect by engraving or carving the design in intaglio in the mold surface, and the molded piece, thus produced, shows the lettering in relief. On the other hand, where the specification calls for letters or figures in intaglio on the finished piece, it is necessary to begin with the highest point in relief on the design and cut away from that to the flat surfaces of the molded part. This, of course, involves much greater skill, often requires considerable handwork, and greatly increases tool costs. When cavities are hobbed the reverse is true. Of course, nongeometrical designs in bas-relief or in intaglio can be produced today by means other than hand engraving. Engraving or pantograph machines will rough out all kinds of freehand design, using brass or white metal masters to guide the cutting tools. This method permits wood carvings and clay or wax originals to be used as either negative or positive masters for the decoration or lettering. This form of engraved surface gives the designer much latitude and permits the use of intricate freehand forms.

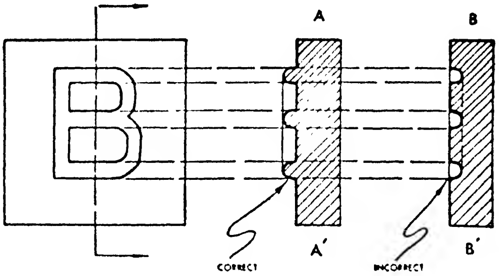


FIG. 22.19 — Bas-relief lettering or engraving. *AA′*, raised letters on a molded piece allows engraving the mold — a cheap procedure. *BB′*, sunken letters on a molded piece means cutting away the mold around the letter—an expensive operation.

NOTE: If a hob is used in building a mold, the reverse is true.

Hobbing, which is the process of sinking a hardened steel replica of the piece to be molded into a softer steel blank, offers an excellent means of producing the desired pattern either in bas-relief or in intaglio. Parts produced in this way in multiple cavity molds are exact impressions of the master hob. Frequently a single die cavity may be an intricate and laborious machining problem. Machining of the hob, however, may be simple by comparison and allows unlimited and rapid production of the cavities.

Intaglio lettering and engraving are frequently called for on instrument cases and panels and a demand exists for lettering or designs that are formed by sharp or incised lines. These designs are then wiped or rubbed in with contrasting colors. Combination of bas-relief and intaglio work produces excellent effects. In using filled-in intaglio work, make sure that the cut-in lines in the molded part, which are to receive the contrasting color, are narrow. These lines should not be over 1/32 in. so that the paint, when daubed on and then wiped off the surface, will not be wiped out of the lines.

There is a demand for individual engraving on plastics items, and machines are available for this type of work. The engraving is accomplished by cutting the letters or designs with rotating cutters which are driven by a small electric motor. After the design or lettering is cut (approximately 0.005 in. deep for plastics), it can be filled in to the desired contrast with gold, silver, black, white, or colored pastes, or with lacquers. Engraving on flat, curved, or oval surfaces is possible, and a permanent result is obtainable because the recessed depth prevents wiped-in color from wearing off.

Inlays. Metal inlays of varying designs from sheet metal 0.005 to 0.010 in. thick can be cemented to molded plastics surfaces with a special adhesive. Afterwards they are lacquered to prevent tarnishing.

Three methods of incorporating metal inlays in molded plastics parts are generally used. One is to cement an acid-etched inlay to the surface of a preform with a special adhesive. A second method consists in holding the inlays in position on the mold at the bottom of the cavity by small pins that fit into small holes in the inlays. These pins prevent the inlays from moving during the molding operation.

In a third method the inlay is first cemented or pressed to a blank of phenolic resin molding board. This blank is then inserted in the mold cavity, face down, and the mold is loaded with a charge of molding material in the usual manner. The result is a strongly embedded design showing no line of demarcation between the blank and the molded section.

Snap-In or Press-In Method. The plastics part is molded with proper recess into which a colored lithographed flanged metal disk is pressed after molding. Trade-marks and nameplates can be fitted into beer spigots for identifying brands, and can be used for numerous other applications.

Surface Finish. All molded parts require a surface finish consistent with their application. Parts for industrial service or which are to function as inside pieces of electrical or mechanical service need not be highly polished. For parts which require any varying degree of luster, from a satin to a mirror-like finish, plastics give a faithful reproduction of the surface finish of the mold cavity. Each piece leaves the mold mirroring faithfully the luster or special characteristics of the mold surface.

A combination of surface finishes offers much to the designer in obtaining unique or pleasing contrasts. Contrasting colors or different types of plastics also can be combined to produce beautiful effects. At present, radio cabinets are being produced with housings in phenolics; the tops in urea; and the grilles in cellulose acetate. An almost infinite variety of combinations can be obtained in various colors. Another method of finish which offers the designer and manufacturer a method of economy on many products is varying the face or front of the part by substitution. For instance, one radio manufacturer has produced three models which are identical in mechanical construction. However, by inserting a plate of different design in the mold cavity, the face of each model is changed and therefore presents an entirely different appearance.

ASSEMBLY ACCESSORIES

Designers and manufacturers are frequently confronted with the need of fastening devices for assembling various sections into complete units quickly and economically. The electrical wiring device industry has shown itself skilled in the methods of fastening. In practically all cases, metal fastenings as inserts were eliminated in the molding operation, thus saving production time at the molding press. It is often possible to avoid the use of metal inserts during the molding operation by employing one of many ingenious methods of fastening. Accuracy is attained and inserts " stay put," as for example, the inserts and embedded bearings used in telephone handsets.

Speed nuts and speed clips have proved of great advantage in plastics molding. They permit economical and rapid assembly because of the ability to provide molded hobs on the panels or other parts to be assembled. The speed nuts and clips are snapped over the hobs and bosses provided. Figure 22.20 illustrates several ingenious applications of nut and clip fastenings.

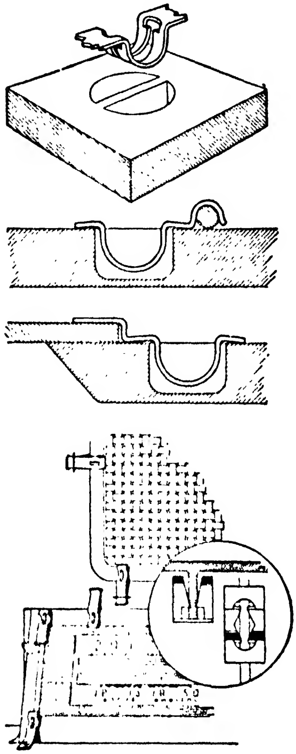


FIG. 22.20 — Speed-nut and speed-clip fastenings.

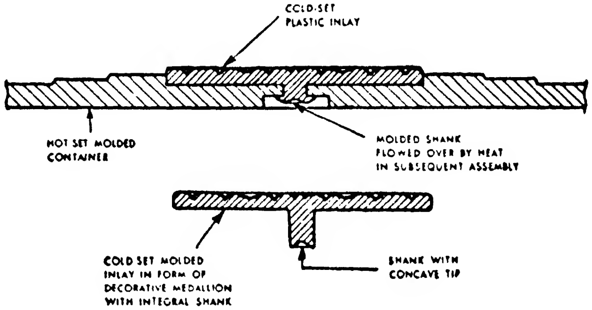


FIG. 22.21 — Inserting cold-set plastics inlay in molded part.

Selection of the method best suited to fastening of plastic and metal or other component pieces requires careful consideration of the type of plastic used, design of part, assembly procedure, and whether the finished product is to be for utilitarian purposes or for decorative use.

Rivets. In the molding of thermosetting materials, standard brass tubular rivets can be used to advantage. The metal rivets are molded or embedded in the plastics part and then fastened to the metal sections by spinning over the rivets. Figure 22.21 illustrates further the possibility of employing thermoplastic inlays to plastics, metal and wood parts. The molded plastics inlay is designed to have one or more integral bosses, hubs, or self shanks usually hollow at the tips, thus permitting them to be softened, flowed, or " headed up," as is commonly done with soft metal rivets. This method offers much to the decorator and designer where contrasts between chrome-plated hardware, die castings, metal stampings, jewelry, and colorful plastics can be combined to advantage.

COLOR AND PLASTICS[2]

Because color and design of plastics are so closely associated, a few of the basic color characteristics are here included. A popular fallacy, for instance, places the combination of black and white as most legible, whereas tests indicate that it comes far down the list. One investigator, Le Courrier, places white on black as No. 10 in a comparative legibility table in which black on yellow comes first. Such a list is shown in Table A. It is interesting in this connection that several watch manufacturers are now departing from the use of the traditional black and white for dials, to use combinations such as blue or green against white, which are more legible.

TABLE A

Legibility of Color Combinations
(Le Courrier)

Order of Legibility	Decoration	Background
1	Black	Yellow
2	Green	White
3	Red	White
4	Blue	White
5	White	Blue
6	Black	White
7	Yellow	Black
8	White	Red
9	White	Green
10	White	Black

TABLE B

Comparative Visibility at Distance

Color	Miles
Red	3
Green	2.5
White	2
Yellow	1
Blue	0.5
Violet	0.5

Another quality of color which should be recognized is visibility at a distance. Blue and violet, for example, become indistinguishable at a distance of about half a mile, whereas red can be identified at three miles or more. The diagram of the primary and secondary colors shown in Fig. 22.22 forms a good means of visualizing the structure of the spectrum. From the three primary colors, any of the thousands of colors used in the plastics industry may be developed. Yellow and red, for instance, make orange, which forms one of the group of three secondary colors.

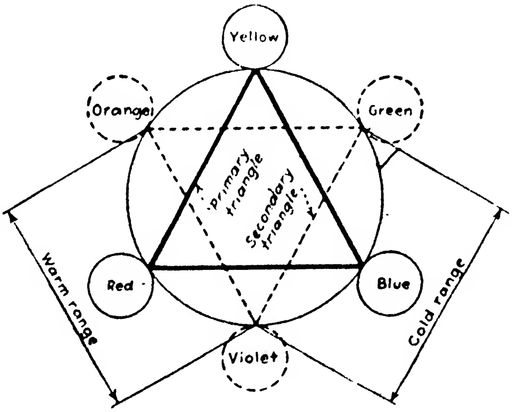


FIG. 22.22 — A color diagram helps to visualize the scheme of color mixing and blending. All of the colors used in industry may be derived from the three primary colors, yellow, red and blue.

In a similar way, any other two primary colors, blended equally, produce a secondary color, and any two secondary colors produce a tertiary color. For example, the two secondary colors, orange and green, will produce

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[2] From Herbert R. Simonds, *Industrial Plastics*, 2d ed., Pitman New York, 1941.

the tertiary color, citron. Violet and green produce olive, and orange and violet produce russet.

Color variation may be made either by using varying parts of two or more established colors, or by mixing any one color with black or white. Variations of the latter character are known as tints and shades of the foundation color, the tints usually designating the blending with white, and the shades the blending with black.

Colors produce varying emotional reactions which seem fairly well standardized for most people. Thus blue is known as a cold color, whereas red is a warm color, and most color variations take on either a cool or a warm connotation, depending upon whether the blue or red element predominates. Russet, for instance, which contains both blue and red, is a warm color because the red predominates.

When plastics products are given the cool colors, they usually appear larger than they actually are, and, conversely, when the warm colors are used they appear smaller. If a high color contrast is desired, it is more easily secured by using a warm color against a cool color than by contrasting two warm colors.

Color harmony is a complicated and highly specialized subject which becomes the life work of some designers. Therefore, only the briefest statement of principles can be given here. Harmony in color usually exists when there is a common color present. Thus, orange and green harmonize with each other because yellow is in each. For the same reason, brown harmonizes with orange, green with crimson, orange with light blue, and gray with lavender.

The addition of a little gray to any two colors tends to make them harmonize, and in a similar way, white may be mixed with one color and black with another to bring the two into closer harmony. However, in spite of the above, no set rules can be established, as the relative amount of color used on a product often determines the effect, independent of the actual color relationship. For example, a small amount of a discordant color may actually tend to emphasize the harmony of two other and more extensively used colors.

The value of any color from a sales point of view is as dependent upon association as upon intrinsic qualities, and a favorable association may develop from advertising or publicity. Thus a red store front, while in itself not particularly pleasing, may become identified with a certain store chain and may thus take on a definite advantageous property. Designers who have studied the question of value of color on automobiles admit their inability to give any rules for attractiveness or sales appeal. Any one color, however appealing at first, loses its value as soon as it becomes identified with mass production, and from this fact one definite rule emerges. " Break up the uniformity of any one model by using several different color schemes." On the other hand, having once identified a certain product with a specific color, it then may become important to maintain this color unchanged, and this brings up one of the most difficult points in the whole realm of colors in industry. The human eye is a variable instrument, and even a color expert may see differently when he has a bad headache. As a rule, light delicate pastel colors which appeal to women have the highest ratio of sales value, while the darker, cold and somber colors are less stimulating to the buying instinct.

DESIGN OF INSERTS FOR MOLDED PLASTICS PARTS

In discussing inserts for molded plastics it should be evident that they should be so designed as to perform their required functions most economically. The design must take into account such factors as: (1) Required mechanical strength of insert in the plastics part; (2) Tolerance on position of insert; (3) Tolerance on threads in insert; (4) Tolerance on length of projecting portion of insert; (5) Required electrical characteristics of insert in the plastics part; (6) Molding material to be used; (7) Method of molding to be used; (8) Position of insert in plastics part with relation to manner of molding; (9) Position of insert in plastics part with relation to flow of material in molding; (10) Amount of molded plastics around insert; (11) General size and shape of working portion of insert; (12) Material of which insert is made; (13) Methods of manufacturing insert; (14) Operations to be performed on insert after molding; (15) Effect of insert on scrap loss during molding or assembly.

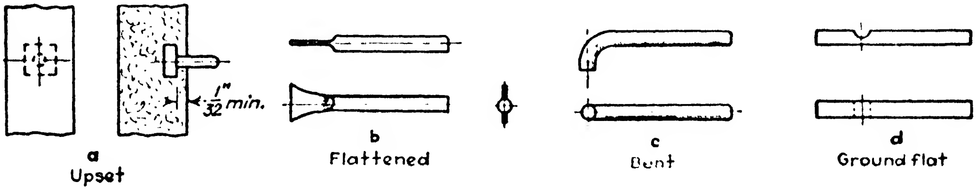

FIG. 22.23 — Location and design of various inserts.

Not all of these factors, of course, apply to every insert. Inserts can be roughly classified as: (1) Rod or wire inserts; (2) Inserts with male threads; (3) Inserts with female threads; (4) Spun-over type inserts; (5) Stamped or punched inserts; (6) Miscellaneous.

In general these rod inserts (Fig. 22.23) must be used with comparatively soft or free flowing molding materials. Their use will probably be restricted to injection molded or transfer molded articles or very favorable designs in compression molded articles. Very little side flow of material under pressure can be permitted as the inserts will bend readily or even shear off. Insert (a) may also lift out of position due to flow of material. A hardened insert such as (d) may be so displaced in molding as to spring out of position when removed from the mold.

In Fig. 22.24 these rod inserts, (a) and (b), must be located from the projecting end and supported by the end during molding. Pressure may upset the insert to the size of hole in the mold which if slightly rough will cause scoring on withdrawal. Flash or dirt in the hole will change the projecting length or if the inserts are supported by knock-out pins the length will vary because of variation in seating of the knock-out bar. There is no general rule about length of insert embedded in the plastic as this will depend upon the pull which the insert must stand, the molding material used, the insert material used, and the flow of material against the insert. In undercutting inserts, such as (b), the undercut should be quite shallow and preferably in the knurled section. The depth of groove should not ordinarily exceed the width of the groove. A half round shape of groove is quite satisfactory in most cases. In insert (d) the embedded shoulders will provide anchoring against axial displacement. An insert such as (e) can be used in place of (c) or (d) frequently. This has the advantage that the stock used is of finished diameter. An upset insert such as (f) can also be used.

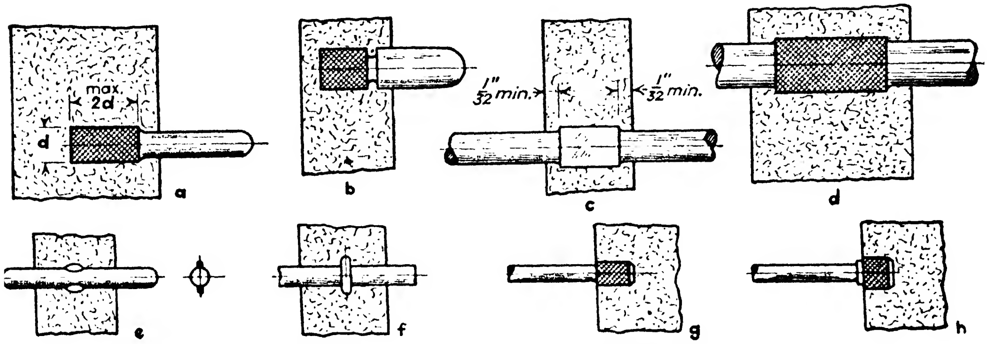

Fig 22.24 — Use of knurled and upset inserts.

Where the projecting length of insert is important, or where the surface must be kept free from scoring or flash, a shouldered insert such as (g) or (h) should be used. This should be chamfered as shown, as should all inserts, and may be undercut if desired.

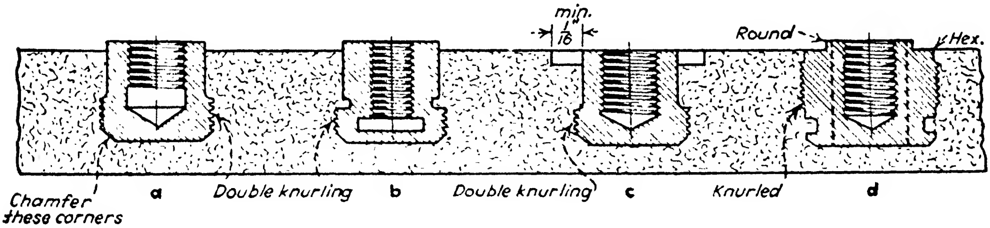

Fig. 22.25 — Typical tapped inserts.

Referring to Fig. 22.25, while inserts with female threads should *preferably* extend above the molding surface, in practice this can be done on only perhaps 10 per cent of them. This is desirable, of course, as it helps support the insert in position at the same time that it prevents material flowing into the threads. Insert (c) results in rather weak mold construction and also requires concentricity of center hole and shoulder as a pilot is ordinarily used in the threaded hole. Insert (d) should ordinarily have thick surrounding walls in thermosetting plastics to prevent cracking.

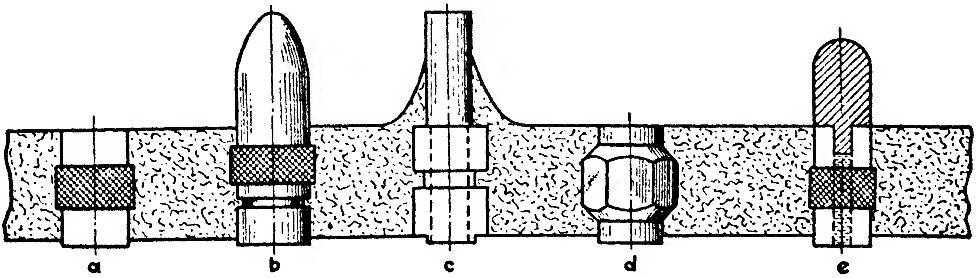

Fig. 22.26 — Inserts in through holes.

The amount of knurling (Fig. 22.26) will largely be governed by the cost of knurling. The extended portion of (a) and (d) will ordinarily be received by recesses in the bottom of the die while inserts (b) and (c) will ordinarily be piloted into the top member of the die. It is general practice to mold through inserts with through holes. Holes may be retapped after molding to remove molded material, or as in (e), a loose threaded pin may be used on the top side to enter the top member of the mold.

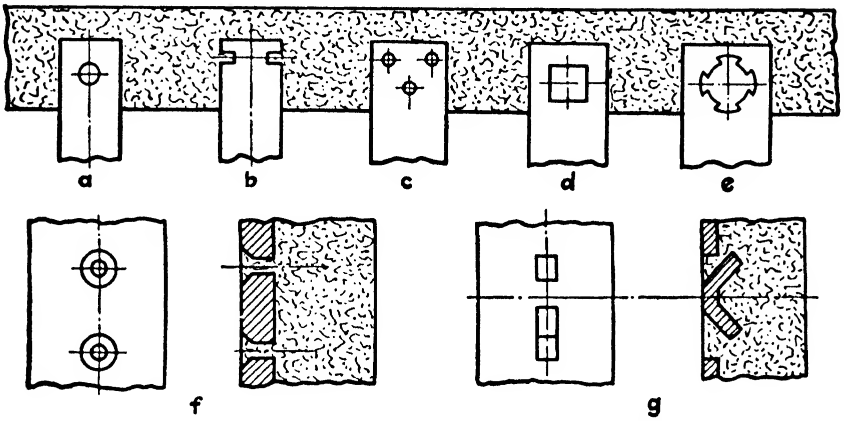

Fig. 22.27 — Various types of inserts in electrical work.

In Fig. 22.27, the holes in (d) and (e) are rather expensive to obtain and present little or no advantage over types (a), (b) and (c). Trouble will frequently be had with (f) in obtaining good anchorage as material will fill the holes and then continue to flow past, forming a flow or cleavage line of low strength.

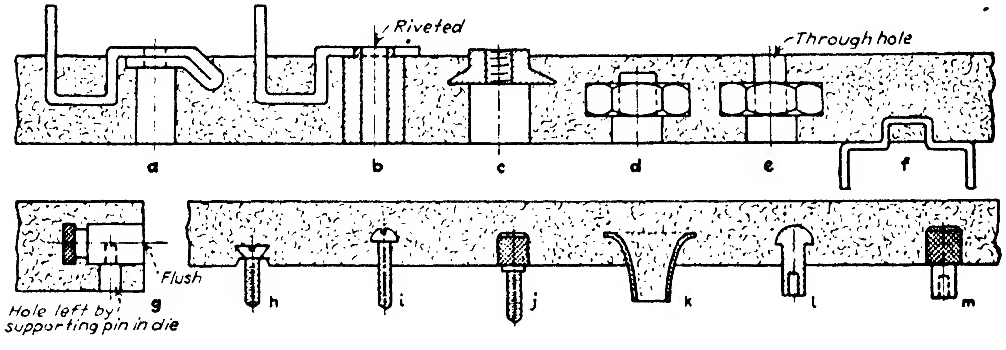

Fig. 22.28 — Imbedded threads offer difficulties and usually may be avoided.

While many punched, stamped or formed inserts (Fig. 22.28) are used, difficulty is usually had in holding them to proper size to fit the mold. Inserts with male threads may be similar to (h), (i) or (j). Flat head or oval head screws can be satisfactorily used when supported as in (h). Round head screws used as in (i) are not very satisfactory as pressure on the head shortens the lead of the thread and molded material gets in the threads, necessitating a cleaning operation. Insert (j) is much more feasible as it eliminates both these defects.

For spun-over inserts, eyelets such as (k), can sometimes be used although rivets as

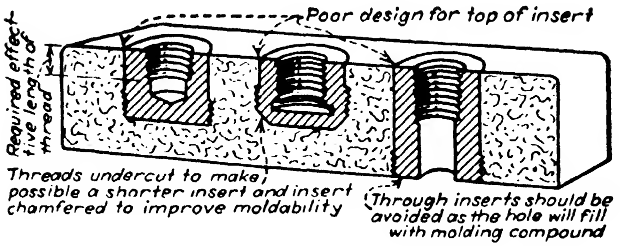

FIG. 22.29 — Inserts in molded plastics pieces should be carefully designed to prevent the molding compound from entering threads. Outer faces of inserts if flush with the surface of the molded part unless in perfect alignment offer an opportunity for molding compound to flow into spaces not tightly sealed. Inserts should be as short as possible and chamfered to reduce possibility of displacement during molding.

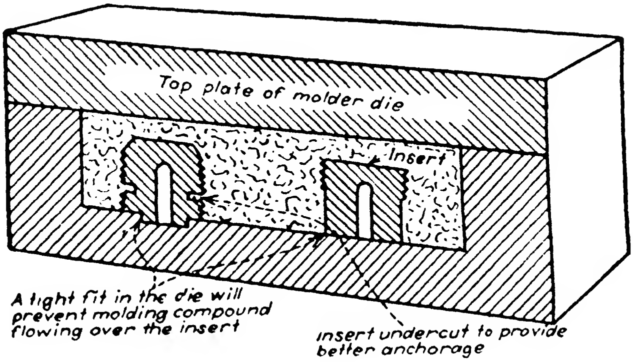

FIG. 22.30 — Designing the mold with a recess which holds the insert tightly will prevent the molding compound flowing over the insert when molding pressure is applied.

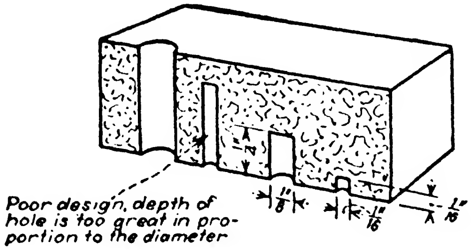

FIG. 22.31 — Holes are easier to mold if they go all the way through a molded piece. Core pins for through holes can be piloted into and be supported by holes in either half of the die. Holes not going all the way through should be limited to a depth of twice the diameter. Small holes 1/16 in. or less in diameter should not be deeper than the diameter.

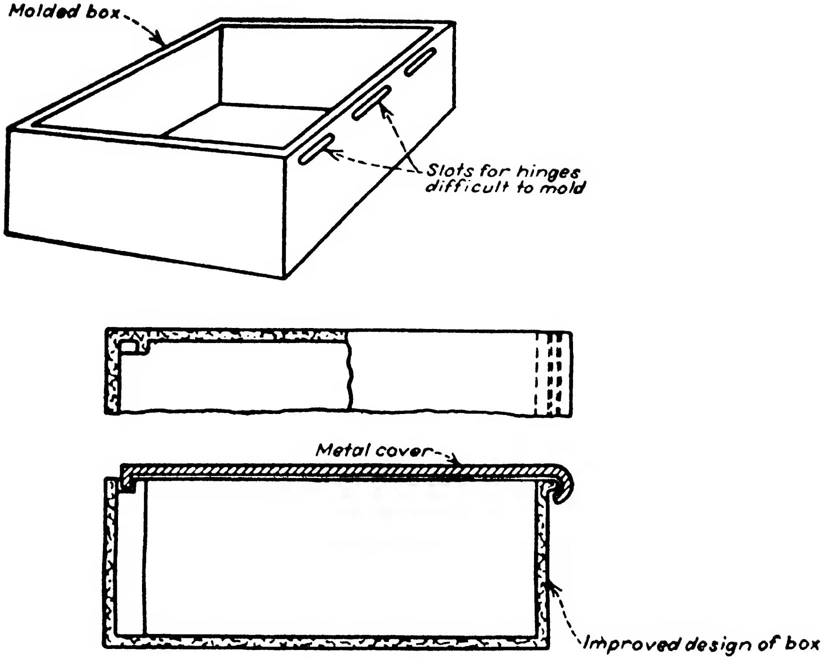

FIG. 22.32 — Boxes designed with slots in the sides for cover hinges are impractical because of difficulties involved in stripping from the mold. An improved design is shown that does not involve any molding difficulties.

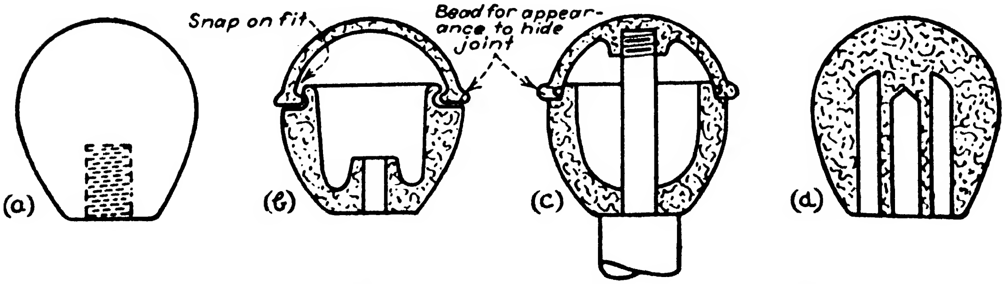

FIG. 22.33 — Four designs of molded balls or knobs, showing how material can be saved and curing time shortened by making them hollow as in *b*, *c*, and *d*.

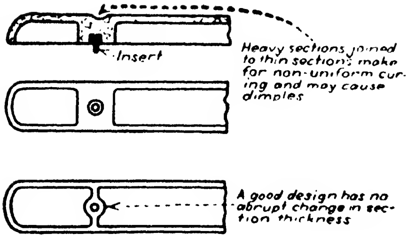

FIG. 22.34 — High rejection percentages can be caused by the raising of blisters or the formation of dimples at heavy sections after the piece has been removed from the die. Variation in flow of the material caused by a change of volume in cavity can result in a streaked or rippled effect and also warping.

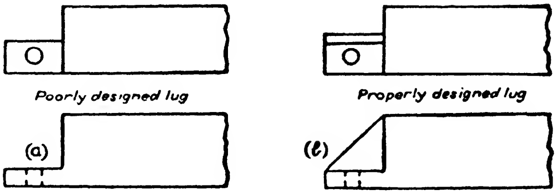

FIG. 22.35. — Design *a* costs more because it cannot be cleaned by tumbling which might break off the lug. By adding a reinforcing rib as shown at *b* the lug is greatly strengthened, and it can withstand tumbling shocks without breaking.

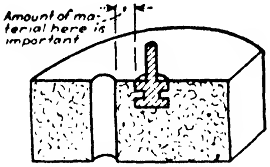

FIG. 22.36 — Thickness of material between an insert and the wall of a hole should be at least 1/32 in., and between holes the thickness should be at least 1/16 in. so that the molding material can flow and fill properly before setting and for strength of tool.

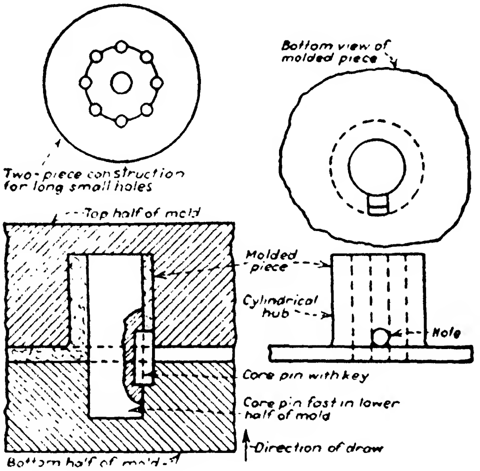

FIG. 22.37 — Method of molding a hole at right angles to direction of draw in side wall of an interior hub or wall.

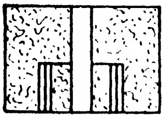

FIG. 22.38 — For long holes of small diameter a two-piece construction can be used to avoid long slender core pins. Inner piece is cold when inserted in warm outer part. Tight shrink fits are readily obtained since the outer part will shrink after being assembled to inner part.

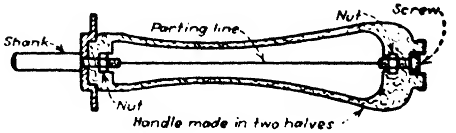

FIG. 22.39 — Design for a handle made of two molded halves. Advantages obtained in use of this design are: saving in compound and more rapid production since less curing time is necessary.

(1) or screw machine inserts as (m) are to be preferred, (m) being most satisfactory on thermosetting plastics.

Figures 22.29 to 22.40 give a few pointers[3] illustrating ways to improve designs of molded parts that make molding less difficult, save material and shorten curing time; they also improve the appearance of the product.

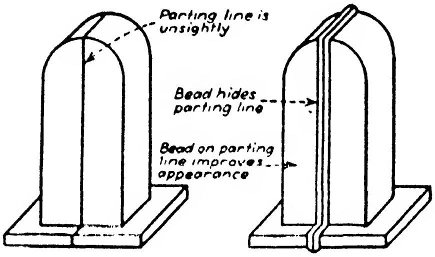

Fig. 22.40 — Unsightly parting lines can be hidden by throwing up a bead at the joint so that they form a part of the appearance design. A bead also permits the part to withstand cleaning by tumbling without scratching.

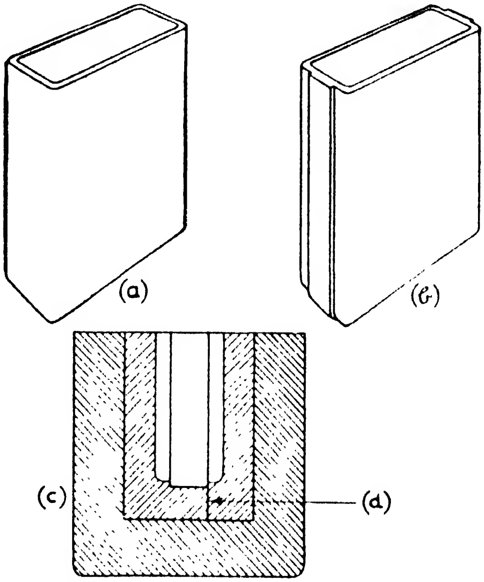

Fig. 22.41 — Bosses in the design often simplify die construction.

Design of a part should take into consideration the mark left by the parting of a split mold. The plain surface of the finished piece in Fig. 22.41a will be marred where steel parts of the mold jam, whereas the incorporation of a decorative boss in the original design, as indicated in Fig. 22.41b, helps to overcome the difficulty.

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[3] F. W. Warner, Product Engineer, General Electric Co.

PART VIII

Commercial Considerations

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CHAPTER XXIII
Plant Practice

CHAPTER XXIV
Selection of Materials

CHAPTER XXV
Estimating and Paper Work
in the Plastics Industry

CHAPTER XXVI
Workers' Welfare

CHAPTER XXIII

PLANT PRACTICE

ROUTINE PLANT INSPECTION AND PHYSICAL TESTING OF PLASTICS[1]

Many of the tests applied to plastics also are applied to other materials, and conform largely with familiar laboratory techniques. In measuring some properties it has been found desirable to modify tests, according to the type of plastic tested, so that the same property may be measured somewhat differently in different plastics. For example, test specimens of different size and shape are found desirable to measure tensile properties in different plastics.

In general, tests in common use have been designed more to measure batch-to-batch uniformity in plastics than definitely to ascertain the relative merits of different plastics for various applications, in which certain properties may be required. This is true especially of plastics which can only be made into a finished article by a molding operation, and whose probable properties in their final form can only be estimated by means of test specimens molded from them.

It must be recognized that the relative suitability and success of molding operations applied to test specimens and to commercial articles may impart somewhat different properties to them, dependent upon the response of various plastics to these operations. Many of the properties of plastics vary with atmospheric conditions to which the plastics have been exposed, and this is a possibility which must be provided for in their tests, and a factor which must be allowed for in considering results obtained.

It is much more convenient to bring plastics to some arbitrary standard condition for test which can be achieved easily and quickly, than to simulate various conditions of service, which may be achieved slowly and require more elaborate conditioning and testing facilities. In general, the former practice is followed in inspection tests. Many tests used for plastics will be found described in publications of the American Society for Testing Materials.

Properties possessed by plastics in finished form, upon which their suitability for various usages most frequently depends, and which are commonly measured are:

Dielectric strength (short time, step by step, fatigue)
Power factor
Dielectric constant.
Insulation, volume, and surface resistance
Arc resistance and tracking
Compressive, flexural, impact, and tensile strength (including elongation)
Resistance to water and various chemical substances
Stability to heat and to light
Dimensional stability
Shrinkage from mold dimensions in molded articles
Taste and odor
Hardness
Surface smoothness
Color clarity
Index of refraction
Clarity to light transmission
Flammability
Specific gravity

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[1] Prepared in co-operation with J. H. Adams, Bakelite Corporation.

Obviously, properties in which superiority is shown, or properties indicative of quality, and therefore of interest to measure, differ in different types of plastics.

Properties chosen for test or measurement usually are favorable ones for which the plastic was chosen or potentially unfavorable ones which must be guarded against. For example, power factor measurements primarily are of interest in a limited number of plastics showing the low power losses which make them especially suited to certain applications. Thermosetting plastics show too little elongation in tension to measure, while thermoplastic plastics may show very large elongations whose measurement may be quite informative. Any tendency to soften under no more than moderate heat or to ignite readily may be liabilities to watch in thermoplastic plastics.

Most of the apparatus required to measure finished properties is standard testing laboratory apparatus. As a rule, ovens to dry, or humidity chambers to humidify test specimens prior to test, are either required or are highly desirable, as may also be an air conditioned test room. For plastics from which commercial articles can be produced only by a molding operation, molds and a small steam or electrically heated hydraulic press, with which loads varying up to about 30 tons can be applied, are requisite for molding standard test specimens.

Dielectric strength tests require suitably shaped electrodes with a rack for supporting them in contact with the test specimen, and a transformer with variable voltage control, with which high voltages (50,000 to 100,000 volts) can be built up across the electrodes at any desired rate, or held at will at any desired value. Because tests frequently are made under oil, a glass tank for oil, amply large to hold specimen and rack, usually is required. A laboratory oven with suitably insulated wires leading in to electrodes also may be required for tests, particularly fatigue tests made at elevated temperatures.

Power factor and dielectric constant tests require either a conjugate Schering, or high voltage Schering, parallel resistance, series resistance; or for cycles no higher than 1000 per second, a transformer bridge to measure the capacitance of a capacitor with air or the plastic under test as the dielectric.

Insulation resistance tests require a source of direct-current potential, preferably dry or storage batteries, a sensitive galvanometer with suitable shunts, a calibrating resistance 100,000 to 1,000,000 ohms, switches and keys, suitable electrodes, and a humidity control cabinet, in which test specimens can be conditioned and held at constant humidity during test.

Various arc resistance tests are in use. One type of test requires a small transformer with a variable resistance or inductance in its primary circuit to control current in the secondary, a milliammeter to measure this current, a motor-driven interrupter to make and break this current at specified rates and form an intermittent arc across a spark-gap consisting of three pointed electrodes resting on the test specimen and held in a fixed position in a block. Another type of test requires a storage battery supplying current through an automobile distributor, driven by a motor at specified speed, to the primary of an ignition coil connected in series with a rheostat for current control. The secondary of the ignition coil is connected to two electrodes bearing on the test specimen, one of which is fixed and one of which is mounted on a driving mechanism such that, with an arc formed, the electrodes can be drawn apart at a constant speed to determine the length to which charring of the test specimen will permit the arc to be drawn. Tracking tests may be performed by dripping salt solution on a small disk electrode, surrounded by an annual electrode under a fixed potential.

Compressive, flexural, and tensile strength tests may be made with standard testing machines used for such tests and having capacities of about 20,000 to 30,000 lb., although in some cases special specimen holders may be required. Two types of testing machine are in use for impact strength tests, the simple beam or Charpy, and the cantilever beam or Izod. In the former, a rectangular test specimen is supported at both ends, and is struck in the middle. In the latter, the specimen is held at one end and struck at the other. The capacity of these machines is usually 2 ft.-lb., and the two types are considered to reveal information of different significance and usefulness. Milling equipment may be needed for notching impact strength test specimens.

Apparatus required for water absorption and tests of chemical resistance usually consists of micrometers and an analytical balance for measuring and weighing test specimens before and after immersion, beakers, flasks, or other vessels for immersing specimens in solutions, and an oven for maintaining test solutions at some elevated temperature. If direct information as to the effect of water or chemicals on certain properties of plastics is desired, equipment also must be available for measuring these properties before and after exposure.

Measurements of heat stability require an oven in which test specimens can be baked for specified times at specified temperatures, and possibly an analytical balance for determining changes in weight. If direct information as to the effect of heat on certain properties of plastics is desired, equipment also must be available for measuring these properties before and after exposure. Special equipment has been designed and may be built to determine the temperature at which a certain distortion of a plastic occurs, or the deformation which occurs under a fixed load at a fixed temperature. This equipment is described in American Society for Testing Materials publications.

Accelerated tests for light stability require some type of ultra-violet or sun lamp. No lamp, however, exactly duplicates in a short time the results of longer exposure to sunlight, and differences of opinion exist as to what type is most informative.

Measurements of dimensional stability require suitable gauges for measuring test specimens and apparatus for drying and humidifying them.

Taste tests require suitable containers in which the plastic can be confined in more or less intimate contact with substances, effects upon taste of which are readily apparent or of particular interest. Equipment for maintaining these containers at some constant temperature is very desirable. Odor tests may be made by confining test specimens in a closed container at some specified temperature, odors developed within the container being judged by personal observation, either with or without such aids as the osmometer. With equipment for chemical analyses available, determinations may be made of substances readily soluble from the plastic and thought of as particularly liable to impart taste or odor to it.

Hardness may be measured by standard scratch-hardness testers, abraders, or indentation hardness testers, dependent upon what aspect of hardness is of interest.

Properties of plastics having to do with their appearance may be judged visually, or including index of refraction, measured more precisely with standard instruments for making optical measurements.

Flammability measurements require a standard fusee, flame, or source of heat to ignite the plastic and a shield on which it will burn (insofar as it will) under controlled conditions.

Specific gravity may be measured by any of the standard methods having requisite accuracy.

Various volatiles, various extractables, and ash contents of plastics may be determined as aids to their identification. These are well known laboratory operations, requiring standard chemical apparatus.

In addition to properties possessed by plastics in their finished forms, properties governing their molding quality are measured in plastics subjected to molding operations. Properties measured are granulation, bulk, tableting qualities, plasticity, adhesiveness for mold surfaces, or tendencies to attack same. Measurements of bulk and granulation require standard dry measures, test sieves; a mechanical sieve shaker is desirable. Tableting qualities are usually judged in a standard tableting machine. Plasticity may be measured roughly with any mold and press suitable for molding plastics by determining how much of an over-charge will be expelled from the mold. A mold with a small orifice through which plastics extrude in varying amounts, depending upon their plasticity, also suffices for rough measurements. The Rossi-Peakes flow tester is available commercially as a machine especially designed to measure various plasticity factors with accuracy. Equipment used to measure general molding qualities is largely devised by the laboratory using it. See Test Methods for Physical Properties, Chapter III, page 58.

PRODUCTION CONTROL

Like most chemical industries, the quality of plastics is largely dependent upon chemical control. For the most part automatic controls are used throughout the industry. However, there are many instances where the product itself must be checked. Plastics formed through combination of condensation and polymerization usually require some form of drying operation. Throughout the operation spot checks must be made to determine uniformity. Usually, some physical characteristic of the resin which can be readily checked is determined. The plastics flow is one such property. The frequency of check is dependent upon the rate of travel through the drier and the amount of material being dried.

Irrespective of the amount of care used there will be small variations in the properties. To overcome this, the plastics batches are blended.

Plastics are available in a wide variety of plasticities. In addition they may be fast or slow curing. They may contain a variety of fillers. The production control department of any manufacturing plant is vital to the interests of the molder. No general procedure of test is used throughout the industry but each company has worked out a method adaptable to its own products.

Usually in addition to control tests, the manufacturer sets up special tests involving moldability, permanence, and suitability. For example the Plaskon Company before the actual commercial production of the famous Toledo Scale cover, built a room capable of holding several hundred covers, which was so controlled that the expected durability of the covers could be determined in a relatively short period of time. Today, even though this job has been in current production, covers are being continually checked. This ensures against failure on the consumers' counter.

In some instances, the presses and molds in use for checking plastics by the manufacturer exceed those in some molding shops. It is not uncommon to find the plastics manufacturer setting up pilot plants to check the suitability of his product for certain uses.

Pulp companies, producing materials for the resin industry, have set up miniature resin plants to test the uniformity of their products. This has been found to be a better approach to the problem than relying entirely on the usual pulp tests which in many cases fail to differentiate between the pulp acceptable or unacceptable for the plastics industry.

Testing of Incoming Raw Materials. Incoming raw materials are tested for two reasons: (1) To determine their conformance with established requirements as a basis for acceptance and rejection of the shipment of material. The limits assigned are usually as wide as the manufacturing basis will permit in order to minimize difficulty and expense in obtaining raw materials. (2) To determine characteristics of the incoming shipment which will be used in formulating the molding compound.

The following are examples of the types of materials tested and of the tests applied for phenol-formaldehyde plastics.

Wood flour
Moisture content
Acetone extraction
Oil absorption
Ash content
Bulk
Fineness
Color (visual)

Formaldehyde
Specific gravity
Per cent methanol
Per cent formaldehyde
Reactivity
Turbidity
Acidity
Color

Cresylic Bodies
Per cent orthocresol
Per cent phenol
Distillation range (Engler)
Water content
Odor
Melting point
Per cent pyridines
Appearance
Resinification

Hexamethylenetetramine
Ash content
Color
Moisture content
Concentration
Fineness

Dyes
Color
Ash content
Acetone extractable matter
Alcohol extractable matter
Moisture content
Fineness

Pigments
Fineness
Ash content
Oil absorption
Moisture content
Color

Waxes
Melting point
Cleanliness

Stearates
Fineness
Color
Ash content
Ash content washed material
pH

Papers and Cloths
Bursting strength
Tensile strength
Moisture absorption
Densometer
Oil penetration
Basic weight
Thickness
Width
Color
Ash content

Most of these tests are recognized chemical tests and many of them are covered by A.S.T.M. test methods. Some tests are peculiar to the companies making them.

On certain materials such as the cresylic bodies, formaldehyde, and catalysts, the tests are used as a basis for modification of formulas in order to promote obtaining uniformity in different batches of material.

Testing of Semi-Finished Products. Semi-finished products mean such things as phenolic resins, phenolic varnishes, phenolic molding powders, and phenolic laminated materials. Typical tests applied to these materials follow:

Phenolic Resins
- Flow point
- Fineness (after grinding)
- Cure

Phenolic Molding Powders
- Flow
- Cure
- Shrinkage
- Dielectric strength
- Specific gravity
- Flexural strength
- Impact strength
- Bulk factor
- Pourability
- Moisture absorption
- Per cent acetone soluble matter (where required)
- Per cent ash content (where required)
- Power factor (where required)
- Tensile strength (where required)

Phenolic Varnishes
- Viscosity
- Specific gravity
- Cure
- Flow point
- Per cent acetone soluble matter

Phenolic Laminated Material
- Resin content
- Volatile content
- Squeeze-out
- Per cent acetone soluble matter

As in "Testing of Incoming Raw Materials," quite a number of these tests are either standard A.S.T.M. tests or are being considered by A.S.T.M. at the present time.

Testing of Finished Products. The testing of finished products can usually be segregated into two classes: one, more or less general tests for quantity of moldings, while the second consists of more or less special tests for specific characteristics.

1. *General Tests*
   - Specific gravity
   - Flexural, impact and bending tests made on Dynstat
   - Appearance
   - Tests for cure such as boil test or cycle test on ureas or acetone extraction test on phenolics

2. *Specific Tests*
   - Tests for weathering in a weatherometer, by outdoor exposure or in a humidity tank
   - Drop test for strength
   - Test for ammonia
   - Coefficient of linear expansion

Ability to withstand hydrostatic bursting pressure
Tests for odor and taste
Resistance to chemicals
Hi-potting
X-ray examination

The specific gravity test is believed to be the best all-round, quick test for checking quality of phenolic molded parts. If the specific gravity is normal for the material involved, the part will usually have normal physical and electrical properties. With average molded parts considerably more intricate than the simple test specimens used for control work, it is customary to find that the specific gravity of commercial moldings will run as much as 3 per cent below the values obtained by control laboratories on their test specimens.

The Dynstat is a handy testing machine for making physical tests on specimens cut from molded parts. The machine requires a test specimen approximately ½ by ¼ by ⅛ in. thick. It is equipped for running impact strength, flexural strength, and bending angle on this specimen supported as a cantilever beam. Impact strengths in English units range from 0.03 ft.-lb. on wood-flour filled materials to about 1.3 ft.-lb. on rag-filled phenolic materials. It is not possible to duplicate other impact tests. On the flexural tests the Dynstat checks reasonably well with standard A.S.T.M. tests, but with a tendency to be slightly high. The bending test is related to the modulus of elasticity of the material and is not often used. The principal value of the Dynstat is in making comparative tests on two or more materials in the same mold.

On inspecting finished parts for appearance, one usually checks for low-density sections, cracks, or blisters. On jobs requiring high finish, the finish is also noted.

The boil test and cycle test on ureas are well established.

The acetone extraction test for cure on phenolic molded parts determines the percentage of uncured resin plus the percentage of acetone soluble materials that are present in the ingredients going into the molding powder. This test is covered in Navy Specification 17 P 4.

The Atlas weatherometer is one type used for weathering tests. This exposes one side of specimens to ultra-violet light and moisture on periodic cycles. The correlation with actual exposure is in the range from 7 to 1 to 10 to 1. In other words, one week's test in the Atlas weatherometer is roughly equal to two months of outdoor exposure.

Exposure to 100 per cent relative humidity at 100° F. is a severe test for most molded parts and probably represents an accelerated life test for applications in very humid surroundings. It has been observed that radio cabinets which have failed in three weeks' exposure in such a humidity tank have given service trouble in six months in Thailand (Siam).

In certain applications, it is necessary to use materials having a very low ammonia content. Test is made by immersing for 48 hr. a specimen of approximately 100 gm. in 1 liter of distilled water and then running a Nessler test on the distilled water. It is necessary by actual experience to correlate the amount of ammonia which can be permitted with service troubles.

In testing for odor and taste, it is customary to immerse small specimens in 10 cc. of distilled water in a closed quart jar with a slice of fresh sweet butter. Specimens are held over night in a refrigerator, after which they are brought up to room temperature. The butter is smelled and tasted.

Tests for action of chemicals are usually performed to duplicate as nearly as possible service conditions.

Where misplacement of metallic inserts or the presence of foreign bodies in molded parts is a serious matter, it is not uncommon to use an X-ray fluoroscope to check the molded parts involved.

Regular A.S.T.M. tests are applied to phenolic laminated materials.

Inspection. The inspection given any particular molded part depends principally on the importance of the part and on the quality level currently maintained in the production of the part. In other words, if production is running at a very high level of quality for any given part, less inspection is required than if the production is running at a low level of quality on the same part. Inspection will vary from a quick spot check on a few parts to a very thorough inspection of all parts.

Most plastics parts receive only a visual inspection for such defects as low density, porous (not filled out), cracks, blisters, burned compound, unacceptable finish, misplaced or damaged inserts, omitted operations of incomplete operations. In such inspections, simple equipment such as an illuminated magnifying lens, scale, and drills may be used.

More complicated inspection consists of simple gauging operations such as thread gauging, plug, or snap gauging.

Still more complicated inspection involves the use of complicated gauges to check warpage and the relationship of important points or surfaces.

It is frequently necessary for the inspector to check specific gravity to ensure proper physical soundness or to hi-pot parts to ensure satisfactory electrical performance. As pointed out before, where misplacement of metallic inserts or the presence of foreign bodies may give trouble, the inspectors should examine parts on an X-ray fluoroscope.

Where customers' specifications require such things as an ammonia content not to exceed so many parts per million, or the ability of the piece to withstand the drop of a 1-lb. steel ball so many inches to a certain part of the piece when supported in a given manner, arrange to perform such tests on enough finished parts to ensure that the customer's specification is being met. Here, again, it is not infrequent to make quite a few tests at the beginning of production until some background of information is obtained, after which, if parts run satisfactorily, the frequency of testing is decreased to a level which is believed adequate to maintain quality.

Customers occasionally have service troubles and may come back to ask an opinion on the plastics parts which may have been involved. The check is usually limited to a check of specific gravity and cure and visual observation. If the material seems to be properly molded, the breakdown can usually be attributed either to some special circumstances in the use of the part or to poor design (including application of wrong material). The conditions under which the part is used are closely re-examined and if it appears that a change in material will correct the trouble, such change is made and parts are checked by accelerated tests if possible, otherwise by awaiting field experience.

PRICE AND PRODUCTION[2]

A customer may tell a molder that he wishes a million molded pieces delivered at the rate of 100,000 a month and may place his contract on that basis and yet later, if he finds he needs 200,000 a month, he is surprised if the molder offers any objection in assuming the increased business. Actually, such an increase, if extended over a relatively short period, may cause the molder a loss on the whole contract if he has figured closely in the first place and then readjusts his equipment for the larger production. In all plastics molding, the relation between the mold price, the piece price, and the monthly production is important, as indicated by the following examples:

TABLE 122. PRICE AND PRODUCTION

Number of Cavities	Cost of Mold	Piece Price	Production per Month	Total Cost of Mold and 100,000 Pieces	Total Cost of Mold and 1,000,000 Pieces
1	$ 200	5.0¢	10,000	$ 5,200	$50,200
2	375	4.0¢	16,000	4,375	40,375
5	900	3.6¢	30,000	4,500	36,900
10	1,700	3.4¢	50,000	5,100	35,700
30	5,000	3.1¢	100,000	8,100	36,000
60	7,200	3.0¢	130,000	10,200	37,200

It will be noted that for a total order of 100,000 pieces (fifth column above), the lowest cost is for a two-cavity mold producing at the rate of 16,000 pieces per month. If the total order is extended to a million pieces (sixth column above), the lowest cost is for a ten-cavity mold producing at the rate of 50,000 per month. In either case, an increase in monthly production, with equipment as indicated, would result in an increase in total cost. This, of course, is all based on the assumption that operating conditions in the plant remain unchanged. In actual practice, some overtime work might increase monthly production without adding much to the total cost. The table does not include interest on investment and other overhead expenses which might also alter results.

Because the mold is so expensive, molding companies have adopted the practice of spreading the mold cost through the first order. There is also the temptation for them to go even beyond this, in closely competitive business, by taking a chance of getting future business and distributing the mold cost over that as well.

It is considered better practice, however, for the molding company to charge the customer the actual cost of molds and, when they are built, to consider them the customer's property. Here, of course, he runs the danger of having the customer take away the molds and his business with them. To guard against this liability, some molders make a mold charge to the customer of say 90 per cent of the cost, and then never actually transfer ownership.

Automatic Presses. The decreased labor costs and increased speed of production that result from the use of automatic presses must always be balanced by the invest-

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[2] From Herbert R. Simonds, *Industrial Plastics*, 2d ed., Pitman, New York, 1941.

ment. In many cases, however, those advantages, coupled with lower cost of mold and virtual elimination of flash, make automatic presses most economical.

The following are a few examples of savings effected by use of automatic presses, as quoted by Edward S. Walker and G. W. Glenn (F. J. Stokes Machine Co.).

> A toy manufacturer substituted an automatic molding for a die casting and savings paid the entire cost of the press, mold, and installation in 100 days.
>
> One electrical manufacturer cut the cost of moldings from one cent to approximately 1/10 cent each. Another electrical manufacturer bought an automatic machine and four-cavity mold for the price he would have paid for a conventional 50-cavity mold, and was able to meet his production requirements.
>
> Costs are greatly reduced by use of this type of machine in many cases. An aluminum part turned in a screw machine was found to cost $76 per thousand, but a plastics molding actually of superior quality was turned out for $12 per thousand. An automatic molded toaster leg was found to have a shop cost of $1.70 per thousand; the former method had cost $15 per thousand.
>
> The machines require no operating attention and thus may be run almost continually.
>
> Output is high; with one cavity running on a 60-second cycle, as many as 10,080 moldings may be produced a week. A four-cavity mold on the same job can produce one million parts in 173 days.
>
> A Stokes machine, used in the plant of a toy manufacturer, produces what is at present the highest output attained. Using a subcavity mold for 19 pieces, the machine produces one million pieces in 35 days.

With fully automatic presses now available, the art of plastics molding, aided by the developments in plastics molding materials, becomes less dependent upon skilled operators and consequently unit costs are largely determined by the initial investment in molds, the cost of the material selected, and cost of power for operation.

Usually, by taking some forethought, the designer can reduce mold costs by designing the single-cavity hand mold, ordinarily made up for production and acceptance studies, for later adaptation and installation in the automatic molding machine.

Because it is not unusual to operate automatic molding machines continuously 7 days of 168 hr. per week, it is possible to make a lot of a few thousand pieces with an automatic press and a single-cavity mold before a multiple-cavity mold could be completed. Also, on this basis of operation, if a single-cavity mold can be made in 2 weeks and if it would take 4 weeks to make a 12-cavity semi-automatic mold for the same piece, more than 32,000 molded pieces could be made on an automatic press with a 1 min., 30 sec. cycle running 168 hr. per week before 12-cavity mold with a 2 min., 30 sec. cycle running 40 hr. per week could produce the same number.

Thermosetting or thermoplastic materials can be handled in the automatic molding machine. Granular or powdered molding material is loaded into the hopper of the machine, from which a charge measured by a micrometer volume-metering device is fed by gravity through tubes to the cavity or cavities of the open mold.

Loading the storage hopper with new material, carrying the finished parts to a tumbling barrel, loading and unloading the barrel, are the only operations requiring labor after the machine has been set up for production, because after molding and ejection, the piece is lifted free of the mold by a blast of air from a jet and falls into a chute leading to a catch box.

Filling the mold with a definite volume of material, closing the mold and the press, de-gassing or breathing, applying a predetermined pressure, controlling the mold temperature, timing the cure, opening the press and mold, ejecting the molded part and blowing it into a discharge chute, and starting a new cycle — all these operations are performed automatically without loss of time between operations in the automatic molding press. (See Fig. 23.1.)

Because the amount of material that is charged into the molds is accurately measured, the mold can be designed with flash that is paper thin, so thin that it can often be removed in assembling operations thus eliminating punching, shearing, drilling, and grinding for flash removal. The material that is ordinarily wasted in flash is considerably reduced with this system of measuring the charge and, of course, the value of the amount so saved is in proportion to the unit cost of the material.

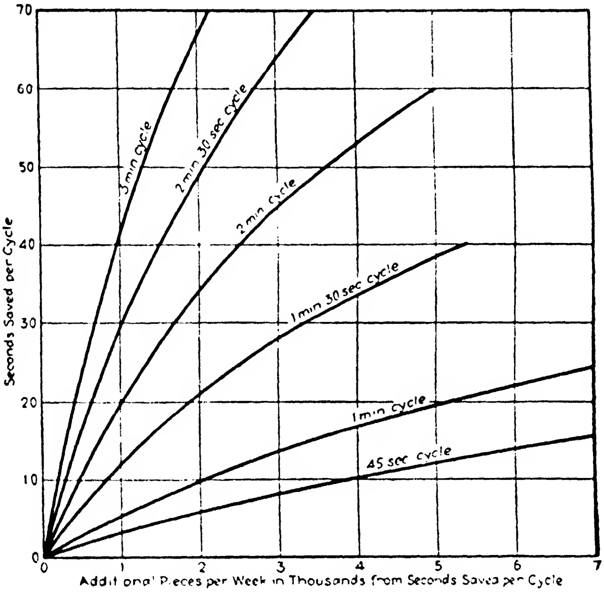

FIG. 23.1 — Importance of saving seconds in molding cycle time is graphically illustrated. Curves show additional pieces that can be molded per 168-hr. week by cutting seconds off the time of various molding cycles.

Uniform physical properties and dimensions of the molded part are assured as the time and temperature of the cure, as well as the molding pressure, are maintained constant for all pieces made in the single cavity. Uniformity in dimensions may be an important factor if the molded piece is later assembled with other parts.

Another type of press (Fig. 23.2) working on an internally threaded piece produces at a high rate and at low total cost. The press used is provided with a three-compartment powder-measuring device and three separate cavities each equipped with an unscrewing device to remove molded pieces from the threaded forces. The outside surface of the molded part is fluted or grooved axially so that, as the mold is rotated by the stripping motor, the molded part also rotates and screws off the force. The force moving upward also carries the piece upward in the mold during the unthreading operation which is completed just as the piece is free of the cavity. The piece is then blown into the chute by means of an air jet. The unscrewing device is automatically timed to synchronize with other press operations.

This part is an excellent example of how seconds saved in the molding cycle are reflected in costs. Data taken from a cost study of 3000 of these parts made of a phenolic plastics material show that at 12 cents per pound the material cost $2.61, the cost of power for operating and curing was 23 cents with a rate of 1.5 cents per kw.-hr., and the production time for 3000 pieces was 12.5 hr. The molding time per cycle was 45 sec., which includes 27 sec. for curing. Three single-cavity flash-type molds were used in the press. Weight of piece is 3.1 gm. Total cost per piece is less than 0.1 cent, not including overhead and finishing.

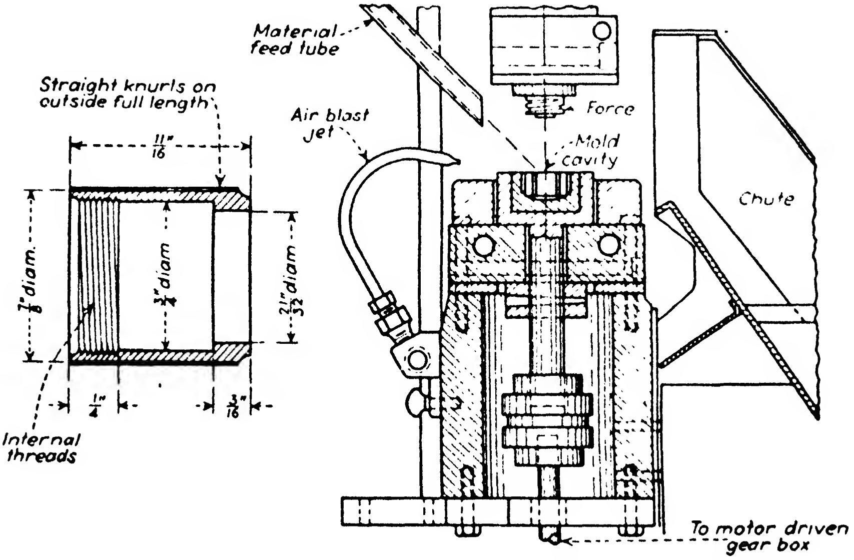

Fig. 23.2 — Set-up showing mold for automatic production of threaded caps.

Typical Fully Automatic Presses. These machines give continuous operation, 168 hr. per week if desired, and mold all standard types of materials. They are equipped with automatic de-gassing, and press control is by a time-cycle mechanism. The molds may be changed, the time-cycle retimed, and the material-metering device reset in 20 to 30 min.

A mold costing $200 can produce 200,000 moldings at a mold cost of 0.1 cent per piece.

Case Histories. A 60-gm. cord retriever part cost $60 per 1000 pieces in a 5-cavity hand mold. After redesigning for automatic molding at 46 gm., the cost was reduced to $12 per 1000 pieces.

A piece weighing 3.8 gm., for a toy locomotive, cost $1.32 per 1000 pieces for material and machine operation at 1.5 cent per kw.-hr.

Power. Electrically powered and heated, no hydraulic pumps, valves, accumulators or pipe fittings needed. Only requirement air supply 70–90 lb. per sq. in.

Output.	1 machine (60-sec. cycle)	1-cavity	10,080 pieces per week
	1 machine (60-sec. cycle)	4-cavity	1,000,000 pieces per 173 days
	1 machine (60-sec. cycle)	19-cavity	1,000,000 pieces per 35 days

TABLE 123. ADDITIONAL PRODUCTION PER SINGLE CAVITY

For Time Cycle of	Additional pieces per cavity per week from seconds saved per cycle. (Based on 168-hr. week.)				
	15 sec.	30 sec.	45 sec.	60 sec.	90 sec.
45 sec.	6,720				
1 min.	3,360	10,080			
1 min. 30 sec.	1,360	3,360	6,720		
2 min.	1,720	1,680	3,020	5,040	
2 min. 30 sec.	440	1,008	1,730	2,690	
3 min.	305	672	1,120	1,690	3,360

TABLE 124. COST STUDY OF AUTOMATIC MOLDING *

KEY

A — Completely Automatic Press (1-cavity mold)
B — Conventional Semi-Automatic Press (6-cavity mold)
C — Conventional Semi-Automatic Press (12-cavity mold)

	A	B	C
Delivery starts after (weeks)	2.0	3.5	4.0
Order filled in (weeks)	7.0	9.0	7.5
Mold costs (dollars)	450	1800	3000
Heat, power and labor costs (dollars)	15	125	80

* An order for 40,000 ash trays; production and cost comparison; various molding methods.

THE FUTURE OF PLASTICS

How all-inclusive will the plastics industry become? What new fields will it enter? It has already invaded the well-entrenched strongholds of glass, wood, and metal. The familiar bottle cork has given way by the millions to plastics closures. Plastics are tops in the lighting field. Plastics plywood is displacing some aluminum in aviation. Plastics in several forms threaten some of the steel and chrome in the automobile, and many natural fibers are being replaced by synthetic filaments throughout industry.

The future of plastics will consist in enlarging some of these uses. With the present war program two opposing forces are in play. The shortage of strategic materials — copper, tin, chromium, aluminum — has spurred the use of plastics so that some of the items in experimental stage as future plastics possibilities have been brought forcibly and suddenly into actual consideration. Overnight, plastics manufacturers found themselves sold out for months ahead, even pushing every available unit of equipment into 100 per cent production. Then with little warning the plastics manufacturer faced the sudden realization that the raw materials for plastics were essential for war purposes — to wit, the use of formaldehyde for the manufacture of pentaerythritol explosives; then, to add confusion, the equipment used for processing methanol, the base material for formaldehyde, could be easily converted into the manufacture of ammonia — an essential in the preparedness effort. In similar manner many other of the vital ingredients of different types of plastics have become scarce. So the future of plastics is beclouded at the moment by the war but the clouds will not deter the industry's forward motion. Instead they will stimulate research along new lines of thought. Probably better and cheaper plastics will result. Most certainly newer methods of forming plastics will be achieved. The one great drawback to molding — expensive steel molds — may be overcome.

If the term " plastics " is enlarged to include synthetic materials of construction we have indeed just scratched the surface of future possibilities. Properties, seemingly fantastic today, will undoubtedly be commonplace tomorrow.

Stronger plastics must be produced. New fibrous fillers are needed. There will be closer co-operation between the farmer and the resin chemist.

Extruded thermoplastics now much in demand may be increased to include the thermosetting plastics. This will require adjustments on the part of both the resin manufacturer and machine builder.

Can plastics replace metals? It is often stated that some plastics are stronger than steel. It is true that some plastics are exceptionally strong, but there are two factors to be considered simultaneously: one, strength; the other, moldability. Based on small test pieces, some plastics are fully as strong as steel; usually, however, it is difficult to mold such plastics on a large-scale basis. They do not flow readily. Future plastics will embody these high-strength properties with good flow. Plastics have replaced some metals and will replace more.

The future of plastics goes hand in hand with the war program.

In the future, newer building materials will be available. Wood can be made practically indestructible by impregnating it with resin solution. The raw material is at hand; it remains for the future to find appropriate uses for this material.

FUTURE RESEARCH[3]

Just as the alchemist of old constantly sought the elixir of life, so the modern plastics chemist seeks the ideal plastic. He imagines and strives to produce a material that has the properties of many classes of known plastics — the color and light stability of ureas, the transparency of methacrylates, the strength of fabric-filled phenolics and ease of molding of the thermoplastics that closely approach punch-press operation or the continuity of extrusion molding — all for the price of the lowest grade of phenolics. The following table illustrates his ideal:

All progressive plastics manufacturers and some independent laboratories have well equipped research departments staffed by especially trained chemists, men who accept calmly consistent daily reversals. In the highly competitive plastics field, they must envisage the commercial possibilities of their endeavor. A chemist's prime functions are: (1) to find new plastics, (2) to improve present plastics, (3) to find new and cheaper raw materials, (4) to find improved methods of manufacture, (5) to find new applications, and (6) to find new plasticizers, accelerators, fillers, and plastics materials in general.

Equipment for research is relatively simple: a good dryer, preferably steam heated; a small mixer such as a Banbury; a blender or shredder; several small hydraulic

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[3] From *Modern Industry,* August 15, 1941.

TABLE 125. HOW AN "IDEAL PLASTIC" WOULD COMPARE WITH THREE COMMON METALS *

	Specific Gravity	Tensile Strength lb. per sq. in.	Toughness	Rigidity lb. per sq. in.	Price per lb. (cents)	Resistance		
						To heat	To acids	To alkalies
" Ideal Plastic "	1.06	50,000	8 ft.-in.	20,000	12	550° F. (chars)	Complete	Complete
Strip Steel (Cold-Rolled)	7.8	50,000	45 ft.-lb.	25,000	3	2,500° F. (melts)	None	None
Stainless Steel (18-8 Alloy)	7.8	85,000	70 ft.-lb.	40,000	30	2550° F. (melts)	Resists 50%	Resists 90%
Aluminum (Aircraft — 24S-T)	2.77	68,000	No data	No comparable data	40	936-1180° F. (melts)	Resists some	Resists some

* From *Modern Industry*, August 15, 1941.

presses; small " rubber " rolls for " connecting " plastics; vacuum dryers; autoclaves; and the usual run of laboratory glassware.

Technique involves a complete survey of existing patents and literature, followed by small-scale laboratory investigation. If a promising resin is developed it must be made on a pilot plant basis. Sample moldings must be carefully tested for durability, light-fastness, mechanical strength, electrical properties, toxicity, and several other factors.

Researchers are actively engaged in trying to find new plastics. Some chemurgists are engaged in trying to utilize agricultural products and certain waste materials. Others are investigating surface coatings, adhesives, lignin plastics, cotton-filled plastics, soya plastics, etc. Just out of the laboratory are Caffelite, made from surplus coffee beans, Zein plastics made from corn, sulfur plastics, crystal-clear Columbia plastics. Indeed no raw material or farm product available in large quantities will escape the searching eye of the plastics chemist.

CHAPTER XXIV

SELECTION OF MATERIALS

Selection of the material for a plastics product is based on the physical and chemical properties desired by a customer along with (1) cost of material, (2) availability of material, (3) cost of production, (4) appearance of the product, and (5) type of design.

Before deciding on material and type of molding or other fabrication, it often is advisable for the customer to make a careful study of his problem in consultation with an industrial designer who knows materials and types of fabrication. If the customer's request indicates a new venture in the field of plastics products it would be wise to consult with a number of manufacturing companies to take advantage of their research and experimental work. The desirability of consulting molders and plastics material suppliers for information cannot be too strongly recommended. The material supplier may prevent serious mistakes in the selection of plastics by suggesting newer materials, which may help do the job more adequately. Often, a skilled materials engineer and molder can suggest a minor change or two and even, at times, can make suggestions for improving the molded piece so that it can be produced more economically. The final selection of material is often left to the molding or fabricating company which thus takes over the responsibility for both selection of material and method of production. The fabricator in turn shifts some responsibility to the manufacturer of molding powder or other raw material.

Cost of materials varies from 10 cents per pound for phenolics (low-grade) to $2.20 per pound for methyl methacrylate (boilable grade) and is directly affected by the size of the order. For instance, from one company it may be necessary to purchase 5000 lb. of urea to get the minimum price.

Availability of material is an especially important consideration during a war emergency. The question then becomes not what is most suitable for an application, but of the materials that still can be secured which, if any, will do the job. Priorities and government allocations govern the use of nearly all plastics and of most source chemicals as well.

Cost of production varies with: (1) molding or other fabricating, (2) design, and (3) quantity. The quantity may also govern the choice of material and the type of fabrication; e.g., one of the large companies, anticipating a small demand, produced an indicator window for an instrument case in cast phenolic which, after the necessary machining, cost $2.00 per window. The demand after the first run warranted placing an order in 10,000 lots, and it was decided to make the piece by injection molding of polystyrene on which only simple finishing operations were necessary. The first 5000 pieces produced by this method cost only $0.23 each, and after that, the $500 cost of the mold was amortized and each piece cost 13 cents.

Molding is the cheapest process for a large order, but for a small order it is better, if feasible, either to use a stock mold or to have a part machined from stock materials because of the expense of the mold, which is included in the cost of production. The customer (Company A) buys the mold and, when the order is completed, sometimes turns the mold over to the molding company (Company B). If a second customer (Company C) is interested in using the mold, Company B will buy it from Company A to make parts for Company C. In case of reordering, Company A would usually have priority claim to the mold.

Molding is essential for complicated design. This also limits the choice of materials, e.g., comparing urea and phenolic: phenolic is much more easily molded and urea cannot be molded in very thick sections.

Compression molding is the best for most complicated designs and injection molding for a large quantity of small pieces. Machining has the advantage that orders can be filled quickly since no time is required for the design and construction of a mold.

Discovery of new plastics and extensive experimentation have resulted in grades and varieties of plastics that will fit almost any requirements of physical and chemical properties. It is, however, impossible to find all desirable characteristics in one plastic; for example, excellent water resistance and electrical properties may be obtained in combination with wide range of color but in a material of little strength and high cost. The following table analyzes the characteristics and main fields of use for the plastics.

TABLE 126. SELECTION OF MATERIALS FOR SOME TYPICAL PRODUCTS*

USE	First Choice	Second Choice	Third Choice
Acid pipe line and fittings	Rubber	Vinyl	Phenolic
Airplane propellers	Phenolic plywood	Cellulose esters, covered	Phenolic, laminated
Airplane windows	Methyl methacrylate	Vinyl	—
Bearings (anti-friction), heavy duty	Phenolic, laminated	—	—
light duty	Phenolic, molded	—	—
Black piano keys	Phenolic	—	—
Brake linings	Phenolic	Rubber	Natural resins
Business machine housings	Phenolic	Polystyrene	Urea
Buttons	Phenolic, casein	Urea	Cast phenolic
Calendar and picture frames	Urea	Phenolic	Cast phenolic
Cameras	Phenolic	Polystyrene	Cellulose esters
Cigarette holders	Phenolic	Cast phenolic	Rubber
Closures (bottle caps)	Phenolic	Urea	Polystyrene
Condenser insulating sheets	Polystyrene	Vinyl	—
Dental instruments (handles)	Phenolic	Methyl methacrylate	Urea
Dental plates	Modified vinyl copolymers	Acrylate	Phenolic, rubber
Dishes	Urea	Phenolic	Polystyrene
Doors (surface)	Phenolic	Urea	—
Electrical insulation, 60 cycle	Phenolic	Urea	Rubber
Electrical insulation, 1000 cycle	Phenolic	Urea	Rubber
Electrical insulation, 1,000,000 cycle	Polystyrene	Rubber, phenolic	—
Electrical insulation, 50,000,000 cycle	Polystyrene	Rubber	—
Eyeglass frames (transparent)	Cellulose esters	Vinyl	Polystyrene
Eyeglass frames (opaque, safety type)	Phenolic	Vinyl	Cellulose esters
Fountain pens	Polystyrene	Cellulose esters	Rubber
Gears, cut	Phenolic, laminated	—	Phenolic impregnated wood
Gears, molded	Phenolic, impact	—	—
Grinding wheels	Phenolic	Rubber	Alkyd
Gun stocks	Phenolic	—	—
Gun shoulder butts	Phenolic	Rubber	—
Hair brush back	Methyl methacrylate	Cast phenolic	Cellulose esters
Handles (decorative)	Cast phenolic	Cellulose esters	Urea molded phenolic
Handles (heat resisting)	Phenolic	—	—
Handles (mechanical)	Phenolic	Cellulose esters	Vinyl
Ignition parts	Phenolic	Rubber	—
Lampshades	Urea	Methyl methacrylate	Phenolic, vinyl
Light reflectors	Acrylate	Polystyrene	Clear phenolic
Phonograph records	Vinyl	Shellac	Phenolic
Plywood	Phenolic	Urea	Casein
Radio cabinets	Phenolic	Urea	Cast phenolic
Radio insulation	Polystyrene	Phenolic	Rubber
Rayon spinning pots	Molded phenolic	—	—

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* Prepared for this handbook by A. J. Weith.

TABLE 126. SELECTION OF MATERIALS FOR SOME TYPICAL PRODUCTS* — (*Continued*)

USE	First Choice	Second Choice	Third Choice
Safety glass	Vinyl	Cellulose ester	Glyptal
Slide fastener	Cellulose esters	Phenolic	—
Switch plates and electrical outlets	Phenolic	Urea	—
Table tops (laminated surface)	Urea	Phenolic	—
Table tops (laminated base)	Phenolic	—	—
Telephone handles	Phenolic	Urea	—
Transparent rods for table legs	Methyl methacrylate	Cast phenolic	Polystyrene, vinyl
Trays	Rubber	Phenolic	Phenolic plybond
Tubes for decorative chairs and tables	Methyl methacrylate	Cast phenolic	Polystyrene, vinyl
Umbrella handles	Cellulose esters	Phenolic	Casein
Varnish compositions (coatings)	Phenolic	Urea	Natural resins
Varnish compositions (impregnating)	Phenolic	Urea	—
White piano keys	Urea	Methyl methacrylate	Cellulose esters
Window displays	Urea	Phenolic molded	Phenolic, laminated

* Prepared for this handbook by A. J. Weith.

TABLE 127. PLASTICS COMPARATOR *

Plastic Material	Ease of Molding	Finish	Water Resistance	Acid Resistance	Caustic Resistance	Solvent Resistance	Toughness (Impact Strength)	Flexural Strength	Tensile Strength	Color Stability	Cold Flow	Dimensional Change on Aging	Heat Resistance (Continuous Heat)	Flammability	Heat Insulation	Specific Gravity	Hardness	Loss Factor, 60 cycle	Loss Factor, 1 Megacycle	Resistivity	Dielectric Strength	Moldability around inserts
Thermosetting																						
Phenolic: general purpose	1†	2	6	3	4	1	9	3	3	7	1	4	2	3	2	8	5	8	7	7	4	2
Phenolic: low-loss	3	2	3	4	4	1	11	3	7	7	1	2	3	1	7	12	3	4	2	3	3	2
Phenolic: heat-resistant	2	2	3	4	4	1	10	4	8	7	1	1	1	1	7	13	2	9	10	8	8	2
Phenolic: acid and alkali-resistant	4	2	4	2	3	1	10	6	8	7	1	5	3	2	2	5	4	9	9	7	7	3
Phenolic: shock-resistant	5	5	7	4	5	1	2	1	5	7	1	6	3	4	3	10	5	9	9	9	8	1
Phenolic: transparent	6	3	4	3	3	1	7	1	2	7	1	5	3	2	2	6	4	5	6	4	6	3
Urea	2	2	9	4	4	1	8	1	1	1	2	7	6	5	5	11	1	7	8	5	2	4
Thermoplastic																						
Polystyrene	1	2	1	1	1	3	7	2	7	4	3	1	5	6	1	1	6	1	1	1	1	6
Cellulose Acetate	2	4	11	4	6	3	4	6	9	3	8	9	5	6	4	7	9	5	5	6	5	5
Cellulose Acetate Butyrate	3	4	8	4	4	3	1	5	10	3	6	8	4	6	6	4	8	4	5	6	5	5
Ethyl Cellulose	1	5	10	4	2	3	3	2	6	6	7	8	5	6	4	2	8	3	4	3	1	5
Methyl Methacrylate	4	1	5	2	2	3	6	1	3	2	4	8	5	6	2	3	7	6	3	2	2	6
Vinyl (no filler)	4	3	2	1	1	2	5	1	3	5	5	3	7	6	2	9	7	2	3	2	1	5

* Prepared by the Bakelite Corp., 1941.

† Numbers indicate order of merit, 1 being highest.

TABLE 128. GUIDE TO SELECTION BASED ON CHARACTERISTICS OF MATERIALS

Plastic	Characteristics Determining Fields of Use	Main Fields of Use	Trade Names
Phenol-Formaldehyde (Molded)	Good electrical insulating properties, low cost, easily molded, good dimensional stability, resistance to heat, water, common solvents and chemicals, available in all colors, excellent strength around inserts.	Electrical parts, machine housings, closures, corrosion resistant parts, ashtrays, handles, buttons, pistol grips, telephone equipment, radio cabinets, engine parts, bomb parts.	Bakelite Durez Durite Heresite Indur Makalot Resinox Textolite
(Laminated)	Good electrical insulating properties, excellent strength. Large thin sections easily formed in low cost molds. Good dimensional stability. Sheets, rods and tubes are standard forms.	Architectural paneling, table and counter tops, gear wheels, electrical equipment, heavy industrial parts, U. S. Army helmet liners, chemical equipment, bearings, housings, airplane parts.	Celoron Dilecto Duraloy Formica Insurok Lamicoid Micarta Ohmoid Panelyte Phenolite Spauldite Synthane Taylor Textolite Ucinite
(Cast)	Nonflammable, odorless, tasteless, available in pastels, transparent, translucent, and opaque, easily machined.	Hardware, jewelry, novelties, tableware, industrial machine parts, handles and knobs, displays, brush backs, instrument housings, buttons.	Bakelite Cast Resinoid Catalin Gemstone Marblette Monsanto Opalon Prystal
Phenol-Furfural (Molded)	Similar to Phenol-Formaldehyde, excellent molding properties, available in dark colors only.	Mechanical parts, electrical insulation, housings, containers.	Durite
Urea-Formaldehyde (Molded)	Low heat transference, high dielectric strength, odorless, tasteless, translucent to opaque, lightweight, hard surface, bright, lustrous colors from white to jet black.	Lighting appliances, reflectors and switch plates, buttons and buckles, housings, containers, closures, dials, handles and knobs, tableware, hardware, piano keys, toys.	Bakelite Urea Beetle Plaskon

TABLE 128. GUIDE TO SELECTION BASED ON CHARACTERISTICS OF MATERIALS — (*Continued*)

Plastic	Characteristics Determining Fields of Use	Main Fields of Use	Trade Names
Urea-Formaldehyde (Laminated)	Translucent, colorful, rigid. Sheets and tubes are standard forms.	Illuminating accessories, architectural paneling, signs.	Beetle Formica Insurok Lamicoid Micarta
Melamine-Formaldehyde (Molded)	Excellent arc resistance, low moisture absorption, good dimensional stability, excellent dielectric strength, available in wide range of colors, resistant to alkalies, long flow period, good heat resistance.	Electrical insulation, tableware.	Melmac
(Laminated)	Excellent arc resistance and low moisture absorption. Good dielectric properties.	Electrical insulation.	Melmac
Polyvinyl Chloride-Acetate (Molded and sheet materials)	Resistant to water, acids and alkalies, good impact resistance, nonflammable, tasteless, odorless, non-toxic, available transparent to opaque in variety of forms.	Sound recordings, containers, closures, book covers and bindings, dials, paper coatings, tin can linings, drawing instruments, combs, tooth brushes.	Vinylite Series V Resins
(Fiber)	High strength, other physical properties same as above.	Filter cloths, knitted and woven goods such as clothing, fishnets, tent and awning cloth, shoes, raincoats, hose.	Vinyon
Polyvinyl Chloride (Plasticized)	Rubberlike, long flexing life, good resistance to water, sunlight, acids, alkalies and alcohols, slow burning, non-toxic.	Tubing, cable coverings, waterproof coatings, washers and gaskets.	Flamenol Koroseal Vinylite Series Q Resin

TABLE 128. GUIDE TO SELECTION BASED ON CHARACTERISTICS OF MATERIALS — (*Continued*)

Plastic	Characteristics Determining Fields of Use	Main Fields of Use	Trade Names
Polyvinyl Acetate	Tasteless, odorless, moisture resistant, stable to heat and light, tacky above 200° F, soluble in ketones, esters, chlorinated hydrocarbons, aromatic hydrocarbons, alcohol.	Adhesive, laminating glue, vehicle for inks and lacquers, intricate moldings, plastic wood, stiffening agent.	Vinylite Series A Resin Vinylseal
Polyvinyl Acetal (aldehyde reaction products)	Resistant to water absorption, heat, sunlight and exposure to ultra-violet, high tensile strength, tough, retain properties at high and low temperatures.	Safety glass interlayer, adhesive, rubberlike sheeting, tarpaulin.	Alvar (polyvinyl acetal) Butacite (polyvinyl butyral) Butvar (polyvinyl butyral) Formvar (polyvinyl formaldehyde) Saflex (polyvinyl acetal) Vinal (polyvinyl acetal) Vinylite Series X Resin (polyvinyl butyral)
Vinylidene Chloride (Molded)	High tensile strength, tasteless and odorless, available in wide range of colors, tough and highly resistant to wear, good dielectric strength, resistant to water, acids, alkalies and common solvents.	Spray gun parts, chemical equipment, novelties, housings, containers, handles.	Saran
(Extruded)	Exceptionally high tensile strength. Other physical properties same as for molded.	Hose and tubing, upholstery webbing and covering, filters, screens, fishing equipment, tapes and ribbons, funnels, valve and piston parts, wire coating.	Saran
Polyvinyl Alcohol	Resistant to oils, gas, and most common solvents, rubberlike, hot-resistant to acids and alkalies, unaffected by aging, available transparent to opaque, good tensile strength, high resistance to abrasion.	Hose and tubing, gloves, washers, diaphragms, gaskets, chemical equipment.	PVA Resistoflex

TABLE 128. GUIDE TO SELECTION BASED ON CHARACTERISTICS OF MATERIALS — (*Continued*)

Plastic	Characteristics Determining Fields of Use	Main Fields of Use	Trade Names
Polystyrene (Molded)	Excellent electrical properties, available water-clear transparent to opaque, resistant to water, acids, alkalies, most chemicals, soft surface, good dimensional stability, low specific gravity, high index of refraction, edge-lighting ability.	Molded electrical insulation, containers and closures, novelties, instrument panels, reflectors, tableware, combs, housings, refrigerator parts and interior trim, cable insulation.	Bakelite Polystyrene Loalin Lustron Styron
Methyl Methacrylate (Cast)	Light weight, excellent resistance to weathering, available water-clear transparent to wide range of colors, dimensional stability, edge-lighting ability, soft surface, easily fabricated.	Aircraft enclosures, safety shields, furniture, wall panels, novelties, illuminating accessories, models, dials, tableware, decorative accessories.	Lucite Plexiglas
(Molded)	Both compression and injection molding without plasticizers. Physical properties similar to the cast.	Lenses, models, dentures, jewelry, brushbacks, combs, pipe stems, automobile trim, illuminating instruments.	Crystalite Lucite
Nylon (Molded)	Tough, good resistance to heat, water, most chemicals and light, high index of refraction, excellent electrical properties, high tensile strength, elasticity, range of colors. (Not molded at present.)	Electrical insulating parts.	Nylon
Nylon (Extruded)	Very high tensile strength. May be cold drawn to increase strength. Physical properties similar to molded.	Industrial bristles, bristles for toilet brushes, strings for tennis rackets, musical instruments, fishing equipment and surgical sutures, tire carcasses.	Exton Nylon
		Thread for clothing, parachutes.	Nylon

TABLE 128. GUIDE TO SELECTION BASED ON CHARACTERISTICS OF MATERIALS — (*Continued*)

Plastic	Characteristics Determining Fields of Use	Main Fields of Use	Trade Names
Cellulose Nitrate	Water resistant, toughness, flammability, high impact strength, easily fabricated, dimensional stability, available in wide range of colors and mottles.	Fountain pens, toilet articles, drawing instruments, shoe heel covering, musical instrument coverings, novelties, jewelry, piano and typewriter keys, dials, golf club parts, brushes, hammer heads, movie film.	Celluloid Monsanto Cellulose Nitrate Nixonoid Pyralin
Cellulose Acetate (Molded)	Nonflammable, high impact strength, high dielectric strength, available in wide range of colors, transparent to opaque and mottled, molding and fabricating versatility.	Combs, automobile interior hardware, toys, housings, containers, eyeglasses and goggle frames, electrical insulation, bathroom fixtures and hardware, airplane enclosures, gas mask lenses, novelties and jewelry.	Bakelite Cellulose Acetate Fibestos Lumarith Nixonite Plastacele Tenite I
(Sheet)	Convenient form (most any thickness). Physical properties same as above.	Packaging, table mats, book covers and bindings, film, lampshades, watch crystals, antenna housings, dial faces.	Lumarith Protectoid Vuepak
Cellulose Acetate Butyrate (Molding)	Same as cellulose acetate but with better dimensional stability and flow characteristics.	Extruded moldings for architectural purposes, handles, automobile and furniture hardware, shower heads, beer scrapers.	Tenite II
Ethyl Cellulose (Molding)	Tough, water resistant, dimensional stability, good aging properties, available in wide range of colors, flexible.	Automobile and furniture hardware, chair seats and backs, housings and containers, novelties and jewelry.	Ethocel
(Sheet)	Physical properties same as for moldings.	Packaging, book covers and bindings, watch crystals, dial fans.	Ethofoil

TABLE 128. GUIDE TO SELECTION BASED ON CHARACTERISTICS OF MATERIALS — (*Continued*)

Plastic	Characteristics Determining Fields of Use	Main Fields of Use	Trade Names
Casein (Sheets, rods and tubes)	Slightly water absorbent, easily polished and machined, good colorability but colors may fade, nonflammable.	Buttons, buckles, beads, games, novelties.	Ameroid Galorn
Cold Molded Compounds: Refractory (Inorganic)	Heat resistant, good dielectric strength, low cost, slightly water absorbent.	Electrical insulation, heat insulators, arc resistors, heavy duty wheels.	Aico Alphide Coltstone Hemit Textolite
Cold Molded Compounds: Non-Refractory (Organic)	Water absorbent, high heat resistance, easily molded. Low cost. Low mold cost.	Heat insulators, electrical parts, particularly plugs, heavy duty wheels.	Aico Amerine Ebrok Garit Gummon Okon Textolite Thermoplax

TABLE 129. MANUFACTURING PROCEDURE COMPARED FOR DIFFERENT MATERIALS *

		Stamped Sheet Steel	Die-Cast Zinc	Molded Plastics
Quantity	Large	Favorable	Favorable	Favorable
	Medium	Fair	Fair	Favorable
	Small	Very poor	Very poor	Fair
Tooling cost		Medium high	High	Moderate
Time for tooling		Slow	Slow	Slow
Quantity delivery parts		Fast	Fast	Fast
Finishing required		Pickle, plate, paint	Trim, paint	Tumble
Fastening other parts		Moderate	Very good, drill and tap	Favorable with inserts
Intricacies of piece (side draws, undercuts, etc.)		Fair	Excellent	Poor †
Strength needed in thin sections		Excellent	Satisfactory	Depends on material
Sales appeal (form)		Poor — two dimensions only	Fair	Excellent
Sales appeal (color)		Fair (paint, plate)	Fair (paint, plate)	Excellent (brilliant colors, translucent, transparent)
Accuracy of dimensions		Very good	Fair	Fair
Cost of material		Low	Moderate	Moderate
Weight		Medium	Heavy	Light
Electrical properties		Conductor	Conductor	Insulator

* From F. J. Stokes Machine Co.

† Moderate, for manual compression molding.

CHAPTER XXV

ESTIMATING AND PAPER WORK IN THE PLASTICS INDUSTRY

The youthful plastics industry has not yet worked out standardized cost accounting, methods of estimating, or purchasing procedure, therefore difficulties result. Anything which cuts down cost of estimating should help. It is important to send a good questionnaire to the prospective customer. The more information secured, the better. The following forms are reproduced here because they indicate what some companies are doing individually.

FORM A

CUSTOMER...

Order No. ....   Date...............................

QUANTITY

Part or Material Number	Defense*	Civilian			Total	Description
		A*	B*	C*		

* See reverse side for explanation.

AFFIDAVIT

State of ....

County of ....

The undersigned being duly sworn deposes and says that —

1. This affidavit is made on behalf of and by authority of......................

....

2. The facts herein set forth are, to the best of his knowledge and belief, true and correct.

3. The above order placed with .... constitutes supplies as designated above.

Sworn to and subscribed before me this

.... day of ...., 19...

....

Signature.

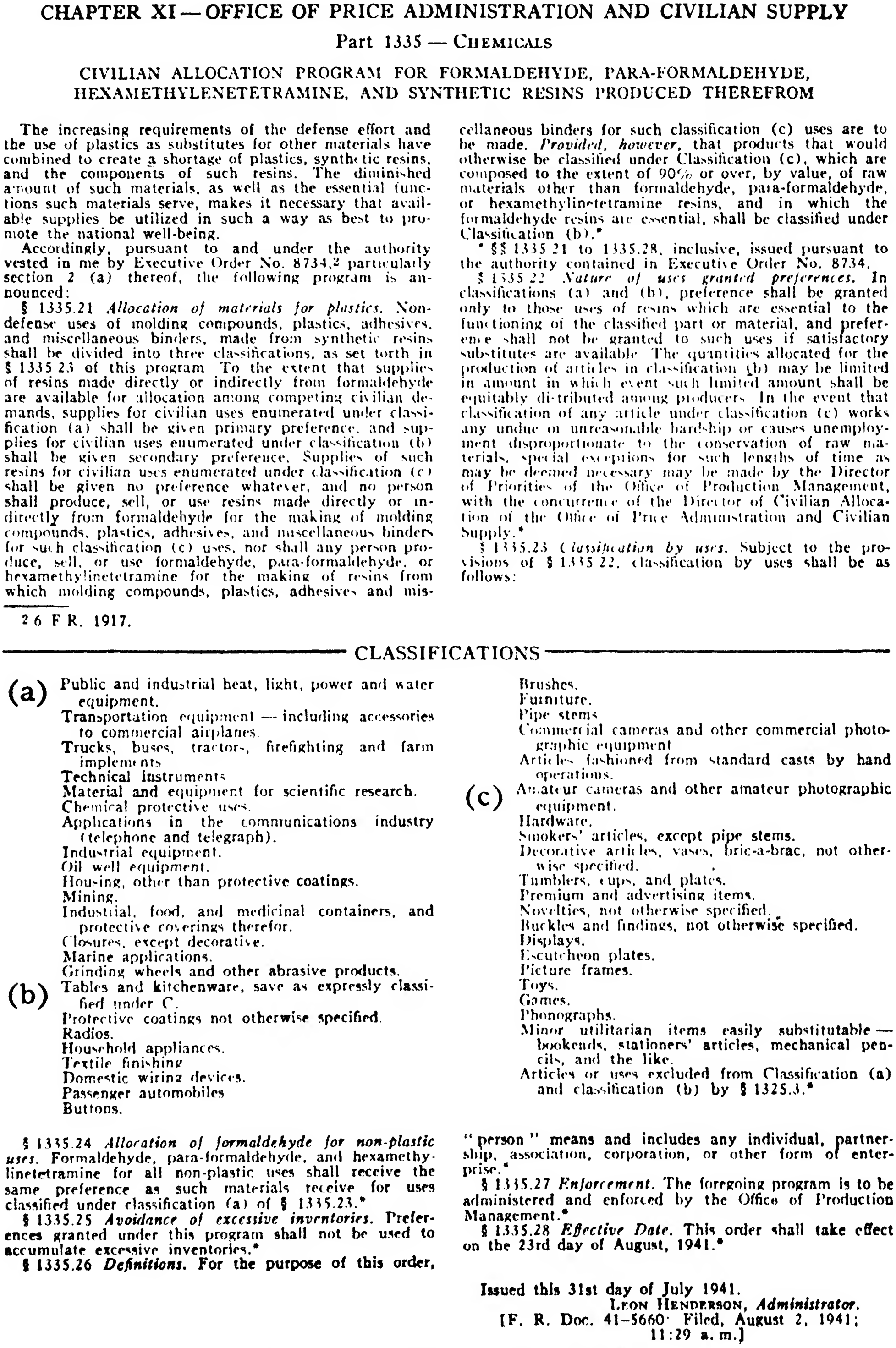
....

Notary Public.

My commission expires:

* Defense Supplies are those entering, directly or indirectly, at any stage of production, into material for delivery carrying a preference rating of A-10 or higher.

FIG. 25.1 — Government form.



CHAPTER XI — OFFICE OF PRICE ADMINISTRATION AND CIVILIAN SUPPLY

Part 1335 — Chemicals

CIVILIAN ALLOCATION PROGRAM FOR FORMALDEHYDE, PARA-FORMALDEHYDE, HEXAMETHYLENETETRAMINE, AND SYNTHETIC RESINS PRODUCED THEREFROM

The increasing requirements of the defense effort and the use of plastics as substitutes for other materials have combined to create a shortage of plastics, synthetic resins, and the components of such resins. The diminished amount of such materials, as well as the essential functions such materials serve, makes it necessary that available supplies be utilized in such a way as best to promote the national well-being.

Accordingly, pursuant to and under the authority vested in me by Executive Order No. 8734,[2] particularly section 2 (a) thereof, the following program is announced:

§ 1335.21 *Allocation of materials for plastics.* Non-defense uses of molding compounds, plastics, adhesives, and miscellaneous binders, made from synthetic resins shall be divided into three classifications, as set forth in § 1335 23 of this program To the extent that supplies of resins made directly or indirectly from formaldehyde are available for allocation among competing civilian demands, supplies for civilian uses enumerated under classification (a) shall be given primary preference, and supplies for civilian uses enumerated under classification (b) shall be given secondary preference. Supplies of such resins for civilian uses enumerated under classification (c) shall be given no preference whatever, and no person shall produce, sell, or use resins made directly or indirectly from formaldehyde for the making of molding compounds, plastics, adhesives, and miscellaneous binders for such classification (c) uses, nor shall any person produce, sell, or use formaldehyde, para-formaldehyde, or hexamethylinetetramine for the making of resins from which molding compounds, plastics, adhesives and miscellaneous binders for such classification (c) uses are to be made. *Provided, however,* that products that would otherwise be classified under Classification (c), which are composed to the extent of 90% or over, by value, of raw materials other than formaldehyde, para-formaldehyde, or hexamethylinetetramine resins, and in which the formaldehyde resins are essential, shall be classified under Classification (b).*

* §§ 1335 21 to 1335.28, inclusive, issued pursuant to the authority contained in Executive Order No. 8734.

§ 1335 22 *Nature of uses granted preferences.* In classifications (a) and (b), preference shall be granted only to those uses of resins which are essential to the functioning of the classified part or material, and preference shall not be granted to such uses if satisfactory substitutes are available The quantities allocated for the production of articles in classification (b) may be limited in amount in which event such limited amount shall be equitably distributed among producers In the event that classification of any article under classification (c) works any undue or unreasonable hardship or causes unemployment disproportionate to the conservation of raw materials, special exceptions for such lengths of time as may be deemed necessary may be made by the Director of Priorities of the Office of Production Management, with the concurrence of the Director of Civilian Allocation of the Office of Price Administration and Civilian Supply.*

§ 1335.23 *Classification by uses.* Subject to the provisions of § 1335 22, classification by uses shall be as follows:

CLASSIFICATIONS

(a) Public and industrial heat, light, power and water equipment.
Transportation equipment — including accessories to commercial airplanes.
Trucks, buses, tractors, firefighting and farm implements
Technical instruments
Material and equipment for scientific research.
Chemical protective uses.
Applications in the communications industry (telephone and telegraph).
Industrial equipment.
Oil well equipment.
Housing, other than protective coatings.
Mining.
Industrial, food, and medicinal containers, and protective coverings therefor.
Closures, except decorative.
Marine applications.
Grinding wheels and other abrasive products.

(b) Tables and kitchenware, save as expressly classified under C.
Protective coatings not otherwise specified.
Radios.
Household appliances.
Textile finishing
Domestic wiring devices.
Passenger automobiles
Buttons.
Brushes.
Furniture.
Pipe stems
Commercial cameras and other commercial photographic equipment
Articles fashioned from standard casts by hand operations.

(c) Amateur cameras and other amateur photographic equipment.
Hardware.
Smokers' articles, except pipe stems.
Decorative articles, vases, bric-a-brac, not otherwise specified.
Tumblers, cups, and plates.
Premium and advertising items.
Novelties, not otherwise specified.
Buckles and findings, not otherwise specified.
Displays.
Escutcheon plates.
Picture frames.
Toys.
Games.
Phonographs.
Minor utilitarian items easily substitutable — bookends, stationers' articles, mechanical pencils, and the like.
Articles or uses excluded from Classification (a) and classification (b) by § 1325.3.*

§ 1335.24 *Allocation of formaldehyde for non-plastic uses.* Formaldehyde, para-formaldehyde, and hexamethylinetetramine for all non-plastic uses shall receive the same preference as such materials receive for uses classified under classification (a) of § 1335.23.*

§ 1335.25 *Avoidance of excessive inventories.* Preferences granted under this program shall not be used to accumulate excessive inventories.*

§ 1335.26 *Definitions.* For the purpose of this order, "person" means and includes any individual, partnership, association, corporation, or other form of enterprise.*

§ 1335.27 *Enforcement.* The foregoing program is to be administered and enforced by the Office of Production Management.*

§ 1335.28 *Effective Date.* This order shall take effect on the 23rd day of August, 1941.*

Issued this 31st day of July 1941.
Leon Henderson, *Administrator.*
[F. R. Doc. 41-5660 Filed, August 2, 1941; 11:29 a. m.]

---

[2] 6 F R. 1917.

Fig. 25.1 — Government form. *Continued*

REQUEST FOR ESTIMATE ON..........................
(Type of material)

CUSTOMER ....

PART.................................... Drawing.................
(Send 2 copies of M.P. drawing if available)

Suggested Grade .... Color....................

What Finish is Desired...

Operating Condition to which Part will be Subjected:

Electrical ....
(Arc resistance; Dielectric, potential and how applied; Frequency)

Mechanical ....
(Tension, Compression, Shock, Abrasion)

Temperature ....
(Generally, Phenolic materials withstand 130° C. max.-Pastel materials 100°)

Chemical ....
(Moisture, Acid, Caustics, Etc.)

If Not a New Part, What Material is Now Used ....

Why is Present Material Unsatisfactory ....

Required Production: Per Year................Max. Weekly Rate.............
(Unless otherwise stated, mold will be designed, if practical, for max. weekly capacity)

Quote in Lots of ....

Are Inserts Required.......................Number per Part...............

Will Inserts be Furnished by: G.E. Co.?............. Or Customer?............

Insert Drawings ....
(Send two copies of all insert drawings if available)

Are Samples or Models of Molded Part and Inserts Being Forwarded..............

Dimensions Essential for Proper Functioning of Part.......................

....

Design Changes Permissible to Improve Molding Conditions.....................

....

REMARKS: ....

....

(Sign).......................................

Date....................... (Office).....................

(Reverse side of sheet may be used for additional remarks and sketches)

Fig. 25.2 — General Electric Plastics Department estimate form.

Customer.. Dwg. No..............................

Type of Mold	
Hob	
Hobbing	
Mach. Hobbing	
Cavity	
Wedges	
Liners	
Inserts	
Plunger	
Pins	
Frame	
Assembly	
Chrome Plate	
Set-up Time	
Personal Time	
Model	
Templates	
Total Hours	
Total hrs. @ $1.00 per hr.	
I.M.E. @ 115%	
Material	
Total	
Gross Margin	
Total Est. Cost	

No. of Cavities	
Fixtures	
Cleaning Fix.	
Drill Jig	
Curing Form	
Inspection Fix.	
Gauges	
Total Est. Cost	

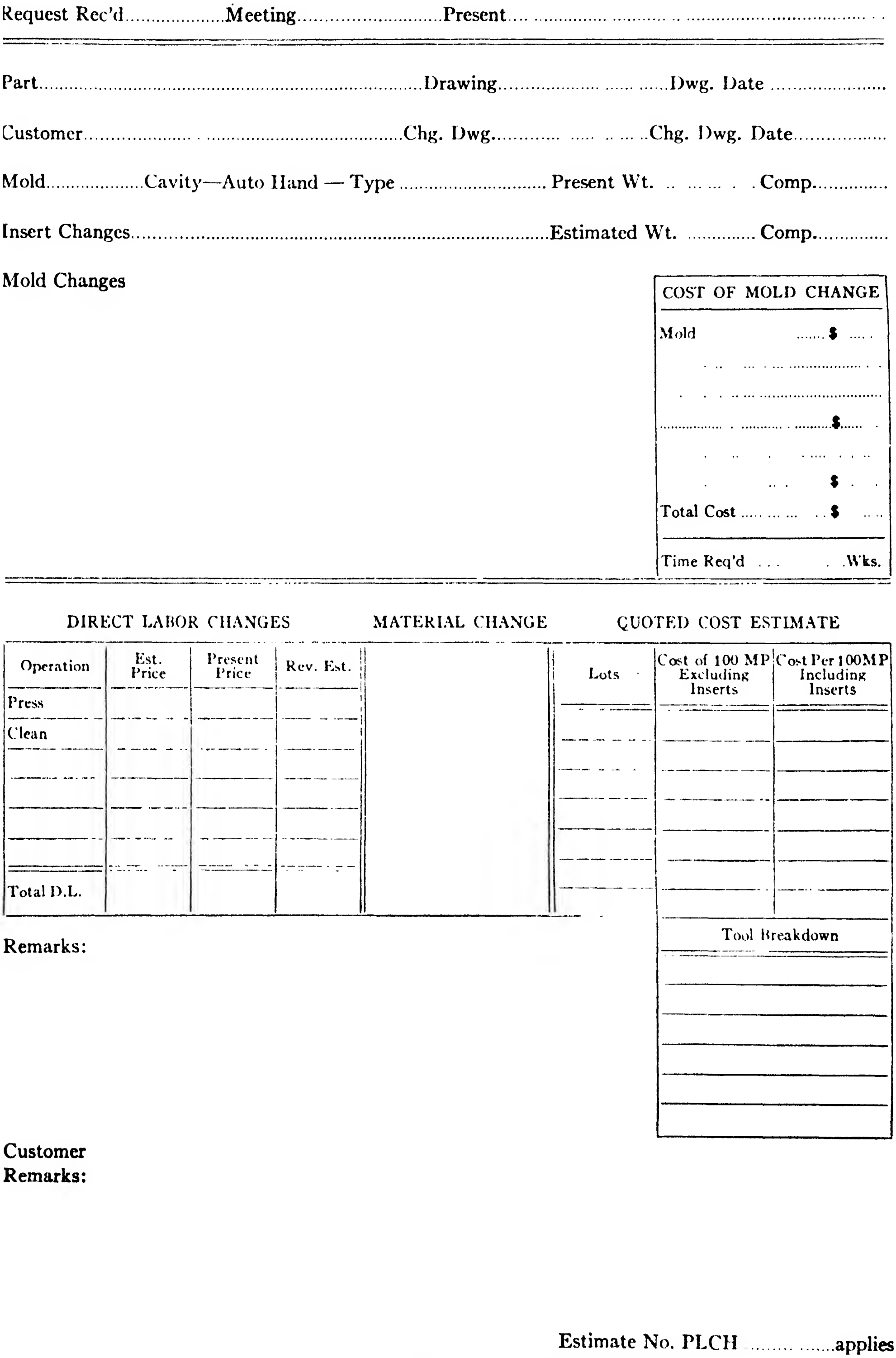
Promise to Customer

Drafting	
Mold	
Samples	
Est. Cost of Drafting	

Estimated by...
Date

Approved by...
Date

Fig. 25.3 — P. L. Q. estimate form.



Request Rec'd....................Meeting............................Present..

Part..Drawing..............................Dwg. Date.......................

Customer...Chg. Dwg....................................Chg. Dwg. Date..................

Mold....................Cavity—Auto Hand — Type..............................Present Wt. ....Comp...............

Insert Changes..Estimated Wt. ....Comp...............

Mold Changes

COST OF MOLD CHANGE	
Mold	.......$ .....
	$......
	$
Total Cost	$ .....
Time Req'd ...	Wks.

DIRECT LABOR CHANGES				MATERIAL CHANGE
Operation	Est. Price	Present Price	Rev. Est.	
Press				
Clean				
Total D.L.				

QUOTED COST ESTIMATE		
Lots	Cost of 100 MP Excluding Inserts	Cost Per 100MP Including Inserts

Remarks:

Tool Breakdown

Customer
Remarks:

Estimate No. PLCH ....applies

FIG. 25.4 — Change sheet — mold and molded part.

Date ____________________ Cost Request No. ____________

Product ____

Cost Classification — Group __________ Pressings __________ Gauge __________

FORMULATION

Raw Material	“A” *Lbs.*	“B” *Lbs.*	*Unit Cost*	*Amount*
Total Solids				
Grand Total				

Mixing

% Solvent in Formula..............................

% Solvent in Standard ....

“ A ” lbs. equals original formula

“ B ” lbs. equals revised formula

corrected to standard solvent content.

Standard lbs. raw materials per lb. mixed dough..

Mixed plastic dough divisor for above dollars..

Unit raw material cost of mixing..

FIG. 25.5 — Cost computation sheet.

Standard raw material cost per 100 lb. mixed dough

Add or subtract solvent variation from standard

Mixing cost

Total cost mixed dough, per 100 lb.

Cost mixed dough to rolled dough..........lb. used

Rolling cost

Total cost rolled dough, per 100 lb.

Cost rolled dough to pressed cakes..........lb. used

Pressing cost

Total cost pressed cake, per 100 lb.

Cost pressed cake to raw sheets..........lb. used

Sheeting cost

Total cost raw sheets, per 100 lb.

Cost raw sheets to finish. Sheets

Polishing and finishing cost

Total mfg. cost finished sheet, per 100 lb.

COST PER 100 POUNDS

Total mfg. cost in bulk

Packing, shipping and other direct cost..........%

Total out of pocket cost

Selling expense..........% of bulk cost

Total after selling expense

Research, administrative and all other charges

Lb. this material per sheet

Cost per sheet

FIG. 25.5 — Cost computation sheet. *Continued*

SHORT METHOD

ARTICLE

B/P Part No.

Yearly Requirements

Samples Promised Wks.

Mold Est. by	Cost Est. by	Approved by	Size of Press Ton

TOOL COST

MATERIAL		
LABOR HRS. @		
DESIGNING		
ENGR. OR SINKINGS		
BISCUIT MOLD		
DRILL JIG		
TAPPING FIX		
ENGINEERING		
WASTE		
TOTAL		
PRICE QUOTED		

REMARKS

Company Name

Attn. of

Date

Est. No.

Address

Salesman

City State

M

No. of Molds	Cav. Ea.	Total Cav.	Shots per Hour	Prod. in 10 Hrs.	Wkly. Prod.	Single Shift Double Shift

Material	No.	Color	Lots	COST PER M

Molding Labor	Hours					
Mold—Full Time Half Time		.	@			
Weighing Powder			@			
Preform			@			
Setting Mold			@			

Finishing Dept.	Mach.		Bench				
File or scrape							
Insp. Pack							
Pack. — Ship							
Tumble							
Spin							
Drill							
Tap							
Buff							
Sanding							
MACH. LABOR @ HR.							
BENCH LABOR @ HR.							

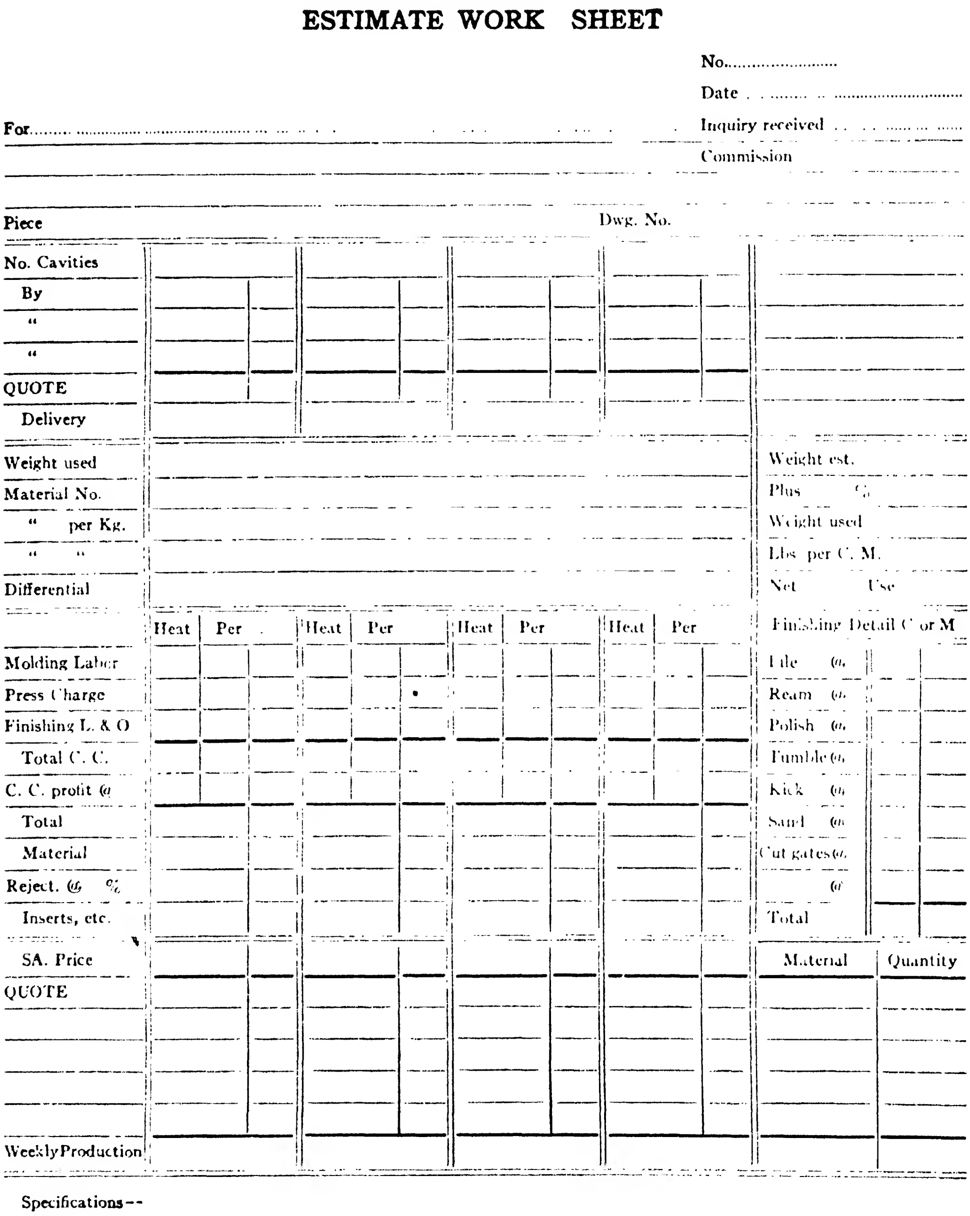
TOTAL ALL O.H. AND DIRECT LABOR				
MATERIAL PURCHASES				
Powder				
Waste				
Inserts				
Pack. Mat.				
Mold Maint.				
TOTAL MATERIAL COST				
TOTAL COST OF LABOR ALL O.H. AND MAT'L				
Waste of Finished Pieces %				
Sale Cost				
Profit %				
Sales Price				
Price Quoted				

Fig. 25.6 — Estimate work sheet.

Dwg. No.
PLQ — PLCH
........Cav. ....Type ....Size ...... .Compound Date
Change
Similar to.

PRESS	Est	Act	FINISH	Est	Act	FINISH	Est	Act
Open			Tumble, straight			Tap, Handling		
			Ball			1st insert		
Discharge						Other inserts		
			File, Size			Thru Hole		
Clean			Notch			Other Holes		
			Handling			Blind Hole		
Load			Finish			Other Holes		
Close			Knife, Size					
			Insert			Punch		
V1 1st insert			Handling			Handling		
Other inserts						Type Fix.		
			Spindle, Size					
V2 Pills			Stop					
			Position			Paint		
V3 Form								
			Wire Wheel			Assemble		
V4 Pins			Handling					
						Bake		
V5 Span Fork			Grind, Size					
			Handling			Sp. Gr.		
V6 Loose Pin Top			Gauge					
						Hi-Pot Test		
V7 Unscrew			Surface, Grind					
			Fixture			Navy Stamp		
V8 Side Wedge			Stroke					
Machine			Size					
			Gauge					
V9 Deep Cav.			Sand, Inches					
V10 Handling			Emery Wheel					
			Inches Line					
			Buff, Size					
			Prefinish					
Total			Drill, Fixture			Total Finishing		
			Depth					
Factor			Size			Estimated by.... .....Date..............		
			No Holes.					
No. Cav.						Approved by............Date...... ..		
Piece Rate								

FIG. 25.7 — Labor estimate sheet.



ESTIMATE WORK SHEET

No.........................

Date ....

For...

Inquiry received ....

Commission

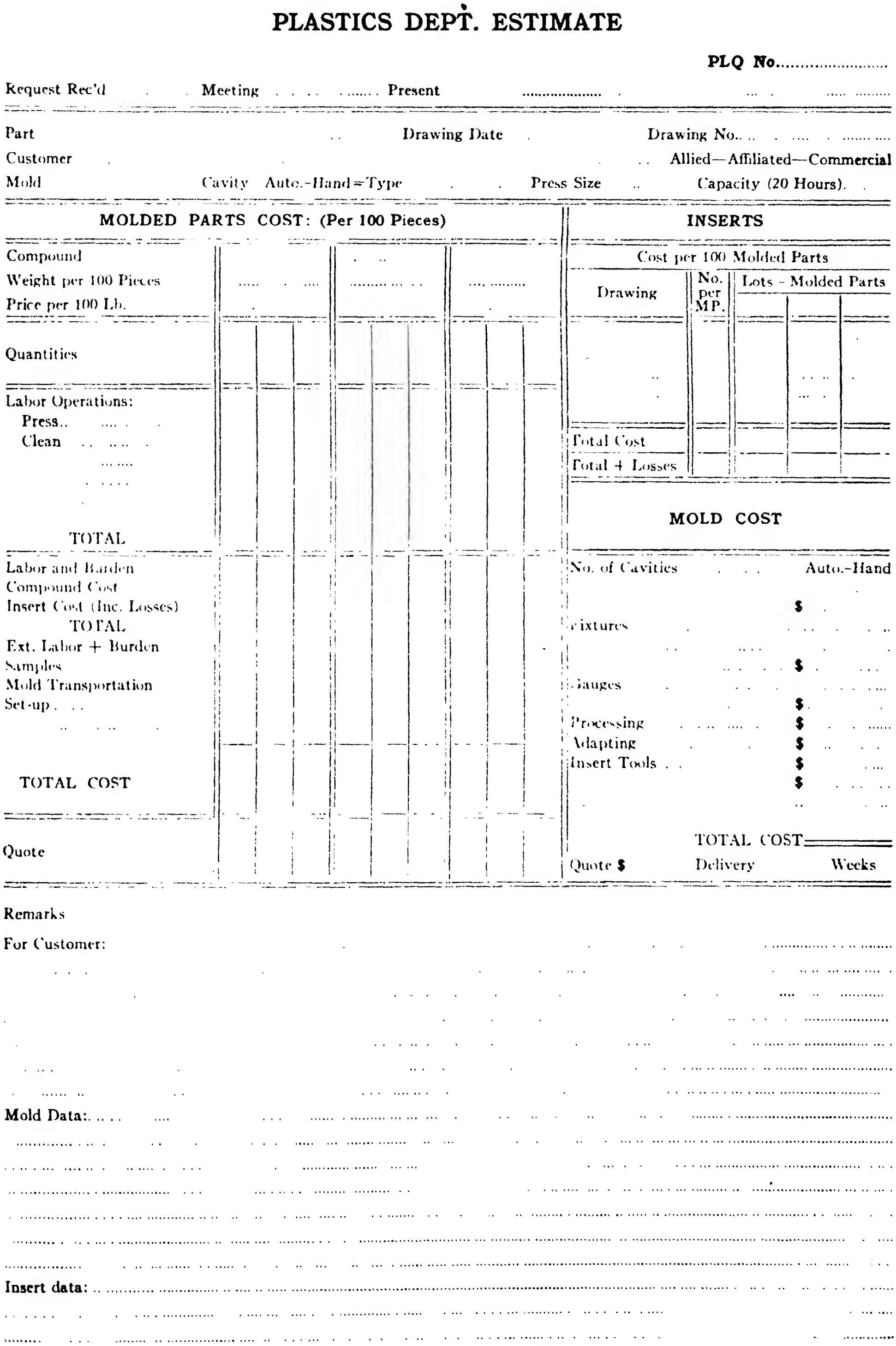
Piece

Dwg. No.

No. Cavities									
By									
"									
"									
QUOTE									
Delivery									
Weight used									Weight est.
Material No.									Plus %
" per Kg.									Weight used
" "									Lbs per C. M.
Differential									Net Use
	Heat	Per	Heat	Per	Heat	Per	Heat	Per	Finishing Detail C or M
Molding Labor									File @
Press Charge									Ream @
Finishing L. & O									Polish @
Total C. C.									Tumble @
C. C. profit @									Kick @
Total									Sand @
Material									Cut gates @
Reject. @ %									@
Inserts, etc.									Total
SA. Price									Material | Quantity
QUOTE									
Weekly Production									

Specifications--

FIG. 25.8 — Another form of estimate sheet.



PLASTICS DEPT. ESTIMATE

PLQ No.

Request Rec'd Meeting Present

Part Drawing Date Drawing No.

Customer Allied—Affiliated—Commercial

Mold Cavity Auto.-Hand=Type Press Size Capacity (20 Hours).

MOLDED PARTS COST: (Per 100 Pieces)

Compound									
Weight per 100 Pieces									
Price per 100 Lb.									
Quantities									
Labor Operations:									
Press									
Clean									
TOTAL									
Labor and Burden									
Compound Cost									
Insert Cost (Inc. Losses)									
TOTAL									
Ext. Labor + Burden									
Samples									
Mold Transportation									
Set-up									
TOTAL COST									
Quote									

INSERTS

Cost per 100 Molded Parts

Drawing	No. per M.P.	Lots - Molded Parts		
Total Cost				
Total + Losses				

MOLD COST

No. of Cavities Auto.-Hand

$

Fixtures

$

Gauges

$

Processing $

Adapting $

Insert Tools $

$

TOTAL COST

Quote $ Delivery Weeks

Remarks

For Customer:

Mold Data:

Insert data:

Fig. 25.9 — Estimators' work sheet.

INJECTION MOLDED PLASTICS

Customers Part No. .... Estimate No. ....

Estimator .... Date ....

Customer ....

Part ....

Delivery Requirements ....

Materials — R

Molding powder

Color

Grams ea .... per M ....

Grams sprue .... " M ....

Total wt. in pounds per M ....

Add ...... % for rejection ....

...... lbs. at .... ¢ per lb. ....

Other materials per M moldings

No.	Item	$ per M
....	....	....
....	....	....
....	....	....
....	....	....

Total .... $ ....

Labor — A

Mold —	pc/hr	$/M ....
Clip —	"	" ....
Fin.	"	" ....
Drill	"	" ....
Tap	"	" ....
Wipe	"	" ....
Spray	"	" ....
Stamp	"	" ....
Assemble	"	" ....
Polish	"	" ....
Inspect	"	" ....
Ship	"	" ....

Total $ per 1000 moldings ....

Factory Exp. M .... % of A ....

Machine Charge

$ per day .... $/M ....

Recap.

Labor ....

Factory exp. ....

Machine chg. ....

Mfg. Cost ....

Mold Maintenance .... % Mfg. Cost ....

Estimated Scrap .... % " " ....

Total Cost ....

Signed by ....

Approved by ....

Tools and Jigs

Design Cost $ ....

Est. Mfg. Cost $ ....

Actual Mfg. Cost ....

Break in Charge ....

Mold & tool cost $ ....

Delivery promise .... weeks

No. Cavities ....

Remarks ....

....

....

....

....

Set up chg. if less than .... M(8 hrs) ....

Color Change if less than .... M(8 hrs) ....

Material price breaks-pc. equivalents

50–99	lbs.	equiv.	to	to	pc.
100–499	"	"	"	"	"
500–999	"	"	"	"	"
1000–4999	"	"	"	"	"
5000–9999	"	"	"	"	"
10000–29999	"	"	"	"	"

Summary per M

Quantity						
Mfg. Cost						
Set up						
Color Chg.						
Material						
Mold Amt.						
S.S. Tax.						
Special						
Special						
Special						
Total						
Quote						

Remarks ....

....

....

....

....

....

....

....

FIG. 25.10 — Cost estimate.

Bulletin Mi—11

MATERIALS TO BE MIXED — Give weights, percentages, or other description....

....................................Viscosity of finished product..........

Viscosity of liquid components at mixing temperature.......Specific Gravity.......

If physical characteristics are unknown, compare to Water, Motor Oil, Syrup, Molasses (Underline) and send 2 to 8 oz. sample for our laboratory test.

What result is desired (Underline). State in your own words what criterion you will use to tell whether the mixer is satisfactory, i.e. what is the job the mixer is supposed to perform ....

....

1\. A blend of liquids. 2. Dissolving Materials. 3. Keeping Solids in suspension. 4. Forming an Emulsion. 5. Stirring while cooking, etc. 6. ....

....

Are undissolved solids present?...........Give lb. per gal............Particle size and Sp. G.................... Give settling time if suspension.................

Are abrasives present?......... What Kind?......... How Much? (lbs. per gal.)

........................Give sieve analysis or send dry sample for laboratory test.

How is mixing operation carried on at present? ....

H. P. Used.................... Is present mixing satisfactory..................

Maximum time for mixing operation.............. Temperature?..............

What degree of agitation is desired — Violent, Medium, Mild (Underline)

What would be effect of too little agitation?...................................

Of too much agitation?..

Is operation to be in open tank, closed tank (Air Tight, Under Pressure Vacuum).

(Underline.) Give lb. per square inch or inches of vacuum........................

Shape of top.............................Shape of bottom — Flat, Dish, Cone (Underline)

...... Tank, Kettle, Vat, etc. (Write in your term).................

Tank Dimensions — Diameter........ Height........ Capacity in Gallons.......

Tank Material.............. Thickness at Rim (Including Flange)..............

If container is irregular in shape or contains heating coils, baffles, or other members, draw dimensioned sketch and show location. (Use back of this sheet.)

Size of batch usually mixed, depth to which tank is filled and distance from top to liquid level. Gallons................ Depth Filled................ Depth from top............ Will Mixer be operated while filling and/or drawing off?...........

Outline mixing cycle giving minimum batch or depth, order of adding material, etc.

....

....

....

....

FIG. 25.11 — Mixing problem work sheet.

No. 2

CLOSED TANK UNITS PRESSURE AND VACUUM

If tank is closed (air tight, pressure, vacuum) and *not over ten feet* deep, enclose print or accurate sketch of tank showing available openings, position, dimensions, bolt circle of flange. Give preference as to how mixer enters tank, through side or top. If no opening exists in top we furnish print showing proper location of flange nozzle to be welded in. Give thickness or gage of metal in sides and heads.

Side Entering Units
Large Tanks

If tank is over ten feet deep it will be necessary to enter through the side of tank. Send sketch showing wall thickness, manner of construction, material, exact inside and outside diameter and location of exterior structural parts which might interfere with installation.

Working Conditions

Will mixer be used indoors or outdoors..

Are conditions dry, steamy, dusty, wet...

Are products to be mixed inflammable or explosive...........................

What current is available — Voltage, Frequency, and Phase......................

If possible specify type of motor you prefer — Splash Proof, Totally Enclosed, Explosion Proof. Do you require special insulation?..............................

What construction metals or materials have you found to be satisfactory in handling the liquid to be mixed?...

Name .... Title ....

Company ....

Street .... City .... State........

Note: Every point in this work sheet is important. The mechanical details, horsepower, propeller size, type of unit, etc., can only be decided upon, after reviewing *every point*.

We earnestly solicit your cooperation in furnishing these essential engineering data. Since every mixing operation presents its own problem, we feel that each case is entitled to individual consideration. Mixers *must* be fitted to their job, and are never sold by this company merely as an electrical appliance. All information furnished us is held in *strict confidence*. Our free engineering service is in our opinion unequalled by any other manufacturer of mixers. Help us to help you, without obligation on your part.

MIXING EQUIPMENT CO., INC.

Mi-11 Send me additional copies of this work sheet; 2 ☐, 4 ☐, 6 ☐

Revised — February 1940.

FIG. 25.11 — Mixing problem work sheet. *Continued*

DATA SHEET

1. Materials to be mixed or processed..

....

....

2. Alternatively materials are physically similar to..............................

....

....

3. Average weight per cubic foot of material = ...lb.

4. Nature of final product desired..

....

....

5. Material or Materials are of nature described below — check which:

a. Corrosive (describe) ....pH = ...

b. Abrasive ....

c. Adhesive ....

d. Lumpy ....

e. Tough ....

f. Elastic ....

g. Fibrous ....

h. Friable ....

i. Dispersible ....

j. Volatile ....

k. Inflammable ....

6. Make and capacity of mixers (if any) at present used.........................

....

7. Horse power used on present mixers...

8. Present mixing cycle:

a. Charging = ...Minutes

b. Mixing = ...Minutes

c. Discharging = ...Minutes

d. Cleaning = ...Minutes

9. Current characteristics ....phase............cycle. ....volts.

10. **PROPOSAL DESIRED** based on the following data:

a. Working capacity................gallons or................cubic feet.

b. Total capacity ....gallons or................cubic feet.

c. Working surfaces in contact with mix to be (check which):

1. Cast Iron ....
2. Cast Steel ....
3. Welded Steel ....
4. Stainless Steel ....
5. Bronze ....
6. Nickel ....
7. Plated ....
8. Other (describe) ....

d. Must machine be cleaned between batches.....................................

e. Size of batch desired 1.....lb. 2. ....gallons. 3. Maximum volume...cu. ft.

f. Output desired to be processed per 8 hour day...............................

(or) state number of machines required......................................

FIG. 25.12 — Form for processing equipment.

g. Nature of treatment or processing required (check which):

1. Mixing ....
2. Kneading ....
3. Masticating ....
4. Compounding ....
5. Dispersing ....
6. Dissolving ....
7. Shredding ....
8. Reacting ....
9. Drying ....
10. Solvent Liberation ....

h. Mixing Chamber check whether: ....

1. Tilting ...... 2. Stationary .... 3. Stepped Trough.......

4. Open .... 5. Covered .... 6. Type cover desired....

....

7. Under vacuum.................how much ....inches

8. Under Internal Pressure.... ...how much ....lb. per sq. in.

9. Jacketed for heating. a. Trough...... b. Ends...... c. Blades......

d. Cover...... Heating medium...... Pressure or temperature......

10. Jacketed for cooling. a. Trough....... b. Ends....... c. Blades......

d. Cover......... Cooling medium......... Temperature.........

11. **GENERAL INFORMATION,** as for instance size and number of cover openings. Size and type of outlet valves or outlet doors (if stationary or stepped trough mixing chamber used), preferences as to gasket and packing material, type of main drive desired and any other details to which you want to call particular attention: ....

....

....

....

....

....

....

....

....

Date............194... Submitted by:.................. Title..............

Name of Company....................................

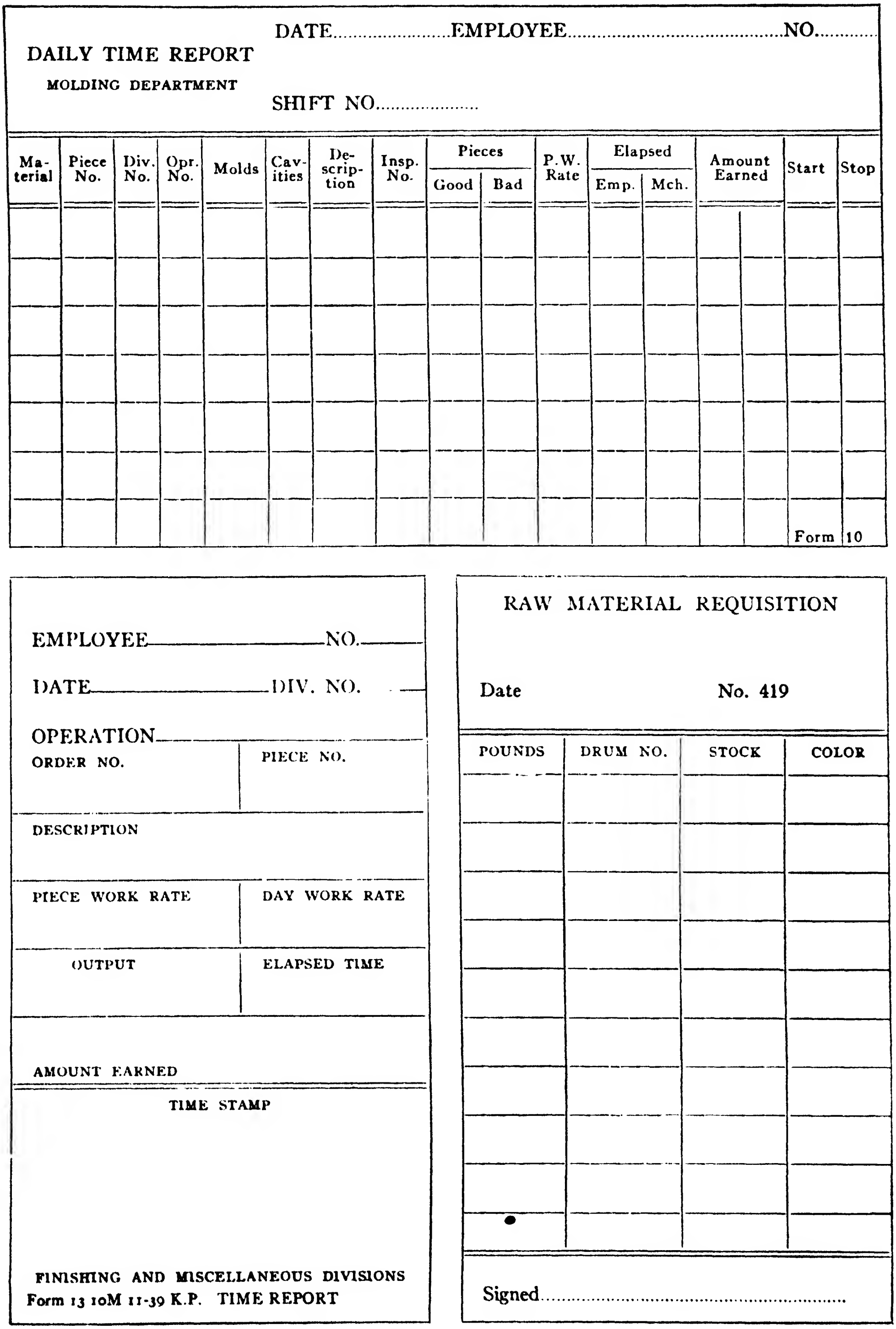
Division or Dept. ....

Address ....

....

Telephone Number ....

Fig. 25.12 — Form for processing equipment. *Continued*



DAILY TIME REPORT

MOLDING DEPARTMENT

DATE........................EMPLOYEE..NO.............

SHIFT NO.....................

Material	Piece No.	Div. No.	Opr. No.	Molds	Cavities	Description	Insp. No.	Pieces		P.W. Rate	Elapsed		Amount Earned	Start	Stop
								Good	Bad		Emp.	Mch.			
														Form	10

EMPLOYEE____________________NO.________

DATE____________________DIV. NO. ____

OPERATION________________________

ORDER NO.	PIECE NO.
DESCRIPTION	
PIECE WORK RATE	DAY WORK RATE
OUTPUT	ELAPSED TIME
AMOUNT EARNED	

TIME STAMP

FINISHING AND MISCELLANEOUS DIVISIONS

Form 13 10M 11-39 K.P. TIME REPORT

RAW MATERIAL REQUISITION

Date No. 419

POUNDS	DRUM NO.	STOCK	COLOR

Signed...

Fig. 25.13 — Estimate and material requisition.

CURRENT ASSETS

1. Cash in Bank
2. Petty Cash
3. Securities — liquid
4. Accounts Receivable
5. Advance to Employees
6. Reserve for Bad Debts
7. Bills Receivable

Inventories

8. Raw Material
9. Inserts
10. Finished Goods (80% Sales Value)
11. Miscellaneous Replacement (Reparable Returns)
12. Packing Supplies
13. Customers' Molds (not yet billed)
14. Coal
15. Finishing Supplies
16. Tool Room

FIXED ASSETS

17. Land
18. Land Assessments
19. Real Estate, Buildings
20. Real Estate, Additions to Buildings
21. Reserve — Depreciation Buildings
22. Plant and Equipment
23. Reserve — Plant & Equipment Depreciation
24. Private mold inventory
25. Private mold depreciation and obsolescence reserve
26. Suspense Accounts
27. Furniture and Fixtures
28. Furniture and Fixtures Depreciation Reserve
29. Compensation Insurance prepaid
30. Other Insurance prepaid
31. Taxes — prepaid
32. Patents

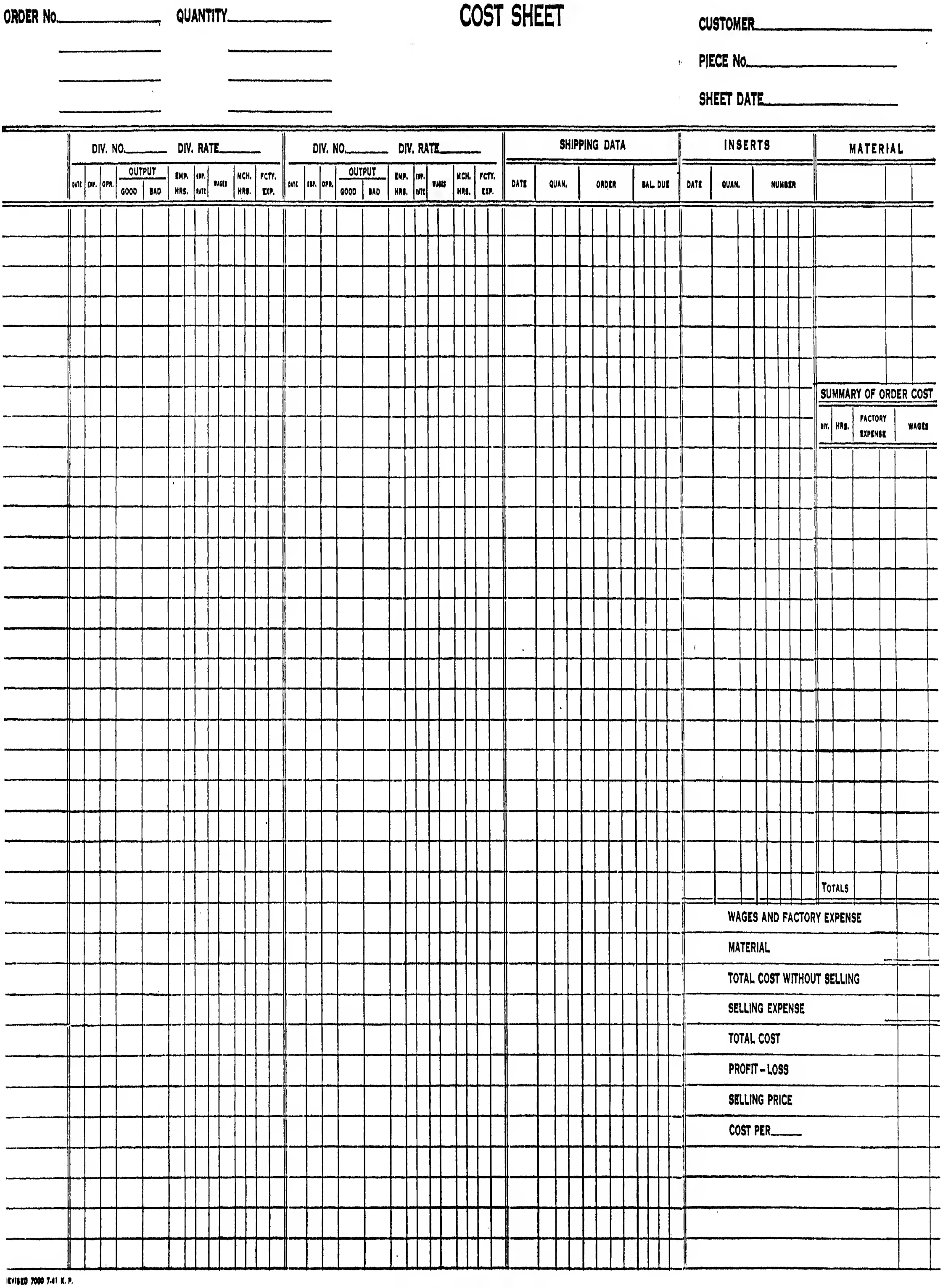
CURRENT LIABILITIES

101. Accounts Payable Trade
102. Accrued Payroll
103. Accrued Taxes
104. Accrued Interest
105. Notes Payable

FIXED LIABILITIES

111. Mortgage
112. Preferred Stock
113. Common Stock
114. Surplus
115. Dividends

FIG. 25.15 — Listings for a balance sheet.



ORDER No.______ QUANTITY______

COST SHEET

CUSTOMER______

PIECE No.______

SHEET DATE______

DIV. NO.____ DIV. RATE____										
DATE	EMP.	OPR.	OUTPUT		EMP. HRS.	EMP. RATE	WAGES	MCH. HRS.	FCTY. EXP.
			GOOD	BAD					

DIV. NO.____ DIV. RATE____									
DATE	EMP.	OPR.	OUTPUT		EMP. HRS.	EMP. RATE	WAGES	MCH. HRS.	FCTY. EXP.
			GOOD	BAD					

SHIPPING DATA			
DATE	QUAN.	ORDER	BAL. DUE

INSERTS		
DATE	QUAN.	NUMBER

MATERIAL

SUMMARY OF ORDER COST			
DIV.	HRS.	FACTORY EXPENSE	WAGES
TOTALS			

WAGES AND FACTORY EXPENSE

MATERIAL

TOTAL COST WITHOUT SELLING

SELLING EXPENSE

TOTAL COST

PROFIT – LOSS

SELLING PRICE

COST PER______

REVISED 7000 7-41 K. P.

Fig. 25.14. Cost Sheet.

PIECE No.________

DIV. NO.______ DIV. RATE______										DIV. NO.______ DIV. RATE______										DIV. NO.______ DIV. RATE______										DIV. NO.______ DIV. RATE______										
DATE	EMP.	OPR.	OUTPUT		EMP. HRS.	EMP. RATE	WAGES	MCH. HRS.	FCTY. EXP.	DATE	EMP.	OPR.	OUTPUT		EMP. HRS.	EMP. RATE	WAGES	MCH. HRS.	FCTY. EXP.	DATE	EMP.	OPR.	OUTPUT		EMP. HRS.	EMP. RATE	WAGES	MCH. HRS.	FCTY. EXP.	DATE	EMP.	OPR.	OUTPUT		EMP. HRS.	EMP. RATE	WAGES	MCH. HRS.	FCTY. EXP.	
			GOOD	BAD									GOOD	BAD									GOOD	BAD									GOOD	BAD						

Fig. 25.14. Cost Sheet (*Continued*)

INCOME

201. Merchandise Sales
202. Mold Sales
203. Discounts on Purchases
204. Interest on accounts receivable
205. Non-operating revenue
206. Royalties

EXPENSE

300. Merchandise Credits
301. Raw Materials
302. Inserts
303. Freight, Cartage and Express Incoming
304. Molding Wages — Direct Labor
305. Finishing Wages — Direct Labor

MANUFACTURING OVERHEAD

Wages

306. Superintendence
307. Machine Shop
308. Non-Productive
309. Power
310. Weighers
311. Inspectors
312. Packing and Shipping
313. Heat, Light and Power
314. Plant and Equipment Repairs and Replacements
315. Machine and Tool Supplies
316. Mold Repairs
317. Finishing Supplies
318. Shop Expense
319. Packing Material

SALES EXPENSES

325. Salaries
326. Sales Expense Miscellaneous Account
327. Travelling Expense
328. Research and Development
329. Advertising
330. Commissions
331. Freight, Cartage and Express Outgoing

ADMINISTRATION EXPENSE

335. Officers' Salaries
336. Office Salaries
337. Stationery and Printing
338. Auditing
339. Postage
340. Legal Expenses
341. Telephone & Telegraph
342. Office Expenses
343. Discount on Sales
344. Interest Payable
345. Compensation Insurance
346. General Insurance
347. Taxes, Real and Personal
348. Bad Debts
349. Outside Labor

Depreciation

350. Buildings, and Real Estate
351. Plant and Equipment
352. Molds
353. Furniture and Fixtures
354. Charity
355. Patents
356. Pensions
357. Federal Revenue Taxes

FIG. 25.16 — Listings for an operating statement.

CHAPTER XXVI

WORKERS' WELFARE

In resin manufacturing plants, the problems of health maintenance are complex but not serious. Most plastics manufacturing plants are new, and due thought has been given to the workers' safety in setting them up.

Plastics are made from chemicals, and safety practices common to the chemical industry apply to those engaged in making resins or manufacturing products from them. Although the molder, unless he manufactures his own materials, has little direct contact with the raw chemicals used in resin manufacture, he nevertheless must give some thought to the health of his workers. Molding shops should be well ventilated to remove the dust and odors accompanying the use of molding powders. Some workers suffer from a form of dermatitis caused by phenol-formaldehyde molding compound due to a hypersensitivity to formaldehyde. Some workers are allergic to phenol itself.

In a study made by the U. S. Public Health Service ("Skin Hazards in American Industry," Part II, *Public Health Bulletin* 229, September, 1936, pp. 1–12), it was found that a large number of workers were sensitive to formaldehyde and others to phenol, cresol, or hexamethylenetetramine.

In order to determine to which of these substances the patient is sensitive, patch tests can be performed by a doctor with (1) a 4 per cent solution of formaldehyde; (2) a 2 per cent aqueous solution of phenol; and (3) dry powdered hexamethylenetetramine. The patches may remain on the normal skin for 24 hr. without causing a reaction. A sensitive individual will react to the patch of a substance to which he is sensitive.

To protect the workers against the irritants in phenol-formaldehyde resins, manufacturing processes should be totally enclosed. If this is not possible, hoods with suction exhausts should be placed over open processes so that dust and fumes are drawn away from the worker and out of the room. The workrooms should be ventilated by intake and exhaust fans to remove dust and fumes. The floors, walls, ceilings, and machines should be washed down or vacuum cleaned at frequent intervals to keep them free from dust and irritating chemicals. Clean work clothes consisting of long sleeves, long-legged underclothes and long-sleeved coveralls fastened at the neck and wrists, and rubber gloves extending under the sleeves of the coveralls, should be provided. New workers who are hypersensitive to the resins but have only mild eruptions may be given protective ointments in addition to the protective clothing and may work for a period of three or four weeks in the hope that they will develop an immunity or become "hardened." If this does not occur, they should be removed from the job. If the patient's livelihood depends on his continuing at the job, an attempt may be made by a physician to de-sensitize him to the chemical to which he is sensitive. This should be done by beginning with minute doses administered subcutaneously and gradually increased. The results of each injection should be carefully watched so as avoid severe constitutional reactions.

A textbook on the subject of toxicity of the various chemicals used in modern industry has been written by Alice Hamilton, (*Industrial Toxicology,* Harper & Brothers, 1934). *Public Health Bulletins* 215 and 229, " Skin Hazards in American Industry, Parts I and II," describe industrial processes and their skin hazards in nineteen industries. These bulletins may be obtained by writing to the Surgeon General, U. S. Public Health Service, Washington, D. C.

When it is definitely determined that a worker is allergic to any of the ingredients of a molding compound, it is better to transfer him to some other plant. In most cases of minor irritation, only cleanliness is necessary to ward off skin irritation. Some skin preparations can be applied which offer certain degrees of protection. The Milburn Company of Detroit markets one such preparation known as Ply. Such preparations usually consist of soap emulsions of stearic acid. The thin film of stearic acid protects the skin. The following formula has proved of merit in protecting workers' skin against some chemicals.

Stearic acid	18.0 parts
Amino glycol	1.5 parts
Glycerin	5.0 parts
Magnesium stearate	10.5 parts
Water	65.5 parts

The stearic acid should be melted. The amino glycol and glycerin should then be dissolved in water heated to the same temperature as the melted stearic acid. Mix thoroughly the two solutions. To this mixture add the magnesium stearate. The consistency of the mix may be controlled by the addition of further amounts of water.

One problem of protecting the worker in molding shops consists mainly of setting up protective devices around fast-moving presses, gears, and the like, and is approached in exactly the same manner as in a machine shop. When cold molding was more predominant, missing fingers were common identification of the molder's trade. Fortunately, this problem has been nearly eliminated with compression molding. With the automatic injection molding machines, safety guards are incorporated at the outset and should be left on the machine.

Operations involving milling are dangerous unless adequate protection is afforded. The milling of plastics materials requires appreciable power, and there is ever-present danger that a careless operator may be caught accidentally while handling the material on the mill. Inasmuch as the equipment is unique to the rubber and plastics industries, the design of safety equipment for the mills is also unique to this class of machinery. The problem has three important phases.

The first of these is the design of power cutout and adequate braking in order to stop the equipment quickly and without damage. The second is a suitable arrangement of tripping devices located to permit almost involuntary operation by an operator in distress. The third is largely a question of an employer's responsibility to his operator to install and maintain the best available safety equipment.

The first rubber mills had no power cutout, no brakes, and no method of stopping except the use of an obstruction thrown into the bite of the rolls. This has frequently been referred to as a " crowbar " brake. Although the method often would stop a mill, the operator did not always have within his reach a suitable implement to throw into the bite of the rolls. When such an implement was found the inevitable result was severe damage to the rolls or frame of the mill. After stoppage of the mill was accomplished, however, it was not certain that fracture of one of the rolls would permit rotation of the portion of the broken roll on the gear end. This was obviously an inadequate method of braking from several important points of view.

The first important advance was the introduction of a throw-out clutch on the high-speed drive shaft. Then, even after the clutch was disconnected, the rolls were carried through several revolutions by inertia. As mechanical drives from line shafts gave way to electric motors the mechanical throwout became unnecessary, but brakes were still lacking.

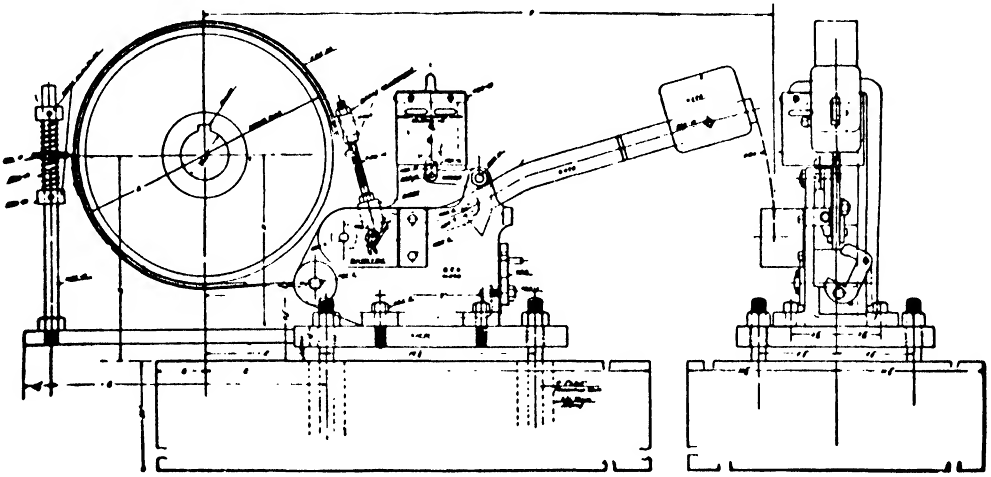


Fig. 26.1 — Mechanical type of brake.

Today both mechanical and electrical brakes are available. Both classes operate on the high-speed drive shaft and utilize the mechanical advantage of the chain of reducing gears to obtain quick stopping action. The mechanical type of brake employs a weight-actuated lever as shown in Fig. 26.1 to apply the brake. Normally the lever is in the elevated position, but when the release mechanism is operated, the power to the electric drive is cut off and the brake lever is released. The brake of Fig. 26.1 is electrically held by a solenoid and is applied by breaking the current through a solenoid. Mechanically held brakes are also used, and these employ a system of levers terminating in a hook on the brake lever to apply the brake simultaneously with the switching off of the power to the motor. The motor in either case cannot be started again without resetting the brake by hand. The electrically held brake has the advantage of remote control and is better suited to multiple-mill installations driven by a single motor. Further reference to Fig. 26.1 will show that a catch is provided to lock the brake as soon as it is once applied.

Mechanically actuated brakes, whether electrically or mechanically held, provide rapid and positive stoppage of mills without injury to their drives or rolls. They are simple and reliable in operation and low in first cost and are used in the majority of installations for these reasons.

Electric braking on mills and calenders is relatively new. The three major groups in the electrical class are dynamic braking, regenerative braking, and plugging.

Both dynamic and regenerative braking require that the mill drive be either a synchronous motor or a direct-current motor. This requirement often necessitates a compromise with the type of motor drive that might otherwise be chosen for the service. Dynamic braking is rapid in the early stages, but an intrinsic fault of the method is that its effectiveness drops off as the speed decreases. It involves a succession of changes in electrical connections by heavy contactors and the use of relays to give full field for effective braking. The equipment is expensive and requires specialized maintenance skill to assure reliable operation. Regenerative braking has the advantage of maintaining full braking power at all speeds and does not involve the opening and closing of heavy contacts. This method is applied chiefly on direct-current adjustable voltage calender drives, but it is high in first cost.

The third group, employing plugging, is applied to polyphase induction motor drives. This consists of changing the electrical connections to reverse the motor while running at full speed. It requires the use of control equipment to change the electrical connections, including relays to disconnect the motor as it approaches a dead stop. This method is not approved by some of the states for the machinery of the rubber and plastics industries.

The second phase of the safety problem, involving the proper arrangement of tripping mechanisms, has received a great deal of study. The first is a safety bar that is usually adjustable in height. This can be operated by the head or free arm of the operator and should be placed at about shoulder level to be readily accessible and most effective. The other arrangement is a safety cable at either side of the calender in such a position that it can be operated either by the free arm or by foot. In some cases other devices that can be operated by foot have been provided. It has also been proposed that mills be equipped with photoelectric cells and a beam of light passing from one side of the mill to the opposite side where it is focused on the photoelectric cell. Any opaque object that passes through the beam will actuate the brake mechanism and stop the mill. This form of tripping mechanism could be relied upon as definitely as any, but it has the disadvantage of being inconvenient while materials are being added to the mix on the mill or at times during the ordinary manipulation of the batch on the rolls.

The third phase of this problem is perhaps the most important one at the present time. It involves the obligation of employers to ensure a reasonable degree of safety to their operators in the milling and calendering of rubber and plastics. Unfortunately, it is still necessary that certain employers be forced to accept safety devices. It is also unfortunate that safety devices are not always properly maintained in effectiveness. Rigid and periodic inspection of installed safety equipment should be the practice of every mill room. Much remains to be accomplished in the adoption of safety codes by the various states, although precedents have been established. Essential features of such codes are specifications governing the location of tripping bars and cables, and the statement of maximum roll travel for a given mill after the brake is applied. Various methods may be employed to measure roll travel. For example, an electric pencil operated by a mercury switch temporarily mounted on the trip bar may be used. In spite of the fact that the rubber industry is today one of the heavy industries, and in spite of the fact that the mixing of rubber is definitely hazardous, certain of the important states in the rubber industry today have no safety code. It is appropriate that this opportunity be taken to emphasize the importance of enforcing safety installations.

References. 1. "Safety Code for Rubber Mills and Calenders," Bulletin No. 447 of the United States Bureau of Labor Statistics, United States Government Printing Office, June, 1927.

2. "Tentative Safety Code for Mills and Calenders," State of New Jersey, Department of Labor, Bureau of Electrical Equipment, C. George Krueger, Deputy Commissioner, November 1, 1939.

3. "Safety First and Efficiency," by Joseph W. Thropp, *The India Rubber World.*

As a whole, plastics enjoy a fairly low workers' injury rate, as may be seen by referring to Table 130, page 911.

Most of the molding powder manufacturers maintain some sort of clinical service for their employees. A characteristic example of such an operation is followed by one producer of molding powder, who has a small infirmary in which employees may consult a doctor daily at a specified time. In addition every employee is required to have a thorough medical examination at the local clinic. At no cost to himself he is given a real " going over " including X rays of the chest. All new employees are checked and, if found to have respiratory troubles, are kept under surveillance. If the condition is aggravated by working with molding powders, they are transferred to other work or released.

Safety education should be encouraged in molding and resin plants. The following chart should be of interest in promoting workers' safety.

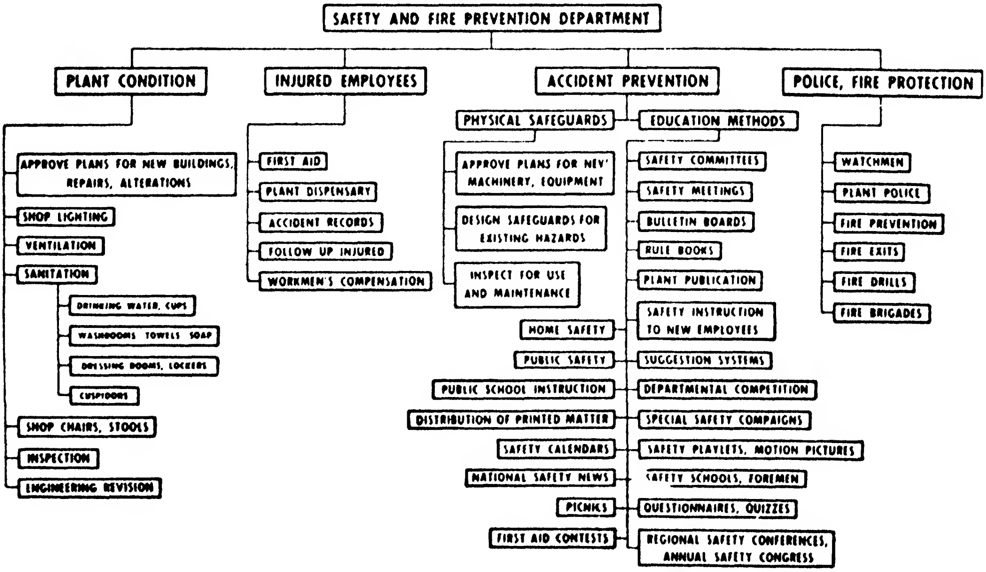


FIG. 26.2 — Outline of activities for a typical safety and fire prevention department. These duties are described in detail in Safe Practices Pamphlet No. 42 of the National Safety Council.

ANTIDOTES OF POISONS

Acetic Acid: Emetics, magnesia, chalk, soap, oil.
Acetylene: Same as for carbon monoxide.
Arsenic, Paris Green: Milk, raw egg, sweet oil, lime water, flour and water.

TABLE 130. DISABLING INJURIES, 1939, CHEMICAL INDUSTRY, BY INDUSTRIAL GROUPS*

Industrial Group	Number of Indus-trial units	Man-Hours Worked (thou-sands)	Average Number of Employees	Number of Disabling Injuries				Time Charges				Injury Rates	
				Death and Perm. Total	Perm. Partial	Tem-porary Total	Total	Death and Perm. Total	Perm. Partial	Tem-porary Total	Total	Fre-quency	Se-verity
All groups	417	305,535	144,378	40	172	2,073	2,285	240,000	106,005	39,090	385,095	7.48	1.26
Laboratories	13	4,202	2,062	0	0	3	3	0	0	16	16	0.71	0.003
Industrial Gases	8	4,303	2,109	1	1	5	7	6,000	60	101	6,161	1.63	1.43
Alcohol and Solvents Manufacturing	5	2,010	951	0	0	7	7	0	0	124	124	3.48	0.06
Plastics Manufacturing	16	13,485	6,704	0	15	36	51	0	4,459	647	5,106	3.78	0.38
Acid Manufacturing	40	19,739	9,623	4	16	56	76	24,000	10,250	1,701	35,951	3.85	1.82
Chlorine and Alkali Manufacturing	12	15,206	6,645	2	3	57	62	12,000	400	2,246	14,646	4.08	0.96
Carbon Products	13	9,397	4,629	1	12	35	48	6,000	6,497	1,013	13,510	5.11	1.44
Dye Manufacturing	7	11,602	5,752	1	7	56	64	6,000	3,268	1,268	10,536	5.52	0.91
Paint and Varnish Manufacturing	37	21,864	10,742	1	4	136	141	6,000	1,500	2,878	10,378	6.45	0.47
Pharmaceutical and Fine Chemical Manufacturing	29	43,631	15,977	3	13	377	393	18,000	9,728	5,655	33,383	9.01	0.77
Explosives Manufacturing	59	27,702	13,822	11	20	253	284	66,000	12,810	4,347	83,157	10.25	3.00
Soap Manufacturing	31	24,760	12,556	2	32	234	268	12,000	15,573	5,129	32,702	10.82	1.32
Coal Tar Distillers	17	1,155	558	1	0	16	17	6,000	0	224	6,224	14.72	5.39
Fertilizer Manufacturing	12	8,150	4,018	3	6	122	131	18,000	5,850	2,186	26,036	16.07	3.19
Salt Manufacturing	12	4,340	2,163	0	2	74	76	0	700	1,508	2,208	17.51	0.51
Vegetable Oil Manufacturing	30	7,609	3,850	0	9	131	140	0	8,315	2,473	10,788	18.40	1.42
Not Otherwise Classified	76	86,380	42,217	10	32	475	517	60,000	26,595	7,574	94,169	5.99	1.09

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*Chemical & Metallurgical Engineering, October, 1940.

Carbolic Acid: Any soluble nontoxic sulfate, after provoking vomiting with zinc sulfate; uncooked white of egg in abundance, milk of lime, saccharate of calcium, olive or castor oil with magnesia in suspension, ice, washing the stomach with equal parts water and vinegar; give alcohol or whiskey or about four fluid ounces camphorated oil at one dose.

Carbon Monoxide: Remove to fresh air immediately and call for pulmotor; apply artificial respiration for at least one hour or until the pulmotor arrives. Administration of oxygen containing 5 per cent carbon dioxide is beneficial; inhalation of ammonia or amyl nitrate is often of value.

Chloroform, Chloral, Ether: Dash cold water on head and chest, artificial respiration.

Ethylene: Same as for carbon monoxide.

Gas (illuminating): Same as for carbon monoxide.

Hydrochloric Acid: Magnesia, alkali carbonates, albumen, ice.

Hydrocyanic or Prussic Acid: Hydrogen peroxide internally, and artificial respiration, breathing ammonia or chlorine from chlorinated lime, ferrous sulfate followed by potassium carbonate, emetics, warmth.

Iodine: Emetics, stomach siphon, starchy foods in abundance, sodium thiosulfate.

Lead Acetate: Emetics, stomach siphon, sodium, potassium or magnesium sulfates; milk, albumen.

Mercuric Chloride or Corrosive Sublimate: Zinc sulfate, emetics, stomach siphon, white of egg, milk, chalk, castor oil, table salt, reduced iron.

Nitrate of Silver: Salt and water.

Nitric Acid: Same as for hydrochloric acid.

Phosphoric Acid: Same as for hydrochloric.

Sodium Hydroxide or Potassium Hydroxide: Vinegar, lemon juice, orange juice, oil, milk.

Sulfuric Acid: Same as for hydrochloric acid with the addition of soap or oil.

Sulfurous Acid or Sulfur Dioxide: Mustard plaster on chest; narcotics, expectorants.

Wood Alcohol (Methyl Alcohol or Methanol): Emetic or wash out stomach (stomach tube) with a solution of 10 grains sodium citrate per ounce of water. Give milk, white of egg, or flour in water, purgative of magnesium sulfate (15 g.); stimulate and combat collapse. In case of cardiac or pulmonary failure use artificial respiration. Physicians may administer atropine, digitalin or strychnine as stimulants; to cause perspiration and elimination of the poison use 0.1 grain of pilocarpine hydrochloride.

BURNS AND SCALDS

Exclude air by thin paste of starch, flour, or baking soda. Ordinary oils such as vaseline, olive or castor oil, lard or cream may be used only on first degree burns which are characterized by a reddening of the skin. Lime water mixed with an equal part of raw linseed oil makes an excellent dressing. An especially valuable material for all types of burns is picric acid gauze which may be applied in the form of a compress.

After treatment with any of the above materials, cover with a sterile cloth or with cotton and hold in place with a light bandage.

For second and third degree burns apply a freshly prepared 5 per cent tannic acid solution. Place several layers of sterile gauze over the burned area, saturate with the tannic acid solution and bandage loosely.

ACID AND ALKALI BURNS

With either, wash off as quickly as possible with a large quantity of water. Water from a tap may be allowed to flow over burns.

Acids

While the injury is being washed, have procured lime water, or lime water and raw linseed oil mixed together in equal proportions, or a mixture of baking soda and water or soap suds and apply freely. For acid in the eye, wash quickly as possible with water and then with lime water.

Alkalies

Wash with a large quantity of water as for acid burns. Neutralize with weak vinegar, hard cider, or lemon juice. For lime or other strong alkali burns in the eye, wash with weak solution of vinegar or with olive oil or a saturated solution of boric acid.

FIRE PRECAUTIONS AND CHEMICAL HAZARDS

Acetone: Dilute with a spray of water to avoid spread of burning liquid. Use suitable gas mask.

Alcohol: See under acetone.

Ammonia: Use water and dilute acid. Use suitable gas mask.

Benzol or Benzene: Use water to cool containers which are endangered; extinguish flame with sand, earth, fire foam or carbon tetrachloride fire extinguishers. Use suitable gas mask.

Calcium Carbide: Do not use water, for it generates acetylene, an inflammable and explosive gas; cut off electric current to avoid ignition of gas. Remove containers to a dry place. Use gas mask.

Carbon Disulfide: Use water to cool containers that are endangered; extinguish blaze with sand, earth, fire foam or carbon tetrachloride fire extinguishers. Use suitable gas mask.

Carbon Tetrachloride: Do not use a fire extinguisher filled with carbon tetrachloride (pyrene or carbona) on flames caused by an electrical short circuit in a confined space; the carbon tetrachloride may be decomposed into toxic gases.

Celluloid: Use large volumes of water and sand. The smoke contains oxides of nitrogen that are injurious. Use suitable gas mask.

Chlorine: Spray with water. The pungent nature of the gas makes the use of a gas mask imperative.

Collodion: See under carbon disulfide.

Ether: See under carbon disulfide.

Gasoline: See under carbon disulfide.

Hydrochloric Acid: Use large volumes of water, also chalk or soda. Use gas mask.

Hydrocyanic or Prussic Acid: Suitable gas mask is essential because of the extremely poisonous nature of the vapors. Provide ventilation.

Lacquer Solvents: See under carbon disulfide.

Magnesium: Do not use water. Use sand or earth to extinguish flames. Remove containers to a dry place.

Nitric Acid and Oxides of Nitrogen: Use large volumes of water. Do not use sand or earth. Use gas mask.

Potassium: Do not use water. Remove containers to a dry place. Extinguish flames with sand or earth. For storage, potassium is kept immersed in petroleum.

Potassium Hydroxide: Use large volumes of water or dilute acids.

Phosphorus: Use water and wet sand. Use gas mask. For storage, white phosphorus must be kept immersed in water. Red phosphorus is less dangerous.

Sodium: See under potassium.

Sodium Hydroxide: See under potassium hydroxide.

Sulfur: Extinguish with water or sand. Use gas mask.

Sulfuric Acid: See under hydrochloric acid.

Turpentine: See under acetone.

PART IX

Appendix - Glossary - Bibliography

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Appendix — Useful Tables — Conversion
Tables — General Glossary — Chemical
Glossary — Bibliography

APPENDIX

THE INFLUENCE OF TEMPERATURE ON THE MECHANICAL PROPERTIES OF MOLDED PHENOLIC MATERIALS [*]

By T. S. Carswell,[†] D. Telfair,[†] and R. U. Haslanger[†]

Synopsis

Data showing the variation of the impact, flexural, and tensile strengths with temperature are given for molded phenolic compositions containing wood flour, asbestos. macerated fabric, and cord fillers and for a pure resin composition. Impact values between −80° and 250° C. (−112° and 480° F.), flexural values between −80° and 180° C. (−112° and 355° F.) and tensile values between −80° and 230° C. (−112° and 445° F.) are presented. The practical importance of these data are discussed.

A knowledge of the effect of temperature on the mechanical properties of molded compositions is becoming increasingly important with the growing demand for plastics in structural uses. Many molded parts for military purposes[1, 2, 20] are going into applications which require that they be serviceable over the temperature range from 51° to 70° C. (−60° to 160° F.) As a result, specifications are being written by the Army and Navy to cover the mechanical properties of plastics at these temperatures. Requests have recently been received from various divisions of both Services for data on this subject. Numerous aircraft manufacturers using plastics in structural applications, as well as the National Advisory Committee for Aeronautics, have expressed a vital need for figures showing the change of mechanical strengths with temperature.

Relatively little significant information on the mechanical properties of plastic materials intended for structural uses has been available in the literature until recently. A publication in 1939 by Jacobi and Thum[3] describes in great detail the physical properties of phenolic compositions at room temperature. Additional information is given in articles by de Bruyne[4], Genung[5], Melville[6], Haut[7], and others[8, 9, 10]. In general, these workers have failed to emphasize the importance of changes in temperature on the physical properties under consideration.

Within the last year Delmonte[11] has reported on the shear strength of molded phenolic materials over a limited temperature range. The variation of flexural strength and the deflection at failure for a number of compression molded plastics at temperatures from −70° to 200° C. (−94° to 390° F.) is described by Nitsche and Salewski[12], while a determination of static tensile, compressive, stiffness, and bending

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[*] Reprinted by courtesy of American Society for Testing Materials, Philadelphia, Pa., Vol. 42, 1942.

[†] Research Director, Research Physicist and Research Chemist, respectively, Plastics Division, Monsanto Chemical Co., Springfield, Mass.

properties, and fatigue strengths of three laminated phenolic materials at −39° C., −18° C., and 25° C. (− 38° F., 0° F. and 77° F.) are included in *Air Corps Technical Report No. 4648*[13]. Kistler[21] and Kozlov[22] have also reported on the effect of temperature on the mechanical properties of plastics.

Almost no previous work has been reported on the effect of temperature on the impact strength or of elevated temperature on the tensile strength of molded phenolic compositions. Research work was undertaken to study the change of impact, tensile, and flexural strengths over the temperature range from −80° to 250° C. (−112° to 480° F.). Molded compositions employing wood flour, asbestos, macerated fabric, and cord fillers, as well as a pure resin composition, were evaluated. Creep properties, shear, and compressive strengths for these materials are also being studied over the same temperature range and will be reported at a later date.

The data reported here are short-time temperature effects. The effect of extended conditioning at temperatures other than room temperature, 25° C. (77° F.), has been touched upon briefly by Place[14] who studied phenolic laminated materials over a limited temperature range. The Society's Committee D-20 on Plastics has set up a tentative method for determining the permanent effect of heat on plastics. Further work along these lines is extremely important for the evaluation of plastic materials for structural applications.

Because the physical properties of the molded material depend to a marked degree upon the technique used in the preparation of the materials and test specimens[15], a knowledge of this technique is essential if the results are to be properly evaluated.

The filled materials studied contained 50 per cent phenol-aldehyde resin and 50 per cent filler with the exception of the asbestos-filled material which contained 40 per cent resin and 60 per cent filler. This change was necessary to give a moldable composition.

The wood-flour filled and asbestos-filled molding compositions were prepared by rolling the resin and filler on a set of differential rolls in the usual manner for the preparation of general purpose phenolic molding compounds. Three typical phenol-aldehyde resins were evaluated in connection with the wood-flour filler:

1. A typical one-stage, basic catalyzed resin.
2. A typical two-stage, acid catalyzed resin.
3. A semi-two-stage, dual catalyzed resin.

No appreciable difference in properties was exhibited over the temperature range, and so the two-stage resin was used in connection with the other fillers and for the preparation of the pure resin molding compound.

The high impact materials, macerated fabric, cord, and sisal fiber fillers were blended with the resin in a wet-mix process. Mixing was held to the minimum necessary to assure a properly blended material in order to prevent disintegration of the filler and assure the maximum strengths. The wet resin-filler mix was dried, and the resin polymerized further to give a moldable composition.

Table I gives the molding conditions for the various materials. The variation in the pressures on the 5 by 7 by 3/16-in. slabs was necessitated by the variations in the plasticity of the several molding compositions. All specimens were compression molded.

TABLE I. MOLDING CONDITIONS

Material	Specimen	Mold Temperature, deg. Cent.	Pressure, lb. per sq. in.	Molding Time, min.
Wood-flour filled phenolic molding compound Specific gravity = 1.35 to 1.37 (molded)	A.S.T.M. 5 by ½ by ½-in. specimen (D 256 − 38)[a]	170	4000	10
	5 by 7 by 3/16-in. slab for A.S.T.M. tension specimen	170	3000	10
Pure phenolic resin compound Specific gravity = 0.96 to 0.98 (molded)	A.S.T.M. 5 by ½ by ½-in. specimen	170	4000	10
	A.S.T.M. Type 1. Tension specimen 0.150 in. thick (D 638 − 41T)[b]	170	6200	5—Cure 5—Cool[c]
Asbestos filled phenolic molding compound Specific gravity = 1.94 to 1.96 (molded)	A.S.T.M. 5 by ½ by ½-in. specimen	170	4000	10
	5 by 7 by 3/16-in. slab for A.S.T.M. tension specimen	170	7000	10
Cord filled phenolic molding compound Specific gravity = 1.35 to 1.37 (molded)	A.S.T.M. 5 by ½ by ½-in. specimen	170	4000	10
	5 by 7 by 3/16-in slab for A.S.T.M. tension specimen	170	7000	15
Fabric filled phenolic molding compound Specific gravity = 1.35 to 1.37 (molded)	A.S.T.M. 5 by ½ by ½-in. specimen	170	4000	10
	5 by 7 by 3/16-in. slab for A.S.T.M. tension specimen	170	7000	15

[a] Standard Methods of Test for Impact Resistance of Electric Insulating Materials (D 256 − 38), 1939 Book of A.S.T.M. Standards, Part III, p. 252.

[b] Tentative Methods of Tension Testing of Plastics (D 638 − 41 T), 1941 Supplement to Book A.S.T.M. Standards, Part III, p. 457.

[c] Because of the difficulty in molding this type of material the mold was chilled before removing the specimen.

The tension specimens for all the filled materials were machined from 5 by 7 by 3/16-in. slabs, following the requirements for type 1 test specimen in the A.S.T.M. Tentative Methods of Tension Testing of Plastics (D 638 − 41 T),* except for the 7-in over-all length. The pure resin was molded in a compression mold of the type specified for producing type 1 samples according to Methods D 638. This was necessary since the 5 by 7 by 3/16-in. slab could not be satisfactorily molded and machined of this material.

Impact and flexural test specimens, ½ by ½ by 5-in. bars, of the pure resin and asbestos and wood-flour filled material were molded in a 5-bar gang mold as specified in A.S.T.M. Tentative Specifications for Molds for Test Specimens of Molded Materials Used for Electrical Insulation (D 647 − 41 T).† The impact grade materials, cord sisal fiber, and macerated fabric filled, were molded in a single bar mold specified in Specifications D 647 as is customary for this type of material. Dimensions were held to 0.512 ± 0.006 in. on the variable dimensions for all specimens.

All specimens were conditioned after molding, according to A.S.T.M. Tentative Methods of Preconditioning Plastics and Electrical Insulating Materials for Testing (D 618 − 41 T)‡ for 48 hr. at 50° ± 3° C. (122° ± 5.4° F.), and placed in a desiccator after removal from the oven. Prior to testing, the specimens were conditioned at the desired temperature for from 4 to 5 hours. Tests were run immediately upon removal of the test specimen from the conditioning chamber.

Impact data were obtained on a Tinius-Olsen impact machine with a capacity of 100-in.-lb. (8 1/3 ft.-lb.), and on a Baldwin-Southwark impact tester (developed by

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* 1941 Supplement to Book of A.S.T.M. Standards, Part III, p. 457.

† *Ibid.*, p. 317.

‡ *Ibid.*, p. 320.

the Bell Telephone Laboratories) having a capacity of 4.0 ft.-lb. Tests were run according to A.S.T.M. Standard Methods of Test for Impact Resistance of Electrical Insulating Materials (D 256 – 38),§ using the notched Izod method in which the stress was applied perpendicular to the direction of the molding pressure.

Tensile and flexural data were obtained on a Tinius-Olsen Universal Tester, a screw-type machine with constant rate of crosshead motion, and 10,000-lb. range. The machine was equipped with an insulated housing which enclosed the tension grips or flexural supports and the specimen. Temperatures from 60° to 225° C. (140° to 437° F.) were obtained by circulating dry air over heaters enclosed in the cabinet. For temperatures from 25° to −80° C. (77° to −112° F.), dry air, precooled by contact with solid carbon dioxide, was circulated in the cabinet. Tension tests were run according to A.S.T.M. Methods D 638 using the type 1 specimen with a thickness of 0.1875 ± 0.008 in. Flexure tests were run according to A.S.T.M. Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 – 39).‖

TENSILE PROPERTIES

Data showing the change of tensile strength with temperature are given in Table II and are graphically presented in A.S.T.M. report, Vol. 42. The tensile strengths for the filled materials decrease with an increase in temperature over the entire temperature range. Within the limits of experimental error, the three materials containing organic fillers (wood flour, cord, and fabric) have identical strengths at the various temperatures. The asbestos filled material stands up somewhat better at the higher temperatures and between 160° to 200° C. (320° to 390° F.) is roughly 25 per cent higher in tensile strength than the other compositions. The pure resin curve is unique in that it shows a maximum value at 25° C. (77° F.) which is about 15 per cent above the strength of the wood-flour filled at the same temperature. Above 25° C. the strength of the pure resin falls off until at 80° C. (175° F.) it is the same as the organic filled compositions. At temperatures below 25° C. the strength drops and at −80° C. (−112° F.) is about 20 per cent of that of the other materials.

TABLE II. TENSILE STRENGTH (LB. PER SQ. IN.) *Versus* TEMPERATURE[a]

Material	−80° C.	−25° C.	25° C.	80° C.	120° C.	150° C.	230° C.
Cord filled phenolic	6210 ± 610 ($n = 5$)	6340 ± 330 ($n = 5$)	6020 ± 400 ($n = 5$)	4830 ± 510 ($n = 5$)	4300 ± 500 ($n = 5$)	4220 ± 400 ($n = 4$)	3280 ± 300 ($n = 5$)
Fabric filled phenolic	6430 ± 340 ($n = 8$)	6370 ± 230 ($n = 8$)	6120 ± 260 ($n = 7$)	5080 ± 180 ($n = 10$)	4430 ± 220 ($n = 9$)	3950 ± 400 ($n = 5$)	....
Wood-flour filled phenolic	6280 ± 230 ($n = 30$)	6490 ± 300 ($n = 28$)	6100 ± 270 ($n = 33$)	4770 ± 180 ($n = 34$)	4430 ± 170 ($n = 36$)	3750 ± 270 ($n = 38$)	....
Unfilled phenolic resin compound	5150 ± 600 ($n = 4$)	5790 ± 1040 ($n = 5$)	6200 ± 400 ($n = 4$)	5200 ± — ($n = 3$)	....	....	....
Asbestos filled phenolic	6670 ± 430 ($n = 4$)	5210 ± — ($n = 3$)	5570 ± 730 ($n = 4$)	5500 ± — ($n = 2$)	....	5150 ± — ($n = 1$)	5170 ± — ($n = 2$)

[a] The number of specimens, n, broken at each temperature is given below each strength figure. The average for the stated number of specimens falls within their given limits 9 times in 10.

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§ 1939 Book of A.S.T.M. Standards, Part III, p. 252.

‖ 1939 Book of A.S.T.M. Standards, Part III, p. 244.

FLEXURAL PROPERTIES

Table III, below, gives further data on the change of flexural strength with temperature. The curves for wood-flour, fabric, and cord filled molded compositions are parallel and show practically a linear decrease in flexural strength with increasing temperature. The asbestos filled also shows a decrease in strength with increasing temperature, but again withstands the higher temperatures better than the organic filled compositions. The data for flexural strength of the unfilled resin are surprising in two respects:

TABLE III. FLEXURAL STRENGTH (LB. PER SQ. IN.) *Versus* TEMPERATURE[a]

Material	−80° C.	−25° C.	25° C.	80° C.	120° C.	150° C.	180° C.
Cord filled phenolic....	15 700 ± 880 (*n* = 10)	15 900 ± 1800 (*n* = 7)	12 900 ± 460 (*n* = 10)	11 800 ± 670 (*n* = 8)	9 720 ± 930 (*n* = 8)	9 200 ± 700 (*n* = 7)	8560 ± 730 (*n* = 7)
Fabric filled phenolic.....	14 800 ± 730 (*n* = 10)	12 400 ± 540 (*n* = 8)	12 000 ± 570 (*n* = 10)	9 500 ± 450 (*n* = 10)	8 010 ± 400 (*n* = 10)	7 330 ± 700 (*n* = 10)	....
Wood-flour filled phenolic	13 100 ± 650 (*n* = 40)	11 700 ± 550 (*n* = 40)	9 770 ± 460 (*n* = 40)	7 880 ± 550 (*n* = 40)	6 200 ± 530 (*n* = 40)	5 380 ± 620 (*n* = 40)	....
Unfilled phenolic resin compound............	12 300 ± 890 (*n* = 10)	12 400 ± 950 (*n* = 10)	13 300 ± 960 (*n* = 10)	12 300 ± 880 (*n* = 9)	10 500 ± 980 (*n* = 8)	10 000 ± 820 (*n* = 8)	....
Asbestos filled phenolic...	13 700 ± 600 (*n* = 10)	11 900 ± 640 (*n* = 10)	10 200 ± 670 (*n* = 10)	9 320 ± 770 (*n* = 10)	8 580 ± 330 (*n* = 10)	7 260 ± 780 (*n* = 10)	....

[a] The number of specimens, *n*, broken at each temperature is given below each strength figure. The average for the stated number of specimens falls within their given limits 9 times in 10.

1. They are higher than expected, about 25 per cent above that of the wood flour filled.

2. They fall off slightly below 25° C. instead of continuing to increase as do the filled materials.

IMPACT PROPERTIES

The effect of temperature on the notched Izod impact strength is given in Table IV on page 922. For the high impact materials, cord, sisal fiber and macerated fabric filled, the strength increases with increasing temperature to a critical point and then falls off sharply. The critical point occurs at from 160° to 170° C. (320° to 340° F.) and is accompanied by charring of the organic filler. The wood-flour filled material exhibits relatively little change of impact strength with temperature up to a critical point at about 160° C. (320° F.), after which the strength falls off sharply. The strength of the pure resin and asbestos filled compositions remains practically constant over the temperature range investigated.

RELIABILITY OF DATA

The impact values recorded in the attached tables represent the average of from 10 to 20 individual observations. In the case of flexural and tensile strength values, from 5 to 11 observations were made for each value reported.

However, in running the tension tests on the asbestos filled and pure resin compositions, many of the specimens broke in the grips before the ultimate strength was reached. Consequently, only a few test results were available for many of the conditions

TABLE IV. IMPACT STRENGTH (FT.-LB. PER IN. OF NOTCH) *Versus* TEMPERATURE[a]

Material	−80° C.	−25° C.	25° C.	80° C.	120° C.
Cord filled phenolic	4.85 ± 0.35 (n = 18)	5.50 ± 0.43 (n = 18)	7.21 ± 0.42 (n = 20)	8.57 ± 0.64 (n = 18)	10.05 ± 0.56 (n = 18)
Fabric filled phenolic	1.61 ± 0.12 (n = 10)	2.01 ± 0.22 (n = 10)	2.37 ± 0.28 (n = 10)	2.95 ± 0.23 (n = 10)	3.11 ± 0.25 (n = 10)
Wood-flour filled phenolic	0.29 ± 0 006 (n = 80)	0.32 ± 0.010 (n = 80)	0.31 ± 0.016 (n = 80)	0.31 ± 0.006 (n = 80)	0.32 ± 0.006 (n = 80)
Unfilled phenolic resin compound	0.269 ± 0.005 (n = 12)	0.260 ± 0.02 (n = 12)	0 248 ± 0.01 (n = 12)	0.233 ± 0.01 (n = 20)	0.224 ± 0.01 (n = 17)
Asbestos filled phenolic	0.300 ± 0.006 (n = 18)	0 278 ± 0.006 (n = 18)	0.284 ± 0.01 (n = 16)	0.283 ± 0 008 (n = 16)	0 282 ± 0 01 (n = 16)

Material	150° C.	170° C.	200° C.	220° C.	250° C.
Cord filled phenolic	11.1 ± 0.46 (n =18)	9 94 ± 0 61 (n = 18)	10.6 ± 0.51 (n = 18	2 47 ± 2 1 (n = 18)	....
Fabric filled phenolic	3 08 ± 0 24 (n = 10)	2.68 ± 0.40 (n = 10)	0.99 ± 0.21 (n = 10)	....	....
Wood-flour filled phenolic	0.33 ± 0 006 (n = 80)	0.31 ± 0.02 (n = 80)	0.25 ± 0.02 (n = 80)	....	....
Unfilled phenolic resin compound	0.225 ± 0 01 (n = 19)	0.230 ± 0 01 (n = 18)	....	....	0.222 ± 0.01 (n = 18)
Asbestos filled phenolic	....	0.293 ± 0 01 (n = 16)	0 288 ± 0.02 (n = 8)	....	0 286 ± 0.01 (n = 16)

[a] The number of specimens, n, broken at each temperature is given below each strength figure.
The average for the stated number of specimens falls within their given limits 9 times in 10.

reported. These data are, therefore, only preliminary, and are presented here to show the trend of results obtained to date.

The limits within which the observed value may be expected to lie 9 times in 10, limits of uncertainty, were calculated according to the A.S.T.M. Manual on Presentation of Data* for the data presented. These limits are included in Tables II, III, and IV and are approximately 6 per cent for flexure, 4 per cent for impact, and 5 per cent for tension tests. The percentage variation in strengths from batch to batch of the same material is of the same order of magnitude.

The data presented for the wood-flour filled phenolic is the average of results on four typical molding compositions, differing only in the basic resin formulation. Results on the individual materials exhibited no appreciable differences in properties over the range investigated.

It should be noted that the notched Izod impact test may be misleading in certain cases where the impact strength of the materials under test is low, and where the specific gravities of different molded materials are substantially different. In low impact materials the energy required to throw the broken end of the test specimen becomes a significant portion of the energy expended, and is dependent on the specific gravity of the molded specimen. For example, the asbestos filled phenolic (specific gravity, 1.95) gives a standard impact value which compares favorably with wood-flour filled molded compositions (specific gravity, 1.36) and pure resin compositions (specific gravity, 0.96). However, the behavior of these materials in machining and general handling indicates that asbestos filled materials have less shock resistance than either of the other two.

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* **Issued as separate publication.**

PRACTICAL IMPORTANCE

Over the temperature range of normal use, −50° to 70° C. (−60° to 160° F.), the mechanical strengths of phenolic molding compositions deviate from the value at 25° C. (77° F.) by about ± 15 per cent. The tensile and flexural strengths show a decrease with increasing temperature. This is offset in the high impact materials by an increase in impact strength with increasing temperatures.

Tensile properties are practically independent of the filler used. The use of cord or macerated fabric, high impact fillers, improves the flexural strengths slightly over the temperature range. Impact strengths may be greatly increased over the entire temperature range by use of fibrous fillers such as macerated fabric, sisal fiber, cord, etc.[16, 17].

The outstanding value of thermosetting materials as compared to thermoplastics lies in the relatively slight effect of temperature on mechanical properties of the phenol aldehydes. This is well illustrated in Fig. 7 which shows the change in impact strength with temperature for various plastic materials[18, 19]. Comparing the wood-flour filled phenolic composition with injection-molded polystyrene it may be seen that the critical point is roughtly 100° C. (212° F.) higher for the phenolic. The maximum temperature of serviceability for thermoplastics ranges from 40° C. (105° F.) for polyvinyl butyral containing 9 per cent plasticizer to 90° C. (195° F.) for cellulose acetate containing 27 per cent plasticizer. The high impact phenolic materials are serviceable at temperatures as high as 160° to 170° C. (320° to 340° F.). At temperatures below 25° C. (77° F.) the impact strengths of cellulose acetate, cellulose nitrate, and polyvinyl butyral fall off sharply, giving values less than 50 per cent of that of the cord filled phenolic.

It must be emphasized that the data presented are strictly and necessarily of an empirical nature. For comparative results, a number of mechanical properties have been determined by A.S.T.M. methods on standard approved specimens. The results obtained give data for similar materials tested under identical conditions. It is often difficult to use the actual numerical values in evaluating a specific material for a particular application, but these values do serve as a basis for selecting the most suitable material. Since the form factor, mold design, molding conditions, treatment following molding, and numerous other factors affect the strength of the molded article, the final evaluation of the material should be based on actual service tests on the finished product.

Molded phenolic compositions, particularly those of the higher impact type, possess mechanical properties which make them practical as materials for use in structural applications.

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USEFUL TABLES

USEFUL TABLES

Tables have been used profusely throughout the handbook and accordingly only those which did not seem appropriate elsewhere are included here. Readers are again requested to refer to the general index for specific items not found here.

Details of tests for specific gravity and tensile strength may be found by referring to A.S.T.M. Standards and Specifications prepared by Committee D-9 and D-20 of the American Society for Testing Materials, Philadelphia, Pa.

TABLE I. MODULUS OF ELASTICITY* IN TENSION OF SOME MATERIALS

Lead (cast)	700,000	Brass	9,000,000
Phenolic (fabric laminated)	1,000,000	Copper (hard-drawn)	18,000,000
Pine (static bending)	1,200,000	Carbon steel	30,000,000
Phenolic (paper base)	2,100,000	Tungsten	60,000,000

* In pounds per square inch.

TABLE II. THERMAL CONDUCTIVITY OF MATERIALS*

Conductivity measured in British thermal units transmitted per hour per square foot of material 1 in. thick, per degree Fahrenheit difference in temperature of the two faces

Silver	2920.0	Pine wood	0.958
Steel, 1.0 carbon	328.0	Wood pulp board	0.39
Glass, plate	5.53	Cork, ground	0.31
Wool	0.261		

* From Paul M. Tyler, U. S. Bureau of Mines.

TABLE III. DENSITIES AND REFRACTIVE INDICES OF SYNTHETIC RESINS

	Specific Gravity	*Refractive Index**
Chlorinated diphenyl resin	1.713	1.703
Cresylic acid formaldehyde	1.20	1.645
Cumar	1.14	1.617
Ethylene glycol phthalate	1.352	1.570
Glycerol phthalate	1.389	1.575
Phenol formaldehyde	1.25	1.647
Phenol formaldehyde resin, modified	1.10	1.545
Phthalic anhydride resin	1.210	1.573
Toluene sulfonamide formaldehyde resin	1.35	1.596
Urea, thiourea formaldehyde resin	1.477	1.660
Vinyl resin, commercial grade	1.18	1.480
Vinyl acetate polymer	1.15	1.473

* + 0.003.
− 0.003.

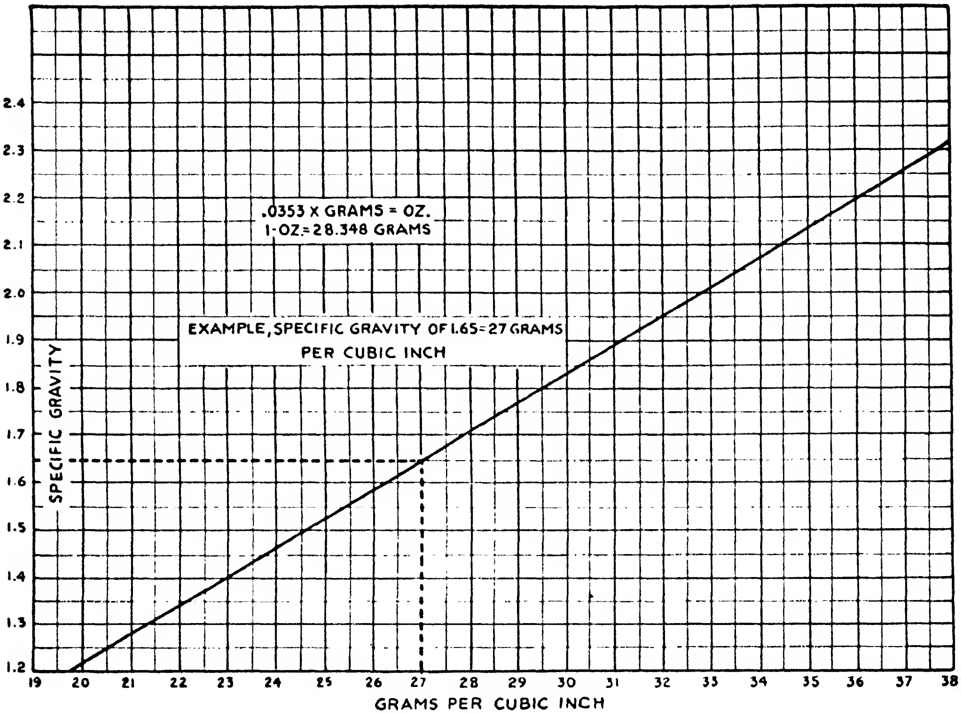


Fig. App. 1 — Conversion table: Specific gravity to grams per cubic inch.

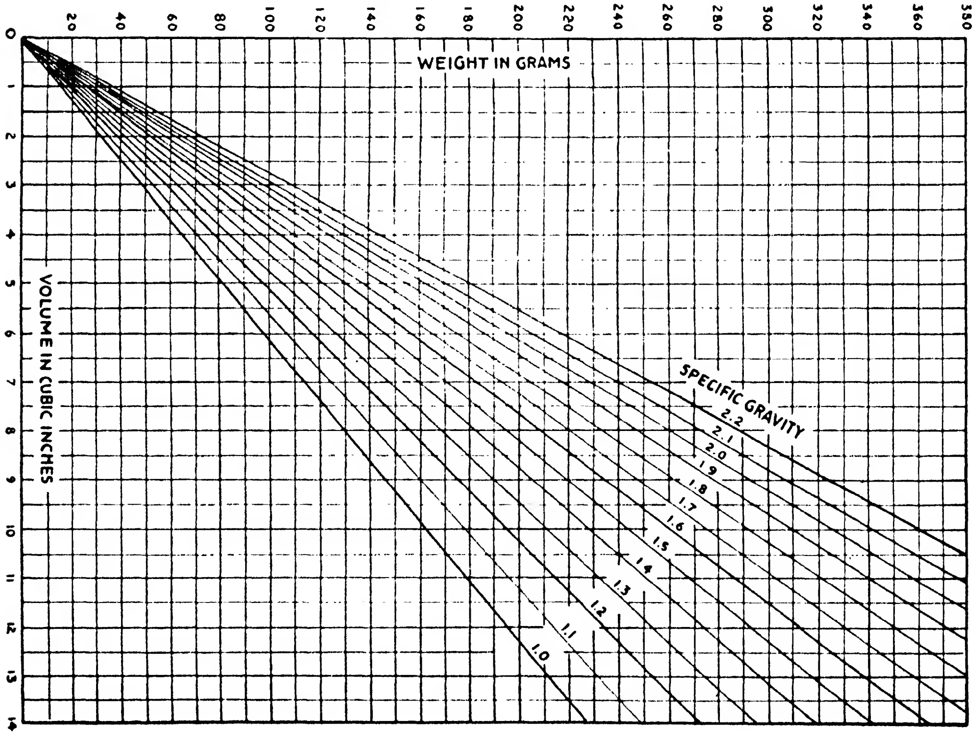


Fig. App. 2 — Chart for determining weight from volume.

TABLE IV. DENSITIES AND REFRACTIVE INDICES OF NATURAL RESINS AND THEIR GLYCEROL ESTERS

	Density	*Refractive Index**
Congo ester	1.076	1.506
Congo (fused to 30% loss in wt.)	1.050	1.545
Congo (hard amber)	1.059	1.545
Congo (No. 1 pale)	1.066	1.540
Dammar (No. 1 Singapore)	1.062	1.515
East India gum	1.087	1.537
Kauri (grade 303)	1.043	1.565
Manila ester	1.090	1.506
Manila (hard)	1.072	1.544
Mastic	1.070	1.536
Pontianac (fine, select)	1.068	1.545
Rosin ester	1.095	1.496
Rosin (Grade M Wood)	1.069	1.525
Sandarac	1.078	1.545
Shellac bleached (dry)	1.110	1.534
Shellac orange (superfine)	1.152	1.516

* + 0.003.
− 0.003.

TABLE V. CONSTANTS OF OILS USED IN PAINT, VARNISH, AND LACQUER INDUSTRY

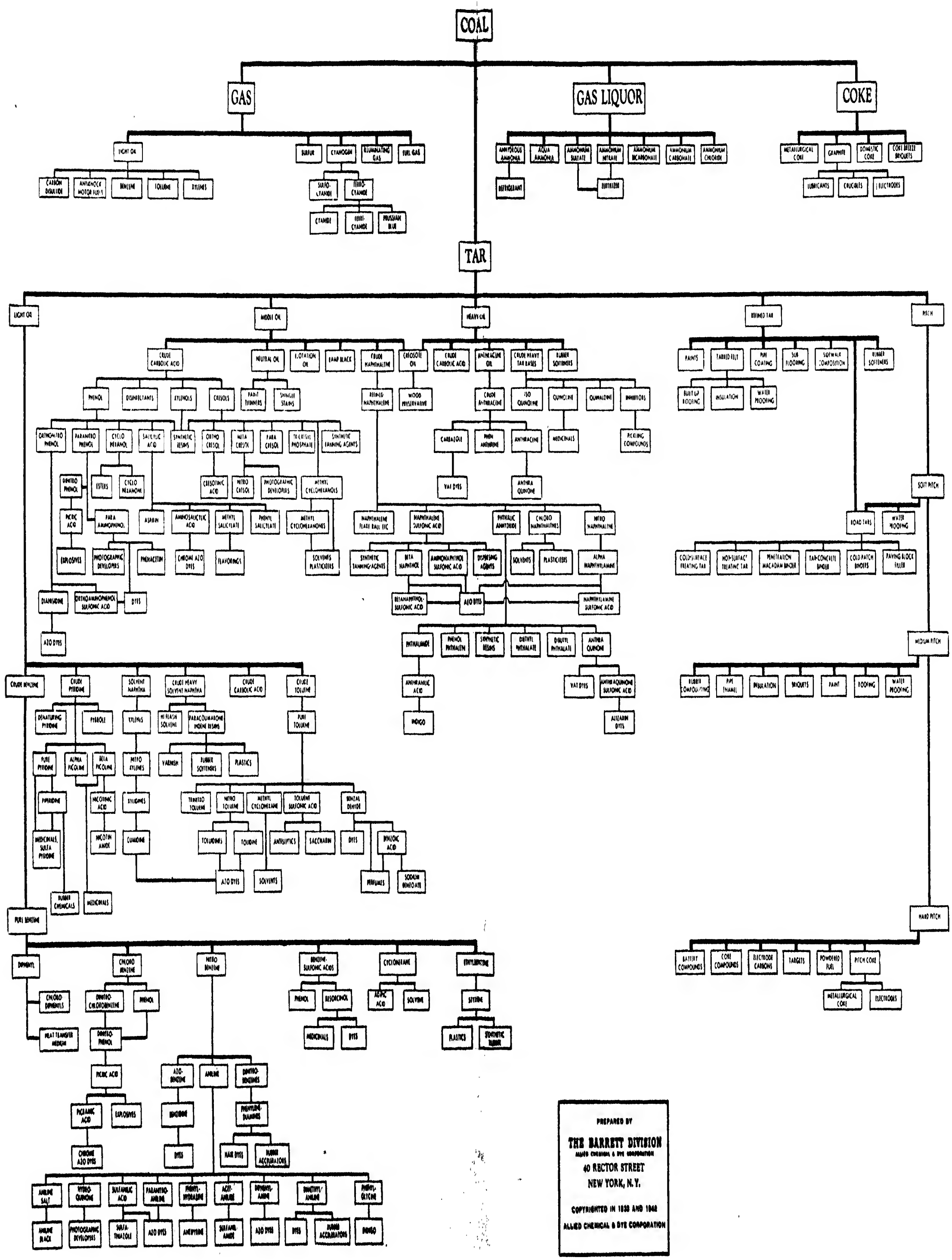
	Specific Gravity 15.5° C./15.5° C.	Pounds Per Gallon	Saponification Number	Refractive Index 25° C.
Castor Oil	0.963	8.02	180-184	1.4772
China wood Oil	0.943	7.85	190-194	1.5170
Corn Oil	0.921	7.67	189-192	1.4800
Cottonseed Oil	0.924	7.70	191-196	1.4720
Hempseed Oil	0.930	7.74	190-193	1.4780
Linseed Oil (Refined)	0.934	7.78	188-196	1.4779
*Linseed Oil (Boiled)	0.941	7.84	188-196	1.4895
*Linseed Oil (Kettle Bodied)	0.965	8.06	189-194	1.4966
Lumbang Oil (Soft)	0.938	7.81	190-194	1.4929
Menhaden Oil	0.930	7.74	187-196	1.4800
Oiticica Oil	0.966	8.04	184-190	1.5141
Peanut Oil	0.921	7.67	186-196	1.4790
Perilla Oil	0.936	7.79	188-194	1.4802
Poppyseed Oil	0.926	7.71	190-197	1.4740
Rapeseed Oil	0.915	7.62	170-180	1.4706
Safflower Oil	0.926	7.71	—	1.4730
Sardine Oil	0.927	7.72	190-193	1.4785
Soybean Oil	0.924	7.70	189-196	1.4813
Sunflower Oil	0.924	7.70	188-194	1.4796
Walnut Oil	0.926	7.71	191-196	1.4770

* Typical.

TABLE VI. PHYSICAL AND CHEMICAL PROPERTIES OF THE COMMON WAXES

	Sp. Gr.	Ref. Ind.	M.P.° C.	Setting Point	Sap. No.	Unsap. Matter %	Acid Val.	Fatty Acid %
Arctic sperm oil	0.878	1.456/25°	9	—	77–79	—	—	—
Bayberry (Myrtlewax) not a true wax	0.993–0.997	—	41	—	206–216	—	—	—
Beeswax	0.960–0.974	1.440/75°	62–66	60–63	90–101	55.5	20	47.8
Cane sugar wax	0.980	—	58	—	80–90	69.0	12	33.3
Candelilla wax	0.972	1.456/75°	66–70	63–68	50–65	74.0	10–20	29.0
Carnauba wax	0.992–0.998	1.472/43°	83–84	80–87	67–88	55	2.5	48.0
Chinese insect wax	0.932–0.970	—	81–83.5	80–81	82–93	49.5	3	51.5
Cottonseed wax	—	—	—	—	150–160	—	—	—
Flaxseed wax	0.908	—	62–70	—	100–150	—	54.5	—
Japan wax, not a true wax	0.976–0.993	1.4518	52–59	—	219–237	0.7–15	6–20	90
Montan wax	—	—	73–84	70–80	30–45	—	15–20	11–15
				74–127			73–83	56–64
							(Dist.)	(Dist.)
Ozokerite, Ceresin wax	0.913–0.923	1.4415–1.4464	59–76	76	1.3	100	0	0
Palm wax	—	—	—	—	—	—	—	—
Paraffin wax, not a true wax	0.870–0.910	1.4331–1.4450	26–56	—	0–1.3	100	0	0
			35–75					
Sperm whale oil: Head oil	0.879	1.459	12	—	66–76	40	1.5	—
Body oil	0.876	1.462/25°	—	—	88–93	—	—	—
Spermaceti	0.933–0.963	1.4198	41–59	—	122–134	51.5	0.5–1.0	53.5
Wool wax	0.945	1.480	37–41	—	101–104	—	12.2	—
							50%	

PRODUCTS DERIVED FROM COAL



PREPARED BY

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TABLE VII. SPECIFICATIONS FOR COKE OVEN LIGHT OIL DISTILLATES AND OTHER COAL TAR SOLVENTS

	Distillation				Color	Specific Gravity at 15.5° C.	Acid Wash not darker than	Barrett Copper Corrosion Test	Sulfur Compounds as H_2S or SO_2	Solidifying Point	Acidity	Flash Point approx. ° F.
	Max. Range ° C.	First Drop (or Fixed Point)	Per Cent at Fixed Temperature	Dry Point (or Fixed Point)								
				BENZOLS								
Thiophene Free Benzol	1	Not below 79.2° C.	All within 1° C. including 80.2° C.	Not above 81.2° C.	Water white	0.882 to 0.886	No. 2	Passes	(1) None	—	None	(*)10–15
Nitration Pure Benzol	1	Not below 79.2° C.	All within 1° C. including 80.2° C.	Not above 81.2° C.	Water white	0.8820 to 0.8860	No. 2	Passes	None	Not below 4.85° C.	None	(*)10–15
Industrial Pure Benzol	2	Not below 78.2° C.	All within 2° C. including 80.2° C.	Not above 82.2° C.	Water white	0.875 to 0.886	No. 3	Passes	None	—	None	(*)10–15
Industrial 90% Benzol	41.8	Not below 78.2° C.	At least 90% shall distil at 100° C.	Not above 120° C.	Water white	0.875 to 0.886	No. 6	Passes	None	—	None	(*)10–15
				TOLUOLS								
Nitration Pure Toluol	1	Not below 109.4° C.	All within 1° C. including 110.4° C.	Not above 111.4° C.	Water white	0.8690 to 0.8730	No. 2	Passes	None	—	None	(*)35–40
Industrial Pure Toluol	2	Not below 108.4° C	All within 2° C.	Not above 112.4° C	Water white	0.864 to 0.874	No. 4	Passes	None	—	None	(*)35–40
				XYLOLS								
Nitration Xylol	3	Not below 137.2° C.	All within 3° C.	Not above 140.5° C.	Water white	0.865 to 0.870	No. 6	Passes	None	—	None	(*)80
Five Degree Xylol	5	Not below 137° C.	All within 5°C. including 139.5° C.	Not above 143° C.	Water white	0.860 to 0.870	No. 6	Passes	None	—	None	(*)80
Ten Degree Xylol	10	Not below 135° C.	All within 10° C.	Not above 145° C.	Water white	0.860 to 0.870	No. 6	Passes	None	—	None	(*)80
Industrial Xylol	(*)25–30	Not above 135° C.	Not over 5% shall distil at 130° C. 90 to 95% shall distil at 145° C.	Not above 155° C.	Water white	0.850 to 0.870	No. 10	Passes	None	—	None	(*)80
Solvent Naphtha	(*)25–30	Not above 135° C.	Not over 5% shall distil at 130° C. 90 to 95% shall distil at 145° C.	Not above 155° C.	Water white	0.850 to 0.870	No. 10	Not specified	None	—	None	(*)80

TABLE VII. SPECIFICATIONS FOR COKE OVEN LIGHT OIL DISTILLATES AND OTHER COAL TAR SOLVENTS — (*Continued*)

	Distillation				Color	Specific Gravity at 15.5° C.	Acid Wash not darker than	Barrett Copper Corrosion Test	Sulfur Compounds as H_2S or SO_2	Solidifying Point	Acidity	Flash Point approx. ° F.
	Max. Range ° C.	First Drop (or Fixed Point)	Per Cent at Fixed Temperature	Dry Point (or Fixed Point)								
OTHER INDUSTRIAL COAL TAR SOLVENTS												
Cumene Fraction	(*)10–15	—	95% shall distil between 165.5–175.5° C. 50% point shall be between 169–171° C.	—	Water white	—	(2) No. 10	Not specified	Not specified	—	Not specified	(*)Not below 100
Hi-Flash Solvent 185 D. P.	35	Not below 150° C.	—	Not above 185° C.	Water white (6)	0.855 to 0.890	(2) No. 9	Not specified	None	—	Not specified	Not below 100
Hi-Flash Solvent 200 D. P.	50	Not below 150° C.	90% shall distil at approx. 180° C.	Not above 200° C.	Water white (6)	0.855 to 0.890	(2) No. 9	Not specified	None	—	Not specified	Not below 100
Refined S. H. Solvent	(*)40–50	Shall distil 5% at not below 140° C.	60–70% shall distil between 150–170° C. 90% shall distil at not above 170° C.	Not above 180° C.	Water white (6)	0.862 to 0.872	(2) No. 9	Not specified	None	—	Not specified	(*) Not below 90
Crude Light Solvent	(*)70–75	(*)Not above 135° C.	Not over 5% shall distil at 130° C. 90–95% shall distil at 160° C.	Not above 180° C.	Light amber	0.860 to 0.885	Not specified	Not specified	Not specified	—	(*)None	(*)80–90
Heavy Solvent	(*) 110–140	Shall distil 10% at not below 160° C.	70% point shall be between 195–203° C.	Shall distil 95% at not above 270° C.(4)	Amber to dark red	0.915 to 0.945	Not specified	Not specified	Not specified	(3) Not above 10° C.	Not specified	Not below 100
Wire Enamel Solvent	(*) 110–140	Shall distil 10% at not below 160° C.	70% point shall be between 195–203° C.	Shall distil 95% at not above 270° C.	Straw to dark amber	0.915 to 0.950	Not specified	Not specified	Not specified	(5) Below −20° C.	Not specified	Not below 100
Special Heavy Solvent	(*) 65–85	Shall distil 10% at not below 160° C.	—	Shall distil 90% at not above 200° C.	Straw to amber	0.880 to 0.970	Not specified	Not specified	Not specified	—	Not specified	Not below 100

NOTES

(1) No trace of thiophene or carbon disulfide.
(2) Using 60° Bé acid and standing 5 minutes.
(3) Limpid point, in.
(4) Residue shall be a liquid.
(5) No crystals at −20° C.
(6) Substantially water white.
(*) Descriptive but not part of specifications.

All tests shall be performed in accordance with Barrett Testing Methods as given in Specifications for Coke Oven Light Oil Distillates.

TABLE VIII. PROPERTIES OF CERTAIN FLAMMABLE MATERIALS

Material	Flash Point ° F.	Ignition Temp. ° F.	Explosive Limits per cent in air		Vapor Density
			Lower	Upper	
Acetaldehyde	Less than −17	365-716	4	57	1.52
Acetic acid (glacial)	107-111	800-925	4	—	2.07
Acetic anhydride	110-141	600-675	—	—	3.52
Acetone	Less than 4, 36	932-1292	2-3	9-13	2.00
Acetylene	gas	763-959	2.5-3.2	52.2-82	0.90
Ammonia (anhydrous)	gas	1204	16-16.1	25-27	0.59
Amyl acetate	70-92	710-815	1.1	—	4.49
Aniline	79-183	987-1418	—	—	3.22
Benzine	More than 0-5	475	1.1-2.6	4.8-5.9	4.48
Benzyl acetate	216	—	—	—	5.17
Benzyl alcohol	212	817	—	—	3.72
Butylene	gas	—	1.7	9.0	1.94
Butyraldehyde	More than 20-64	—	—	—	2.48
Butyric acid	170	—	—	—	3.04
Camphor	125-180	—	0.61	3.5	5.24
Chloroethyl acetate	129-153	—	—	—	4.22
Coal-tar oil	More than 80	—	—	—	—
Cresylic acid	110	—	—	—	—
Dibutyl phthalate	316-360	—	—	—	9.58
Dichlorethylene	57-63	856	5.6-10	11.4-13	3.35
Ethyl acetate	23-41	800-925	2.3-2.5	11.4-11.5	3.04
Ethyl alcohol	48-90	700-1036	2.8-4.0	9.5-19.0	1.59
Ethyl chloride	Less than 37, 0	966	3.6-4.3	11.2-15	2.22
Ethylene	gas	1008-1110	3.0-4.2	14.1-38	0.97
Ethylene glycol	232-241	775-781	3.2	—	2.14
Formaldehyde	90	—	—	—	1.03
Furfural	132-151	600-675	2	—	3.31
Methane	gas	999-1452	4.9-6.2	12.7-16	0.55
Methyl chloride	gas	1170	8-8.3	17.2-19.7	1.74
Naphtha	Less than 45, 110	490-531	1.2	6.0	—
Nitrocellulose (wet with solvent)	40	—	—	—	—
Nitrochlorobenzene	261	—	—		5.43
Phenol	172-174	1319	—	—	3.24
Phthalic anhydride	330	—	—	—	6.21
Propane	gas	871-1090	2.0-2.4	7.0-9.5	1.52
Soybean Oil	566	—	—	—	—
Toluol	35-86	986-1490	1.0-3.0	6.0-7.0	3.14
Triethanolamine	355	—	—	—	5.14
Varnish shellac	40-70	—	—	—	—
Vinyl chloride	—	—	4	22	2.15
Xylene	76-122	900-1150	1.0-1.2	5.3-6.0	3.66

TABLE IX. CAPACITIES OF HYDRAULIC RAMS IN TONS

Dia.	Pressure in Pounds per Square Inch																					Gal. per Inch	Gal. per Ft.	Area	Dia
	300	500	600	750	1000	1200	1500	1800	2000	2250	2500	2750	3000	3500	4000	4500	5000	5500	6000	6500	7000				
1	0.12	0.20	0.24	0.29	0.39	0.47	0.59	0.71	0.79	0.88	0.98	1.08	1.18	1.37	1.57	1.77	1.96	2.16	2.36	2.55	2.76	0.003	0.041	0.79	1
1½	0.27	0.44	0.53	0.66	0.88	1.06	1.33	1.59	1.77	1.99	2.21	2.43	2.65	3.09	3.53	3.98	4.42	4.86	5.30	5.74	6.19	0.008	0.092	1.77	1½
2	0.47	0.79	0.94	1.18	1.57	1.88	2.36	2.83	3.14	3.53	3.93	4.32	4.71	5.50	6.28	7.07	7.85	8.64	9.42	10.2	11.0	0.014	0.163	3.14	2
2½	0.74	1.23	1.47	1.84	2.45	2.95	3.68	4.42	4.91	5.52	6.14	6.75	7.36	8.59	9.82	11.0	12.3	13.5	14.7	16.0	17.2	0.023	0.255	4.91	2½
3	1.06	1.77	2.12	2.65	3.53	4.24	5.30	6.36	7.07	7.95	8.84	9.72	10.6	12.4	14.1	15.9	17.7	19.4	21.2	23.0	24.7	0.031	0.367	7.07	3
3½	1.44	2.41	2.89	3.61	4.81	5.77	7.22	8.66	9.62	10.8	12.0	13.2	14.4	16.8	19.2	21.6	24.1	26.5	28.9	31.3	33.7	0.042	0.500	9.62	3½
4	1.88	3.14	3.77	4.71	6.28	7.54	9.42	11.3	12.6	14.1	15.7	17.3	18.8	22.0	25.1	28.3	31.4	34.6	37.7	40.8	44.0	0.054	0.653	12.6	4
4½	2.39	3.98	4.77	5.96	7.95	9.54	11.9	14.3	15.9	17.9	19.9	21.9	23.9	27.8	31.8	35.8	39.8	43.7	47.7	51.7	55.7	0.069	0.826	15.9	4½
5	2.95	4.91	5.89	7.36	9.82	11.8	14.7	17.7	19.6	22.1	24.5	27.0	29.5	34.3	39.3	44.2	49.1	54.0	58.9	63.8	68.7	0.085	1.02	19.6	5
5½	3.56	5.94	7.13	8.91	11.9	14.3	17.8	21.4	23.8	26.7	29.7	32.7	35.6	41.6	47.5	53.5	59.4	65.3	71.3	77.2	83.2	0.103	1.33	23.8	5½
6	4.24	7.07	8.48	10.6	14.1	17.0	21.2	25.4	28.3	31.8	35.3	38.9	42.4	49.5	56.5	63.6	70.7	77.8	84.8	91.9	99.0	0.122	1.47	28.3	6
6½	4.98	8.30	9.96	12.4	16.6	19.9	24.9	29.9	33.2	37.3	41.5	45.6	49.8	58.1	66.4	74.7	83.0	91.3	99.6	108	116	0.144	1.72	33.2	6½
7	5.77	9.62	11.5	14.4	19.2	23.1	28.9	34.6	38.5	43.3	48.1	52.9	57.7	67.3	77.0	86.6	96.2	106	115	125	135	0.167	2.00	38.5	7
7½	6.63	11.0	13.3	16.6	22.1	26.5	33.1	39.8	44.2	49.7	55.2	60.7	66.3	77.3	88.4	99.4	110	121	133	144	155	0.191	2.30	44.2	7½
8	7.54	12.6	15.1	18.8	25.1	30.2	37.7	45.3	50.3	56.5	62.8	69.1	75.4	88.0	101	113	126	138	151	163	176	0.218	2.61	50.3	8
8½	8.51	14.2	17.0	21.3	28.4	34.0	42.6	51.1	56.7	63.8	70.9	78.0	85.1	99.3	113	128	142	156	170	184	199	0.246	2.95	56.7	8½
9	9.54	15.9	19.1	23.9	31.8	38.2	47.7	57.3	63.6	71.6	79.5	87.5	95.4	111	127	143	159	175	191	207	223	0.275	3.30	63.6	9
9½	10.6	17.7	21.3	26.6	35.4	42.5	53.2	63.8	70.9	79.7	88.6	97.5	106	124	142	159	177	195	213	230	248	0.307	3.68	70.9	9½
10	11.8	19.6	23.6	29.5	39.3	47.1	58.9	70.7	78.5	88.4	98.2	108	118	137	157	177	196	216	236	255	276	0.340	4.08	78.5	10
11	14.3	23.8	28.5	35.6	47.5	57.0	71.3	85.5	95.0	107	119	131	143	166	190	214	238	261	285	308	333	0.411	4.94	95.0	11
12	17.0	28.3	33.9	42.4	56.5	67.9	84.8	102	113	127	141	156	170	198	226	254	283	311	339	368	396	0.490	5.88	113	12
13	19.9	33.2	39.8	49.8	66.4	79.6	99.5	119	133	149	166	183	199	232	265	299	332	365	398	431	465	0.575	6.90	133	13
14	23.1	38.5	46.2	57.7	77.0	92.4	115	139	154	173	192	212	231	269	308	346	385	423	462	500	539	0.666	8.00	154	14
15	26.5	44.2	53.0	66.3	88.4	106	133	159	177	199	221	243	265	309	353	398	442	486	530	574	619	0.765	9.18	177	15
16	30.2	50.3	60.3	75.4	101	121	151	181	201	226	251	276	302	352	402	452	503	553	603	653	704	0.870	10.4	201	16
17	34.0	56.7	68.1	85.1	113	136	170	204	227	255	284	312	340	397	454	511	567	624	681	738	794	0.983	11.8	227	17
18	38.2	63.6	76.3	95.4	127	153	191	229	254	286	318	350	382	445	509	573	636	700	763	827	891	1.10	13.2	254	18
19	42.5	70.9	85.1	106	142	170	213	252	284	319	354	390	425	497	567	638	709	780	851	921	992	1.23	14.7	284	19
20	47.1	78.5	94.2	118	157	188	236	283	314	353	393	432	471	550	628	707	785	864	942	1021	1100	1.36	16.3	314	20
21	52.0	86.6	104	130	173	208	260	312	346	390	433	476	520	606	693	779	866	952	1039	1126	1212	1.50	18.0	346	21
22	57.0	95.0	114	142	190	228	285	342	380	428	475	523	570	665	760	855	950	1045	1140	1235	1330	1.65	19.7	380	22
23	62.3	104	125	156	208	249	312	373	415	467	519	571	623	727	831	935	1039	1143	1246	1350	1454	1.80	21.6	415	23
24	67.9	113	136	170	226	271	339	407	452	509	565	622	679	792	905	1018	1131	1244	1357	1470	1583	1.96	23.5	452	24
25	73.6	123	147	184	245	295	368	442	491	552	614	675	736	859	982	1104	1227	1350	1473	1595	1718	2.13	25.5	491	25

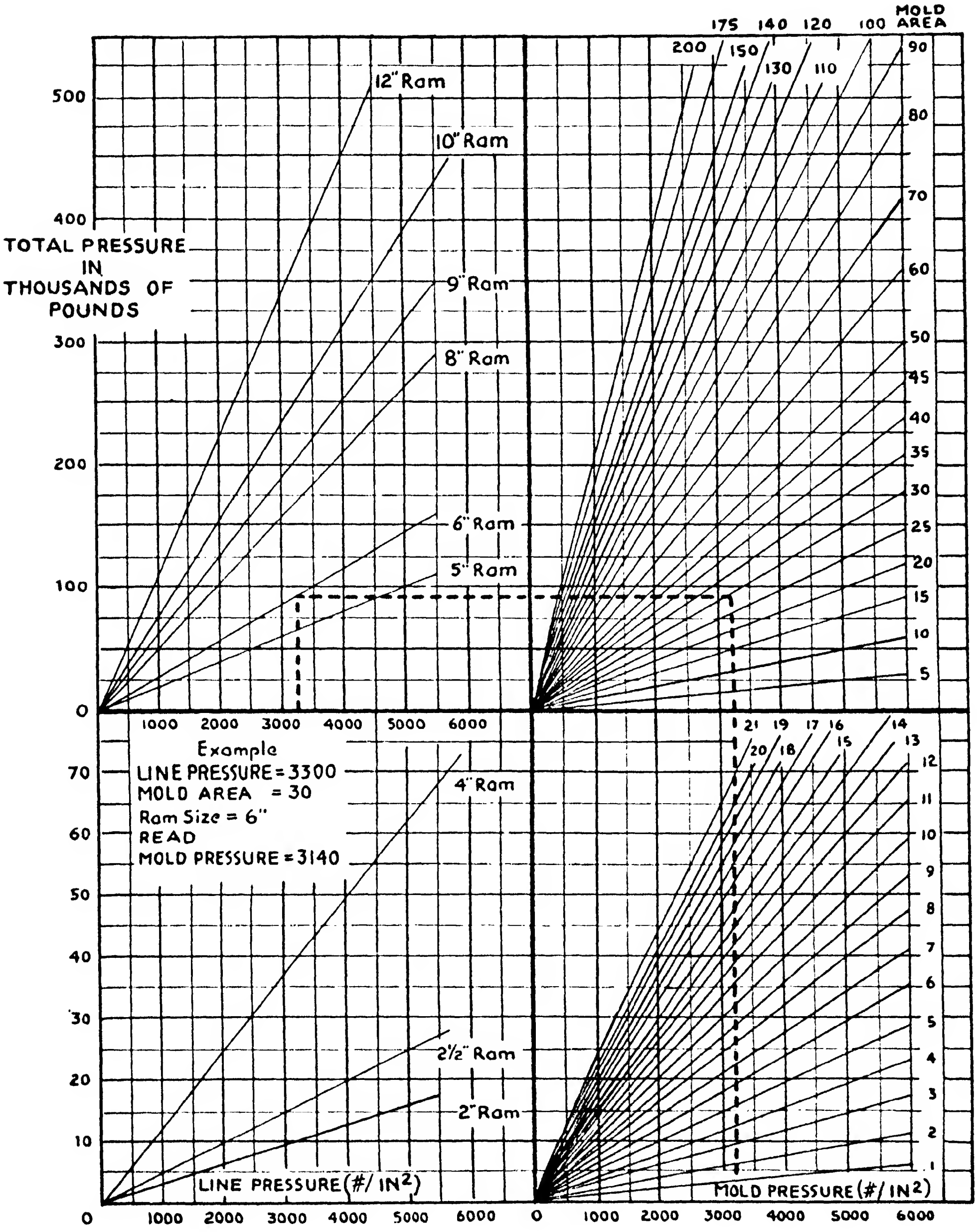

FIG. App. 4 — Hydraulic pressure relations.

TABLE IX. CAPACITIES OF HYDRAULIC RAMS IN TONS— *(Continued)*

Dia.	Pressure in Pounds per Square Inch																					Gal. per Inch	Gal. per Ft.	Area	Dia.
	300	500	600	750	1000	1200	1500	1800	2000	2250	2500	2750	3000	3500	4000	4500	5000	5500	6000	6500	7000				
26	79.6	133	159	199	265	319	398	478	531	597	664	730	796	929	1062	1195	1327	1460	1593	1726	1858	2 30	27 6	531	26
27	85.9	143	172	215	286	344	429	515	573	644	716	787	859	1002	1145	1288	1431	1575	1718	1861	2004	2.48	29.7	573	27
28	92.4	154	185	231	308	369	462	554	616	693	770	847	924	1078	1232	1385	1539	1693	1847	2001	2155	2.67	32.0	616	28
29	99.1	165	198	248	330	396	495	594	661	743	826	908	991	1156	1321	1486	1651	1816	1982	2147	2312	2.86	34 3	661	29
30	106	177	212	265	353	424	530	636	707	795	884	972	1060	1237	1414	1590	1767	1944	2121	2297	2474	3 06	36.7	707	30
31	113	189	226	283	377	453	566	678	755	849	943	1038	1132	1321	1510	1698	1887	2076	2264	2453	2642	3.27	39.2	755	31
32	121	201	241	302	402	483	603	724	804	905	1005	1106	1206	1408	1608	1810	2011	2212	2413	2614	2816	3.48	41.8	804	32
33	128	214	257	321	428	513	641	770	855	962	1069	1176	1283	1497	1711	1924	2138	2352	2566	2780	2994	3 70	44 4	855	33
34	136	227	272	340	454	545	681	817	908	1021	1135	1248	1362	1589	1816	2043	2270	2497	2724	2951	3178	3.94	47.2	908	34
35	144	241	289	361	481	577	722	866	962	1082	1203	1323	1443	1684	1924	2165	2405	2646	2886	3127	3367	4.17	50.0	962	35
36	153	254	305	382	509	611	763	916	1018	1145	1272	1400	1527	1781	2036	2290	2545	2799	3054	3308	3563	4.41	52.9	1018	36
37	161	269	323	403	538	645	806	968	1075	1210	1344	1478	1613	1882	2150	2419	2688	2957	3226	3494	3763	4.65	55.9	1075	37
38	170	284	340	425	567	680	851	1021	1134	1276	1418	1559	1701	1985	2268	2552	2835	3119	3402	3686	3969	4.91	58.9	1134	38
39	179	299	358	448	597	717	894	1075	1195	1344	1493	1643	1792	2091	2389	2688	2986	3285	3584	3882	4181	5.17	62.1	1195	39
40	188	314	377	471	628	754	942	1131	1257	1414	1572	1728	1885	2199	2513	2827	3142	3456	3770	4084	4398	5.44	65.3	1257	40
41	198	330	396	495	660	792	990	1188	1320	1485	1650	1815	1980	2310	2641	2971	3301	3631	3961	4291	4621	5.72	68.6	1320	41
42	208	346	416	520	693	831	1039	1247	1385	1559	1732	1905	2078	2425	2771	3117	3464	3810	4156	4503	4849	6.00	72.0	1385	42
43	218	363	436	542	726	871	1089	1307	1452	1634	1815	1997	2178	2541	2904	3267	3631	3994	4357	4720	5083	6.29	75 4	1452	43
44	228	380	456	570	760	912	1140	1368	1521	1711	1901	2091	2281	2661	3041	3421	3801	4181	4562	4942	5322	6.58	79 0	1521	44
45	239	398	477	596	795	954	1193	1431	1590	1789	1988	2187	2386	2783	3181	3578	3976	4374	4771	5169	5567	6.89	82.6	1590	45
46	249	415	499	623	831	997	1246	1496	1662	1870	2077	2285	2493	2908	3324	3739	4155	4570	4986	5401	5817	7.19	86 3	1662	46
47	260	434	520	651	867	1041	1301	1561	1735	1952	2169	2386	2602	3036	3470	3904	4337	4771	5205	5639	6072	7.51	90 1	1735	47
48	271	452	543	679	905	1086	1357	1629	1810	2036	2262	2488	2714	3167	3619	4072	4524	4976	5429	5881	6333	7.83	94.0	1810	48
49	283	471	566	707	943	1131	1414	1697	1886	2121	2357	2593	2829	3300	3771	4243	4714	5186	5657	6129	6600	8.16	98.0	1886	49
50	295	491	589	736	982	1178	1473	1767	1963	2209	2454	2700	2945	3436	3927	4418	4909	5400	5890	6381	6872	8.50	102	1963	50
52	319	531	637	796	1060	1270	1590	1910	2120	2390	2650	2920	3190	3720	4250	4780	5310	5840	6370	6900	7430	9.19	110	2124	52
54	344	573	687	859	1150	1370	1720	2060	2290	2580	2860	3150	3440	4010	4580	5150	5730	6300	6870	7440	8020	9.91	119	2290	54
56	369	616	739	924	1230	1480	1850	2220	2460	2770	3080	3390	3690	4310	4930	5540	6160	6770	7390	8000	8620	10.7	128	2463	56
58	396	660	793	991	1320	1590	1980	2380	2640	2970	3300	3630	3960	4620	5280	5940	6600	7270	7930	8590	9250	11.4	137	2642	58
60	424	707	848	1060	1410	1700	2120	2540	2830	3180	3530	3890	4240	4950	5650	6360	7070	7780	8480	9190	9900	12.2	147	2827	60
	.175	.292	.350	.438	.583	.700	.875	1.05	1.17	1.31	1.46	1.60	1.75	2.04	2.33	2.62	2.92	3.21	3.50	3.79	4.08	H. P. per gal. per min.			

TABLE X. STEAM TABLE

Based on gauge pressure lb. per sq. in. = absolute pressure (when 0 is complete vacuum) minus atmospheric pressure (taken as 14.69 lb. per sq. in. average).

Gauge pressure lb./sq.in.	Temperature		Gauge pressure lb./sq. in.	Temperature		Gauge pressure lb./sq. in.	Temperature		Gauge pressure lb./sq. in.	Temperature	
	°F.	°C.		°F.	°C.		°F.	°C.		°F.	°C.
0	212.0	100.0	51	298.6	148.1	102	339.0	170.6	152	366.8	186.0
1	215.3	101.8	52	299.6	148.7	103	339.7	170.9	153	367.3	186.3
2	218.2	103.5	53	300.6	149.2	104	340.3	171.3	154	367.8	186.5
3	221.5	105.3	54	301.6	149.8	105	340.9	171.6	155	368.3	186.8
4	224.3	106.9	55	302.5	150.3	106	341.5	172.0	156	368.7	187.1
5	227.1	108.4	56	303.5	150.8	107	342.1	172.3	157	369.2	187.3
6	229.8	109.9	57	304.4	151.3	108	342.8	172.7	158	369.6	187.6
7	232.3	111.3	58	305.4	151.9	109	343.4	173.0	159	370.1	187.8
8	234.8	112.6	59	306.3	152.4	110	344.0	173.3	160	370.6	188.1
9	237.1	113.9	60	307.2	152.9	111	344.6	173.7	161	371.0	188.3
10	239.4	115.2	61	308.1	153.4	112	345.2	174.0	162	371.5	188.6
11	241.5	116.4	62	309.0	153.9	113	345.8	174.3	163	371.9	188.9
12	243.7	117.6	63	309.9	154.4	114	346.4	174.7	164	372.4	189.1
13	245.8	118.8	64	310.8	154.9	115	347.0	175.0	165	372.9	189.4
14	247.8	119.9	65	311.6	155.4	116	347.6	175.3	166	373.3	189.6
15	249.7	121.0	66	312.5	155.8	117	348.2	175.7	167	373.8	189.9
16	251.6	122.0	67	313.3	156.3	118	348.8	176.0	168	374.2	190.1
17	253.4	123.0	68	314.2	156.8	119	349.3	176.3	169	374.7	190.4
18	255.2	124.0	69	315.0	157.2	120	349.9	176.6	170	375.2	190.6
19	257.0	125.0	70	315.9	157.7	121	350.5	176.9	171	375.6	190.9
20	258.7	126.0	71	316.7	158.2	122	351.1	177.3	172	376.0	191.2
21	260.4	126.9	72	317.6	158.6	123	351.7	177.6	173	376.5	191.4
22	262.0	127.8	73	318.4	159.1	124	352.2	177.9	174	376.9	191.6
23	263.6	128.7	74	319.2	159.5	125	352.8	178.2	175	377.4	191.9
24	265.2	129.6	75	320.0	160.0	126	353.4	178.5	176	377.8	192.1
25	266.7	130.4	76	320.7	160.4	127	353.9	178.8	177	378.2	192.4
26	268.2	131.2	77	321.5	160.8	128	354.5	179.1	178	378.7	192.6
27	269.7	132.1	78	322.2	161.2	129	355.0	179.4	179	379.1	192.9
28	271.2	132.9	79	323.0	161.7	130	355.5	179.7	180	379.6	193.1
29	272.6	133.7	80	323.8	162.1	131	356.1	180.0	181	380.0	193.3
30	273.9	134.4	81	324.6	162.5	132	356.6	180.3	182	380.4	193.6
31	275.3	135.2	82	325.3	163.0	133	357.2	180.6	183	380.8	193.8
32	276.6	135.9	83	326.1	163.4	134	357.7	180.9	184	381.2	194.0
33	278.0	136.7	84	326.8	163.8	135	358.2	181.2	185	381.7	194.3
34	279.3	137.4	85	327.5	164.2	136	358.8	181.5	186	382.1	194.5
35	280.5	138.1	86	328.2	164.6	137	359.3	181.8	187	382.5	194.7
36	281.8	138.8	87	328.9	164.9	138	359.8	182.1	188	382.9	195.0
37	283.0	139.5	88	329.6	165.3	139	360.3	182.4	189	383.3	195.2
38	284.2	140.1	89	330.3	165.7	140	360.8	182.7	190	383.8	195.4
39	285.4	140.8	90	331.0	166.1	141	361.3	183.0	191	384.2	195.7
40	286.6	141.5	91	331.7	166.5	142	361.8	183.3	192	384.6	195.9
41	287.8	142.1	92	332.4	166.9	143	362.3	183.5	193	385.0	196.1
42	289.0	142.8	93	333.1	167.3	144	362.8	183.8	194	385.2	196.3
43	290.1	143.4	94	333.8	167.7	145	363.3	184.1	195	385.9	196.6
44	291.2	144.0	95	334.5	168.1	146	363.8	184.4	196	386.3	196.8
45	292.3	144.6	96	335.2	168.4	147	364.3	184.5	197	386.7	197.0
46	293.4	145.2	97	335.8	168.8	148	364.8	184.9	198	387.1	197.3
47	294.5	145.8	98	336.5	169.2	149	365.3	185.2	199	387.5	197.5
48	295.5	146.4	99	337.1	169.5	150	365.8	185.5	200	387.9	197.7
49	296.5	146.9	100	337.8	169.9	151	366.3	185.7			
50	297.5	147.5	101	338.4	170.2						

TABLE XI. TAP AND DRILL SIZES

Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill No.
2 x 48	50	7 x 32	30	13 x 20	15	18 x 20	A
2 x 56	49	8 x 24	30	13 x 22	15	19 x 16	B
2 x 64	48	8 x 30	30	13 x 24	13	19 x 18	C
3 x 40	47	8 x 32	29	14 x 20	13	19 x 20	D
3 x 48	45	9 x 24	29	14 x 22	11	20 x 16	D
3 x 56	44	9 x 28	28	14 x 24	9	20 x 18	F
4 x 32	43	9 x 30	27	15 x 18	10	20 x 20	H
4 x 36	42	9 x 32	25	15 x 20	8	22 x 16	J
4 x 40	41	10 x 24	25	15 x 22	6	22 x 18	L
5 x 30	40	10 x 30	22	15 x 24	5	24 x 14	M
5 x 32	40	10 x 32	21	16 x 16	7	24 x 16	N
5 x 36	38	11 x 24	21	16 x 18	6	24 x 18	O
5 x 40	37	11 x 28	17	16 x 20	5	26 x 14	O
6 x 30	35	11 x 30	17	17 x 16	6	26 x 16	P
6 x 32	35	12 x 20	19	17 x 18	2	28 x 14	R
6 x 36	33	12 x 22	17	17 x 20	2	28 x 16	S
6 x 40	32	12 x 24	17	18 x 16	2	30 x 14	U
7 x 28	32	12 x 28	15	18 x 18	1	30 x 16	V
7 x 30	31						

DRILLS — LETTER SIZES

Diameter, Inches	Decimals of 1 Inch	Diameter, Inches	Decimals of 1 Inch	Diameter, Inches	Decimals of 1 Inch
A 15/64	0.234	J	0.277	S	0.348
B	0.238	K 9/32	0.281	T 23/64	0.358
C	0.242	L	0.290	U	0.368
D	0.246	M 19/64	0.295	V 3/8	0.377
E 1/4	0.250	N	0.302	W 25/64	0.386
F	0.257	O 5/16	0.316	X	0.397
G	0.261	P 21/64	0.323	Y 13/32	0.404
H 17/64	0.266	Q	0.332	Z	0.413
I	0.272	R 11/32	0.339		

DRILLS — NUMBER SIZES

No.	Decimals of 1 Inch	No.	Decimals of 1 Inch	No.	Decimals of 1 Inch	No.	Decimals of 1 Inch
1	0.2280	21	0.1590	41	0.0960	61	0.0390
2	0.2210	22	0.1570	42	0.0935	62	0.0380
3	0.2130	23	0.1540	43	0.0890	63	0.0370
4	0.2090	24	0.1520	44	0.0860	64	0.0360
5	0.2055	25	0.1495	45	0.0820	65	0.0350
6	0.2040	26	0.1470	46	0.0810	66	0.0330
7	0.2010	27	0.1440	47	0.0785	67	0.0320
8	0.1990	28	0.1405	48	0.0760	68	0.0310
9	0.1960	29	0.1360	49	0.0730	69	0.0292
10	0.1935	30	0.1285	50	0.0700	70	0.0280
11	0.1910	31	0.1200	51	0.0670	71	0.0260
12	0.1890	32	0.1160	52	0.0635	72	0.0250
13	0.1850	33	0.1130	53	0.0595	73	0.0240
14	0.1820	34	0.1110	54	0.0550	74	0.0225
15	0.1800	35	0.1100	55	0.0520	75	0.0210
16	0.1770	36	0.1065	56	0.0465	76	0.0200
17	0.1730	37	0.1040	57	0.0430	77	0.0180
18	0.1695	38	0.1015	58	0.0420	78	0.0160
19	0.1660	39	0.0995	59	0.0410	79	0.0145
20	0.1610	40	0.0980	60	0.0400	80	0.0135

TABLE XII. BUTTON MEASUREMENTS

British			French		
No. of Lines	Inches	Millimeters	No. of Lines	Inches	Millimeters
5	1/8	3.175	3	17/64	6.75
10	1/4	6.350	6	17/32	13.50
15	3/8	9.525	9	51/64	20.25
20	1/2	12.700	12	1 1/16	27.00
25	5/8	15.875	15	1 21/64	33.75
30	3/4	19.050	18	1 19/32	40.50
35	7/8	22.225	21	1 55/64	47.25
40	1	25.400	24	2 1/8	54.00
45	1 1/8	28.575	27	2 25/64	60.75
50	1 1/4	31.750	30	2 21/32	67.50
55	1 3/8	34.925	33	2 59/64	74.25
60	1 1/2	38.100	36	3 3/16	81.00
65	1 5/8	41.275	39	3 29/64	87.75
70	1 3/4	44.450	42	3 23/32	94.50
75	1 7/8	47.625			
80	2	50.800			
85	2 1/8	53.975			
90	2 1/4	57.150			
95	2 3/8	60.325			
100	2 1/2	63.500			

TABLE XIII. TABLE OF ROCKWELL CORRESPONDING HARDNESS NUMBERS

Rockwell C Scale 120° Cone 150-kg. Load	Approximate Corresponding Numerals	Rockwell C Scale 120° Cone 150-kg. Load	Approximate Corresponding Numerals	Rockwell C Scale 120° Cone 150-kg. Load	Approximate Corresponding Numerals
70	775	46	440	22	233
69	760	45	427	21	227
68	743	44	415	20	223
67	727	43	405	19	218
66	710	42	390	18	214
65	695	41	380	17	210
64	680	40	370	16	205
63	665	39	360	15	200
62	650	38	350	14	196
61	635	37	340	13	192
60	620	36	330	12	187
59	607	35	322	11	183
58	590	34	313	10	180
57	578	33	304	9	176
56	565	32	295	8	173
55	552	31	287	7	169
54	538	30	280	6	166
53	526	29	274	5	163
52	514	28	268	4	161
51	503	27	263	3	158
50	487	26	255	2	155
49	475	25	250	1	153
48	463	24	245	0	151
47	452	23	239		

TABLE XIV. TABLE OF BRINELL HARDNESS NUMBERS

Impression mm. Diam. 10 mm. Ball 3000-kg. load	Brinell No.	Impression mm. Diam. 10 mm. Ball 3000-kg. load	Brinell No.	Impression mm. Diam. 10 mm. Ball 3000-kg. load	Brinell No.
2.20	780	3.05	401	4.15	212
2.25	745	3.10	388	4.20	207
2.255	725	3.15	375	4.25	201
2.30	712	3.20	363	4.30	197
2.35	682	3.25	352	4.35	192
2.375	668	3.275	346	4.40	187
2.40	654	3.30	341	4.425	185
2.45	627	3.35	331	4.45	183
2.475	614	3.40	321	4.50	179
2.50	602	3.45	311	4.55	174
2.525	590	3.50	302	4.60	170
2.55	578	3.55	293	4.65	167
2.60	555	3.60	285	4.675	165
2.625	545	3.65	277	4.70	163
2.65	534	3.70	269	4.75	159
2.70	514	3.75	262	4.80	156
2.725	504	3.775	258	4.825	154
2.75	495	3.80	255	4.85	152
2.80	478	3.85	248	4.90	149
2.85	461	3.90	241	4.93	147
2.872	452	3.95	235	4.95	146
2.90	444	4.00	229	5.00	143
2.95	429	4.05	223	5.03	141
3.00	415	4.10	217	5.05	140

TABLE XV. SCREEN SCALE SIEVES FOR CLOSER SIZING

This screen scale has as its base an opening of 0.0029 in., which is the opening in 200-mesh 0.0021-in. wire, the standard sieve, as adopted by the U. S. Bureau of Standards, the openings increasing in the ratio of the fourth root of two or 1.189.

Mesh	Diameter of Wire Decimal of an Inch	For Closer Sizing Sieves from 0.0015″ to 3000″ Ratio $\sqrt[4]{2}$ or 1.189	Mesh	Diameter of Wire Decimal of an Inch	For Closer Sizing Sieves from 0.0015″ to 3000″ Ratio $\sqrt[4]{2}$ or 1.189
2½	.088	.312	32	.0118	.0195
3	.070	.263	35	.0122	.0134
3½	.065	.221	42	.0100	.0168
4	.065	.185	48	.0092	.0116
5	.044	.156	60	.0070	.0097
6	.036	.131	65	.0072	.0082
7	.0328	.110	80	.0056	.0069
8	.032	.093	100	.0042	.0058
9	.033	.078	115	.0038	.0049
10	.035	.065	150	.0026	.0041
12	.028	.055	170	.0024	.0035
14	.025	.046	200	.0021	.0029
16	.0235	.0390	250	.0016	.0024
20	.0172	.0328	270	.0016	.0021
24	.0141	.0276	352	.0014	.0017
28	.0125	.0232	400	.001	.0015

TABLE XVI. DIAMETERS* AND AREAS† OF CIRCLES

Diam.	Area	Diam.	Area	Diam.	Area	Diam.	Area	Diam.	Area
1/64	0.00019	5/16	1.3530	9/16	9.9678	13/16	26.535	10	78.540
1/32	0.00077	3/8	1.4849	5/8	10.321	7/8	27.109	1/8	80.516
3/64	0.00173	7/16	1.6230	11/16	10.680	15/16	27.688	1/4	82.516
1/16	0.00307	1/2	1.7671	3/4	11.045			3/8	84.541
3/32	0.00690	9/16	1.9175	13/16	11.416	6	28.274	1/2	86.590
1/8	0.01227	5/8	2.0739	7/8	11.793	1/8	29.465	5/8	88.664
5/32	0.01917	11/16	2.2465	15/16	12.177	1/4	30.680	3/4	90.763
3/16	0.02761	3/4	2.4053			3/8	31.919	7/8	92.886
7/32	0.03758	13/16	2.5802			1/2	33.183		
1/4	0.04909	7/8	2.7612	4	12.566	5/8	34.472	11	95.033
9/32	0.06213	15/16	2.9483	1/16	12.962	3/4	35.785	1/2	103.87
5/16	0.07670			1/8	13.364	7/8	37.122		
11/32	0.09281			3/16	13.772			12	113.10
3/8	0.11045	2	3.1416	1/4	14.186	7	38.485	1/2	122.72
13/32	0.12962	1/16	3.3410	5/16	14.607	1/8	39.871		
7/16	0.15033	1/8	3.5466	3/8	15.033	1/4	41.282	13	132.73
15/32	0.17257	3/16	3.7583	7/16	15.466	3/8	42.718	1/2	143.14
1/2	0.19635	1/4	3.9761	1/2	15.904	1/2	44.179		
17/32	0.22165	5/16	4.2000	9/16	16.349	5/8	45.664	14	153.94
9/16	0.24850	3/8	4.4301	5/8	16.800	3/4	47.173	1/2	165.13
19/32	0.27688	7/16	4.6664	11/16	17.257	7/8	48.707		
5/8	0.30680	1/2	4.9087	3/4	17.721			15	176.71
21/32	0.33824	9/16	5.1572	13/16	18.190	8	50.265	1/2	188.69
11/16	0.37122	5/8	5.4119	7/8	18.665	1/8	51.849		
23/32	0.40574	11/16	5.6727	15/16	19.147	1/4	53.456	16	201.06
3/4	0.44179	3/4	5.9396			3/8	55.088	1/2	213.82
25/32	0.47937	13/16	6.2126	5	19.635	1/2	56.745		
13/16	0.51849	7/8	6.4918	1/16	20.129	5/8	58.426	17	226.98
27/32	0.55914	15/16	6.7771	1/8	20.629	3/4	60.132	1/2	240.53
7/8	0.60132			3/16	21.125	7/8	61.862		
29/32	0.64504	3	7.0686	1/4	21.648			18	254.47
15/16	0.69029	1/16	7.3662	5/16	22.166	9	63.617	1/2	268.80
31/32	0.73708	1/8	7.6699	3/8	22.691	1/8	65.397		
		3/16	7.9798	7/16	23.211	1/4	67.201	19	283.53
1	0.7854	1/4	8.2958	1/2	23.758	3/8	69.029	1/2	298.65
1/16	0.8866	5/16	8.6179	9/16	24.301	1/2	70.882		
1/8	0.9940	3/8	8.9462	5/8	24.850	5/8	72.760	20	314.16
3/16	1.1075	7/16	9.2806	11/16	25.406	3/4	74.662	1/2	330.06
1/4	1.2272	1/2	9.6211	3/4	25.967	7/8	76.589		

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* Inches.
† Square inches.

TABLE XVII. WIRE AND SHEET METAL GAUGES

Sizes in Decimal Parts of an Inch

Number of Gauge	American Steel & Wire or Washburn and Moen	Birmingham or Stubs	American or Brown & Sharpe	Imperial Wire Gauge	U. S. Standard
	Steel Wire	Iron Wire	Non-Ferrous	British	Sheets
5/0	0.4305	0.500	0.5165	0.432	0.429
4/0	0.3938	0.454	0.460	0.400	0.398
3/0	0.3625	0.425	0.40964	0.372	0.368
2/0	0.3310	0.380	0.3648	0.348	0.337
1/0	0.3065	0.340	0.32486	0.324	0.306
1	0.2830	0.300	0.2893	0.300	0.276
2	0.2626	0.284	0.25763	0.276	0.2604
3	0.2437	0.259	0.22942	0.252	0.2451
4	0.2253	0.238	0.20431	0.232	0.2298
5	0.2070	0.220	0.18194	0.212	0.2145
6	0.1920	0.203	0.16202	0.192	0.1991
7	0.1770	0.180	0.14428	0.176	0.1838
8	0.1620	0.165	0.12849	0.160	0.1685
9	0.1483	0.148	0.11443	0.144	0.1532
10	0.1350	0.134	0.10189	0.128	0.1379
11	0.1205	0.120	0.090742	0.116	0.1225
12	0.1055	0.109	0.080808	0.104	0.1072
13	0.0915	0.095	0.071961	0.092	0.0919
14	0.0800	0.083	0.064084	0.080	0.0766
15	0.0720	0.072	0.057068	0.072	0.0689
16	0.0625	0.065	0.05082	0.064	0.0613
17	0.0540	0.058	0.045257	0.056	0.0551
18	0.0475	0.049	0.040303	0.048	0.0490
19	0.0410	0.042	0.03589	0.040	0.0429
20	0.0348	0.035	0.031961	0.036	0.0368
21	0.03175	0.032	0.028462	0.032	0.0337
22	0.0286	0.028	0.025347	0.028	0.0306
23	0.0258	0.025	0.022571	0.024	0.0276
24	0.0230	0.022	0.0201	0.022	0.0245
25	0.0204	0.020	0.0179	0.020	0.0214
26	0.0181	0.018	0.01594	0.018	0.0184
27	0.0173	0.016	0.014195	0.0164	0.0169
28	0.0162	0.014	0.012641	0.0149	0.0153
29	0.0150	0.013	0.011257	0.0136	0.0138
30	0.0140	0.012	0.010025	0.0124	0.0123
31	0.0132	0.010	0.008928	0.0116	0.0107
32	0.0128	0.009	0.00795	0.0108	0.0100
33	0.0118	0.008	0.00708	0.0100	0.0092
34	0.0104	0.007	0.006304	0.0092	0.0084
35	0.0095	0.005	0.005614	0.0084	0.0077
36	0.0090	0.004	0.005	0.0076	0.0069
37	—	—	0.004453	0.0068	0.0065
38	—	—	0.003965	0.0060	0.0061
39	—	—	0.003531	0.0052	0.0057
40	—	—	0.003144	0.0048	0.0054

CONVERSION TABLES

TABLE XVIII. TEMPERATURE CONVERSION TABLES

−459.4 to 0		
C.		F.
−273	**−459.4**	
−268	**−450**	
−262	**−440**	
−257	**−430**	
−251	**−420**	
−246	**−410**	
−240	**−400**	
−234	**−390**	
−229	**−380**	
−223	**−370**	
−218	**−360**	
−212	**−350**	
−207	**−340**	
−201	**−330**	
−196	**−320**	
−190	**−310**	
−184	**−300**	
−179	**−290**	
−173	**−280**	
−169	**−273**	−459.4
−168	**−270**	−454
−162	**−260**	−436
−157	**−250**	−418
−151	**−240**	−400
−146	**−230**	−382
−140	**−220**	−364
−134	**−210**	−346
−129	**−200**	−328
−123	**−190**	−310
−118	**−180**	−292
−112	**−170**	−274
−107	**−160**	−256
−101	**−150**	−238
−95.6	**−140**	−220
−90.0	**−130**	−202
−84.4	**−120**	−184
−78.9	**−110**	−166
−73.3	**−100**	−148
−67.8	**−90**	−130
−62.2	**−80**	−112
−56.7	**−70**	−94
−51.1	**−60**	−76
−45.6	**−50**	−58
−40.0	**−40**	−40
−34.4	**−30**	−22
−28.9	**−20**	−4
−23.3	**−10**	14
−17.8	**0**	32

0 to 100					
C.		F.	C.		F.
−17.8	**0**	32	10.0	**50**	122.0
−17.2	**1**	33.8	10.6	**51**	123.8
−16.7	**2**	35.6	11.1	**52**	125.6
−16.1	**3**	37.4	11.7	**53**	127.4
−15.6	**4**	39.2	12.2	**54**	129.2
−15.0	**5**	41.0	12.8	**55**	131.0
−14.4	**6**	42.8	13.3	**56**	132.8
−13.9	**7**	44.6	13.9	**57**	134.6
−13.3	**8**	46.4	14.4	**58**	136.4
−12.8	**9**	48.2	15.0	**59**	138.2
−12.2	**10**	50.0	15.6	**60**	140.0
−11.7	**11**	51.8	16.1	**61**	141.8
−11.1	**12**	53.6	16.7	**62**	143.6
−10.6	**13**	55.4	17.2	**63**	145.4
−10.0	**14**	57.2	17.8	**64**	147.2
−9.44	**15**	59.0	18.3	**65**	149.0
−8.89	**16**	60.8	18.9	**66**	150.8
−8.33	**17**	62.6	19.4	**67**	152.6
−7.78	**18**	64.4	20.0	**68**	154.4
−7.22	**19**	66.2	20.6	**69**	156.2
−6.67	**20**	68.0	21.1	**70**	158.0
−6.11	**21**	69.8	21.7	**71**	159.8
−5.56	**22**	71.6	22.2	**72**	161.6
−5.00	**23**	73.4	22.8	**73**	163.4
−4.44	**24**	75.2	23.3	**74**	165.2
−3.89	**25**	77.0	23.9	**75**	167.0
−3.33	**26**	78.8	24.4	**76**	168.8
−2.78	**27**	80.6	25.0	**77**	170.6
−2.22	**28**	82.4	25.6	**78**	172.4
−1.67	**29**	84.2	26.1	**79**	174.2
−1.11	**30**	86.0	26.7	**80**	176.0
−0.56	**31**	87.8	27.2	**81**	177.8
0	**32**	89.6	27.8	**82**	179.6
0.56	**33**	91.4	28.3	**83**	181.4
1.11	**34**	93.2	28.9	**84**	183.2
1.67	**35**	95.0	29.4	**85**	185.0
2.22	**36**	96.8	30.0	**86**	186.8
2.78	**37**	98.6	30.6	**87**	188.6
3.33	**38**	100.4	31.1	**88**	190.4
3.89	**39**	102.2	31.7	**89**	192.2
4.44	**40**	104.0	32.2	**90**	194.0
5.00	**41**	105.8	32.8	**91**	195.8
5.56	**42**	107.6	33.3	**92**	197.6
6.11	**43**	109.4	33.9	**93**	199.4
6.67	**44**	111.2	34.4	**94**	201.2
7.22	**45**	113.0	35.0	**95**	203.0
7.78	**46**	114.8	35.6	**96**	204.8
8.33	**47**	116.6	36.1	**97**	206.6
8.89	**48**	118.4	36.7	**98**	208.4
9.44	**49**	120.2	37.2	**99**	210.2
			37.8	**100**	212.0

100 to 1000					
C.		F.	C.		F.
38	**100**	212	260	**500**	932
43	**110**	230	266	**510**	950
49	**120**	248	271	**520**	968
54	**130**	266	277	**530**	986
60	**140**	284	282	**540**	1004
66	**150**	302	288	**550**	1022
71	**160**	320	293	**560**	1040
77	**170**	338	299	**570**	1058
82	**180**	356	304	**580**	1076
88	**190**	374	310	**590**	1094
93	**200**	392	316	**600**	1112
99	**210**	410	321	**610**	1130
100	**212**	413	327	**620**	1148
104	**220**	428	332	**630**	1166
110	**230**	446	338	**640**	1184
116	**240**	464	343	**650**	1202
121	**250**	482	349	**660**	1220
127	**260**	500	354	**670**	1238
132	**270**	518	360	**680**	1256
138	**280**	536	366	**690**	1274
143	**290**	554	371	**700**	1292
149	**300**	572	377	**710**	1310
154	**310**	590	382	**720**	1328
160	**320**	608	388	**730**	1346
166	**330**	626	393	**740**	1364
171	**340**	644	399	**750**	1382
177	**350**	662	404	**760**	1400
182	**360**	680	410	**770**	1418
188	**370**	698	416	**780**	1436
193	**380**	716	421	**790**	1454
199	**390**	734	427	**800**	1472
204	**400**	752	432	**810**	1490
210	**410**	770	438	**820**	1508
216	**420**	788	443	**830**	1526
221	**430**	806	449	**840**	1544
227	**440**	824	454	**850**	1562
232	**450**	842	460	**860**	1580
238	**460**	860	466	**870**	1598
243	**470**	878	471	**880**	1616
249	**480**	896	477	**890**	1634
254	**490**	914	482	**900**	1652
			488	**910**	1670
			493	**920**	1688
			499	**930**	1706
			504	**940**	1724
			510	**950**	1742
			516	**960**	1760
			521	**970**	1778
			527	**980**	1796
			532	**990**	1814
			538	**1000**	1832

1000 to 2000					
C.		F.	C.		F.
538	**1000**	1832	816	**1500**	2732
543	**1010**	1850	821	**1510**	2750
549	**1020**	1868	827	**1520**	2768
554	**1030**	1886	832	**1530**	2786
560	**1040**	1904	838	**1540**	2804
566	**1050**	1922	843	**1550**	2822
571	**1060**	1940	849	**1560**	2840
577	**1070**	1958	854	**1570**	2858
582	**1080**	1976	860	**1580**	2876
588	**1090**	1994	866	**1590**	2894
593	**1100**	2012	871	**1600**	2912
599	**1110**	2030	877	**1610**	2930
604	**1120**	2048	882	**1620**	2948
610	**1130**	2066	888	**1630**	2966
616	**1140**	2084	893	**1640**	2984
621	**1150**	2102	899	**1650**	3002
627	**1160**	2120	904	**1660**	3020
632	**1170**	2138	910	**1670**	3038
638	**1180**	2156	916	**1680**	3056
643	**1190**	2174	921	**1690**	3074
649	**1200**	2192	927	**1700**	3092
654	**1210**	2210	932	**1710**	3110
660	**1220**	2228	938	**1720**	3128
666	**1230**	2246	943	**1730**	3146
671	**1240**	2264	949	**1740**	3164
677	**1250**	2282	954	**1750**	3182
682	**1260**	2300	960	**1760**	3200
688	**1270**	2318	966	**1770**	3218
693	**1280**	2336	971	**1780**	3236
699	**1290**	2354	977	**1790**	3254
704	**1300**	2372	982	**1800**	3272
710	**1310**	2390	988	**1810**	3290
716	**1320**	2408	993	**1820**	3308
721	**1330**	2426	999	**1830**	3326
727	**1340**	2444	1004	**1840**	3344
732	**1350**	2162	1010	**1850**	3362
738	**1360**	2480	1016	**1860**	3380
743	**1370**	2498	1021	**1870**	3398
749	**1380**	2516	1027	**1880**	3416
754	**1390**	2534	1032	**1890**	3434
760	**1400**	2552	1038	**1900**	3452
766	**1410**	2570	1043	**1910**	3470
771	**1420**	2588	1049	**1920**	3488
777	**1430**	2606	1054	**1930**	3506
782	**1440**	2624	1060	**1940**	3524
788	**1450**	2642	1066	**1950**	3542
793	**1460**	2660	1071	**1960**	3560
799	**1470**	2678	1077	**1970**	3578
804	**1480**	2696	1082	**1980**	3596
810	**1490**	2714	1088	**1990**	3614
			1093	**2000**	3632

2000 to 3000					
C.		F.	C.		F.
1093	**2000**	3632	1371	**2500**	4532
1099	**2010**	3650	1377	**2510**	4550
1104	**2020**	3668	1382	**2520**	4568
1110	**2030**	3686	1388	**2530**	4586
1116	**2040**	3704	1393	**2540**	4604
1121	**2050**	3722	1399	**2550**	4622
1127	**2060**	3740	1404	**2560**	4640
1132	**2070**	3758	1410	**2570**	4658
1138	**2080**	3776	1416	**2580**	4676
1143	**2090**	3794	1421	**2590**	4694
1149	**2100**	3812	1427	**2600**	4712
1154	**2110**	3830	1432	**2610**	4730
1160	**2120**	3848	1438	**2620**	4748
1166	**2130**	3866	1443	**2630**	4766
1171	**2140**	3884	1449	**2640**	4784
1177	**2150**	3902	1454	**2650**	4802
1182	**2160**	3920	1460	**2660**	4820
1188	**2170**	3938	1466	**2670**	4838
1193	**2180**	3956	1471	**2680**	4856
1199	**2190**	3974	1477	**2690**	4874
1204	**2200**	3992	1482	**2700**	4892
1210	**2210**	4010	1488	**2710**	4910
1216	**2220**	4028	1493	**2720**	4928
1221	**2230**	4046	1499	**2730**	4946
1227	**2240**	4064	1504	**2740**	4964
1232	**2250**	4082	1510	**2750**	4982
1238	**2260**	4100	1516	**2760**	5000
1243	**2270**	4118	1521	**2770**	5018
1249	**2280**	4136	1527	**2780**	5036
1254	**2290**	4154	1532	**2790**	5054
1260	**2300**	4172	1538	**2800**	5072
1266	**2310**	4190	1543	**2810**	5090
1271	**2320**	4208	1549	**2820**	5108
1277	**2330**	4226	1554	**2830**	5126
1282	**2340**	4244	1560	**2840**	5144
1288	**2350**	4262	1566	**2850**	5162
1293	**2360**	4280	1571	**2860**	5180
1299	**2370**	4298	1577	**2870**	5198
1304	**2380**	4316	1582	**2880**	5216
1310	**2390**	4334	1588	**2890**	5234
1316	**2400**	4352	1593	**2900**	5252
1321	**2410**	4370	1599	**2910**	5270
1327	**2420**	4388	1604	**2920**	5288
1332	**2430**	4406	1610	**2930**	5306
1338	**2440**	4424	1616	**2940**	5324
1343	**2450**	4442	1621	**2950**	5342
1349	**2460**	4460	1627	**2960**	5360
1354	**2470**	4478	1632	**2970**	5378
1360	**2480**	4496	1638	**2980**	5396
1366	**2490**	4514	1643	**2990**	5414
			1649	**3000**	5432

NOTE: — The numbers in bold face type refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right.

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	**1**	1.8	3.33	**6**	10.8
1.11	**2**	3.6	3.89	**7**	12.6
1.67	**3**	5.4	4.44	**8**	14.4
2.22	**4**	7.2	5.00	**9**	16.2
2.78	**5**	9.0	5.56	**10**	18.0

TABLE XIX. PLASTICS PRODUCTION CONVERSION TABLE

Wt. in grams	Number per lb.	*Pounds Required to Produce Quantities of					
		5,000	10,000	20,000	50,000	100,000	250,000
5.0	90.8	55.1	110.	220.	551.	1100.	1380.
6.0	75.7	66.2	133.	265.	662.	1330.	3300.
7.0	64.8	77.2	155.	309.	772.	1550.	3860.
8.0	56.7	88.2	177.	353.	882.	1770.	4410.
9.0	50.4	99.2	199.	397.	992.	1990.	4970.
10.0	45.4	110.0	220.	441.	1100.	2210.	5510.
11.0	41.3	121.	242.	485.	1210.	2420.	6060.
12.0	37.8	133.	265.	560.	1325.	2650.	6620.
13.0	34.9	144.	287.	573.	1440.	2870.	7170.
14.0	32.4	155.	309.	617.	1550.	3090.	7720.
15.0	30.2	166.	331.	662.	1655.	3310.	8270.
16.0	28.3	177.	353.	706.	1770.	3530.	8830.
17.0	26.7	188.	375.	750.	1880.	3750.	9380.
18.0	25.2	199.	397.	794.	1990.	3970.	9920.
19.0	23.9	210.	418.	838.	2100.	4180.	10,500.
20.0	22.7	220.	441.	881.	2210.	4420.	11,030.
21.0	21.6	232.	463.	926.	2320.	4630.	11,580.
22.0	20.6	243.	486.	972.	2430.	4860.	12,150.
23.0	19.7	254.	508.	1015.	2540.	5080.	12,700.
24.0	18.9	265.	529.	1060.	2650.	5290.	13,250.
25.0	18.1	276.	551.	1100.	2760.	5510.	13,780.
26.0	17.4	287.	575.	1150.	2870.	5750.	14,400.
28.0	16.2	309.	617.	1235.	3090.	6170.	15,450.
30.0	15.1	331.	662.	1320.	3310.	6620.	16,510.
32.0	14.1	355.	709.	1420.	3550.	7090.	17,750.
34.0	13.3	376.	752.	1505.	3760.	7520.	18,800.
36.0	12.6	397.	794.	1590.	3970.	7940.	19,850.
38.0	11.9	420.	840.	1680.	4200.	8400.	21,000.
40.0	11.3	441.	882.	1765.	4410.	8820.	22,100.
42.0	10.8	463.	925.	1855.	4630.	9250.	23,200.
44.0	10.3	486.	972.	1945.	4860.	9720.	24,300.
46.0	9.85	508.	1016.	2030.	5080.	10,160.	25,400.
48.0	9.45	529.	1060.	2120.	5290.	10,600.	26,500.
50.0	9.05	552.	1105.	2210.	5520.	11,300.	27,800.
52.5	8.65	578.	1157.	2320.	5780.	11,570.	28,900.
55.0	8.25	607.	1213.	2430.	6070.	12,130.	30,300.
57.5	7.85	637.	1274.	2550.	6370.	12,740.	31,900.
60.0	7.55	661.	1322.	2650.	6610.	13,220.	33,100.
62.5	7.25	690.	1380.	2760.	6900.	13,800.	34,500.
65.0	6.95	720.	1440.	2880.	7200.	14,400.	36,000.
67.5	6.70	747.	1495.	2990.	7470.	14,950.	37,400.
70.0	6.45	772.	1542.	3090.	7720.	15,420.	38,600.
75.0	6.05	827.	1655.	3310.	8270.	16,550.	41,300.
80.0	5.67	882.	1765.	3530.	8820.	17,650.	44,200.
85.0	5.34	937.	1875.	3750.	9370.	18,750.	46,800.
90.0	5.04	993.	1985.	3970.	9930.	19,850.	49,700.
95.0	4.77	1050.	2100.	4190.	10,500.	21,000.	52,400.
100.0	4.54	1100.	2200.	4410.	11,000.	22,000.	55,100.

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* No allowance made for flash.

TABLE XX. INTERCONVERSION TABLE FOR UNITS OF VOLUME AND WEIGHT AND ENERGY

To Convert From	Multiply By										
	B.t.u.	P. C. U.	Cal.	Ft.-lb.	Ft.-tons	Kg.-m.	Hp.-hr.	Kw.-hr.	Joules	Lb. C	Lb. H_2O
B.t.u.	1.00000	0.555556	0.251996	778.000	0.389001	107.563	$0.0_3 3929$	$0.0_3 2931$	1055.20	$0.0_4 6876$	0.001031
P. C. U.	1.80000	1.00000	45.3593	1400.40	0.700202	193.613	$0.0_3 7072$	$0.0_3 5276$	1899.36	$0.0_3 1238$	0.001855
Calories	3.96832	2.20462	1.00000	3091 36	1.54368	426.844	0.001559	0.001163	4187.37	$0.0_3 2729$	0.004089
Ft.-lb.	0.001285	$0.0_3 7141$	$0.0_3 3239$	1.00000	0.000500	0.138255	$0.0_6 5050$	$0.0_6 3767$	1.35625	$0.0_7 8840$	$0.0_5 1325$
Ft.-tons	2.57069	1.42816	0.647804	2000.00	1 00000	276.511	0.001010	$0.0_3 7535$	2712.59	$0.0_3 1768$	0.002649
Kg.-m.	0.009297	0.005165	0.002343	7.23301	0.003617	1.00000	$0.0_5 3653$	$0.0_5 2725$	9.81009	$0.0_6 6394$	$0.0_6 9580$
Hp.-hr.	2544.99	0.141388	641.327	1980000	990.004	273747	1.00000	0.746000	2685473	0.175044	2.62261
Kw.-hr.	3411.57	1895.32	859.702	2654200	1327.10	366959	1.34041	1.00000	3599889	0.234648	3.51562
Joules	$0.0_3 9477$	$0.0_3 5265$	$0.0_3 2388$	0.737311	$0.0_3 3687$	0.101937	$0.0_6 3724$	$0.0_6 2778$	1.00000	$0.0_7 6518$	$0.0_6 9766$
Lb. C	14544.0	8080.00	3665 03	113150_3	5657.63	1564396	5.71434	4.26285	153470_3	1.00000	14.9876
Lb. H_2O	970.400	539.111	244.537	754971	377.487	104379	0.381270	0.284424	1023966	0.066744	1.00000

" P. C. U." refers to the " pound-centigrade unit." The ton used is 2000 pounds. " Lb. C " refers to pounds of carbon oxidized, 100% efficiency equivalent to the corresponding number of heat units. " Lb. H_2O " refers to pounds of water evaporated at 100° C. = 212° F. at 100% efficiency.

TABLE XXI. FRACTIONS INTO DECIMALS

Fractional Diameter	Decimal Diameter	Millimeter Diameter	Area of Circle	Circum. of Circle	Surface of Sphere	Volume of Sphere	Fractional Diameter	Decimal Diameter	Millimeter Diameter	Area of Circle	Circum. of Circle	Surface of Sphere	Volume of Sphere
							1	1.00000	25.400	.78540	3.1416	3.14160	.52363
1/64	.015625	.397	00019	04909	.00076	—	1/64	1.01563	25.796	.81014	3.1907	3.24056	.54858
1/32	.031250	.794	00077	.09818	.00308	.00002	1/32	1.03125	26.193	.83525	3.2398	3.34100	.57419
3/64	.046875	1.191	00173	.14726	.00692	00006	3/64	1.04688	26.590	.86077	3.2888	3.44308	.60064
1/16	062500	1.588	00307	.19635	.01228	00013	1/16	1.06250	26.988	.88664	3.3379	3.54656	.62806
5/64	078125	1.984	00479	.24544	.01916	00025	5/64	1.07813	27.384	.91292	3.3871	3.65168	.65619
3/32	.093750	2.381	00690	.29452	.02761	00043	3/32	1.09375	27.781	.93956	3.4361	3.75824	.68500
7/64	.109375	2.778	.00939	.34361	.03756	.00068	7/64	1.10938	28.178	.96661	3.4852	3.86644	.71488
1/8	.125000	3.175	01227	.39270	.04908	00102	1/8	1.12500	28.575	.99403	3.5343	3.97612	.74551
9/64	.140625	3.572	.01553	.44179	.06212	00145	9/64	1.14063	28.972	1.02183	3.5834	4.08732	.77701
5/32	.156250	3.969	01917	.49087	.07668	00200	5/32	1.15625	29.369	1.05001	3.6325	4.20004	.80937
11/64	171875	4.366	02320	.53996	09280	00266	11/64	1.17188	29.766	1.07859	3.6816	4.31436	.84264
3/16	187500	4.763	02761	.58905	.11044	00345	3/16	1.18750	30.163	1.10754	3.7306	4.43016	.87681
13/64	203125	5.159	03240	.63814	.12960	00439	13/64	1.20313	30.559	1.13688	3.7798	4.54752	.91187
7/32	218750	5.556	03758	68722	.15032	00548	7/32	1.21875	30.956	1.16659	3.8288	4.66636	.94785
15/64	234375	5.953	04314	73631	.17256	00674	15	1.23438	31.353	1.19671	3.8779	4.78684	.98479
1/4	250000	6.350	04909	78540	19636	00818	1/4	1.25000	31.750	1.22719	3.9270	4.90876	1.0227
17/64	265625	6.747	05541	.83419	22164	00981	17/64	1.26563	32.147	1.25807	3.9761	5.03228	1.0614
9/32	281250	7.144	06213	.88357	24852	01165	9/32	1.28125	32.544	1.28931	4.0252	5.15724	1.1013
19/64	296875	7.541	06922	.93266	27688	01369	19/64	1.29688	32.941	1.32096	4.0743	5.28384	1.1421
5/16	312500	7.938	07670	98175	30680	01598	5/16	1.31250	33.338	1.35297	4.1233	5.41188	1.1839
21/64	.328125	8.334	08156	1.0308	33824	01849	21/64	1.32813	33.735	1.38539	4.1725	5.54156	1.2266
11/32	.343750	8.731	09281	1.0799	.37124	02127	11/32	1.34375	34.131	1.41817	4.2215	5.67268	1.2705
23/64	359375	9.128	.10143	1.1290	40572	02430	23/64	1.35938	34.528	1.45135	4.2706	5.80540	1.3152
3/8	375000	9.525	.11045	1.1781	.44180	02761	3/8	1.37500	34.925	1.48490	4.3197	5.93960	1.3611
25/64	390625	9.922	11984	1.2272	.47936	03120	25/64	1.39063	35.322	1.51885	4.3688	6.07540	1.4081
13/32	.406250	10.319	12962	1.2763	.51848	.03511	13/32	1.40625	35.719	1.55316	4.4179	6.21264	1.4560
27/64	.421875	10.716	.13978	1.3254	.55912	03931	27/64	1.42188	36.116	1.58788	4.4670	6.35152	1.5052
7/16	437500	11.113	.15033	1.3744	60132	04385	7/16	1.43750	36.513	1.62296	4.5160	6.49184	1.5553
29/64	453125	11.509	16125	1.4235	64500	04870	29/64	1.45313	36.910	1.65844	4.5652	6.63376	1.6065
15/32	.468750	11.906	17257	1.4726	69028	05393	15/32	1.46875	37.306	1.69429	4.6142	6.77716	1.6589
31/64	.484375	12.303	18426	1.5217	.73704	05949	31/64	1.48438	37.703	1.73054	4.6633	6.92216	1.7125
1/2	.500000	12.700	19635	1.5708	78540	06545	1/2	1.50000	38.100	1.76715	4.7124	7.06860	1.7671
33/64	.515625	13.097	20881	1.6199	.83524	07177	33/64	1.51563	38.497	1.80417	4.7615	7.21668	1.8229
17/32	531250	13.494	22165	1.6690	88660	07848	17/32	1.53125	38.894	1.84155	4.8106	7.36620	1.8798
35/64	.546875	13.891	23489	1.7181	93956	08562	35/64	1.54688	39.291	1.87933	4.8597	7.51732	1.9379
9/16	562500	14.288	.24850	1.7671	99400	09318	9/16	1.56250	39.688	1.91748	4.9087	7.66992	1.9974
37/64	.578125	14.684	.26250	1.8162	1.05000	.10115	37/64	1.57813	40.085	1.95603	4.9579	7.82412	2.0577
19/32	.593750	15.081	27688	1.8653	1.10752	10958	19/32	1.59375	40.481	1.99495	5.0069	7.97980	2.1195
39/64	.609375	15.478	.29164	1.9144	1.16656	.11846	39/64	1.60938	40.878	2.03427	5.0560	8.13708	2.1824
5/8	.625000	15.875	30680	1.9635	1.22720	12783	5/8	1.62500	41.275	2.07395	5.1051	8.29580	2.2468
41/64	.640625	16.272	32232	2.0126	1.28928	13765	41/64	1.64063	41.672	2.11404	5.1542	8.45616	2.3120
21/32	.656250	16.669	33824	2.0617	1.35296	14798	21/32	1.65625	42.069	2.15448	5.2033	8.61792	2.3788
43/64	.671875	17.066	.35454	2.1108	1.41816	15880	43/64	1.67188	42.466	2.19534	5.2524	8.78136	2.4467
11/16	.687500	17.463	.37122	2.1598	1.48488	17013	11/16	1.68750	42.863	2.23655	5.3014	8.94620	2.5161
45/64	.703125	17.859	38829	2.2089	1.55316	18200	45/64	1.70313	43.260	2.27817	5.3506	9.11268	2.5866
23/32	.718750	18.256	40574	2.2580	1.62296	19442	23/32	1.71875	43.656	2.32015	5.3996	9.28060	2.6584
47/64	.734375	18.653	.42357	2.3071	1.69428	20737	47/64	1.73438	44.053	2.36254	5.4487	9.45016	2.7315
3/4	.750000	19.050	.44179	2.3562	1.76716	22089	3/4	1.75000	44.450	2.40530	5.4978	9.62120	2.8062
49/64	.765625	19.447	46038	2.4053	1.84152	23496	49/64	1.76563	44.847	2.44844	5.5469	9.79376	2.8817
25/32	.781250	19.844	.47937	2.4544	1.91748	24967	25/32	1.78125	45.244	2.49196	5.5960	9.96784	2.9589
51/64	.796875	20.241	.49873	2.5035	1.99492	.26495	51/64	1.79688	45.641	2.53588	5.6451	10.14352	3.0375
13/16	.812500	20.638	.51849	2.5525	2.07396	.28084	13/16	1.81250	46.038	2.58016	5.6941	10.32064	3.1177
53/64	.828125	21.034	.53862	2.6016	2.15448	.29736	53/64	1.82813	46.435	2.62485	5.7433	10.49940	3.1987
27/32	.843750	21.431	.55914	2.6507	2.23656	.31451	27/32	1.84375	46.831	2.66990	5.7923	10.67960	3.2817
55/64	.859375	21.828	58003	2.6998	2.32012	.33230	55/64	1.85938	47.228	2.71536	5.8414	10.86144	3.3657
7/8	.875000	22.225	60132	2.7489	2.40528	.35077	7/8	1.87500	47.625	2.76117	5.8905	11.04468	3.4514
57/64	.890625	22.622	.62298	2.7980	2.49192	.36989	57/64	1.89063	48.022	2.80740	5.9396	11.22960	3.5381
29/32	.906250	23.019	.64504	2.8471	2.58016	38971	29/32	1.90625	48.419	2.85398	5.9887	11.41592	3.6268
59/64	.921875	23.416	.66747	2.8962	2.66988	.41021	59/64	1.92188	48.816	2.90097	6.0378	11.60388	3.7168
15/16	.937500	23.813	.69029	2.9452	2.76116	.43143	15/16	1.93750	49.213	2.94832	6.0868	11.79320	3.8083
61/64	953125	24.209	.71349	2.9943	2.85396	.45335	61/64	1.95313	49.610	2.99608	6.1360	11.98432	3.9007
31/32	.968750	24.606	.73708	3.0434	2.94832	.47603	31/32	1.96875	50.006	3.04419	6.1850	12.17676	3.9954
63/64	.984375	25.003	.76104	3.0925	3.04416	.49943	63/64	1.98438	50.403	3.09272	6.2341	12.37088	4.0911

TABLE XXI. FRACTIONS INTO DECIMALS — (*Continued*)

Fractional Diameter	Decimal Diameter	Millimeter Diameter	Area of Circle	Circum. of Circle	Surface of Sphere	Volume of Sphere
2	2.00000	50.800	3.1416	6.2832	12.5664	4.1888
1/64	2.01563	51.197	3.1909	6.3323	12.7636	4.2874
1/32	2.03125	51.594	3.2406	6.3814	12.9624	4.3879
3/64	2.04688	51.991	3.2906	6.4305	13.1624	4.4899
1/16	2.06250	52.388	3.3410	6.4795	13.3640	4.5939
5/64	2.07813	52.785	3.3918	6.5287	13.5672	4.6986
3/32	2.09375	53.181	3.4430	6.5777	13.7720	4.8054
7/64	2.10938	53.578	3.4946	6.6268	13.9784	4.9138
1/8	2.12500	53.975	3.5466	6.6759	14.1864	5.0243
9/64	2.14063	54.372	3.5989	6.7250	14.3956	5.1354
5/32	2.15625	54.769	3.6516	6.7741	14.6064	5.2486
11/64	2.17188	55.166	3.7048	6.8232	14.8192	5.3637
3/16	2.18750	55.563	3.7583	6.8722	15.0332	5.4809
13/64	2.20313	55.960	3.8122	6.9214	15.2488	5.5986
7/32	2.21875	56.356	3.8664	6.9704	15.4656	5.7185
15/64	2.23438	56.753	3.9211	7.0195	15.6844	5.8402
1/4	2.25000	57.150	3.9761	7.0686	15.9044	5.9641
17/64	2.26563	57.547	4.0315	7.1177	16.1260	6.0887
9/32	2.28125	57.944	4.0873	7.1668	16.3492	6.2155
19/64	2.29688	58.341	4.1435	7.2159	16.5740	6.3441
5/16	2.31250	58.738	4.2000	7.2649	16.8000	6.4751
21/64	2.32813	59.135	4.2570	7.3141	17.0280	6.6066
11/32	2.34375	59.531	4.3143	7.3631	17.2572	6.7410
23/64	2.35938	59.928	4.3721	7.4122	17.4884	6.8762
3/8	2.37500	60.325	4.4301	7.4613	17.7204	7.0144
25/64	2.39063	60.722	4.4886	7.5104	17.9544	7.1530
13/32	2.40625	61.119	4.5475	7.5595	18.1900	7.2942
27/64	2.42188	61.516	4.6068	7.6086	18.4272	7.4373
7/16	2.43750	61.913	4.6664	7.6576	18.6656	7.5829
29/64	2.45313	62.310	4.7264	7.7068	18.9056	7.7289
15/32	2.46875	62.706	4.7868	7.7558	19.1472	7.8775
31/64	2.48438	63.103	4.8476	7.8049	19.3904	8.0281
1/2	2.50000	63.500	4.9087	7.8540	19.6348	8.1813
33/64	2.51563	63.897	4.9703	7.9031	19.8812	8.3348
17/32	2.53125	64.294	5.0322	7.9522	20.1288	8.4910
35/64	2.54688	64.691	5.0946	8.0013	20.3784	8.6493
9/16	2.56250	65.088	5.1572	8.0503	20.6288	8.8103
37/64	2.57813	65.485	5.2204	8.0995	20.8816	8.9717
19/32	2.59375	65.881	5.2838	8.1485	21.1352	9.1357
39/64	2.60938	66.278	5.3477	8.1976	21.3908	9.3019
5/8	2.62500	66.675	5.4119	8.2467	21.6476	9.4708
41/64	2.64063	67.072	5.4765	8.2958	21.9060	9.6400
21/32	2.65625	67.469	5.5415	8.3449	22.1660	9.8121
43/64	2.67188	67.866	5.6069	8.3940	22.4276	9.9863
11/16	2.68750	68.263	5.6727	8.4430	22.6908	10.164
45/64	2.70313	68.659	5.7388	8.4922	22.9552	10.341
23/32	2.71875	69.056	5.8054	8.5412	23.2216	10.521
47/64	2.73438	69.453	5.8723	8.5903	23.4892	10.704
3/4	2.75000	69.850	5.9396	8.6394	23.7584	10.889
49/64	2.76563	70.247	6.0073	8.6885	24.0292	11.075
25/32	2.78125	70.644	6.0754	8.7376	24.3016	11.264
51/64	2.79688	71.041	6.1438	8.7867	24.5752	11.455
13/16	2.81250	71.438	6.2126	8.8357	24.8504	11.649
53/64	2.82813	71.835	6.2819	8.8849	25.1276	11.843
27/32	2.84375	72.231	6.3515	8.9339	25.4060	12.040
55/64	2.85938	72.628	6.4215	8.9830	25.6860	12.240
7/8	2.87500	73.025	6.4918	9.0321	25.9672	12.443
57/64	2.89063	73.422	6.5626	9.0812	26.2504	12.645
29/32	2.90625	73.819	6.6337	9.1303	26.5348	12.852
59/64	2.92188	74.216	6.7053	9.1794	26.8212	13.060
15/16	2.93750	74.613	6.7771	9.2284	27.1084	13.272
61/64	2.95313	75.010	6.8495	9.2776	27.3980	13.484
31/32	2.96875	75.406	6.9221	9.3266	27.6884	13.699
63/64	2.98438	75.803	6.9952	9.3757	27.9808	13.916

Fractional Diameter	Decimal Diameter	Millimeter Diameter	Area of Circle	Circum. of Circle	Surface of Sphere	Volume of Sphere
3	3.00000	76.200	7.0686	9.4248	28.2744	14.137
1/32	3.03125	76.994	7.2166	9.5230	28.866	14.582
1/16	3.06250	77.788	7.3662	9.6211	29.465	15.039
3/32	3.09375	78.581	7.5173	9.7193	30.069	15.503
1/8	3.12500	79.375	7.6699	9.8175	30.680	15.979
5/32	3.15625	80.169	7.8241	9.9157	31.296	16.462
3/16	3.18750	80.963	7.9798	10.014	31.919	16.957
7/32	3.21875	81.756	8.1371	10.112	32.548	17.459
1/4	3.25000	82.550	8.2958	10.210	33.183	17.974
9/32	3.28125	83.344	8.4561	10.308	33.824	18.496
5/16	3.31250	84.138	8.6179	10.407	34.472	19.031
11/32	3.34375	84.931	8.7813	10.505	35.125	19.573
3/8	3.37500	85.725	8.9462	10.603	35.784	20.129
13/32	3.40625	86.519	9.1126	10.701	36.450	20.691
7/16	3.43750	87.313	9.2806	10.799	37.122	21.268
15/32	3.46875	88.106	9.4501	10.897	37.800	21.851
1/2	3.50000	88.900	9.6211	10.996	38.484	22.449
17/32	3.53125	89.694	9.7937	11.094	39.175	23.054
9/16	3.56250	90.488	9.9678	11.192	39.872	23.674
19/32	3.59375	91.281	10.143	11.290	40.572	24.299
5/8	3.62500	92.075	10.321	11.388	41.284	24.942
21/32	3.65625	92.869	10.499	11.486	41.996	25.589
11/16	3.68750	93.663	10.680	11.585	42.720	26.254
23/32	3.71875	94.456	10.861	11.683	43.444	26.924
3/4	3.75000	95.250	11.045	11.781	44.180	27.611
25/32	3.78125	96.044	11.230	11.879	44.920	28.306
13/16	3.81250	96.838	11.416	11.977	45.664	29.016
27/32	3.84375	97.631	11.603	12.076	46.412	29.730
7/8	3.87500	98.425	11.793	12.174	47.172	30.466
29/32	3.90625	99.219	11.984	12.272	47.936	31.205
15/16	3.93750	100.013	12.177	12.370	48.708	31.965
31/32	3.96875	100.806	12.371	12.468	49.484	32.728
4	4.00000	101.600	12.566	12.566	50.264	33.510
1/32	4.03125	102.394	12.764	12.665	51.056	34.300
1/16	4.06250	103.188	12.962	12.763	51.848	35.102
3/32	4.09375	103.981	13.162	12.861	52.648	35.918
1/8	4.12500	104.775	13.364	12.959	53.456	36.751
5/32	4.15625	105.569	13.567	13.057	54.268	37.588
3/16	4.18750	106.363	13.772	13.155	55.088	38.443
7/32	4.21875	107.156	13.979	13.254	55.916	39.312
1/4	4.25000	107.950	14.186	13.352	56.744	40.195
9/32	4.28125	108.744	14.396	13.450	57.584	41.084
5/16	4.31250	109.538	14.607	13.548	58.428	41.991
11/32	4.34375	110.331	14.819	13.646	59.276	42.909
3/8	4.37500	111.125	15.033	13.744	60.132	43.847
13/32	4.40625	111.919	15.249	13.843	60.996	44.789
7/16	4.43750	112.713	15.466	13.941	61.864	45.749
15/32	4.46875	113.506	15.684	14.039	62.736	46.721
1/2	4.50000	114.300	15.904	14.137	63.616	47.713
17/32	4.53125	115.094	16.126	14.235	64.504	48.709
9/16	4.56250	115.888	16.349	14.344	65.396	49.723
19/32	4.59375	116.681	16.574	14.432	66.296	50.753
5/8	4.62500	117.475	16.800	14.530	67.200	51.801
21/32	4.65625	118.269	17.028	14.628	68.112	52.852
11/16	4.68750	119.063	17.257	14.726	69.028	53.923
23/32	4.71875	119.856	17.488	14.824	69.952	55.009
3/4	4.75000	120.650	17.721	14.923	70.884	56.116
25/32	4.78125	121.444	17.955	15.021	71.820	57.226
13/16	4.81250	122.238	18.190	15.119	72.760	58.354
27/32	4.84375	123.031	18.427	15.217	73.708	59.498
7/8	4.87500	123.825	18.665	15.315	74.660	60.663
29/32	4.90625	124.619	18.906	15.413	75.624	61.832
15/16	4.93750	125.413	19.147	15.512	76.588	63.019
31/32	4.96875	126.207	19.390	15.610	77.560	64.223

TABLE XXI. FRACTIONS INTO DECIMALS — (*Continued*)

Fractional Diameter	Decimal Diameter	Millimeter Diameter	Area of Circle	Circum. of Circle	Surface of Sphere	Volume of Sphere
5	5.0000	127.000	19.635	15.708	78.540	65.450
1/16	5.0625	128.588	20.129	15.904	80.516	67.929
1/8	5.1250	130.175	20 629	16.101	82 516	70.482
3/16	5.1875	131.763	21.135	16 297	84 540	73 085
1/4	5.2500	133 350	21.648	16.493	86 592	75.767
5/16	5.3125	134.938	22.166	16.690	88.664	78.497
3/8	5.3750	136.525	22.691	16.886	90.764	81.308
7/16	5.4375	138.113	23.221	17.082	92.884	84.168
1/2	5.5000	139.700	23.758	17 279	95 032	87.113
9/16	5.5625	141.288	24.301	17.475	97.204	90.107
5/8	5.6250	142.875	24.850	17.671	99.400	93.180
11/16	5.6875	144.463	25.406	17.868	101 624	96.322
3/4	5 7500	146.050	25.967	18.064	103.868	99 549
13/16	5.8125	147.638	26.535	18.261	106 140	102.813
7/8	5 8750	149 225	27.109	18.457	108 436	106.181
15/16	5.9375	150.813	27.688	18.653	110 752	109.588
6	6.0000	152 400	28 274	18.850	113 096	113 096
1/16	6.0625	153.988	28.867	19 046	115 468	116.659
1/8	6.1250	155.575	29.465	19 242	117.860	120 303
3/16	6.1875	157.163	30 069	19 439	120 276	124 022
1/4	6.2500	158.750	30.680	19.635	122.720	127.832
5/16	6 3125	160 338	31 297	19 831	125 188	131.695
3/8	6 3750	161.925	31.919	20.028	127.676	135.656
7/16	6.4375	163.513	32.548	20.224	130 192	139.671
1/2	6 5000	165.100	33.183	20.420	132.729	143.791
9/16	6.5625	166.688	33.824	20 617	135 296	147 965
5/8	6.6250	168.275	34.472	20.813	137 888	152 250
11/16	6.6875	169.863	35 125	21.009	140.500	156 583
3/4	6.7500	171.450	35 785	21.206	143.140	161.031
13/16	6.8125	173.038	36 450	21.402	145 800	165.527
7/8	6 8750	174.625	37.122	21.598	148.488	170.141
15/16	6 9375	176.213	37.801	21.795	151.204	174.812
7	7.0000	177.800	38.485	21 991	153.940	179.579
1/16	7.0625	179.388	39.175	22.188	—	—
1/8	7.1250	180 975	39.871	22 384	—	—
3/16	7.1875	182.563	40.574	22.580	—	—
1/4	7.2500	184.150	41.282	22.776	—	—
5/16	7.3125	185.738	41.998	22.973	—	—
3/8	7.3750	187.325	42.718	23.169	—	—
7/16	7.4375	188.913	43.445	23.366	—	—
1/2	7.5000	190.500	44.179	23.562	—	—
9/16	7.5625	192.088	44.918	23.758	—	—
5/8	7.6250	193.675	45.664	23.955	—	—
11/16	7.6875	195.263	46.416	24.151	—	—
3/4	7.7500	196.850	47.173	24.347	—	—
13/16	7.8125	198.438	47.937	24.544	—	—
7/8	7.8750	200.025	48.707	24.740	—	—
15/16	7.9375	201.613	49.483	24.936	—	—
8	8.0000	203.200	50.265	25.133	—	—
1/16	8.0625	204.788	51.054	25.329	—	—
1/8	8.1250	206.375	51.849	25.525	—	—
3/16	8.1875	207.963	52.649	25.722	—	—
1/4	8.2500	209.550	53.456	25.918	—	—
5/16	8.3125	211.138	54.270	26.115	—	—
3/8	8.3750	212.725	55.088	26.311	—	—
7/16	8.4375	214.313	55.914	26.507	—	—
1/2	8.5000	215.900	56.745	26.704	—	—
9/16	8.5625	217.488	57.582	26.900	—	—
5/8	8.6250	219.075	58.426	27.096	—	—
11/16	8.6875	220.663	59.276	27.293	—	—
3/4	8.7500	222.250	60.132	27.489	—	—
13/16	8.8125	223.838	60.994	27.685	—	—
7/8	8.8750	225.425	61.862	27.882	—	—
15/16	8.9375	227.013	62.737	28.078	—	—
9	9.000	228.600	63.617	28.274	—	—
1/8	9.125	231 775	65.397	28.667	—	—
1/4	9.250	234.950	67 201	29.060	—	—
3/8	9.375	238 125	69.029	29 452	—	—
1/2	9.500	241 300	70.882	29.845	—	—
5/8	9.625	244.475	72.760	30.238	—	—
3/4	9.750	247.650	74.662	30 631	—	—
7/8	9.875	250.825	76.589	31.023	—	—
10	10.000	254.001	78.540	31 416	—	—
1/8	10.125	257.176	80 516	31.809	—	—
1/4	10.250	260.351	82 516	32.201	—	—
3/8	10.375	263.526	84.541	32.594	—	—
1/2	10.500	266.701	86.590	32.987	—	—
5/8	10.625	269.876	88.664	33.379	—	—
3/4	10.750	273.051	90.763	33.772	—	—
7/8	10.875	276.226	92 886	34.165	—	—
11	11.000	279 401	95.033	34.558	—	—
1/8	11 125	282 576	97 205	34 950	—	—
1/4	11 250	285.751	99.402	35.343	—	—
3/8	11.375	288 926	101 62	35 736	—	—
1/2	11.500	292 101	103.87	36.128	—	—
5/8	11.625	295 276	106.14	36 521	—	—
3/4	11.750	298 451	108.43	36.914	—	—
7/8	11.875	301 626	110.75	37.306	—	—
12	12 00	304.801	113.10	37.699	—	—
1/4	12 25	311.150	117 86	38 485	—	—
1/2	12.50	317.500	122 72	39 270	—	—
3/4	12.75	323.850	127.68	40 055	—	—
13	13.00	330.201	132 73	40 841	—	—
1/4	13 25	336.550	137.89	41 626	—	—
1/2	13.50	342.900	143 14	42 412	—	—
3/4	13.75	349.250	148.49	43.197	—	—
14	14 00	355 601	153 94	43 982	—	—
1/4	14 25	361.950	159 48	44 768	—	—
1/2	14.50	368 300	165.13	45 553	—	—
3/4	14.75	374.650	170.87	46.338	—	—
15	15.00	381.001	176.71	47.124	—	—
1/4	15.25	387 350	182.65	47 909	—	—
1/2	15.50	393 700	188.69	48.695	—	—
3/4	15.75	400 050	194.83	49 480	—	—
16	16.00	406.401	201.06	50 265	—	—
1/4	16.25	412.750	207.39	51.051	—	—
1/2	16.50	419.100	213 82	51 836	—	—
3/4	16.75	425.450	220.35	52.622	—	—
17	17.00	431.801	226.98	53.407	—	—
1/4	17.25	438.150	233.71	54.192	—	—
1/2	17.50	444.500	240.53	54.978	—	—
3/4	17.75	450.850	247.45	55.763	—	—
18	18.00	457.201	254.47	56.549	—	—
1/4	18.25	463.550	261.59	57.334	—	—
1/2	18.50	469.900	268.80	58.119	—	—
3/4	18.75	476.250	276.12	58.905	—	—
19	19.00	482.601	283.53	59.690	—	—
1/4	19.25	488.950	291.04	60.476	—	—
1/2	19.50	495.300	298.65	61.261	—	—
3/4	19.75	501.650	306.35	62.046	—	—
20	20.00	508.001	314 16	62.832	—	—
1/4	20.25	514.350	322.06	63.617	—	—
1/2	20.50	520.700	330.06	64.403	—	—
3/4	20.75	527.050	338.16	65.188	—	—

TABLE XXII. WEIGHT OF 1000 PIECES IN POUNDS BASED ON WEIGHT OF ONE PIECE IN GRAMS (454 Grams = 1 Pound)

Weight Per Piece in Grams	Weight Per 1000 Pieces in Pounds	Weight Per Piece in Grams	Weight Per 1000 Pieces in Pounds	Weight Per Piece in Grams	Weight Per 1000 Pieces in Pounds	Weight Per Piece in Grams	Weight Per 1000 Pieces in Pounds	Weight Per Piece in Grams	Weight Per 1000 Pieces in Pounds	Weight Per Piece in Grams	Weight Per 1000 Pieces in Pounds
1	2.2	18	39.6	35	77.0	52	114.5	69	151.9	86	189.4
2	4.4	19	41.8	36	79.2	53	116.7	70	154.1	87	191.6
3	6.6	20	44.0	37	81.4	54	118.9	71	156.3	88	193.8
4	8.8	21	46.2	38	83.7	55	121.1	72	158.5	89	196.0
5	11.0	22	48.4	39	85.9	56	123.3	73	160.7	90	198.2
6	13.2	23	50.6	40	88.1	57	125.5	74	162.9	91	200.4
7	15.4	24	52.8	41	90.3	58	127.7	75	165.1	92	202.6
8	17.6	25	55.0	42	92.5	59	129.9	76	167.4	93	204.8
9	19.8	26	57.2	43	94.7	60	132.1	77	169.6	94	207.0
10	22.0	27	59.4	44	96.9	61	134.3	78	171.8	95	209.2
11	24.2	28	61.6	45	99.1	62	136.5	79	174.0	96	211.4
12	26.4	29	63.8	46	101.3	63	138.7	80	176.2	97	213.6
13	28.6	30	66.0	47	103.5	64	140.9	81	178.4	98	215.8
14	30.8	31	68.2	48	105.7	65	143.1	82	180.6	99	218.0
15	33.0	32	70.4	49	107.9	66	145.3	83	182.8	100	220.2
16	35.2	33	72.6	50	110.1	67	147.5	84	185.0		
17	37.4	34	74.8	51	112.3	68	149.7	85	187.2		

GLOSSARY

GENERAL GLOSSARY

For list of chemical terms, see page 975

Abalyn: Trade name for methyl abietate, $C_{19}H_{29}COOCH_3$, b.p. 360 to 365° C., used as a plasticizer in lacquers and plastics.

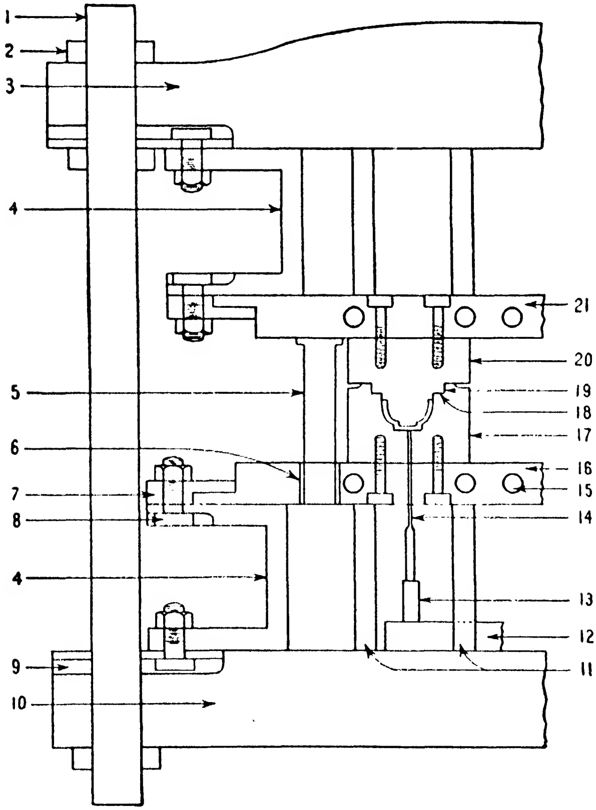
Absolute humidity: Actual density of water vapor in the atmosphere usually expressed in grains per cubic foot.

Accelerator: A substance that hastens a reaction, especially one that reduces the curing or hardening time of thermosetting plastics.

Acetate: A compound containing the acetate group, CH_3COO—; e.g., cellulose acetate, sodium acetate, ethyl acetate; common name for cellulose acetate plastics.

Acetate butyrates: Common name for cellulose acetate butyrate plastics.

Acetone extractables: Materials extracted by acetone from a finely ground plastic sample.



1. Tie Rod
2. Tie Rod Nut
3. Top Press Platen
4. Grid
5. Guidepin
6. Guidepin Bushing
7. Clamps
8. T-Bolt
9. T-Slot
10. Bottom Press Platen
11. Parallel (Spacer)
12. Knockout Frame Assembly
13. Knockout Pin Retainer
14. Knockout Pin
15. Steam Ports
16. Lower Steam Plate
17. Cavity
18. Mold Cutoff
19. Loading Well
20. Force (or plunger)
21. Upper Steam Plates

FIG. Glossary 1 — Compression molding.

Acetylation: The process of introducing one or more acetyl groups into a compound.

Acid number (or acid value): An expression of the amount of free acid in fats, oils, waxes and resins, expressed as the number of milligrams of potassium hydroxide (KOH) required to neutralize one gram of the material being tested.

Acrylates: An important group of thermoplastic resins produced by polymerization of acrylic acid derivatives, particularly methyl methacrylate.

After bake: Baking of parts after they are molded, generally at 250° to 300° F.

After yellowing: The property of becoming yellow from age or exposure often exhibited by clear varnishes and lacquers containing synthetic resins.

Aging: Allowing batches of synthetic resins, coatings, or various plastics materials to stand for some time to allow a natural change to take place, resulting in improved properties.

Air locks: Surface depressions on a molded piece caused by trapped air between the plastics material and the mold surface.

Alizarin dyes: Any of various mordant dyes derived from anthraquinone; important for fast colors for plastics.

Alkyd resins: Synthetic resins prepared from polyhydric alcohols and polybasic acids or anhydrides: e.g., glycerol phthalic anhydride resins.

Alligatoring: A term describing the appearance of lacquer films that have cracked into large segments so as to resemble alligator hide. If the cracking is fine and incomplete it is called " checking."

Alpha cellulose: The most abundant of the three forms of cellulose, insoluble in a 17 to 18 per cent caustic solution, unlike the other two forms; prepared in purified form for use as a filler, especially for ureas.

Amber: A yellowish, clear to opaque fossil resin derived from an extinct conifer; formerly used in the manufacture of some fine varnishes, and for decorative purposes.

Amine-aldehyde resins: See Aminoplasts.

Amines: Derivatives of ammonia by substitution of one or more hydrogens by an alkyl or aryl group. The primary amines are important in the production of amino-aldehyde plastics.

Aminoplasts: General term for synthetic resins from amino or amido compounds.

Amorphous: Devoid of crystalline structure.

Angle press: A press with means of applying horizontal, as well as vertical pressure in the opening and closing of a mold, used for molding such articles as telephone receivers where split molds are required because of threads, bosses or panels on the exterior.

Anhydrous: Free from water; especially free from water of crystallization.

Aniline resins: Amino-aldehyde resins derived from aniline and formaldehyde. See Furfural in Chemical glossary.

Animal resin: A resin of animal origin; e.g., shellac, a product of the lac insect.

Annealing: Heat treatment to reduce brittleness.

Anthraquinone dyes: An important group of dyes derived from anthraquinone; they are vat dyes, i.e., insoluble in water but made soluble by reduction in the dye-bath and, after becoming attached to the fiber to be dyed, regenerated in insoluble form thereon by oxidation.

Arc resistance: The resistance to forming a conducting path under the influence of an arc over the surface of the material.

Aroclor: Trade name for chlorinated diphenyls, ranging from oils to resins, and used as lacquer softeners and coating materials.

Asbestine: An inert pigment consisting of a fibrous variety of talc, or magnesium silicate.

Asphalt: A semi-solid, black, amorphous mineral-like material, similar to coal in appearance and mined similarly, and consisting of a mixture of higher hydrocarbons of the paraffin series.

A-stage: An early stage in the condensation of phenolics and ureas, in which the resins are still soluble and fusible. In this stage they may be used as varnishes.

Azo group: The structural grouping — N = N — resulting from the diazotization of aniline. Many compounds characteristic of this group are useful as dyes.

Back pressure: The resistance which the material offers (owing to its viscosity) to continued flow when the mold is closing.

Bagasse: The residue left after the juice has been pressed from sugar cane, largely crushed fibers.

Bakelite: Trade name for phenol-formaldehyde resins and plastics.

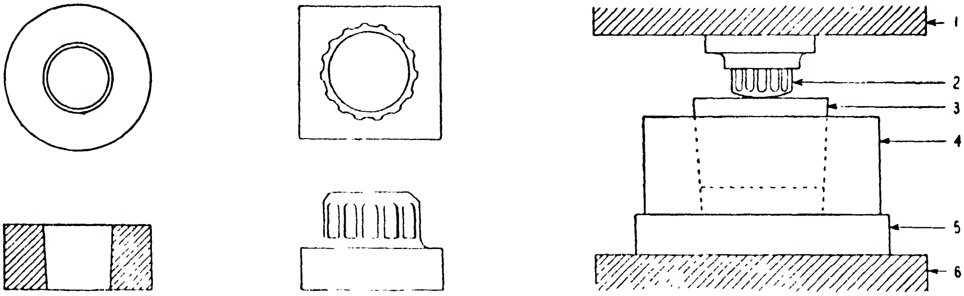
Ball mill: A cylindrical mill with steel balls within the revolving cylinder supplying the grinding action and reducing the size of particles present.

Banana oil: A solvent containing chiefly amyl acetate, with an odor of ripe bananas.

Barytes: A filler material prepared from naturally occurring barium sulfate.

Basic: Alkaline.

Beeswax: An important natural wax obtained from bees' honey combs, m.p. near 140° F.



A. Hobbing Chase.

B. Hob.

C. Hobbing Process or Hob Sinking.

Fig. Glossary 2 — Hob sinking.

1. Top Press Platen
2. Hob
3. Cavity Blank
4. Chase
5. Spacer Blocking
6. Bottom Press Platen

Beetle: Trade name for urea-formaldehyde molding plastics.

Benzine: A solvent mixture of paraffin hydrocarbons less volatile than gasoline but more so than kerosene, obtained by the fractional distillation of petroleum; to be distinguished from *benzene,* an aromatic hydrocarbon.

Binder: The resin or cementing constituent of a plastics compound. All plastics have a binder and some consist of filler components in addition.

Bitumen: A general term for petroliferous substances ranging from true petroleum through the so-called mineral tars to asphalt.

Bleeding: The giving up by a colored material of some of its color, to water or other solvents with which it comes in contact. Most plastics are colored so as to be non-bleeding.

Blister: Undesired, rounded elevation of the surface of a plastic, whose boundaries may be either more or less sharply defined, somewhat resembling in shape a blister on the human skin. A blister may become flattened.

Blood albumins: A natural albuminous product obtained from blood; used in dye preparations and in the manufacture of some adhesives and protein plastics.

Bloom or lubricant-bloom: A bluish or whitish overcast appearing either on the surface of a plastic or dispersed throughout the film; called lubricant-bloom when believed to be caused by lubricants. Also called fog, haze, blush, grease marks. Term Bloom not recommended for use.

Blowing mold: A mold in which a hollow article is blown (as from Celluloid); made in two metal parts, often hinged.

Blush: The clouding or whitening of a plastic wet with solvent or containing solvent, or of a lacquer film because of too rapid drying or high humidity. Also applied to the whitening of certain plastics, e.g., pyroxylin, by hot water or steam, or to whitening from any cause. Term not recommended for use. See Lubricant-bloom, Chalking, or Frosting.

Boil: Bubbles between 1/32 in. and 3/32 in. in diameter trapped in a plastic. Use bubble.

Bonding strength: A measure of the force required to separate the layers of a laminated product or particles of filler (usually fibrous) in a plastics compound.

Bran: The broken coat of the seed of cereal grain, separated from the flour or meal by sifting or bolting.

Bright films: The opposite of bloomed films. A designation of film clarity.

Brinell hardness: A value obtained by the use of the Brinell testing machine, in which a steel sphere of standard size is pressed with a standard pressure into the specimen under test for a standard length of time, the resistance to penetration being stated numerically as the Brinell hardness, the ratio of the pressure on the standardized sphere to the area of the indentation produced.

Bronze powder: Particles of metals or alloys reduced to powder fineness, used in producing nacreous effects in plastics.

B-stage: The stage in the reaction of thermosetting phenolics or urea resins in which they are still thermoplastic but do not entirely fuse or dissolve.

Bubble: Internal, spherical void, or a trapped globule of air or other gas, especially in a transparent or translucent plastic. See Boil, Seed.

Buff: To polish with a buffing wheel.

Bulging: Term not recommended, use Blister or Domed.

Bulk factor: The ratio of the volume of loose molding powder to the volume of the molded article made from it.

Bumping mold: see Degassing.

Buna N (Perbunan): Synthetic rubber produced by the polymerization of butadiene and approximately 25 per cent of acrylonitrile.

Buna S: Synthetic rubber produced by the copolymerization of butadiene and styrene.

Burned: Showing evidence of thermal decomposition through some discoloration, distortion, or destruction of the surface of the plastic. See also Discoloration.

Bursted: The condition resulting from the pulling apart of filler in a laminated plastic, caused by flow or spreading.

Butyl: A form of synthetic rubber developed in America.

Butyrate: A salt or ester of butyric acid; an informal trade term for cellulose acetate butyrate plastics.

Calender: A machine consisting of two or more large rollers revolving at differential speeds against each other; used in coating textiles and paper.

Candelilla wax: Natural wax obtained from a small shrub grown in Mexico and Texas; softer than Carnauba wax, melting at about 156° F.

Canvas: Closely woven, heavy cloth of cotton, hemp, or flax, used as a laminating material.

Carbamide: Another name for urea.

Carbitol: Trade name for monoethyl ether of diethylene glycol used as high boiling lacquer solvent.

Carbolic acid: Another name for phenol.

Carbon black: Gas black; a fluffy black pigment produced by the incomplete combustion of natural gas; used as a pigment or filler in plastics and synthetic rubber.

Carborundum: Trade name for silicon carbide, a very hard abrasive, produced synthetically in an electric furnace from coke, sand, sawdust, and salt.

Carnauba wax: A natural wax, the hardest in use, obtained from the leaves of a Brazilian palm tree; m.p. about 185° F. It is used to modify the consistency of plastics, to polish finished articles, and as a lubricant.

Casein: A protein prepared from cows' milk; informal trade term for casein plastics.

Casein plastics: Hornlike substances obtained from casein, usually rennet casein, hardened through the action of formaldehyde or some other agent, and seasoned by drying.

Cassava: A gum obtained from a tropical plant, used in the manufacture of adhesives and synthetic rubber and as a modifier for some plastics.

Cast resin: Resinous product prepared by pouring liquid resin into a mold and heat-treating the mass to cure it. Hot liquid resin is usually used in the case of phenolics, but cold resin with accelerators may be substituted. In the case of the methacrylates, heating is usually done after pouring.

Casting: Forming a material to a desired shape by pouring it into a mold while liquid and then hardening it. Also refers to the manufacture of film.

Castor oil: A vegetable oil obtained from the seed of a tropical plant, and used as a modifying ingredient (especially as a lubricant) for certain plastics, and as a vehicle for the dispersion of pigments for use in plastics.

Catalin: Trade name for a kind of cast phenolic plastic.

Catalyst: A substance which initiates or alters the rate of a chemical reaction without apparently taking part in the reaction.

Cat's eye: Term not recommended. See Fish-eye.

Celanese: Trade name of a rayon silk made from cellulose acetate.

Celite: A trade name for diatomaceous earth, used as a filler or filter aid.

Cellophane: Trade name for transparent packaging film material prepared from hydrated cellulose obtained by the precipitation of sodium cellulose xanthate in an acid bath.

Celluloid: Trade name for a cellulose nitrate or pyroxylin plastic.

Cellulose: A basic raw material (e.g., cotton or pulped wood) used in the production of cellulose plastics; also used as a filler.

Cellulose acetate: A product of the esterification of cellulose with acetic anhydride and acetic acid.

Cellulose nitrate: A product of the nitration of cellulose by nitric acid mixed with sulfuric acid.

Centigrade: The temperature scale on which the freezing point of water is designated as 0° and the boiling point as 100°.

Centrifuge: A machine used to separate liquids from solids held in suspension or to separate a liquid of one density from that of another by centrifugal force.

Ceresin or ceresin wax: A noncrystalline wax (white to yellow refined ozokerite); m.p. about 190° F.

Chalk: A soft white mineral of sea-shell origin, essentially calcium carbonate; used as a source of whiting (filler or pigment) when ground and purified.

Chalking: Dry, chalk-like appearance or deposit on the surface of a plastic.

Charge: The measurement or weight of material either preformed or in powder form used to load a mold.

Charpy impact test: Impact test, for determining shock strength of materials; in this test the sample bar is supported near its ends and broken by a blow struck midway between the supports.

Chase: The part of a mold which contains the charge and holds it while pressure is being applied in the closing of the mold. Also refers to the iron frame used for making Celluloid " cakes."

Chicken-skin: Term not recommended. See Orange peel.

China clay: Hydrated aluminum silicate, an inert pigment.

Chipped area: A surface irregularity near the edge of a molded piece, appearing as if chipped away, but usually due to an imperfect mold.

Chrysotile: A fibrous, hydrated magnesium silicate, a common mineral; also known as asbestos.

Clarity: Clearness.

Coal tar: A viscous residue formed in the manufacture of gas from coal; an important source material for plastics, dyes, and other synthetics.

Coefficient of expansion: The thermal expansivity; the increase in length per unit length per degree Centigrade rise in temperature.

Cold: Term applied to a flat dull surface on a molded piece, resulting from underheating. Term not recommended. See Dull surface.

Cold flow: Distortion which takes place in plastics under load at low temperatures (room temperature).

Cold molding: A procedure in which a plastic composition is shaped by pressure at ordinary (room) temperature and hardened by subsequent baking.

Cold shots: See Cold slugs, Hard spot.

Cold slugs: Surface or body imperfections in a molded article caused by non-uniformity of temperature of the charge as it flows into the mold. See also Hard spots.

Collodion: A solution of nitrated cellulose in alcohol and ether.

Colloid: Any substance in a state of colloidal dispersion; e.g., dispersed into very minute particles (between 1 and 500 millimicrons) in another substance. Or, commonly, a substance which usually forms colloidal dispersions and is difficult to obtain in true solution, such as glue, gelatin, or albumen.

Colophony: Common rosin.

Compatibility: The ability of two or more substances to mix with each other to form a homogeneous composition of useful plastics properties.

Composition: A mix of two or more materials not chemically united.

Compound: A distinct substance formed by the union of two or more elements in definite proportions by weight — as water is a compound of hydrogen and oxygen. Also loosely used in the plastics industry to denote a mix of filler and binder.

Compression molding: Process of molding in which a measured quantity of plastic is placed in the cavity of a heated open mold and the mold is closed under pressure to consolidate the compound and form to the shape of the mold. Thermosetting compounds are then hardened by further heat under pressure; thermoplastic compounds by chilling the mold (see Fig. G1).

Compressive strength: The crushing load at failure of piece divided by the number of square inches of resisting surface.

Condensation: A chemical reaction in which two or more molecules combine with the separation of water or some other simple substances. See Polymerization.

Conditioning: The process of subjecting a material to a stipulated influence or combination of influences for a stipulated period of time. The influences may be relative humidity, temperature, light, pressure, air, composition or other factors used jointly or separately. *Average room conditions*: 40 per cent relative humidity at 77° F. *Dry room conditions*: 15 per cent relative humidity at 85° F. *Moist room conditions*: 75 per cent relative humidity at 77° F.

Copal: A natural resin of vegetable origin, occurring largely as fossilized material. Used in adhesives and finishes, especially varnishes.

Copolymerization: The polymerization of two or more substances in admixture. Also used synonymously with *interpolymerization*, the polymerization of two or more substances together to yield a product which is not the same as a mixture of the respective separate polymers (as, vinyl chloride-acetate copolymer).

Cords: Heavy opaque strings within transparent or translucent plastics sheets occurring without regularity of direction. Term not recommended. See Striae.

Core: In veneered wood, the central piece of plywood in the construction of the veneer. In 5-ply construction, the grain of the core piece runs parallel to that of the veneer and at right angles to the grain of the other pieces.

Corn protein plastics: See Zein.

Cotton: The fiber of plants of the genus *Gossypium;* as a chemical raw material it is a source of cellulose derivatives including cellulose acetate, pyroxylin, cellulose ethers, and regenerated cellulose.

Cotton flock: Minutely divided cotton fibers; used as filler.

Cotton linters: Short fuzzy fibers adhering to the cotton seed after ginning; used in making cellulose esters.

Crack: Actual fracture.

Crazing: Fine cracks which may extend in a network over or under the surface of or through a plastic.

Cresols: A series of three different (ortho, meta, and para) hydroxyl derivatives of toluene obtained from coal tar or wood tar. See Chemical Glossary.

Cresylic acid: A term used especially to denote a crude mixture of the three cresols.

Cross-banding: The layers of plywood beneath the face veneer, with grain at right angles to that of the veneer and of the core.

Crystalite: Trade name for a methyl methacrylate plastics material.

C-stage: The final stage in the production of thermosetting (phenolic, urea) resins, in which they are infusible and insoluble.

Curing: The change of a binder from a soluble fusible condition to an insoluble-infusible condition by chemical action.

Cut out: A defect of laminated plastics consisting of a depressed area caused by material cut out of the body material.

Dammar (dammar gum): A resin of vegetable origin used in the manufacture of rubber and lacquer compositions and as a modifier for plastics; a yellowish-white amorphous solid; m.p. 120° C., sp. gr. 1.04 to 1.12.

Daylight opening: Space between two platens when a press is open.

Delcalcomania: The process of transferring pictures from a paper support to another surface to be decorated.

Degassing or **Bumping mold:** The opening and closing of a mold to allow the escape of gases early in the molding cycle.

Dehydrogenation: A chemical reaction involving the removal of hydrogen from a compound.

Delamination: The separation of the laminations of a laminated plastic.

Denier: A measure of the fineness of yarns. See under Polyfilaments.

Density: Mass per unit volume.

Dents: Small indentations in molded plastics; usually caused by bulges in the mold or pressing plate.

Destructive distillation: Distillation of a product at high temperatures to cause chemical changes in the original material or in its vapors so that the substances collected as a result of the distillation are decomposition products not present in the original material.

Dew point: Temperature at which condensations of moisture would occur if the existing atmosphere were cooled without change in vapor pressure.

Diatomaceous earth (infusorial earth, kieselguhr, tripoli): A fine powder composed of siliceous skeletons of diatoms, apparent density 0.24 to 0.34; used as a filler for plastics.

Diatoms: Algae with siliceous shell enclosing them; origin of diatomaceous earth.

Dielectric breakdown: The electric potential required to puncture the material.

Dielectric constant: The ratio between the capacity of a condenser with a given dielectric and the same capacity with air as a dielectric.

Dielectric strength: The voltage that will rupture or puncture the material in question when placed between electrodes of a given size.

Digester: A strong closed vessel in which substances are heated under pressure, usually with water or other liquid, in order to change them physically and often chemically.

Dimple: Small surface depression in plastics. Term not recommended. See Sink-mark.

Dirty: Term applied to a plastics piece with foreign particles molded in the surface.

Discoloration: Any change from an initial color possessed by a plastic; a lack of uniformity in color where color should be uniform over the whole area of a plastics object. In the latter sense, where they can be applied, use the more definite terms Mottle, Segregation, or Two-tone.

Dished: Showing a symmetrical distortion of a flat or curved section of a plastics object, so that as normally viewed, it appears concave or more concave. See also Warp.

Disintegration: Crumbling or breaking up into the original components.

Distortion: (1) Change in shape in a plastics article from the original molded form. (2) Larger forms of waviness and other defects causing the distortion of objects viewed through a transparent plastic.

Dogskin: A plastics surface with very small irregularities, usually observable only by reflected light at grazing incidence. Term not recommended. See Orange peel.

Domed: Showing a symmetrical distortion on a flat or curved section of a plastics object, so that as normally viewed, it appears convex or more convex. See also Warp.

Dope: A name commonly applied to a viscous cellulose ester or ether solution, for use upon aircraft fabric, leather, and like surfaces, and for making film.

Dowel pin: A pin, usually of circular section, fitting into a corresponding hole in an abutting piece (as of two parts of a mold).

Draft: Taper or slope of vertical surfaces of mold required to facilitate removal of casting or molding.

Dragon's blood: A dark red vegetable resin obtained from the fruit of a species of trees in the Malay peninsula and formerly used in lacquers. Not a permanent color.

Drip oil: A by-product in the manufacture of illuminating gas, providing a new source of supply for styrene and several other hydrocarbons.

Dry area: An unfilled surface caused by lack of fusion. Term not recommended. See Dry spot or Short.

Dry-bulb temperature: Temperature of the air as indicated by a standard thermometer.

Dry process: Preparation of a plastic in the absence of enough water to produce a solution or slurry; for example, making phenol-formaldehyde resin using solid aldehyde-yielding agents in place of the more common aqueous formaldehyde.

Dry spot: Area of incomplete surface film on laminated plastics; in laminated glass, an area over which the interlayer and the glass have not become bonded.

Drying agents (Dryers, catalysts): Metallic soaps of higher organic acids used to hasten the film formation of resins modified with drying oils.

Drying oils: Oils which " dry " or oxidize to a varnish-like film on exposure to air and sunlight. Linseed oil, China wood oil, and perilla oil are examples.

Ductility: Extent to which a solid can be drawn out into a fine thread.

Dull surface: Lack of gloss or luster in the surface of a plastic, approaching a matte or sand-blasted finish.

Edge sealing: The process of sealing the edges of a laminate. It is necessary with certain plastics which absorb moisture from the air.

Ejector: Device for removing a molded piece from the mold.

Elastic deformation: A deformation in which a substance reverts to its original dimensions on release of the deforming stress.

Elastic limit: For a given material, that stress beyond which any increment of stress produces a permanent strain.

Elasticity: Ability of a material to resume its original form after the removal of the force which has produced a change in form.

Elemi: An aromatic, balsamic, resinous gum used in some lacquers because of its elasticity and adhesive properties.

Elongation: The increase in length of a bar or section under test expressed as a percentage difference between the original length and the length at the moment of rupture.

Emulsifier or emulsifying agent: A substance used to produce an emulsion of two or more immiscible liquids.

Emulsion: A dispersion of one liquid in another with which it is not miscible. The particles are larger than colloidal size and an emulsifying agent must be added to keep them in suspension.

Ester: Reaction product of an alcohol and an acid.

Ester gum: An artificial gum resin, produced by the reaction of a gum resin such as rosin, with an alcohol such as glycerin. Used chiefly in the preparation of varnishes and lacquers.

Esterification: The process of producing an ester.

Ether: Any organic compound characterized by the grouping C—O—C; specifically, ethyl ether.

Ethocel: Trade name for ethyl-cellulose plastic.

Ethyl cellulose: A thermoplastic material prepared by the ethylation of cellulose by diethyl sulfate or ethyl halides and alkali.

Eucolloid: A highly polymerized substance (degree of polymerization over 1000) whose solid is very tough and hard and whose solutions are very viscous.

Eutectic: That mixture of two or more substances which has the lowest melting point of any mixture of those substances.

Extrusion: A molding procedure for producing rods, tubes, etc., whereby a heat-softened plastic is forced through an orifice to produce the cross-section of the article desired. Sometimes used in place of injection.

Factor of safety: The ratio of the ultimate strength of a material to its working stress.

Fading: Any lightening of an initial color possessed by a plastic.

Filler: Inert material which may be added to a resin or other binder for cheapening or for modifying mechanical properties, or to serve as a base for color effects; also called bulking agent.

Filler specks: Visible specks of a filler used, such as wood flour or asbestos, which stand out in color contrast against a background of plastics binder. It should be stated whether the specks are visible before or only after removal of the surface film.

Fillet: A rounded inside corner. The rounding of an outside corner is called beveling.

Fin: Ridge or line left on plastics by the mold parts where they meet in the closing of the mold. Also known as flash.

Fines: See Floats.

Fish-eye: Small globular mass in a transparent or translucent plastic which has not disappeared or blended completely into the surrounding material, creating somewhat the appearance of a fish's eye.

Flameproofing: Modifying plastics, as by incorporation of phosphates, asbestos, and the like, so as to make them more resistant to flame.

Flammability: (1) Ease of ignition, stated as ignition temperature. (2) Rapidity of burning.

Flash: The portion of the charge which flows from or is extruded from the mold during the closing operation. See also Fin.

Flash mold: A type of mold designed to permit escape of excess molding material, relying on back pressure to close the mold to put the piece or pieces under pressure.

Flax: Fiber obtained from the inner bark of the flax plant. The fabric, called linen, is used as a filler for high strength laminated plastics.

Flexural strength: The pressure in pounds necessary to break a given sample when applied to the center of the sample which has been supported at its ends.

Floats, or **asbestos** floats, or **fines:** The form of asbestos most generally used for filler, consisting of very fine short fibers with associated dust and non-fibrous asbestic material.

Flock: Very short fibers such as short cotton fibers, wood fibers, or wool fibers such as those obtained by shearing the nap of cloth; used as an inexpensive filler.

Flow: (1) Movement of heat-softened plastic under application of pressure, allowing it to fill all parts of a mold. (2) Flow or "creep." The gradual continuous distortion of a material under continued load, usually at high temperatures.

Flow lines: Lines appearing on the surface of a piece, generally caused by failure of the material to flow and knit together properly. Term not recommended. See Striae or Weld mark.

Flow marks: Wavy appearance of a plastic caused by flowing of the material.

Fluidity: Rate of flow; reciprocal of viscosity.

Flux: A substance which promotes fusion of a heat-fusible compound.

Fog: Cloudy or dull surface caused by a deposit on mold or pressing plate. Term not recommended. See Haze.

Force: The male part of the mold which enters the chase or die portion, exerting pressure on the material and causing it to flow. "Bottom force" and "top force" refer to the position the force occupies in the mold assembly.

Force dry: A low-temperature (below 180° to 200° F.) cure, as differentiated from a true bake, which involves contact with a temperature above 180° to 200° F.

Foreign matter: Particles of substance included in a plastic which seem foreign to its composition.

Formalin: A 40 per cent aqueous solution of formaldehyde.

Formica: Trade name for a phenolic laminated material.

Frosting: An apparently crystalline pattern on the surface of a plastic.

Fusibility: The ease with which a material is melted.

Galalith: Trade name of a well-known casein plastic of foreign make.

Galorn: A trade name for casein plastic material.

Gas black: Another name for carbon black, produced from natural gas burned in an insufficient supply of air; used as a pigment.

Gas pocket: A clearly defined area caused by trapped gas, resulting in a different degree of reflection over the area. Term not recommended. See Air lock and Heat-mark.

Gate: Opening through which material enters an injection mold.

Gel: The name given to any gelatinous solid mass produced from a solution of a colloid body; opposed to sol.

Gelation: Formation of a gel.

Gilsonite: A black, coal-like substance resembling asphalt.

Glacial acetic acid: Acetic acid in concentrated form, m.p. 16.7° C.

Gloss: Brightness or luster of a body proceeding from a smooth surface.

Glycerol esters: Products of esterification of glycerol with acids; some are useful as plasticizers, e.g., triacetin.

Glycol esters: Products of esterification of glycols with acids; some are useful as solvents or plasticizers, e.g., the glycol acetates.

Glyptal: An alkyd synthetic resin made by heating together phthalic anhydride and glycerol; used in paints, varnishes, lacquers, and as a shellac substitute.

Granular structure: Apparent incomplete fusion of and at least partial retention of their original form by the particles from which a plastic is formed, either within it or on its surface.

Graphite: A crystalline form of carbon, containing traces of Fe, SiO_2; sp. gr. 2.09 to 2.25; used as filler for plastics bearings.

Grease marks: Dull or pitted surface areas caused by excessive amounts of lubricant. Term not recommended. See Lubricant-bloom.

Gum: Viscous exudation from trees or plants which hardens on exposure to air but, unlike a resin, is soluble either in cold water or alcohol. The name is often loosely applied to natural resins in the varnish industry.

Guncotton: Highly nitrated cellulose, of about 13 per cent nitrogen content, used as a propellant charge in gunfire; not used as such in lacquers or plastics.

Hardener: Chemical curing or hardening agent. Example, formaldehyde used to harden protein and for curing some phenolics.

Hardness: Resistance of a substance to surface abrasion or indentation. See Brinell, Rockwell, and Shore scleroscope.

Hard spot: (1) Glossy spot having insufficient impregnation. (2) Small isolated lump of transparent partially colloided material occurring in or under the surface of a transparent plastic. (Also called cat's eye, cold shot, cold slug, fish-eye, stone and tear drop.)

Haze, Internal: Indefinite cloudy appearance within a transparent plastic.

Haze, Surface: An indefinite cloudy appearance on the surface of a plastic not describable by the terms Chalking, Frosting, or Lubricant-bloom.

Heat: The complete cycle of the operation of the mold: assembling, charging, closing, opening, and discharging. Sometimes referred to as a cycle.

Heat-convertible resin: A thermosetting resin convertible by heat to an infusible and insoluble mass.

Heat-mark: Extremely shallow, regular or irregular depression or groove in the surface of a plastic having practically no depth (its area being very large compared with its depth) and visible because of a sharply defined rim or a roughened surface.

Heavy: A molded piece thicker than the mold is designed to make, caused by overcharge or lack of pressure.

Hemicolloids: Linear polymers of molecular weight from 2000 to 10,000 corresponding to an order of polymerization equal to 50 to 100 monomeric units.

Hemp: A tall plant, *Cannabis sativa,* cultivated for its fiber, which is taken from the inner bark and used in making cordage.

Hercolyn: A trade name for dihydro methyl abietate esters, b.p. 365° to 370° C., used as a plasticizer for lacquers and plastics.

Hercose C: A trade name for cellulose acetate butyrate used in coatings.

Hob: A master steel form used to sink a desired mold shape into mild machine steel cavity blank (see Fig. G2, page 957).

Homologous series: A series of organic compounds belonging to the same fundamental group (alcohols, hydrocarbons, etc.), with molecular formulas differing by CH_2 or a multiple of CH_2.

Housing: The framework or structure on which an instrument (radio, scales, adding machine) is built.

Hydrophilic: A substance which absorbs or adsorbs water.

Hydrophobic: A substance which does not absorb or adsorb water.

Hydroxy-carboxylic resins: See Alkyd resins.

Hygrometer: Any properly calibrated instrument which indicates directly or indirectly the humidity of the air. *Absorption hygrometer:* Any of several types of hygrometers containing a hygroscopic substance the length, thickness, or weight of which is a measurable index of the humidity of the atmosphere. Usually such devices are graduated directly either in per cent relative humidity or in regain of stock in process, and are continuously indicating. See Recording hygrometer.

Hygroscopic: Readily absorbing and retaining moisture from the air.

Ignition temperature: The lowest temperature to which a substance must be heated to cause it to take fire.

Impact strength: The mechanical energy absorbed by a standard test piece during fracture by a blow from a pendulum hammer. (1) The energy absorbed by a standard test piece when the action of a pendulum hammer blow is just sufficient to cause fracture. (2) The mechanical energy absorbed by a standard test piece during fracture by a blow from a pendulum hammer. See Charpy and Izod.

Indur: A trade name for phenol-formaldehyde molding plastic.

Inert: Not chemically reactive.

Infusible: Not melting with the application of heat.

Infusorial earth: See Diatomaceous earth.

Injection molding: A molding procedure whereby a heat-softened plastics material is forced into a relatively cool mold which gives the desired shape to the finished article.

Inserts: Integral parts, usually of metal, of a finished molded plastics article, set in position during the molding operation.

Inverted blister: Term not recommended. See Sink-mark.

Iodine number: The percentage of iodine absorbed into chemical combination by oils, waxes, and resins containing " unsaturated " compounds. The iodine number is fairly definite for each type of material and is used to specify or identify products of a given quality.

Isinglass: A form of gelatin derived from the swimming bladders of fishes; used as an adhesive and clarifier.

Isomers: Compounds having the same kind and number of atoms but with different molecular structures and properties.

Izod impact test: Impact test for determining the shock strength of material; in it, the sample bar is held at one end only and is broken by a blow. See also Charpy.

Jacket: An enveloping hollow metal cover for holding circulating steam or water, used to heat or cool the parts it covers (such as mixing vessel, mold, etc.).

Japan wax: A soft wax obtained from sumac bushes growing in Japan; m.p. about 127° F.

Jute: Fiber of Corchorus, used to make twine and as a filler for certain plastics.

Kaolin: An inert natural white pigment, also called " China clay," consisting of hydrated aluminum silicate.

Kauri: A fossil resin from New Zealand, the most used " hard gum " in high quality varnishes. The supply is diminishing and the price rising yearly.

Kerosene: A medium-boiling petroleum distillate, often called " coal oil."

Ketone: A compound containing the carbonyl group (CO) united with the carbon atoms of two hydrocarbon radicals. The ketones are in general colorless volatile liquids, somewhat related to the aldehydes in properties.

Kieselguhr: See Diatomaceous earth.

Knockout pin: A pin used for removal of a molding after opening of the mold (see Fig. G1, page 955).

Lac: A resin of which shellac is the commercial form.

Lacquer: An organic coating composition which dries by evaporation of solvent; specifically, a coating prepared from nitrocellulose combined with a suitable plasticizer.

Lanara: The generic term for casein fiber.

Land: The portion of a mold which provides the separation or cutoff of the flash from the molded piece.

Latent solvent: In paint coatings, an organic thinner that dissolves the nonvolatile constituents only when activated by admixture with a true solvent.

Latex: The juice of plants from which rubber is obtained, usually of a milky color and consistency.

Let-go: An area in laminated glass over which an initial adhesion between interlay and glass has been lost.

Lignin: Resin found in bagasse, corn stalks, wood, etc.; a natural binder for the cell walls.

Lime: A term applied to certain calcium compounds, properly to the oxide.

Lindol: Trade name for tricresyl phosphate, used as a plasticizer for lacquers and plastics.

Linear molecule, or long molecule: A straight-chain molecule.

Lines: Narrow waves which extend a considerable distance in a straight line so that the reflection from the surface appears as a line. See also Air locks.

Linoleum: Trade name for a semiflexible sheet which may be made by coating canvas with hot oxidized linseed oil, rosin, powdered cork, and pigments.

Linseed oil: A yellow to brown liquid pressed from seeds of the flax plant, used in the manufacture of paints and varnishes.

Linters: Short fibers adhering to the cotton seeds after ginning; used as a filler material for plastics, and a base for the manufacture of cellulose derivatives.

Litharge: A fused form of lead monoxide (yellow lead oxide), used as a drier.

Lithopone: An equimolecular mixture of zinc sulfide and barium sulfate prepared by coprecipitation; sp. gr. 4.30; used as a paint pigment and as a filler in plastics.

Lubricant: An addition to the plastics mix or mold coating to prevent the molded pieces from sticking.

Lubricant-bloom: Irregular, cloudy, greasy exudation on the surface of a plastic.

Lucite: A trade name for methyl methacrylate plastics material.

Lumarith: A trade name for cellulose acetate plastics.

Luster: Term used to describe the gloss, shine, or brightness of a finished surface.

Macromolecule: A giant molecule of colloidal dimensions.

Magnesia: Magnesium oxide, MgO, a light earthy white substance made usually by heating magnesium hydroxide or carbonate; used as a filler.

Manila resins or Manila copal: Natural gum resins obtained in the East Indies, including soft, semifossil, and fossil resin. They are spirit-soluble, and used in varnishes.

Marblette: A trade name for cast phenolic plastics.

Masonite: A trade name for a lignin-type plastic.

Mastic: An aromatic, astringent resin used to some extent in the manufacture of spirit varnishes; called also " gum mastic," or " tear gum " (because of its peculiar form).

Melamine: An azine which can be condensed with formaldehyde to form thermosetting resinous products, somewhat resembling urea resins. Can be produced cheaply from dicyanodiamide.

Melamine plastics: Thermosetting plastics formed by melamine and formaldehyde.

Menhaden oil: Fish oil.

Mesh: Size and number of openings in a screen. 4-mesh means 4 openings from the center of a wire to the center of a wire 1 in. from that point. ¼-in. mesh (the fractional part of an inch) means that the space between the wires is ¼ in.

Mesocolloid: A polymer intermediate between a hemicolloid and eucolloid, between degrees of polymerization of 100 and 1000.

Metallic soap: The compound of any metal with an organic acid such as stearic acid; used as driers, lubricants, etc.

Methacrylates: Term applied to polymerized esters of methacrylic acid; transparent, colorless, thermoplastic resins.

Mica: A mineral (muscovite, phlogopite) which is a crystalline silicate of aluminum and other metals, with crystals that can be split into very thin transparent sheets; used as a filler.

Mica specks: Small mica-like spots on the surface of a plastic due to presence of volatile matter during injection.

Micarta: A trade name for phenolic laminated material.

Micron: One thousandth of a millimeter.

Mineral resin: Term sometimes applied to such mineral resin-like materials as gilsonite.

Miscible: Mutually soluble.

Modulus of elasticity: The quotient obtained by dividing the stress per square inch by the elongation in 1 in. caused by this stress.

Mohs' scale: A scale of hardness devised by Mohs, being a relative measure of the hardness of surface by resistance to the scratching of various minerals having increasing degrees of hardness as follows: (1) Talc; (2) Gypsum; (3) Calcite; (4) Fluorite; (5) Opatite; (6) Orthoclase; (7) Quartz; (8) Topaz; (9) Corundum; (10) Diamond.

Moisture absorption: The percentage by weight of water absorbed by a sample immersed in water. The rate of absorption depends on the relationship of weight and area.

Molding: The shaping of a plastic in a mold, by the application of pressure, and usually of heat See Casting.

Molding cycle: The complete time including the heating, curing, and discharge of the mold in making a piece.

Mold marks: A defect in the mold imparted to the material.

Molecular weight: The sum of the weights of the atoms of a molecule.

Molecule: The smallest unit or particle into which a substance can be divided and still retain all oi the chemical identity of that substance.

Monomer: (1) a simple molecule which is capable of reacting with like or unlike molecules to form macromolecules. (2) The smallest repeating structure of a polymer; for addition polymers this represents the original unpolymerized compound.

Montan wax: A natural wax (from peat and brown coal) used as a die lubricant in admixture with plastics composition.

Mottle: Desired or accidental mixture of colors or shades of a color giving more or less distinct or complicated pattern on specks, spots, or streaks of color.

Naphtha: Volatile, flammable liquid obtained as a definite fraction in the distillation of petroleum or by distilling certain carbonaceous materials; used as a solvent.

Natural resins: Resins produced directly by or from the products of plants or animals.

Neoprene: A trade name for a rubber substitute prepared from chloroprene.

Nitrates: A common name for a cellulose nitrate plastic. Other names are nitrocellulose and pyroxylin.

Nitration: The introduction of the nitro group, $-NO_2$, into an organic compound.

Nitric acid: A monobasic acid, HNO_3; used in the manufacture of dyes, Celluloid.

Nitrocellulose: Any of the esters formed by the reaction of nitric acid upon cellulose.

Nixonite: A trade name for cellulose acetate plastic.

Nixonoid: A trade name for cellulose nitrate plastic.

Novolak: A trade name for a permanently fusible and soluble phenol-aldehyde resin used principally in varnishes..

Nozzle: Restricted orifice at the end of the heating cylinder of an injection molding machine.

Nut shells: The horny outer case of such nuts as walnuts, ground and used for filler.

Nylon: A generic name for synthetic fiber-forming polymeric amides having a protein-like chemical structure; used in the forms of bristles, fibers, etc.

Olefins (Alkenes): Unsaturated aliphatic hydrocarbons of the formula C_nH_{2n}, having one double bond; e.g. ethylene.

Opalescence: Diffusion within a sheet of transparent plastic, or at its surface, which interferes with the clarity of vision through the sheet at any angle.

Opalon: A trade name for cast phenolic plastics.

Open bubble: Bubble which has broken partly through the surface of a plastic. See also Bubble, Pinhole.

Optical distortion: An apparent distortion of anything viewed through a transparent plastic, caused by the non-uniform optical character of the plastic, and not by its shape.

Orange peel: Uneven surface somewhat resembling that of an orange peel.

Overcure: A foggy surface resulting from too long a cure.

Ozokerite: A natural hydrocarbon wax of great flexibility, having a melting point of 140° to 200° F.

Paraffin oil: A mixture of liquid hydrocarbons, a refined fraction of mineral oil. Used to some extent as a lubricant.

Paraffin wax: A solid mixture of purified petroleum hydrocarbons melting between 40° and 60° C.

Paraformaldehyde: A solid polymer of formaldehyde, used instead of formaldehyde in the production and cure of certain plastics such as phenolics. Solid polymers of formaldehyde are also called " trioxymethylene " and " polyoxymethylene."

Parlon: A trade name for a chlorinated rubber.

Pearl essence: A pasty preparation of fish scales (guanin) which is chemically treated and incorporated into cellulose derivative lacquers and plastics.

Pebble: An uneven surface having very small uniform irregularities, somewhat similar to the beaded surface of a movie screen; it prevents specular reflection and seriously impairs clear vision through a transparent sheet. Term not recommended. See Orange peel.

Pepper: Very small pits which appear as an area of small specks.

Perbunan: Synthetic rubber produced by the copolymerization of butadiene and acrylonitrile. Formerly known as Buna N.

Perilla oil: An oil obtained from several species of *perilla* grown in China, Japan, and India; used in certain types of varnishes.

Petroleum: Crude mineral oil, chiefly a mixture of hydrocarbons.

Phenol: A compound which contains one or more hydroxyl groups attached to an aromatic nucleus; also specifically, phenol (carbolic acid) C_6H_5OH; other phenols are cresol, resorcinol, naphthol, xylenol.

Phenol-formaldehyde resin: Thermosetting resin made by the reaction between phenol and formaldehyde.

Phenolics: A generic designation for the entire group of phenol-aldehyde plastics.

Phenoplast: General term for phenol-aldehyde resins.

Pigment: A finely divided, insoluble material that imparts a color to the substance to which it is added, or makes it black, white, or gray.

Pill: Term for a preform, a firmly compacted mass of molding powder of predetermined weight made by application of high pressure without heat, and used for convenience in loading molds.

Pimple: Undesired, small, sharp, or conical elevation on the surface of a plastic whose form resembles a pimple in the common sense. See also Blister.

Pinhole: Tiny but apparently very deep hole in the surface of, or through, a thin section of plastic, which usually is round and has a rounded edge.

Piping: Term not recommended. See Sink-mark.

Pit: Small regular or irregular hole in the surface of a plastic, usually having somewhat like diameter and depth, and often dull or rough at the bottom. See also Pinhole, Short.

Pitch: A term applied to pyrogenous residues obtained in the distillation of organic substances, specifically from coal tar.

Plaskon: A trade name for urea-formaldehyde molding plastics.

Plastacele: A trade name for cellulose acetate plastic.

Plaster of Paris: A material made by partially dehydrating gypsum or a natural hydrate form of calcium sulfate; after being mixed with water it sets to form a hard mass. It can be used as a filler.

Plastic flow: Deformation under the action of a sustained force; flow of semi-solids in the molding of plastics.

Plasticity: That property of a material which determines its rate of deformation under standardized conditions.

Plasticizer: A high-boiling material, usually liquid, added to plastics to produce or increase their plastic flow.

Plastic wood: A pasty mixture of cellulose nitrate, wood flour, plasticizers, resins, etc., dispersed in volatile solvents.

Plate mark: A defect in the pressing plate, imparted to the molded material.

Plexiglas: A trade name for methyl methacrylate plastics.

Plywood: Thin sheets of wood glued together, the grains of the layers being (usually) at right angles to one another. Also impregnated wood sheets banded by heat and pressure.

Pock mark: Definitely shaped indentation. Term not recommended. See Pit.

Polychloroprene: A polymer of chlorobutadiene; the latter prepared from acetylene and hydrogen chloride.

Polyhydric alcohol: An alcohol that contains more than one hydroxy group, e.g., $CH_2OH—CH_2OH$.

Polymer: A product of polymerization.

Polymerization: The reaction by which single molecules are linked to form large molecules without change in fundamental chemical composition.

Polystyrene: A thermoplastic synthetic resin, polymer of styrene.

Polysulfides: Solutions of sulfur in alkali sulfides; used in the production of certain synthetic rubber-like materials. See Thiokol.

Polyvinyl acetal: Products derived from polyvinyl esters in which part or all of the acid groups have been replaced by acetal and hydroxyl groups; available in several types depending on the aldehyde or aldehydes used, e.g., Formvar, Alvar, Butvar, etc.

Polyvinyl acetate: Polymerized vinyl acetate; used in lacquers, adhesives, impregnating solutions for textiles and in making molding powders for plastics.

Pontianac: A dark fossilized natural resin from New Caledonia, used in the manufacture of varnishes.

Porcelain: A ceramic formed from baked clay glazed with a fusible substance.

Porosity: Presence of numerous visible voids.

Port: Rounded recessed end of sprue bushing into which the nozzle of the heating cylinder of an injection machine fits during plastics injection.

Positive mold: One designed to have total applied pressure to the piece being molded, and permitting little or no escape of material.

Power factor: The power factor of a dielectric is a measure of the loss of energy in an alternating current field, i.e., the fraction of the energy lost during cyclic charging and discharging of a condenser formed by the dielectric. This term is sometimes applied to plastics to refer to the loss of power due to the use of the specimen on equipment in alternating-current operations.

Precure: A rough surface in molding, caused by the resin setting up before proper pressure is applied in the mold. Term not recommended. See Short.

Predrying: Drying the molding compound to remove moisture, before charging the mold.

Preform: Powder cold-pressed into a pellet to facilitate mold loading.

Preheating: Heating the molding material immediately before charging the mold.

Protein: Complex nitrogenous compounds found in living organisms, and made up of amino acids. The molecular weight varies from 30,000 to over 15,000,000.

Prussian blue: Any of several complex cyanogen compounds of ferric and ferrous iron, used as coloring agent in plastics.

Psychrometer, sling: A psychrometer containing matched dry- and wet-bulb thermometers suitably mounted for swinging through the atmosphere, for simultaneously indicating dry- and wet-bulb temperatures. The thermometer shall be so mounted as to act independently and to face the air current during swinging. See Recording hygrometer.

Pull-up: Delamination of laminated material when fabricated by punching.

Pumice: An abrasive powder made from a porous volcanic stone (pumice stone).

Punching: Fabrication of parts from sheets by use of punching dies.

Punching stock: A special flexible material for punching operations.

Pyralin: A trade name for nitrocellulose plastics.

Pyroxylin: Nitrocellulose of the types used in plastics, films, and coatings. Loosely used to designate pyroxylin plastics.

Quartz: A mineral occurring naturally as hexagonal crystals, commonly colorless and transparent; silicon dioxide. It is used ground as a filler.

Ramie: A tough natural fiber used as a filler material.

Rayon: A generic term for synthetic silk-like filaments made from various solutions of modified cellulose by pressing or drawing the cellulose solution through an orifice and solidifying it in the form of fibers.

Ream: Layers of non-homogeneous material parallel to the surface in a transparent or translucent elastic.

Recording hygrometer or psychrometer: Any approved type of hygrometer or psychrometer equipped with automatic clocking and recording device capable of making a continuous time-relative humidity autograph, or time-wet- and dry-bulb temperature autograph.

Red oxide: Red iron oxide, used as a filler. See also Rouge.

Refractive index: The ratio of the velocity of light in a vacuum to its velocity in the substance. It is also the ratio of the sine of the angle of incidence to the sine of the angle of refraction.

Reinforcement: Filler material in plastics used primarily for strengthening the finished product.

Relative humidity: Ratio of actual density (or pressure) of existing moisture vapor, to maximum possible density (or pressure) at the same temperature, expressed as a percentage.

Release mark: A surface irregularity in a molded piece, usually occurring at the corners which are the final point of release for the mold. See also Air locks.

Relief lines: Parallel scratches or projecting ridges distributed over a considerable area of sheet, and usually produced during a slicing operation. See Sheeter lines.

Rennet: The milk-coagulating enzyme of the stomach.

Rennet casein: Casein coagulated from skim milk with rennet; used in the manufacture of casein plastics.

Resin: A solid or semisolid amorphous organic compound or mixture of such compounds, with no definite melting point and no tendency to crystallize. Resins may be of vegetable or animal origin (e.g., shellac), or may be synthetic. Natural resins are distinguished from *gums* in that the resins are insoluble in water; but certain synthetic water-soluble materials are referred to as resins or resin stages.

Resin flake: Cured (thermosetting) resin flakes remolded in a plastic.

Resinate: A metallic soap in which the organic acid constituent is obtained from rosin.

Resinoid: A class name applied to synthetic resins, especially to thermosetting synthetic resins, and to the final cured resins.

Resinox: A trade name for phenol-formaldehyde resins and molding plastic.

Resite: A C-stage phenol-aldehyde resin.

Resitol: A B-stage phenol-aldehyde resin.

Rockwell hardness: A test for hardness similar to the Brinell in which a hardened steel ball (B scale), or a diamond cone (C scale), is pressed against the material to be tested. See Hardness.

Rosin: A vegetable resin; the molten resinous residue remaining in the still after the distillation of spirits of turpentine from crude turpentine obtained from living pine trees. The molten resin is strained, and solidifies to form a solid: rosin.

Rosin ester: The reaction product of rosin and glycerin. See Ester gum.

Rouge: A red powder consisting of ferric oxide, usually prepared by calcining ferrous sulfate; used as a pigment and for polishing.

Safety glass (Laminated glass): A product made by cementing two sheets of glass together with a sheet of transparent, colorless plastics material between to render it shatterproof.

Sandarac: A hard but brittle natural resin imported from Africa. It has an odor somewhat like turpentine, and a sharp balsamic taste, and is used in varnishes.

Santicizer: A trade name for a series of plasticizers for lacquers and plastics.

Santolite: A trade name for sulfonamide-aldehyde resins, used with plasticizers in plastics.

Saponification number: The number of milligrams of potassium hydroxide required to neutralize all the acid in one gram of resin or other substance.

Satin: A plastic finish having a satin or velvety appearance.

Scaly: Showing a flaked surface appearance.

Scour: Remove grease, dirt, and other extraneous matter from wool.

Scratch: Shallow mark, groove, furrow, or channel.

Seed: Minute bubbles in a plastic, 1/64 in. in diameter. Term not recommended. See Bubble.

Segregation: A close succession of parallel, rather narrow and sharply defined, wavy lines of color on the surface of a plastic differing in shade from surrounding areas, and creating the impression that components of the plastic have separated.

Semi-automatic press: A press in which the mold parts are secured directly to the top and bottom of the press with facilities for automatically parting the mold and ejecting the pieces. Mechanical or hydraulic means are necessary to open the press and mold.

Semigloss: A plastics surface finish having a reflectivity between *satin* and *gloss*.

Semipositive mold: A modified flash mold which at the last 1/32 in. to 1/16 in. of travel becomes positive.

Shear or shearing stress: A force which operates in a plane of an area or in a parallel plane, and tends to cause the plane of the area to slide on the adjacent planes.

Sheeter lines: Parallel scratches or projecting ridges distributed over a considerable area of a plastic sheet, such as might be produced during a slicing operation. Also called " relief lines."

Shellac: An animal resin, produced by insects parasitic on certain trees in India and southern Asia. It is used for varnishes and molding powders and as a modifier for synthetic resins.

Shore scleroscope hardness: The height of rebound (proportional to the hardness) of a diamond-pointed hammer falling by its own weight and under standardized conditions on the object to be tested for hardness.

Short: Incompletely filled out condition in a molding which may be quite obvious, or only evident through absence of surface film in tiny or larger areas, or as lighter, unfused particles of material showing through a covering surface film, accompanied possibly by peculiar thin-skinned blisters. With thermosetting materials, it is important to note whether the short occurs only after a period of prewarming the mold charge, or a delay in closing the mold.

Short finish: A dull surface finish on a plastic.

Shrinkage mark: A series of short creases or wrinkles in a plastic, believed to be caused by shrinkage before complete hardening.

Silica: Silicon dioxide, or silicic anhydride, SiO_2, occuring naturally in crystalline form as quartz.

Single-stage process: A process for making resins in one step; commonly applied to phenolics.

Sink-mark: Dimple-like depression in the surface of a molding where it has retracted from the mold, and which has well-rounded edges, and in which there is no absence of surface film.

Sisal: A long vegetable fiber being used considerably with phenolic and urea resins for molding forms which have long drafts.

Skim: Streaks of dense seeds or pits appearing on a plastics surface.

Slate flour: A grayish, amorphous powder, sp. gr. 2.6 to 3.3; used as a filler.

Slip plane: Plane within a transparent plastic, visible in reflected light, because of poor welding and shrinkage on cooling.

Slurry: A term for a slushy or wet mixture; term used in cold molding for the batch before being ground or screened.

Slush molding: A process for molding hollow castings with accelerated thermoplastic phenolic resins or other casting liquids, in which the liquid is poured into the mold, allowed to set where it touches the mold, and then poured out, leaving a solidified shell.

Smears: Blotches of surface haze in a plastics surface.

Softener: A material added to a plastics mix to produce a soft, pliable end-product. A softener may or may not be a plasticizer.

Softening point: The temperature at which a plastic becomes readily distorted; for a given material the value reported will depend upon the method of test.

Sol: A general term for liquid colloidal dispersions, as distinguished from true solutions.

Solvent: The medium within which a substance is dissolved, most commonly applied to liquids used to bring solids into solution.

Soybeans: Seeds of bean plants, originally Asiatic, used as a source of a semidrying oil and a meal of high protein content.

Specific gravity: The ratio of the weight of the molded piece as compared to the weight of an equal volume of water.

Specific heat: The ratio of the thermal capacity of a substance to that of water at 15° C.

Split chase mold or split ring mold: A mold in which the chase contains an assembly of two or more parts to form undercuts in a molded piece. These parts are removed from the chase with the piece and then separated from the piece.

Spreading: Flow of filler and resin (of a thermosetting plastic) during curing.

Stage A: See A-stage.

Stage B: See B-Stage.

Stage C: See C-Stage.

Standard laboratory atmosphere: Whenever materials are to be tested which are sensitive to variations in temperatures and/or moisture, standard laboratory atmosphere should be considered as consisting of 50% ± 2% relative humidity and a temperature of 77° ± 2° F.

Stearates: Metallic salts of stearic acid, usually calcium, aluminum, or zinc, used in molding powders as die lubricants.

Stearin pitch: Pitch obtained as a residue in the distillation of fatty acids; sp. gr. 0.9 to 1.1; used in paints and as a plastics modifier.

Stones: Any opaque or translucent inclusions embedded in a transparent or translucent plastic. See Hard spot.

Streaks: Narrow strips or bands of surface haze.

Striae: Surface or internal threadlike inhomogeneities in a transparent plastic.

String: Wavy transparent lines within a transparent sheet of plastic. Term not recommended. See Striae.

Stripping: Removal of molded pieces from a die or mold, also the removal of special fractions from mixed liquids through distillation.

Sub-cavity mold: A mold having a common loading cavity for a multiple number of pieces.

Sulfonamide: An amide of sulfonic acids. In combinations, such as a mixture of *o*-toluene with *p*-toluene sulfonamide, used as plasticizers for protein products.

Surface blush: See Surface haze.

Surface haze: A hazy appearance of the surface due to microscopically small surface imperfections.

Sweating: Exudation of small drops of liquid, usually a plasticizer or softener, on the surface of a plastic part.

Synthetic resin: Resins prepared by chemical means.

Synthetic rubber: Any of several synthetic materials resembling rubber, which can be used as rubber substitutes.

Tablets: See Pills.

Tacky: Sticky or adhesive.

Talc: A flaky or fibrous form of hydrated magnesium silicate used as a filler and pigment.

Tars: A term applied to pyrogenous residues obtained in the destructive distillation of organic materials.

Tear drop: Surface blemishes of a scaly appearance usually caused by a non-uniform temperature of the charge as it flows into the mold. Term not recommended. See Fish-eye.

Tenite I: A trade name for cellulose acetate plastic.

Tenite II: A trade name for cellulose acetate butyrate plastic.

Tensile strength: The pulling force in pounds necessary to break a given sample, divided by the area of the cross section in square inches.

Terpene: Any of a series of isomeric hydrocarbons, $C_{10}H_{16}$, obtained by the distillation of plants, especially the conifers.

Thermal conductivity: The time rate of transfer of heat by conduction through unit thickness, across unit area for unit difference of temperature.

Thermal expansivity: The coefficient of expansion; the increase in length per unit length per degree Centigrade rise in temperature.

Thermoplastic: Capable of being repeatedly softened by heat; used also as a noun to designate a plastic of this character.

Thermosetting: Capable of being hardened by heat; used also as a noun, to designate a plastic of this character.

Thiokol: A trade name for a synthetic rubber made from a polysulfide base.

Titanium pigments: Pigments prepared from or including titanium oxide, a white compound.

Tornesit: A trade name for a chlorinated rubber used principally in paints. See Parlon.

Toughness: A property of plastics which can be expressed numerically when judged in terms of the area beneath the tensile stress-strain curve from the beginning of the moment of failure.

Toxicity: The state of being poisonous. Benzene and formaldehyde, for example, are toxic.

Transfer molding: A type of molding similar to injection molding but applied to thermosetting plastics.

Translucent: Allowing the passage of some light, but not a clear view of any object.

Tripoli: A porous siliceous earth resulting from the natural decomposition of siliceous sandstone, used as an abrasive, polishing powder, and filler.

Tumbling: A process of polishing, creating a smooth finish, or applying an even coating of some material on small plastics objects by placing them in a tumbling barrel with various finishing or polishing compounds and wooden pegs or other similar objects. Slow turning of the barrel causes the pieces to rub against each other and against the pegs. Many articles can be finished at once this way.

Tung oil: A yellow oil obtained from the fruit of *Aleurites cordata;* used in the manufacture of quick-drying varnishes and as a modifier or lubricant for plastics.

Turpentine: An oil obtained by distilling the extracted sap obtained by wounding living pine trees; used as a solvent for paints and varnishes.

Two-stage process: Method of making phenol-formaldehyde resins in which less than the required amount of aldehyde is reacted with phenol in the first stage, more being added later.

Two-tone: Two shades of its nominal color more or less entirely covering adjacent areas on a molding with a more or less sharp line of demarcation between.

Uformite: A trade name for aqueous dispersions of urea-formaldehyde resins; used as adhesives and for the manufacture of laminated material.

Ultra-violet light: Light having a shorter wave length than the violet rays in the spectrum. It is invisible but produces chemical changes in many plastics.

Undercure: A dull surface or pale color on a (thermosetting) plastics piece due to insufficient cure.

Undercut: Any indentation in or protrusion from a piece beyond the direct draw line.

Unfilled: Term applied to a plastics piece having exposed filler fibers due to insufficient resin in the molding composition.

Ureas: Common term for urea plastics; light-colored, thermosetting resins usually filled with alpha cellulose.

Vapor pressure: The pressure at which a liquid and its vapor are in equilibrium at a definite temperature. If the vapor pressure reaches the prevailing atmospheric pressure (1 atm.), the liquid boils.

Varnishes: Organic coatings which dry by evaporation or oxidation; usually are without pigments.

Vehicle: Liquid carrier for pigments (in coatings) which dries to form a film, e.g., linseed oil.

Veneer: Wooden boards made by gluing thin sheets of wood together, usually on a heavier piece of wood, called the core or cross-banding. Expensive woods are ordinarily used only for the outer layer.

Vent: Shallow channel that permits the escape of entrapped air.

Vinsol: A trade name for a resin derived from naval stores, used in protective coatings.

Vinylite: A trade name for a group of copolymers of vinyl acetate and vinyl chloride. Transparent, water-white thermoplastic material.

Vinyon: A trade name for synthetic silk-like fiber, prepared from vinyl polymers.

Viscose: A syrupy, highly viscous, colloidal solution consisting of cellulose xanthate and dilute caustic soda; used in making rayon.

Viscosity: Internal friction or resistance to change of form of a liquid. The constant ratio of shearing stress to rate of shear.

Vistanex: A trade name for a polymerized unsaturated hydrocarbon having properties intermediate between those of rubber and those of plastics (polymerized isobutylene).

Volume resistivity: The resistance in ohms between opposite faces of a centimeter cube of the material.

Vulcanized fiber: A product made by the action of zinc chloride on cellulose; very resistant to chemical action.

Vulcanized rubber: Natural rubber stabilized by chemical reaction with sulfur or sulfur compounds.

Warp: Dimensional distortion in a plastics object after molding or other fabrication. See also Dished, Domed.

Water absorption: Gain in weight, calculated to percentage, of a conditioned plastics test piece after immersion in distilled water at room temperature for 24 hr.

Water mark: Exposed fiber, a mark caused by the presence of water (occurring especially in thermosetting plastics).

Waviness, internal: An appearance of waviness seen in a transparent plastic.

Waviness, surface: Wave-like unevenness, or out-of-plane, in the surface of a plastic.

Wax: Any of a class of substances of plant or animal origin containing esters of higher monohydroxy alcohols and higher fatty acids. Waxes are distinguished from fats and resins in that they do not form soaps when tested with alkalies. The term is also applied to some synthetic materials which resemble beeswax.

Weld mark: Mark formed by the incomplete union of two or more streams of plastic flowing together.

Well: A mark formed by the incomplete union of two or more streams of plastics material.

Wet-bulb temperature: The temperature indicated by the wet-bulb thermometer of a standard sling psychrometer or its equivalent. Theoretically, temperature at which the atmosphere would become saturated by evaporation of water without loss or gain in total heat content of the air and vapor.

Wood flour: Finely ground wood, usually spruce or pine, used as a filler in plastics molding.

Woodmeal: Wood flour filler.

Wood pulp: Wood from which the noncellulosic constituents have been more or less completely separated; used in the manufacture of paper and as a source of cellulose for the manufacture of derivatives.

Wood rosin-colophony: An amorphous solid resin extracted from longleaf pine wood; sp. gr. approximately 1.08; m.p. 70° to 85° C.

Xanthate: Xanthogenate, a salt of xanthic acid of the general type MO·CS·SEt or MO·CSSR, where M is a metal and R an alkyl radical.

Xylene: One of three isomeric liquid hydrocarbons, $C_6H_4(CH_3)_2$, immiscible with water, occurring in coal tar; used as solvent.

Xylenol: Any of six isomeric crystalline compounds of the phenol type, $(CH_3)_2C_6H_3OH$, derived from the xylenes and found in coal tar.

Xylol: Xylene, especially commercial xylene.

Yield value: The lowest pressure at which a plastic will flow, at a specified temperature.

Zanzibar: A very hard, fossil resin obtained from Zanzibar and formerly used extensively in the manufacture of high-grade varnishes.

Zein: Corn protein; used to produce protein-aldehyde plastics somewhat resembling casein plastics.

CHEMICAL GLOSSARY

The chemical glossary consists of a list of most of the more important chemical compounds mentioned in the book, along with a description of their properties and a statement of their use in the plastics industry.

The information is given in the following order:

Name of compound (sometimes followed by synonym); formula; molecular weight; color and form; index of refraction (n); density; melting point; boiling point; solubility; use in plastics.

The index of refraction values are taken at 20° C. (approx. room temperature) unless otherwise indicated by a figure above and to the right of the stated value. Thus x^y indicates a value of x at y° C.

Melting point and boiling point are assumed to be taken at a pressure of 760 mm. Hg (normal atmospheric pressure at sea level) unless a different pressure is indicated. For example, 182.7^{752} indicates boiling point is 182.7 at pressure of 752 mm. Hg.

Density is taken at 20° C. and is referred to the density of water at 4° C. as a base. Specific gravity at other temperatures is shown with superior and inferior figures indicating, respectively, the temperature of the substance and that of water to which it is referred. The density of gases is given in grams per liter at 0° C. and 760 mm. Hg pressure unless otherwise indicated.

All temperatures are Centigrade.

The following abbreviations have been used in the table:

a.	acid	glyc.	glycerin
abs.	absolute	h.	hot
acet.	acetone	insol.	insoluble
alc.	alcohol (ethyl)	lgr.	ligroin
alk.	alkali	liq.	liquid
aq.	aqueous	m.p.	melting point
anhyd.	anhydrous	m.p.d.	melting point with definite decomposition
b.p.	boiling point		
bz.	benzene	me. alc.	methyl alcohol
c.	cold	n	index of refraction
chl.	chloroform	petr. ether	petroleum ether
concd.	concentrated	py.	pyridine
d.	density	sol.	soluble
decomp.	decomposes	soln.	solution
dil.	dilute	tol.	toluene
et.	ethyl	v.	variable
eth.	ether	v. sol.	very soluble
f.p.	freezing point	v. sl. sol.	very slightly soluble
g/l	grams per liter	w.	water
glac.	glacial	∞	soluble in all proportions

Abietic acid: The chief constituent of rosin: $(CH_3)_2CH(CH_3)_2C_{14}H_{16}COOH$ — 302.23; a yellow, amorphous powder; n 1.510, 1.578, 1.618; m.p. 137–166, v.; insol. w., v. sol. alc., v. sol. et., sol. glac. AcOH, acet., bz., CS_2, me. alc.

Rosin and abietic acid derivatives are used as modifiers, especially as plasticizers, in various synthetic resin compositions. Rosin is used as a drier in certain cold molded bituminous preparations and in some alkyd resin compositions to be used for coatings.

Acetaldehyde: CH_3CHO—44.03; a colorless, fuming, inflammable liquid; n 1.3316; d. 0.7834^{18}_{4}; m.p. −123.5; b.p. 21; ∞w., ∞alc., ∞et., ∞bz.

Acetaldehyde reacts with phenol or the cresols to form thermosetting resins similar to the phenolics and also reacts with polyvinyl alcohol to form polyvinyl acetal. Acetaldehyde itself polymerizes to form paraldehyde. It is an intermediate in the manufacture of acetic acid, ethyl acetate, etc., from acetylene.

Acetamide: CH_3CONH_2 — 59.05; colorless hexagonal or rhombohedral deliquescent needles crystallizing from chloroform; n 1.54, 1.46 (stable modification) n 1.370, 1.485, 1.585 (metastable modification); liq. n $1.4274^{78.3}$; d. 1.159^{20}_{4}; m.p. 81; b.p. 222; sol. 97.5^{20}, 178^{60} w., 25.0^{20}, 257.1^{60} alc., sl. sol. et., v. sol. glyc., sol. chl.

Acetanilide: $CH_3CONHC_6H_5$ — 135.08; rhombohedral white leaflets crystallizing from water; d. 1.21^{4}_{4}; m.p. 114; b.p. 305; sol. 563^{25}, 3.5^{80} w., 36.9^{20} alc., sol. et., 13.6^{20}, 44.9^{50} chl., 69.5^{20} me. alc., sol. glyc.

Acetanilide derivatives are used as plasticizers.

Acetic acid: CH_3COOH — 60.03; colorless liquid with a sharp odor; n 1.37182; d. 1.049^{20}_{4}; m.p. 16.6; b.p. 118.1; ∞ w., ∞ alc., ∞ et., insol. CS_2.

Acetic acid is used in the preparation of cellulose acetate and cellulose mixed esters, and in the preparation of polyvinyl acetate. It occurs in dilute form in vinegar.

Acetic anhydride: $(CH_3CO)_2O$ — colorless liquid; n 1.39038; d. 1.08712^{15}_{4}, 1.0820^{20}_{4}; m.p. −73.1; b.p. 140.0; sol. 13.6 c. w. (decomp. w.), ∞ alc., ∞ et., sol. chl., bz.

Employed in combination with or instead of acetic acid in acetylation reactions.

Aceto acetanilide: $CH_3COCH_2CONHC_6H_5$—177.09; leaflets; m.p. 85; sl. sol. w., sol. alc., sol. et., sol. a., alk., h. bz.

Used as a plasticizer (see plasticizer chart).

Acetone: CH_3COCH_3 — 58.05; colorless, inflammable volatile liquid with an ether-like odor and burning taste; n $1.35886^{19.4}$; d. 0.792^{20}_{4}, 0.8186^{0}_{4}; m.p. −95; b.p. 56.5; ∞ w., ∞ alc., ∞ et., sol. chl.

A highly useful solvent, especially in the manufacture of Celluloid and cellulose nitrate lacquers and dopes; and an intermediate in the production of methyl methacrylate plastics.

Acetone cyanohydrin: $(CH_3)_2C(OH)CN$—85.06; colorless liquid; n 1.3996; d. 0.932^{19}; m.p. −19; b.p. 120; 82^{23}; v. sol. w., v. sol. alc., v. sol. et., v. sl. sol. petr. eth.

An intermediate in the manufacture of methyl methacrylate.

Acetyl peroxide: $(CH_3CO)_2O_2$ — 118.05; colorless leaflets; m.p. 30; b.p. 63^{21}; sl. sol. w., v. sol. eth., decomp. NaOH.

An oxidizing agent and polymerization catalyst for such synthetic resins as polystyrene, vinyl ester resins and acrylic resins.

Acetyl triethyl citrate: $C_{14}H_{22}O_8$ — 318; crystalline compound; d. 1.135 at 23° C.; n 1.43^{86} at 23° C.; insol. w.

A plasticizer for cellulose acetate.

Acetylene: CH:CH — 26.02; colorless, inflammable gas; d. liq. 0.6208^{-84}_{4}, solid 0.73^{-85}; gas 1.173° g/l; m.p. −81.8; b.p. −88.5; −83.6 sublimes; sol. 100^{18} cm^3w.; 600^{18} cm^3alc., 2500^{15} cm^3alc., sol. bz., chl.

A raw material for the production of certain synthetic resins, notably vinyl resins and vinylidene chloride resins. It is also a raw material for the production of many solvents and other organic modifiers used in plastics.

Acetylene tetrachloride: $CHCl_2CHCl_2$ — 167.84; colorless, poisonous liquid; n 1.4942; d. 1.600^{20}_{4}; m.p. −43.8 (−36); b.p. 146.3; insol. w., ∞ alc., ∞ eth.

An intermediate product in the manufacture of vinylidene chloride, formed by the reaction of chlorine and acetylene and again reacting with them to form vinylidene chloride.

Acrolein or Acrylic aldehyde: CH_2:CHCHO 56.03; colorless, inflammable liquid, unstable; n 1.39975; d. 0.841^{20}_{4}; m.p. −87.7; b.p. 52.5; sol. 40 w., sol. alc., sol. et.

A substance with an acrid, irritating odor. Acrolein readily polymerizes to form a resin, especially in the presence of small amounts of peroxide formed by contact with air.

Acrylic acid: $CH_2CHCOOH$ — 72.03; colorless liquid; n 1.42^{24}; d. 1.062^{16}; m.p. 12.3; b.p. 141.9; ∞ w., ∞ alc., ∞ et.

An unsaturated acid which polymerizes to form resins.

Acrylonitrile: CH_2:CHCN — 53.03; colorless liquid; m.p. −82; b.p. 78–79; sol. w.

Used as an ingredient in the production of Buna rubbers.

Adipic acid: $COOH(CH_2)_4COOH$ — 146.08; colorless monoclinic prisms; d. 1.366; m.p. 151–3; b.p. 265^{100}; sol. 1.5^{15} w., v. sol. alc., 0.6^{15} et., sol. HNO_3.

A dibasic acid useful for the production of polyamides or Nylons, or for alkyd resins.

Aluminum chloride: $AlCl_3$ — 133.34; hexagonal, white to colorless crystals, very deliquescent with an odor of HCl; d. 2.44^{25}, liq. 1.31^{200}; m.p. $190^{2.5 \text{ atm.}}$; b.p. 182.7^{752}; subl. at 177.8; sol. 69.9^{15} c. w., sol. decomp. h. w., sol. CCl_4, eth., $100^{12.5}$ abs. alc., 0.72^{25} chl., insol. bz.

A catalyst for the reaction of benzene and ethylene to form ethyl benzene, from which in turn styrene, the monomer of polystyrene, is obtained.

Aluminum oxide: Al_2O_3 — 101.94; hexagonal, colorless crystals; d. 3.5–3.9; m.p. 2050; b.p. 2250; sol. 0.000098^{29} c. w., insol. h. w., v. sl. sol. a., alk.

A catalyst for various syntheses, notably the preparation of ethylene from ethyl alcohol, and for various polymerization reactions, especially the polymerization of vinyl esters. Aluminum oxide occurring naturally is called bauxite.

Aluminum sulfate: $Al_2(SO_4)_3$ — 342.12; white powder; d. 2.71; m.p.d. 770; sol. 31.3°, 98.1^{100}, sol. dil. a., sl. sol. alc.

Ammonia: NH_3 — 17.03; colorless gas, $1.325^{16.5}$ liq.; d. 0.7710° g/l; liq. 0.817^{-79}; m.p. −77.7; b.p. −33.35; sol. 89.9° c. w., 7.4^{100} h. w., 13.2^{20} alc., sol. eth.

A source material and (as the hydroxide) a solvent; used with carbon dioxide in the production of urea, and with formaldehyde in the production of hexamethylenetetramine.

Ammonium cyanate: NH_4CNO — 60.05; white crystals; m.p. 60; v. sol. c. w., decomp. h. w., sl. sol. alc., insol. eth.

A compound whose solution on standing changes slowly to urea.

Ammonium oleate: $C_{17}H_{33}COONH_4$ — 302; yellowish soapy mass or yellow powder; insol. w., sol. alc., eth.

An emulsifying agent used to allow polymerization of monomers while held in aqueous emulsion.

Ammonium sulfide: $(NH_4)_2S$ — 68.14; colorless, yellow hygroscopic crystals; m.p.d., v. sol. c. w., decomp. h. w., v. sol. NH_3, sol. alc.

Substance which reacts with calcium cyanamide to form thiourea.

***n*-Amyl acetate or banana oil:** $CH_3COO(CH_2)_4CH_3$ — 130.11; colorless, fragrant liquid; d. 0.879^{20}_{20}; b.p. 148^{737} (145–7); sol. 0.18^{20} w., ∞ alc., ∞ eth.

A solvent for nitrocellulose. Used extensively in lacquers (see solvents chart).

***n*-Amyl alcohols:** Solvent (see solvents chart).

The amyl alcohols are colorless liquids occurring in fusel oil.

Amyl benzoate: Plasticizer, ester (see plasticizer chart).

Amyl borate: Solvent, ester (see solvents chart).

Amyl butyrate: Solvent, ester (see solvents chart).

***n*-Amyl chloride:** Solvent, ester (see solvents chart).

Amyl ether: Solvent, ether (see solvents chart).

Amyl laurate: Solvent, ester (see solvents chart).

Amyl nitrate: Solvent ester (see solvents chart).

Amyl oleate: Solvent, ester (see solvents chart).

Amyl phenyl acetate: Solvent, ester (see solvents chart).

Amyl phenyl-*n*-amyl ether: Solvent, ether (see solvents chart).

Amyl phenyl ether: Solvent, ether (see solvents chart).

Amyl propionate: Solvent, ester (see solvents chart).

Amyl tolyl ether: Solvent, ether (see solvents chart).

Amyl xylyl ether: Solvent, ether (see solvents chart).

Amylene: Solvent, hydrocarbon (see solvents chart).

Aniline: $C_6H_5NH_2$ — 93.06; colorless, oily aromatic liquid; n 1.5863^{20}; d. 1.022^{20}_{4}; m.p. −6.2; b.p. 184.4; sol. 3.4^{20}, 6.4^{90} w., ∞ alc., ∞ eth., ∞ bz.

A raw material for the production of many dyestuffs and other organic compounds and synthetic resins such as aniline-formaldehyde resins. It is also a solvent and paint or other coating remover (see solvents chart).

Anthracene: $C_6H_4{:}(CH)_2{:}C_6H_4$ — 178.08; colorless monoclinic crystals; d. 1.25^{27}_{4}; m.p. 217 (213); b.p. 354–5; insol. w.; 0.076^{16}, 0.83^{355} alc., 1.189 eth., 1.767 chl., 1.500 CS_2; 7.5^{80} bz.

A coal-tar crude important as a base material for the production of numerous dyes.

Arginine: $NH_2C({:}NH)NH(CH_2)_3CH(NH_2)COOH$ — 174.14; prisms crystallizing from water; m.p. 238 decomp.; sol. 15^{21} w., insol. alc., insol. eth.

A basic amino acid whose reaction with formaldehyde is being studied, especially by X ray, in the investigation of the formation of protein plastics such as casein plastics.

Barium peroxide: BaO_2 — 169.36; white-gray powder; d. 4.96; m.p. 450; b.p. −0.800; v. sl. sol. c. w., decomp. h. w., sol. dil. a., insol. acet.

An oxidizing catalyst for various syntheses and polymerization reactions.

Barium sulfate or Barytes: $BaSO_4$ — 233.42; rhombic white crystals; d. 4.50^{15}; m.p. 1580; transformed at 1149 to monoclinic; sol. 0.00023^{18} c. w., 0.00039^{100} h. w., 0.006 in 3% HCl; sl. sol. H_2SO_4.

In its naturally occurring form used as an inorganic filler.

Benzanilide: $C_6H_5CONHC_6H_5$ — colorless leaflets from alcohcl; d. 1.321^{4}_{4}; m.p. 161; b.p. $117\text{-}9^{10}$; v. sl. sol. w., 3.16^{30} alc., sl. sol. eth.

Benzene: C_6H_6 — 78.05; inflammable liquid; n 1.50165; d. 0.8941^{0}_{4}; m.p. 5.48; b.p. 80.08; sol. 0.0802^{22} w., ∞ alc., ∞ eth., ∞ AcOH, acet., tol., sol. chl.

A solvent especially for varnishes and lacquers and starting point in the synthesis of many materials used in plastics, notably aniline, chlorobenzene for phenol, and benzene disulfonic acid for resorcinol.

Benzophenone: $(C_6H_5)_2CO$ — 182.08; A (stable), colorless rhombic prisms; B, colorless monoclinic prisms; d. A, 1.0976^{50}_{50}, B, 1.108^{23}_{4}; m.p. A, 49, B, 26 — 245-8, 8-51; b.p. 306; insol. w., 13.5^{18} alc., 17.5^{13}, sol. chl.

A useful plasticizer (see plasticizer chart).

Benzoyl acetone: $C_6H_5COCH_2COCH_3$ — 162; colorless liquid; n 1.5678 at 25°; d. 1.090 at 15°; m.p. 58; b.p. 261–262; sol. w.

A plasticizer (see plasticizer chart).

Benzoyl peroxide: $(C_6H_5CO)_2O_2$ — 242.08; colorless rhombic crystals from ether; n 1.545; m.p. 103.5 (106–8); b.p. explodes; sl. sol. w., sol. alc., sol. eth., 2.53^{15} CS_2, sol. bz., olive oil.

An oxident and catalyst for polymerization reactions of several important synthetic resins, notably acrylic and vinyl resins.

Benzyl alcohol: A solvent — alcohol (see solvents chart).

Benzyl cellulose: The benzyl ester of cellulose, adaptable for use as a plastic and in coatings. For its chemical properties see the section on the Chemistry of Plastics.

1,3-Butadiene, divinyl, or erythrene: $CH_2{:}CHCH{:}CH_2$ — 54.05; a gas; d. 0.650^{-6}_{4}; m.p. -5^{713}; b.p. −3; insol. w., v. sol. alc., ∞ eth.

A diolefin of a type that polymerizes to form rubber-like substances and hence is used in the production of synthetic rubber.

***n*-Butanol or Butyl alcohol:** $CH_3(CH_2)_2CH_2OH$ — 74.08; colorless liquid; n 1.39931; d. 0.80978^{20}_{4}; m.p. −89.2 to −89.8 (−79.9); b.p. 117.71; sol. $7.9^{20w.}$, ∞ alc., ∞ eth.

An inexpensive, widely used solvent obtained from corn by fermentation. It is widely used in lacquers because it is blush retardant, and dissolves cellulose nitrate in the presence of a minimum amount of solvent ester (see solvents chart).

Butoxyethyl stearate: $C_{17}H_{35}COOC_2H_4OC_4H_9$ — 384; d. 0.885 at 20°; m.p. 16.5; b.p. 214–230 at 4 mm.; insol. w.

A plasticizer (see plasticizer chart).

***n*-Butyl acetate:** A solvent, ester (see solvents chart).

sec-Butyl acetate: A solvent, ester (see solvents chart).

Butyl alcohol: See Butanol. There are four isomeric butyl alcohols.

Butyl amine: A solvent, amine (see solvents chart).

Butyl borate: A solvent, ester (see plasticizer chart).

***n*-Butyl chloride:** A solvent, ester (see solvents chart).

Butyl crotonate: A solvent, ester (see solvents chart).

Butyl ether: A solvent, ether (see solvents chart).

Butyl lactate: A solvent, ester (see solvents chart).

Butyl phthalyl butyl glycolate: $C_4H_9OCOC_6H_4COOCH_2COOC_4H_9$ — 336; liq.; n 1.490 at 25°; d. 1.097 at 25°; b.p. 219 at 5 mm.

A plasticizer, also known as Santicizer B-16 (see plasticizer chart).

***n*-Butyl propionate:** A solvent, ester (see solvents chart).

Butyl stearate: $C_{17}H_{35}COOC_4H_9$ — 340; n 1.4446 at 20°; d. 0.855–0.862 at 25°; m.p. ca. 20; b.p. 220–5 at 25 mm.

A plasticizer (see plasticizer chart).

Butyraldehyde: $CH_3(CH_2)_2CHO$ — 72.06; colorless liquid; n 1.38433; d. 0.817^{20}_{4}; m.p. −99.0; b.p. 75.7; sol. 3.7 w., ∞ alc., ∞ eth.

An aldehyde that can be used in place of formaldehyde in various resins. One of the better known butyraldehyde resins is vinyl butyraldehyde resin.

Butyric acid: $CH_3CH_2CH_2COOH$ — 88.06; colorless liquid; n 1.39906; d. 0.9587^{20}_{4}; m.p. −7.9; f.p. −19; b.p. 163.5; sol. $5.62^{-1.1}$ w., ∞ alc., ∞ eth.

An acid used in the production of cellulose acetate butyrate and other butyric esters for plastics.

Calcium carbide: CaC_2 — 64.08; rhombic gray crystalline compound; d. 2.22; m.p. 2300; decomp. to $Ca(OH)_2 + C_2H_2$ in w., insol. c. HCl, not decomposed by concd. H_2SO_4.

As a source of acetylene, calcium carbide is an important raw material for synthetic resins, especially vinyl ester resins and vinylidene chloride. Acetylene is also the base material for the manufacture of many other organic compounds used in various plastics. The calcium carbide itself is used as a raw material in the production of melamine-formaldehyde resins.

Calcium cyanamide: N:C·N:Ca — 80.10; colorless hexagonal rhombohedral crystals; m.p. 1190; decomp. w. with evolution of NH_3.

The product of calcium carbide and nitrogen passed through the electric furnace, and the source material for dicyanodiamide.

Calcium hypochlorite: $Ca(ClO)_2 4H_2O$ — 215.06; colorless, deliquescent crystals. m.p. decomp.; v. sol. c. w., decomp. h. w., decomp. a.

Bleaching powder, a solution of which is used to bleach cotton linters or other cellulosic material which is being prepared for acetylation or esterification for the production of various cellulose plastics. Fillers may also be bleached with this.

Calcium oxide, or lime: CaO — 56.08; colorless cubic crystals; n 1.83; d. 3.40; m.p. decomp.; sl. sol. c. w., sol. a.

A raw material for the manufacture of calcium carbide and many other synthetic materials used as intermediates or in the finished plastics of various kinds.

Calcium stearate: $(CH_3(CH_2)_{16}COO)_2Ca$ — 606.

A plasticizer and waterproofing agent incorporated in small amounts in such plastics as phenolics.

***d*-Camphor:** $C_{11}H_{16}O$ — 152.12; colorless crystals with a characteristic odor; n 1.532 (1.5462), d. 1.000^{0}_{0}, 0.990^{25}_{4}; m.p. 176–7; b.p. 204 sublimes; sol. 0.1 w., 100 alc., 173 eth., 300 chl., sol. CS_2, bz., me. alc., AcOH, acet.

The chief plasticizer for cellulose nitrate plastics imparting its characteristic odor to Celluloid (see plasticizer chart).

Carbamide: See Urea.

Carbolic acid: See Phenol.

Carbon disulfide: CS_2 — 76.12; colorless, inflammable liquid; n 2.162950^{18}; d. 1.2628^{20}_{4}; m.p. −108.6; f.p. −111, b.p. 46.3; sol. 0.22^{22} w., ∞ al., ∞ eth., ∞ bz.

Used as a solvent and in the manufacture of Cellophane.

Carbon monoxide: CO — 28.00; colorless, odorless, poisonous gas; d. liq. 0.814^{-195}_{4}, 1.250^{0}_{4} g/l; m.p. 207 (−213); b.p. −190 (−192); sol. 0.0044° g., 0.0028^{20} g, 0.0010^{80} g, 3.5° cm³ w., 20^{20} cm³ alc., sol. bz., AcOH, Cu_2Cl_2.

A raw material for the synthetic production of methyl alcohol and of formaldehyde.

Carbon tetrachloride: A solvent, hydrocarbon (see solvents chart).

Cellulose: $(C_6H_{10}O_5)_x$ — $(162.08)_x$; a white, amorphous substance; d. 127–1.61; insol. w., insol. alc., insol. eth., sol. $Cu(NH_3)_4(OH)_2$; insol. all ordinary organic solvents.

Cellulosic materials are treated to purify the cellulose as much as possible, and then subjected to reagents to esterify or etherify them to yield plastics materials.

Cellulose acetate: cellulose ester. See material on Chemistry of Plastics for further information.

Cellulose acetate butyrate: See material on Chemistry of Plastics for further information.

Cellulose ester: See material on Chemistry of Plastics for further information.

Cellulose nitrate: See material on Chemistry of Plastics for further information.

Chloracetyl chloride: Solvent (see solvents chart).

Chlorinated diphenyl: $ClC_6H_4C_6H_5$ — 188.53; crystalline compound.

	m.p.	b.p.	solubility
o-chlorodiphenyl	32	273–4	insol. w., sol. alc., v. sol. eth., sol. lgr., CCl_4
m-chlorodiphenyl	89	284–5	insol. w., sol. alc., sol. eth.
p-chlorodiphenyl	77 (66–75)	291.2^{745} (282)	insol w., sol. alc., sol. eth., sol. lgr.

A plasticizer for certain plastics such as ethyl cellulose (see plasticizer chart).

Chlorine: Cl_2 — 34; yellow gas with irritating odor (poisonous); sol. w.

A raw material for the synthesis of various organic compounds such as vinylidene chloride, chloroform, etc.

Chloroform: A solvent (see solvents chart).

Cresol: $CH_3C_6H_4OH$ — 108.06. One of a series of three compounds.

o-cresol: colorless crystals or liquid; n 1.5453; d. $1.0465\frac{20}{4}$; m.p. 30; b.p. 1915; sol. 3.1^{40}, 5.6^{100} w., ∞^{730} alc., ∞^{730} eth., sol. chl., sol. ordinary organic solvents.

m-cresol: colorless liquid; n 1.5398; d. $1.034\frac{20}{4}$; m.p. 11–2; b.p. 202.8; sol. 2.35^{20}, 5.8^{100} w., ∞ alc., ∞ eth., sol. chl., sol. ordinary organic solvents.

p-cresol: colorless prisms; n. 1.5395; d. $1.0347\frac{20}{4}$; m.p. 36 (32–34); b.p. 202.5; sol. 2.4^{40}, 5.3^{100} w., ∞^{736} alc., ∞^{736} eth., sol. ordinary organic solvents.

Cresols are used to replace phenol partially in phenol-formaldehyde plastics, and in other condensation reactions where phenol may or may not be used.

***o*-Cresyl-*p*-toluene sulfonate:** $CH_3C_6H_4SO_2OC_6H_4CH_3$ — 262; n 1.558 at 25°; d. 1.207 at 25°; m.p. 52.5; sol. 0.0003.

A common plasticizer, known also as Santicizer 10.

Cumarone, or Benzofuran: $\underline{C_6H_4OCH{:}CH}$ — 118.05; a liquid ; n $1.56450^{22.7}$; d. $1.0776\frac{15}{15}$; m.p. −18; b.p. 174 (169); insol. w., sol. alc., sol. eth., insol. alk.

A constituent of high boiling naphtha, which will polymerize alone or with indene to form a resin with properties suited for use as a binder or coating material.

Cyclohexane: A solvent — hydrocarbon (see solvents chart).

Cyclohexanol: A solvent — alcohol (see solvents chart).

Cyclohexanone: A solvent — ketone (see solvents chart).

Cyclohexyl-*p*-toluene sulfonamide: $CH_3C_6H_4SO_2NHC_6H_{11}$ — 253; n 1.542 at 25°; m.p. 86; sol. 0.006 w.

A plasticizer, also known as Santicizer 1–H.

Decalin or decahydronaphthalene: A solvent — hydrocarbon (see solvents chart).

Diacetone alcohol: A solvent — both a ketone and an alcohol (see solvents chart).

Diamyl naphthalene: $C_{10}H_6(C_5H_{11})_2$ — 268; colorless liquid; n 1.5535; d. 0.93–4; b.p. 326–375; insol. w.

A plasticizer (see plasticizer chart).

Diamyl nitrosoamine: A solvent — amine.

Diamyl phthalate: $C_8H_4(COOC_5H_{11})_2$ — 306; colorless liquid; n 1.488^{25}; d. 1.022^{25}; m.p. −55; b.p. 342; sol. 0.010 w.

A plasticizer (see plasticizer chart).

Dibutoxy ethyl phthalate: $C_6H_4(COOC_2H_4OC_5H_9)_2$ — 366; colorless liquid; d. 1.063; m.p. −18; b.p. 220–230^4; sol. 0.1^{25} w.

A plasticizer, also known as Dibutyl Cellosolve phthalate, and Kronisol (see plasticizer chart).

Di-*n*-butylamine: A solvent — amine (see solvents chart).

Dibutyl phthalate: $CH(COOC_4H_9)_2$ — 278.17; colorless oily liquid; d. 1.0465; b.p. 340; sol. 0.04^{25} w., ∞ alc., ∞ eth., ∞ acet., bz.

An important plasticizer for cellulose nitrate and other cellulose derivatives (see plasticizer chart).

Dibutyl sebacate: $C_4H_9OCO(CH_2)_8COOC_4H_9$ — 314; colorless liquid; n 1.4391; d. 0.936^{25}–0.942^{25}; b.p. 344–5; sol. 0.1.

A plasticizer (see plasticizer chart).

Dibutyl succinate: $C_{12}H_{14}O_3(OCOCH_3)_8$ — 678; colorless liquid; n 1.428^{25}; d. 0.974^{25}; m.p. −19; b.p. 255; sol. 0.023 w.

A plasticizer (see plasticizer chart).

Dibutyl tartrate: $C_4H_9OCO(CHOH)_2COOC_4H_9$ — 262; n 1.445^{25}; d. 1.086^{25}; m.p. 21; b.p. 292–312; sol. 0.485 w.

A good plasticizer for cellulose acetate (see plasticizer chart).

1,2-Dichloroethane or ethylene chloride: CH_2ClCH_2Cl — 98.95; colorless liquid; n 1.44432; d. 1.257^{20}_{4}; m.p. −35.3; b.p. 83.5–83.7; sol. 0.92°, 0.869^{20} w., sol. alc., ∞ eth., sol. ordinary organic solvents.

A liquid that reacts with alkali polysulfides to form a rubberlike material (Thiokol).

Dicyanodiamide: $NH_2C(:NH)NHCN$ — 84.06; rhombic leaflets; d. 1.40^{14}_{4}; m.p. 205 (207); b.p. decomp.; sol. 2.26^{13} w., 1.26^{13} alc., 0.01^{13} eth., insol. bz.

A compound prepared from calcium cyanamide and water, and used in the production of melamine, which in turn is used for melamine formaldehyde plastics.

Di-(diethylene glycol monoethyl ether)-phthalate: $C_6H_4(COOCH_2CH_2OCH_2CH_2OC_2H_5)_2$ — 398; colorless liquid; d. 1.121; m.p. −17; b.p. $235\text{–}255^{14}$; sol. w.

A plasticizer, also known as Di-Carbitol phthalate (see plasticizer chart).

Diethoxyethyl adipate: $C_2H_5OC_2H_4OCO(CH_2)_4COOC_2H_4OC_2H_5$ — 290; colorless liquid; n 1.439^{25}; d. 1.036^{25}; m.p. −70; sol. 0.248 w.

A plasticizer (see plasticizer chart).

Diethoxyethyl phthalate: $C_6H_4(COOC_2H_4OC_2H_5)_2$ — 310; n 1.492^{25}; d. 1.120; m.p. 30; b.p. $202\text{–}212^{4}$; sol. 0.195 w.

A plasticizer, also known as Ethox or Di Cellosolve phthalate (see plasticizer chart).

Diethyl adipate: $(CH_2CH_2COOC_2H_5)_2$ — 202.14; colorless liquid; d. 1.009^{20}_{4}; m.p. −21; b.p. $239\text{–}41^{761}$; sol. 0.423^{20} w., sol. alc., sol. eth.

A plasticizer (see plasticizer chart).

Diethylaminoethanol: A solvent — amine. Colorless liquid.

Diethyl carbonate: A solvent — ester (see solvents chart). Colorless inflammable liquid.

Diethyl phthalate: $C_6H_4(COOC_2H_5)_2$ — 222.11; colorless liquid; n 1.5019; d. 1.123^{25}_{4}; b.p. 296.1; insol. w., ∞ alc., ∞ eth., sol. bz.

A plasticizer (see plasticizer chart).

Diethyl sebacate: $([CH_2]_4COOC_2H_5)_2$ — 258.20; colorless liquid; d. 0.9646^{20}_{4}; m.p. 1; b.p. 308; sol. 0.008^{20}_{4} w., sol. alc., sol. eth.

A plasticizer (see plasticizer chart).

Diethyl succinate: $(CH_2COOC_2H_5)_2$ — 174.11; colorless liquid; n 1.42007; d. 1.0402^{20}_{4}; m.p. −21; b.p. 217.7; insol. w., ∞ alc., ∞ eth.

A plasticizer (see plasticizer chart).

Diethyl *d*-tartrate: $(CH[OH]COOC_2H_5)_2$ — 206.11; colorless hygroscopic liquid; n 1.4454^{25}; d. 1.2036^{20}_{4}; m.p. 17; b.p. 280; sl. sol. w., ∞ alc., ∞ eth.; sol. ordinary organic solvents.

A plasticizer.

Diethylene glycol diacetate: $(CH_3COOCH_2CH_2)_2O$ — 190; colorless liquid; d. 1.116; b.p. 250; ∞ water.

A plasticizer (see plasticizer chart).

Diethylene glycol monobutyl ether acetate: Solvent — ester (see solvents chart). Colorless liquid.

Diethylene glycol monoethyl ether acetate: Solvent — ester (see solvents chart). Colorless liquid.

Diethylene glycol monomethyl ether acetate: Solvent — ester (see solvents chart). Colorless liquid.

Diethylene glycol propionate: $(CH_3CH_2COOCH_2CH_2)_2:O$ — 218; colorless liquid; n 1.429^{25}; d. 1.066; b.p. $114\text{–}140^{4}$; sol. 3.60 water.

A plasticizer. Also known as K P — 45.

Diethylene triamine: Solvent — amine (see solvents chart). Colorless liquid.

Dihydroxy ethyl aniline: Solvent — amine (see solvents chart).

Di-isopropanolamine: Solvent — amine (see solvents chart). Colorless liquid.

Dimethoxyethyl phthalate: $C_6H_4(COOC_2H_4OCH_3)_2$; colorless liquid; n 1.500^{25}; d. 1.170; m.p. -60; b.p. $190\text{-}205^4$; sol. 0.838 w.

A plasticizer. Also known as Methox, or Dimethyl Cellosolve phthalate (see plasticizer chart).

Di-(methylcyclohexyl adipate): $CH_3C_6H_{10}OCO(CH_2)_4COOC_6H_{10}CH_3$ — 338; colorless liquid; n 1.4685; d. 1.091; m.p. $-45°$; b.p. $200\text{–}230^{12}$; insol. w.

A plasticizer. Also known as Sipalin A O M (see plasticizer chart).

Dimethyl furan: A solvent — furan.

Dimethyl phthalate: $C_6H_4(COOCH_3)_2$ — 194; colorless liquid; n $1.51546^{20.8}$; d. 1.193^{25}; b.p. 282; sol. 0.5 w.

A plasticizer for cellulose acetate and other cellulose derivatives (see solvents chart).

Dimethyl sulfate: $(CH_3)_2SO_4$; colorless, heavy liquid, almost odorless and very poisonous; n 1.3874; d. 1.3322^{20}_{4}; m.p. -31.8; f.p. -27; b.p. 188; v. sl. sol. w., ∞ alc., sol. eth., sol. bz.

A reagent widely used industrially to introduce the methyl group into an organic molecule. It is used in the preparation of methyl cellulose by direct methylation of cellulose.

Dimethylene urea: $(N{:}CH_2)_2CO$ — 84; the B-stage urea resin, the formation of which from dimethylol urea in the presence of a catalyst is characterized by a change through a viscous liquid to a gel.

Dimethylol urea: $(NHCH_2OH)_2CO$ — 120; a colorless liquid, the principal ingredient of the A-stage urea resin, formed by the condensation of one molecular proportion of urea with two of formaldehyde.

Di-sec-octylamine: A solvent — amine (see solvents chart). Colorless liquid.

Di-sec-octylaminoethanol: A solvent — amine (see solvents chart).

Dioctyl phthalate: $C_6H_4(COOC_8H_{17})_2$ — 390; colorless liquid; d. 0.984; b.p. $215\text{-}230^4$; insol. w.

A plasticizer (see plasticizer chart).

Dioxolane: A solvent — ether (see solvents chart). Colorless liquid.

Diphenyl guanidine or Melaniline: $NH{:}C(NHC_6H_5)_2$ or $C_6H_5NHC({:}NC_6H_5)NH_2$ — 211.13; monoclinic needles crystallizing from alcohol; d. 1.13^{20}_{4}; m.p. 147–8; b.p. decomp. 170; sl. sol. w., 9.1^{20} 90%, 5^{16} alc., v. sl. sol. eth., sol. CCl_4, chl., h. bz., h. tol., dil. mineral a.

An accelerator in rubber and plastics manufacture.

Diphenyl mono-*o*-xenyl phosphate: $(C_6H_5C_6H_4O)(C_6H_5O)_2PO$ — 478; n $1.603\text{–}5^{60}$; d. 1.20^{60}; b.p $285\text{–}330^5$; insol. w.

A plasticizer, also known as Dow Plasticizer 5 (see plasticizer chart).

Diphenyl phthalate: $C_6H_4(COOC_6H_5)_2$ — 318; n 1.572^{74}; d. 1.28^{25}; m.p. 69; b.p. $250\text{–}257^{14}$; insol. w.

A plasticizer.

Dipropyl phthalate: $C_6H_4(COOC_3H_7)_2$ — 250; colorless liquid; n 1.494^{25}; d. 1.071^{25}; b.p. $129\text{–}132^1$; sol. 0.015 w.

A plasticizer.

Divinyl ether, or vinyl ether: $(CH_2{:}CH)_2O$ — 70.05; colorless liquid; d. 0.774^{20}_{20}; b.p. 39 (28.3); insol. w., ∞ alc., ∞ eth.

A vinyl ether which is readily polymerized to a thermoplastic resin.

Di-*o*-xenyl mono-phenyl phosphate: $C_{30}H_{23}O_4P$ — 478; colorless liquid; n $1.603\text{–}5^{60}$; d. 1.20^{60}; b.p. $285\text{–}330^5$; insol. w.

A plasticizer, also known as Dow Plasticizer 6.

Docosane (n): $(CH_3CH_2)_{20}CH_3$ — 310.36; crystals from alcohol; d. 0.778^{44}_{4}; m.p. 44.4; b.p. 317.4 (224^{15}) insol. w., 4^{78} alc., v. sol. eth.

A solvent hydrocarbon.

Ether: See Ethyl ether.

Ethyl acetate: A solvent — ester (see solvents chart). Colorless liquid with fruity odor.

Ethyl aceto-acetate: A solvent — ester. Colorless liquid.

Ethyl alcohol: A solvent — alcohol (see solvents chart). Colorless liquid.

Ethyl benzene: $C_2H_5C_6H_5$ — 106.08; colorless liquid; n $1.49828^{14.5}$; d. 0.8669^{20}_{4}; m.p. −93.9 (−92.8); b.p. 136.15 (134–6); sol. 0.014^{15} w., ∞ alc., ∞ eth.

A raw material for the preparation of vinyl benzene or styrene, which is polymerized to form polystyrene.

Ethyl chloride: CH_3CH_2Cl — 64.50; colorless liquid or gas; d. 0.9214^{0}_{4}; m.p. −138.7; b.p. 12.2; sol. 0.574^{20} w., 48.3^{21} alc., ∞ eth.

Gaseous ethyl chloride is reacted with sodium cellulose under heat and pressure to yield ethyl cellulose for the production of ethyl cellulose plastics.

Ethyl crotonate: A solvent, ester (see solvents chart).

Ethyl ether: A solvent, ether (see solvents chart). Colorless volatile liquid.

Ethyl formate: A solvent, ester (see solvents chart). Colorless liquid.

Ethyl lactate: $CH_3CH(OH)COOC_2H_5$ — 118.08; colorless liquid; d. 1.031^{20}_{4}; b.p. 154 (150–2); ∞ w., v. sol. alc., v. sol. eth.

Ethyl phthalyl ether: Colorless liquid; d. 1.177; b.p. 190.

A solvent for cellulose acetate.

Ethyl phthalyl ethyl glycollate: $C_2H_5OCOC_6H_4COOCH_2COOC_2H_5$ — 280; colorless liquid; n 1.498^{25}; d. 1.180^{25}; b.p. 190^{5}; sol. 0.050 w.

A plasticizer. Also known as Santicizer E–15 (see plasticizer chart).

Ethylene: $CH_2{:}CH_2$ — 28.03; colorless gas; n 1.363^{-100}, ∞ 1.245° g/l; 0.566^{-102}_{4}; m.p. −169.4; f.p. −1.81; b.p. −103.9; sol. 25.6° $^{cm^3}$ w, 360 $^{cm^3}$ alc., sol. eth.

An unsaturated gaseous hydrocarbon used as a starting material in numerous organic syntheses, such as the synthesis of acrylic esters.

Ethylene chloride: CH_2ClCH_2Cl — 98.95; colorless liquid; n 1.44432; d. 1.257^{20}_{4}; m.p. −35.3; b.p. 83.5–83.7; sol. 0.92°, 0.869^{20} w., sol. alc., ∞ eth., sol. ordinary organic solvents.

A compound formed by the direct combination of ethylene and chlorine or by heating glycol with hydrochloric acid. Vinyl chloride may be prepared by treating ethylene dichloride with alcoholic potassium hydroxide.

Ethylene chlorohydrin: CH_2ClCH_2OH — 80.50; colorless liquid; d. 1.213^{20}_{4}; m.p. −69; b.p. 128.8; sol. ∞ w., sol. alc., 2.3^{15} eth.

An intermediate product in the synthesis of acrylic esters for plastics. Also a solvent — halogenated compound (see solvents chart).

Ethylene diamine: A solvent — amine (see solvents chart). Colorless liquid.

Ethylene dibromide: A solvent — halogenated compound (see solvents chart). Colorless liquid.

Ethylene dichloride: A solvent — halogenated compound (see solvents chart). Colorless liquid.

Ethylene glycol: A solvent — glycol (see solvents chart). Colorless liquid.

Ethylene glycol diacetate: $(CH_3OCOCH_3)_3$ — 146; colorless liquid; n 1.414^{25}; d. 1.104^{20}; m.p. −70; b.p. 186; sol. 1.815 w.

A solvent ester.

Ethylene glycol dibutyrate: $(CH_2OCOC_3H_7)_2$ — 202; n 1.424^{25}; d. 1.024^{0}_{4}; m.p. −80; b.p. 240; insol. w, sol. alc.

A plasticizer (see plasticizer chart).

Ethylene glycol diethyl ether: A solvent — ether (see solvents chart).

Ethylene glycol dipropionate: $(CH_2OCOC_2H_5)_2$ — 174; n 1.419^{25}; d. 1.054^{15}; m.p. −80; b.p. 211; sol. 0.160 w.

A plasticizer (see plasticizer chart).

Ethylene glycol monobenzyl ether: solvent — ether (see solvents chart).

Ethylene glycol monobutyl ether: solvent — ether (see solvents chart).

Ethylene glycol monoethyl ether: solvent — ether (see solvents chart).

Ethylene glycol monoethyl ether acetate: solvent — ester (see solvents chart).

Ethylene glycol monomethyl ether: solvent — ether (see solvents chart).

Ethylene glycol monomethyl ether acetate: solvent — ester (see solvents chart).

Ethylene glycol monophenyl ether: solvent — ether (see solvents chart).

Formaldehyde: HCHO — 30.02; colorless gas; d. 0.815^{-20}_{4}; m.p. −92; b.p. −21; sol. w., sol. alc., sol. eth.

An aldehyde most widely used in plastics. It condenses with phenol, urea, aniline, melamine, etc., to form synthetic resins, and is used as a hardener for casein and other protein plastics.

Formamide: $HCONH_2$ — 45.03; colorless liquid; n $1.44530^{22.7}$; d. 1.134^{20}_{4}; 1.1292^{25}_{4}; m.p. 2.55; b.p. 210.7 decomp. ($92\text{–}5^{10}$); sol. ∞ w., ∞ alc., sl. sol. eth., sl. sol. bz.

Used as a curing or hardening agent for zein and other protein plastics.

Furfural or furfuraldehyde: C_4H_3OCHO — 96.03; colorless liquid; n 1.52608; d. 1.1598^{20}_{4}; m.p. −38.7; b.p. 161.7; sol. 8.3^{20} w., ∞ alc., ∞ eth.

An aldehyde obtained from pentosons (found in farm products such as oat hulls, woody fibers, etc.) which can be condensed with phenol and other substances to form synthetic resins and which itself polymerizes.

Furfuryl alcohol: A solvent — furan (see solvents chart).

Glycerol, or Glycerin: $CH_2OHCHOHCH_2OH$ — 92.06; colorless liquid (or rhombic crystals); n 1.4729; d. 1.260^{20}_{4}; m.p. 17.9 (solidifies at considerably lower temperature); b.p. 290; ∞ w., ∞ alc., insol. eth., insol. chl.

Glycerol is used as a modifier in numerous plastics, especially to increase the transparency of cast phenolics. It also has a hardening effect.

Glycerol diacetate: $C_3H_5(OH)(OOCCH_3)_2$ — 176; d. 1.184^{16}; b.p. 176^{40}; ∞ w.

A plasticizer. Also called diacetin (see plasticizer chart).

Glycerol monoacetate: $CH_2OHCHOHCH_2OOCCH_3$ — 134; n 1 4535; d. 1.206^{20}; m.p. 40; b.p. 158^{165}; ∞ w.

A plasticizer. Also called acetin (see plasticizer chart).

Glycerol triacetate: $C_3H_5(OOCCH_3)_3$ — 218; n 1.429^{25}; d. 1.161^{20}; m.p. −78; b.p. 259–262; sol. 6.69^{20} w.

A plasticizer. Also called triacetin (see plasticizer chart).

Glycerol tributyrate: $(CH_3CH_2CH_2CO)_3C_3H_5O_3$ — 302; n 1.4359^{20}; d. 1.035^{20}; m.p. −75; b.p. 315; sol. 0.010 w.

A plasticizer. Also called tributyrin (see plasticizer chart).

Glycerol tripropionate: $C_3H_5(OCOC_2H_5)_3$ — 260; n 1.431^{20}; d. 1.078^{20}; m.p. −50; b.p. $177\text{–}182^{20}$; sol. 0.313.

A plasticizer. Also called tripropionin (see plasticizer chart).

Glycol: See Ethylene glycol.

Glycol diacetate: A solvent — ester (see solvents chart).

Glycol sebacate: $(\text{—}CH_2CH_2OCO(CH_2)_8COO\text{—})\,n$ — (228) n.

A plasticizer. Also called Paraplex.

sec-Heptadecyl alcohol: A solvent — alcohol (see solvents chart).

sec-Heptyl alcohol: A solvent — alcohol (see solvents chart).

Hexamethylenetetramine: $(CH_2)_6N_4$ — 140.13; rhombic crystals from alcohol; m.p. 263; b.p. sublime at 263°; sol. 150^{20} w., 3 alc., insol. eth., sol. H_2SO_4.

A basic catalyst and accelerator used in the manufacture of phenolics, ureas and other plastics.

Hexane: $CH_3(CH_2)_4CH_3$ — 86.11; colorless liquid; n 1.37536; d. 0.6603^{20}_{4}; m.p. −94.3; b.p. 69.0; sol. $0.0138^{15.5}$ w., 50^{33} alc., sol. eth., sol. chl.

A solvent, used especially in the extraction of zein.

sec-Hexyl acetate: A solvent — ester (see solvents chart).

Hexyl alcohols: Solvents (see solvents chart).

Hydrochloric acid: HCl — 36.47; colorless gas or colorless poisonous fuming liquid; n 1.256; d. 1.639° g/l; m.p. −112; b.p. −83.7; sol. 82.3° (gas) c. w., 56.1^{00} (gas) h. w., 327 $^{cm^3}$ alc., sol. eth.

An acid used as a catalyst and in the production of such compounds as vinyl chloride, ethyl chloride, etc.

Hydrogen peroxide: H_2O_2 — 34.02; colorless liquid; n 1.414^{22} (liq.); d. 1.4631°; m.p. −1.7; b.p. 152.1; ∞ c. w., sol. alc., eth., insol. petr. eth.

An oxidizing polymerization catalyst for numerous synthetic resins.

Hydroxyethyl aniline: A solvent — amine.

Hydroxyethyl ethyl aniline: A solvent — amine.

Hydroxyethyl ethylene diamine: A solvent — amine (see solvents chart).

Indene: $\underline{C_6H_4CH_2:CHC}H$ — 116.06; colorless liquid; n $1.57107^{12.7}$; d. 1.006^{20}_{4}; m.p. −2; b.p. 182.4; insol. w., ∞ alc., ∞ eth., sol. pyr., CCl_4, acet., CS_2.

A product of the fractional distillation of coal tar, which polymerizes itself or with cumarone to form light-colored thermoplastic binding materials.

Isoamyl alcohol: Solvent — alcohol (see solvents chart).

Isobutyl acetate: Solvent — ester (see solvents chart).

Isobutyl alcohol: Solvent — alcohol (see solvents chart).

Isophorone: Solvent — ketone (see solvents chart).

Isopropyl acetate: Solvent — ester (see solvents chart).

Isopropyl alcohol: Solvent — alcohol (see solvents chart).

Isopropyl benzene: Solvent — hydrocarbon (see solvents chart).

Isopropyl ether: Solvent — ether (see solvents chart).

Lactic acid: (dil): $CH_3CHOHCOOH$ — 90.95; colorless hygroscopic syrup; n 1.4414; d. 1.249^{15}; m.p. 18; b.p. 122^{15}; sol. ∞ w., ∞ alc., ∞ eth.

Reacts with glycerol to form an alkyd resin; used as a catalyst for the polymerization of vinyls; added with glycerin to phenolics to aid hardening and transparency. Used in making cast phenolic resins.

Magnesium carbonate: $MgCO_3$ — 84.33; triagonal white crystals; n 1.717, 1.515; d. 3.037; m.p. decomp. 350; b.p. $(CO_2)900$; sol. 0.0106 c. w., sol. a., aq. CO_2; insol. acet., NH_3.

A filler or modifier for phenolic resins and synthetic rubber.

Maleic anhydride: $\underline{OCOCH:CHC}O$ — 98.02; colorless rhombic needles from chloroform; d. 0.934^{20}_{4}; m.p. 53 (57–60); b.p. 202 (196); sol. $16.32^{29.7}$ w., v. sl. sol. alc., sol. CCl_4.

Reacts with polyhydric alcohols to form an alkyd resin. Also used as a hardener in ureas, phenolics, alkyds, etc.

Mesityl oxide: A solvent — ether (see solvents chart).

Metastyrene: Another name for polystyrene resin.

Methane or marsh gas: CH_4 — 16.03; colorless gas; d. 0.415^{-164}; m.p. −184; b.p. −161.5; b.p. −161.5; sol. 9^{20} cm^3 w., 60 cm^3 alc., 91^{20} cm^3 eth.

The simplest aliphatic hydrocarbon, starting point for many organic syntheses.

Methoxy ethyl oleate: $C_8H_{17}CH{=}CH(CH_2)_7COOC_2H_4OCH_3$ — 340; d. 0.902; b.p. 195–225^4; insol. w.

A plasticizer. Also called Kapsol, Methyl Cellosolve oleate (see plasticizer chart).

Methyl acetate: A solvent — ester (see solvents chart). Colorless liquid.

Methyl aceto-acetate: A solvent — ester. Colorless liquid.

Methyl acrylate: $CH_2CHCOOCH_3$ — 86.05; colorless liquid; n 1.3984; d. 0.956^{18}_{4}; b.p. 80.5; sol. alc., eth.

A monomer which polymerizes to a clear, colorless, light, tough, thermoplastic resin.

Methyl alcohol: A solvent — alcohol (see solvents chart).

Methyl-*n*-amyl ketone: A solvent — ketone (see solvents chart).

Methyl-*o*-benzoyl benzoate: $C_6H_5COC_6H_4COOCH_3$ — 240; n 1.587^{25}; d. 1.190^{25}; m.p. 52; b.p$_4$ 351; sol. 0.005 w.

A plasticizer (see plasticizer chart).

Methyl cyclohexane: A solvent — hydrocarbon (see solvents chart).

Methyl cyclohexanol: A solvent — alcohol (see solvents chart).

Methyl cyclohexanone glyceryl acetal: $\overline{\underline{C(OCH[CH_2OH]CH_2O)}(CH_2)_4C}HCH_3$ — 172; liquid; n 1.474; d. 1.074; b.p. 130–140^{20}; insol. w.

A plasticizer. Also called Cyclonol (see plasticizer chart).

Methyl dioxolane: A solvent — ether (see solvents chart).

Methyl ethyl ketone: A solvent — ketone (see solvents chart).

Methyl formate: A solvent — ester.

Methyl isobutyl ketone: A solvent — ketone (see solvents chart).

Methyl lactate: A solvent — ester (see solvents chart).

Methyl phthalyl ethyl glycollate: $CH_3OCOC_6H_4COOCH_2COOC_2H_5$ — 266; colorless liquid; n 1.504^{25}; d. 1.220^{25}; b.p. 189; sol. 0.053 w.

An important plasticizer. Also called Santicizer M-17 (see plasticizer chart).

Molybdenum oxide: Mo_2O_3 — 239.90; black crystals; insol. w., insol. a., alk., NH_4OH.

A catalyst.

***n*-Monoamyl aniline:** A solvent — amine.

***n*-Mono-*n*-butyl aniline:** A solvent — amine.

Monobutyl diamylamine: A solvent — amine.

Monochlorbenzene: A solvent — halogenated compound (see solvents chart).

Monoethanolamine: A solvent — amine.

Mono-isopropanolamine: A solvent — amine.

Morpholine: A solvent — amine (see solvents chart).

Morpholine ethanol: A solvent — amine (see solvents chart).

Morpholine ethanol ethyl ether: A solvent — amine (see solvents chart).

Naphthalene: $C_{10}H_8$: colorless monoclinic crystals; n $1.58218^{99.6}$; d. 1.145; m.p. 80.22; b.p. 217.9; sol. 0.003 w., 4.18 c. alc., v. sol. eth., $40.21^{15.6}$ bz., v. sol. chl., CS_2.

A coal-tar product from which a resin can be prepared. Naphthalene may also be used as a plasticizer and as a modifier or active ingredient in various synthetic resins or rubber compositions. It is a raw material in the production of phthalic anhydride and of azo dyes.

Nitric acid: HNO_3 — 63.02; colorless, corrosive, poisonous liquid; n $1.397^{16.4}$; d. 1.502; m.p. −42; b.p. 86; sol. ∞ c.w., ∞ h.w., decomp. al. violently, sol. eth.

A strong mineral acid used in the preparation of cellulose nitrate and other nitrates and dyes and to a limited extent as a catalyst.

Nitrobenzene: $C_6H_5NO_2$ — 123.05; yellow liquid; n 1.55291; d. 1.19867^{25}_{4}; m.p. 5.7; b.p. 210.9; sol. 0.19^{20}, 0.8^{80} w., v. sol. c. alc., v. sol. eth., sol. bz., oils.

Used to some extent as a homogenizing agent and in organic syntheses. It is a solvent for vinyl resins and is used in alkyd resin production.

1-Nitrobutane: A solvent — nitro hydrocarbons.

2-Nitrobutane: A solvent — nitro hydrocarbons.

Nitroethane: A solvent — nitro hydrocarbons (see solvents chart).

Nitromethane: A solvent — nitro hydrocarbons (see solvents chart).

1-Nitropropane: A solvent — nitro hydrocarbons (see solvents chart).

2-Nitropropane: A solvent — nitro hydrocarbons (see solvents chart).

sec-Octyl acetate: A solvent — ester.

sec-Octyl alconol: A solvent — alcohol (see solvents chart).

Oxalic acid: $COOHCOOH{\cdot}2H_2O$ — 126.05; colorless monoclinic crystals; n 1.440, 1.475, 1.625; d. 1.653; m.p. 101, 189 anhyd.; b.p. sublimes 150; sol. 9.5^{15}, 120^{40} w., 23.7^{15} alc., 1.37 anhyd. alc., 16.9 eth., insol. chl., petr. eth.

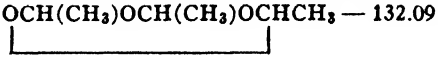
A dibasic acid used in the production of alkyd resins, as an acid catalyst in polymerization reactions, and in the manufacture of dyes.

Ozone: O_3 — 48.00; colorless gas or dark blue liquid; d. 2.144 g/l, liq. 1.71^{-183}; m.p. −251; b.p. −112; sol. 49° cm^3 c. w., sol. alk. solns., oils.

Paracumarone: The name applied to the benzene-soluble resins obtained by the polymerization of cumarone.

Paraformaldehyde (or polyoxymethylene): $(CH_2O)_x$ — $(30.02)_x$; white needles; m.p. 64 (60); b.p. sublimes; sol. 17.2^{18}, 21.1^{25} w., sol. alc., sol. eth.

The solid, polymerized form of formaldehyde. Used like formaldehyde but especially in anhydrous condensations, as an anhydrous phenol-aldehyde condensation.

Paraldehyde:  $OCH(CH_3)OCH(CH_3)OCHCH_3$ — 132.09; colorless liquid; n 1.40486; d. 0.9943^{20}_{4}; m.p. 10.5 (11-2); b.p. 124; sol. 12^{13}, 5.88^{100} w., sol. alc., ∞ eth., ∞ chl., oils.

The polymerized form of acetaldehyde, having in general the same uses. Paraldehyde is used as a hardener for phenol-formaldehyde resins.

Pentaerythritol tetra acetate: $C(CH_2OCOCH_3)_4$ — 304; n 1.54–6; m.p. 257; b.p. 276^{30}; sol. 5.27^{15} w.

A plasticizer (see plasticizer chart).

***n*-Pentane:** $CH_3(CH_2)_3CH_3$ — 72.09; colorless liquid; n $1.3570^{15.7}$; d. 0.626^{20}_{4}, 0.6214^{25}_{4}; m.p. −131.5 (−129.9); b.p. 36.2 (34–35.5); sol. 0.036^{16} w., ∞ alc., ∞ eth.

A petroleum hydrocarbon used as a starting point in various syntheses, as a solvent, etc.

Phenol: C_6H_5OH — 94.05; colorless rhombic needles; n $1.54247^{40.6}$; d. 1.072; m.p. 41; b.p. 182; sol. 6.7^{16}, ∞^{66} w., ∞ alc., v. sol. eth., sol. chl., glyc., CS_2.

One of the principal ingredients in the production of phenol-aldehyde thermosetting plastics.

Phthalic acid: $C_6H_4(COOH)_2$ — 166.05; colorless rhombic or monoclinic crystals from water; d. 1.593; m.p. 206–8 decomp.; b.p. decomp. 191; sol. 0.54^{14}, 18^{99} w., 11.7^{18} alc., 0.69^{15} eth., insol. chl.

A dibasic acid used in the production of alkyd resins, plasticizers and dyes.

Phthalic anhydride: $C_6H_4(CO)_2O$ — 148.03; colorless rhombic needles; d. 1.527^4; m.p. 130.8, b.p. 284.5 sublimes; v. sl. sol. w., sol. alc., sl. sol. eth.

Used for the same purposes as phthalic acid.

Picric acid: $(NO_2)_3C_6H_2OH$ — 229.05; yellow rhombic leaflets from water; d. 1.763; m.p. 121.8; b.p. explodes >300; sol. 1.4^{20}, 6.8^{100} w., 4.91^{20} alc., 1.43 c. CS_2, sol. bz.

An acid catalyst and intermediate inorganic synthesis, as of dyes.

Propylene diamine: A solvent — amine (see solvents chart).

Pyridine: N:CHCH:CHCH:CH — 79.05; colorless liquid; n 1.50919^{21}; d. 0.982; m.p. −42; b.p. 115.3; ∞ w., ∞ alc., ∞ eth., sol. bz.

A useful catalyst for such reactions as urea-aldehyde or phenol-aldehyde condensations.

Resorcinol: $C_6H_4(OH)_2$ — 110.05; colorless rhombic tablets from water or benzene; d. 1.285^{15}; m.p. 110; b.p. 276.5 (281.4); sol. 229^{30} w., 243^{25} alc., v. sol. eth., sol. glyc., bz., amyl alc.

Reacts with many substances to form synthetic resins. Also used in the manufacture of dyes.

Ricinoleic acid: $CH_3(CH_2)_5CHOHCH_2CH{:}CH(CH_2)_7COOH$ — 298.27; colorless liquid or crystalline mass; d. 0.945^{15}; m.p. 17; b.p. 250^{15}; insol. w., ∞ alc., ∞ eth., sol. chl.

Acid obtained by the hydrolysis of castor oil (glyceryl ester). Used as a plasticizer or softening agent, especially for phenol-aldehyde plastics.

Salicylic acid: HOC_6H_4COOH — 138.05; monoclinic colorless needles from water; n 1.565; d. 1.443^{20}_{4}; m.p. 159 (155–7); b.p. sublimes 76; sol. 0.18^{20}, 1.76^{75} w., 39.2^{15} alc., 50.5^{15} eth., sol. chl.

An acid catalyst used as an accelerator or hardener in phenolics, ureas, alkyds, and various coatings.

Sebacic acid: $COOH(CH_2)_8COOH$ — 202.14; thin colorless leaflets; n $1.422^{133.3}$; m.p. 133; b.p. 295^{100}; sol. 0.1^{17}, 2.0^{100} w., v. sol. alc., v. sol. eth.

A dibasic acid used in the production of alkyd resins and Nylons.

Selenium: Se_8 — 633.60; amorphous red powder; d. 4.26; m.p. transition vitreous 40–50°, metallic at 200; b.p. 688; insol. c. w., insol. h. w., sol. H_2SO_4; sl. sol. CS_2, insol. alc.

Used as a catalyst, and also as a filler for fireproofing compounds and giving good electrical insulating properties.

Sodium acetate: $NaC_2H_3O_2$ — 82.02; white powder; d. 1.528; m.p. 324; sol. 119° c. w., 170^{100} h. w., 2.1^{18} alc.

A salt used as a condensation catalyst for phenolics and ureas.

Sodium carbonate (anhyd.): Na_2CO_3 — 105.99; white hygroscopic powder; d. 2.533; m.p. 851; b.p.d.; sol. 7.1° c. w., 45.5^{100} h. w., insol. alc.

A salt used as a catalyst for phenolic resins and others.

Sodium formate: $NaCHO_2$ — 68.00; monoclinic colorless deliquescent crystals; d. 1.92; m.p. 253; sol. 44° c. w., 160^{100} h. w., sl. sol. alc., insol. eth.

A salt used as a catalyst.

Sodium hydroxide: NaOH — 40.00; white deliquescent solid; n 1.3576; d. 2.130; m.p. 318.4; b.p. 1390; sol. 42° c. w., 347^{100} h. w., v. sol. alc., eth., glyc.

A basic catalyst and useful reagent.

Sodium peroxide: Na_2O_2 — 77.99; yellow powder; d. 2.805; m.p. decomp.; sol. c. w., decomp. h. w., sol. dil. a., insol. alc.

An oxidizing catalyst.

Sorbitol: $C_6H_{14}O_6\frac{1}{2}H_2O$ — 191.12; colorless needles; m.p. anhyd. 110 (89–93); sol. w., v. sl. sol. alc., insol. eth.

A polyhydric alcohol used in alkyd resins and phenol-aldehyde resins.

Starch: $(C_6H_{10}O_5)_x$ — 162.08_x; white amorphous powder; n 1.53; d. 1.50^{21}; decomp. at m.p., insol. w., insol. alc., insol. eth.

Used as a dispersing agent in the gelation of rubber and for various plastics such as ureas and phenolics.

Stearic acid: $CH_3(CH_2)_{16}COOH$ — 284.28; colorless monoclinic leaflets; n 1.4299^{802}; d. 0.847^{69}; m.p. 69.4; b.p. 383; sol. 0.034^{25}, 0.1^{37} w., 2.5 c. alc, v. sol. eth., sol. chl., CCl_4, CS_2.

A lubricant, used either in the mold or incorporated in the plastic.

Stearine or glycerol tristearate: $(C_{17}H_{35}COO)_3C_3H_5$ — 890.86; colorless crystals from ether; n 1.4399^{80}; d. $0.862\frac{80}{4}$; m.p. 54.5, 70.8; insol. w., v. sl. sol. alc., sol. eth.

A lubricant.

Styrene or vinylbenzene: $C_6H_5CH{:}CH_2$ — 104.06; colorless liquid; n 1.54344^{17}; d. $0.9074\frac{20}{4}$; b.p. 146; v. sl. sol. w., ∞ alc., ∞ eth.

Raw material (monomer) for polystyrene plastics.

Succinic acid: $COOH(CH_2)_2COOH$ — 118.05; colorless monoclinic crystals; n 1.450, 1.534, 1.610; d. $1.564\frac{15}{4}$; m.p. 185 (189–90); b.p. 235 decomp.; sol. 6.8^{20}, 121^{100} w., $7.5^{21.5}$ alc., 0.3 eth., insol. bz., chl.

An acid catalyst and raw material for the production of some alkyd resins and coatings.

Succinic anhydride: $(CH_2CO)_2O$ — 100.03; colorless needles from alcohol; d. 1.104; m.p. 119.6; b.p. 261; v. sl. sol. w., sol. alc., v. sl. sol. eth.

Used in much the same way as succinic acid.

Sucrose or cane sugar: $C_{12}H_{22}O_{11}$ — 342.17; colorless monoclinic crystals; n 1.5376, 1.5651, 1.5705; d. 1.588^{15}; m.p. 186 decomp.; b.p. decomp., sol. 179°, 487^{100} w., 0.9 alc., insol. eth., sl. sol. me. alc., insol. chl.

A modifier incorporated in some plastics to reduce brittleness, increase transparency, etc.

Sucrose octa-acetate: $C_{12}H_{14}O_3(OCOCH_3)_8$ — 678; d. 1.28^{20}; m.p. 79–86; b.p. $260^{0.1}$; sol. 0.09 w.

A plasticizer (see plasticizer chart).

Sulfuric acid: H_2SO_4 — 98.08; colorless oily liquid or hexagonal crystals; n 1.429; d. 1.834; m.p. 10.49; b.p. 330 (98.3%) decomp.; ∞ c. w.; ∞ h. w.; decomp. alc., miscellaneous organic solvents.

An acid catalyst and a reagent used in preparing dyes and other compounds to be used in plastics.

1,1,2,2-Tetrachlorethane: A solvent — chlorinated hydrocarbon (see solvents chart).

sec-Tetradecyl alcohol: A solvent — alcohol.

Tetraethylene glycol: A solvent — glycol (see solvents chart).

Tetraethylene pentamine: A solvent — amine (see solvents chart).

Tetrahydrofurfuryl alcohol: A solvent — furan (see solvents chart).

Thiourea: NH_2CSNH_2 — 76.11; rhombic prisms from alcohol; d. $1.405\frac{20}{4}$; m.p. 182 (174–6); b.p. decomp.; sol. 9.18^{13} w., sol. alc., v. sl. sol. eth.

Sometimes used with or instead of urea in urea-aldehyde plastics.

Toluene: $C_6H_5CH_3$ — 92.06; colorless liquid; n $1.49782^{16.35}$; d. $0.866\frac{20}{4}$, $0.86234\frac{25}{4}$; m.p. −95; b.p. 110.8; sol. 0.047^{16} w., ∞ alc., ∞ eth., sol. chl., glac. AcOH, acet., CS_2, bz.

A solvent hydrocarbon and raw material, and intermediate in the synthesis of materials used in plastics.

***o*- and *p*-Toluene ethyl sulfonamide:** $CH_3C_6H_4SO_2NHC_2H_5$ — 199; n 1.540^{25}; d. 1.190^{25}; m.p. 18; sol. 0.140 w.

A plasticizer. Also called Santicizer 8 (see plasticizer chart).

***o*- and *p*-Toluene sulfonamide:** $CH_3C_6H_4SO_2NH_2$ — 171; colorless crystals; d. 1.313^{25}; m.p. 137–156; sl. sol. w., alc., eth.

A plasticizer. Also called Santicizer 9 (see plasticizer chart).

Tri-*n*-butyl aconitate: $C_4H_9OCOCHC(COOC_4H_9)CH_2COOC_4H_9$ — 342; n 1.4532^{26}; d. 1.018; b.p. 169–171^{5}; insol. w.

A plasticizer (see plasticizer chart).

Tri-*n*-butyl citrate: $(C_4H_9OCOCH_2)_2C(OH)COOC_4H_9$ — 360; n 1.4431^{25}; d. 1.042^{25}; m.p. −55; b.p. 220–225^{4-5}; sol. 0.008 w.

A plasticizer (see plasticizer chart).

Tributyl phosphate: $(C_4H_9O)_3PO$ — 266; n 1.4248; d. 0.973–0.983; m.p. −20; b.p. 289; sol. 0.033 w.

A plasticizer (see plasticizer chart).

Tri-*n*-butyl tricarballylate: $(C_4H_9OCOCH_2)_2CHCOOC_4H_9$ — 344; n $1.4388^{26.5}$; d. 1.004^{24}; b.p. 305; insol. w.

A plasticizer (see plasticizer chart).

Trichlorbenzene: A solvent — halogenated compound (see solvents chart).

1,1,2-Trichlorethane: A solvent — chlorinated compound (see solvents chart).

1,1,2-Trichlorethylene: A solvent — chlorinated compound (see solvents chart).

Tricresyl phosphate: $(CH_3C_6H_4O)_3PO$ — 368; n 1.556^{25}; d. 1.175^{20}; m.p. −35; b.p. 295^{13}; sol. 0.008 w.

An important plasticizer and fire retardant for cellulose nitrate and other cellulose derivatives. Also called Kronitex A, Lindol. Used also as extreme pressure lubricants, and for vinyl chloride plastics (see plasticizer chart).

Triethanolamine: A solvent — amine.

Triethyl aconitate: $C_2H_5OCOCH{:}C(COOC_2H_5)CH_2COOC_2H_5$ — 258; n 1.4517^{26}; d. 1.096^{25}; b.p. 154–156^{5}; 0.18 w.

A plasticizer (see plasticizer chart).

Triethyl citrate: $(C_2H_5OCOCH_2)_2C(OH)COOC_2H_5$ — 276; n $1.4405^{24.5}$; d. 1.136^{25}; b.p. 150^{3}; sol. 6.1^{20} w.

A plasticizer (see plasticizer chart).

Triethyl phosphate: $(C_2H_5O)_3PO$ — 182; n 1.4055; d. 1.068–1.072; b.p. 210–220; ∞ w.

Triethyl tricarballylate: $(C_2H_5OCOCH_2)_2CHCOOC_2H_5$ — 260; n 1.4324^{26}; d. 1.087^{20}; b.p. 158–60^{5}; sol. 0.62^{20} w.

A plasticizer (see plasticizer chart).

Triethylene glycol: A solvent — glycol (see solvents chart).

Triethylene glycol diacetate: $(CH_2OCH_2CH_2OCOCH_3)_2$ — 234; n 1.437^{25}; d. 1.112^{25}; m.p. 60; b.p. 300; sol. 50 w.

A plasticizer (see plasticizer chart).

Triethylene glycol dibutyrate: $(CH_2OCH_2CH_2OCOC_3H_7)_2$ — 290; n 1.437^{25}; d. 1.033^{25}; m.p. −70; b.p. 154–160^{2}; sol. 0.800 w.

A plasticizer (see plasticizer chart).

Triethylene glycol-di-2-ethyl butyrate: $C_6H_{11}CO(OC_2H_4)_3OCOC_6H_{11}$ — 346; d. 0.995^{25}; b.p. 358; sol. 1.09 w.

A plasticizer. Also called Flexol Plasticizer 3 GH (see plasticizer chart).

Triethylene glycol-di-2-ethyl hexoate: $C_7H_{15}CO(OC_2H_4)_3OCOC_7H_{15}$ — 402; d. 0.968^{25}; b.p. 215^{5}.

A plasticizer. Also called Flexol Plasticizer 3 GO (see plasticizer chart).

Triethylene glycol dipropionate: $(CH_2OCH_2CH_2OCOC_2H_5)_2$ — 262; n 1.436^{25}; d. 1.066; −60; 138–142^{2}; sol. 6.70 w.

A plasticizer (see plasticizer chart).

Triethylenetetramine: A solvent — amine (see solvents chart).

Tri-isopropanolamine: A solvent — amine.

Trimethyl phosphate: $(CH_3O)_3PO$ — 140; n 1.3953; 1.205–1.220; b.p. 190–205; ∞ w.

A plasticizer (see plasticizer chart).

Triphenyl phosphate: $(C_6H_5O)_3PO$ — 326; n 1.563^{25}; d. 1.185^{25}; m.p. 48.5; b.p. 220^{5}; sol. 0.002.

An important plasticizer and fire retardant (see plasticizer chart).

Undecyl alcohol: A solvent — alcohol.

Urea: NH_2CONH_2 — 60.05; colorless tetrahedral crystals; n 1.484, 1.602; d. 1.335; m.p. 132.7; b.p. decomp.; sol. 78^{5}, 119.3^{25} w., 15.8^{20} alc., sl. sol. eth., sol. concd. HCl, insol. chl.

One of the principal raw materials for the light-colored thermosetting urea-formaldehyde plastics.

Vinyl acetate: $CH_2{:}CHOCOCH_3$ — 86; colorless liquid.

A reaction product of acetylene and acetic acid in the presence of a catalyst. Polymerizes to a thermoplastic resin.

Vinyl alcohol: $CH_2{:}CHOH$ — 44.03.

Vinyl alcohol does not exist as such, appearing always as the keto form, acetaldehyde (vinyl alcohol being the enol form of the same compound). For this reason polyvinyl alcohol cannot be prepared by the polymerization of the monomer, but must be made by the hydrolysis of an ester.

Vinyl chloride: $CH_2{:}CHCl$ — 62.48; colorless gas; d. liq. $0.9195\frac{15}{4}$; m.p. −159.7; b.p. −13.9; sl. sol. w., sol. alc., v. sol. eth.

Gaseous product of the reaction of acetylene with hydrochloric acid in the presence of suitable catalysts. Polymerizes to form a colorless thermoplastic resin. See Koroseal.

Vinylidene chloride or 1,1-dichloroethylene: $CH_2{:}CCl_2$ — 96.93; liq.; d. $1.250\frac{15}{4}$; b.p. 37; insol. w.

Monomeric form of polyvinylidene chloride resins, which can be plasticized to form transparent, tough, elastic, rubberlike materials.

Xylene or Xylenol: $C_6H_4(CH_3)_2$ — 106.08; colorless liquid, hydrocarbon.

***o*-Xylene:** n $1.50777^{15.5}$; d. 0.874; m.p. −29 (−27.1); b.p. 144; insol. w., v. sol. alc., eth.

***m*-Xylene:** n $1.4996^{14.8}$; d. 0.8684^{15}; m.p. −53.6 (−47.4); b.p. 138.8; insol. w., v. sol. alc., eth.

***p*-Xylene:** n 1.497; d. $0.8612\frac{20}{4}$; m.p. 15–6 (11–2); b.p. 138; insol. w., v. sol. alc., eth.

A hydrocarbon solvent and raw material or intermediate in various organic syntheses.

Zinc oxide: ZnO — 81.38; white or yellowish amorphous powder; d. 5.47; m.p. 1800; sol. 0.00016^{29} c. w., sol. mineral a., dil. AcOH, NH_4OH.

A white pigment and filler used in plastic and rubber compositions.

PLASTICS TRADE-MARKS AND TRADE NAMES

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Abalyn	Methyl ester of abietic acid	For nitrocellulose, ethyl cellulose, chlorinated rubber, paint and varnish vehicle	Hercules Powder Co., Inc., Wilmington, Del.
Abopon	Water-soluble synthetic resin	For flameproofing, adhesives, insulation, binding material	Glyco Products Co., Inc., New York, N.Y.
Ace	Hard rubber (rods, sheets, tubes)	For molded insulating parts, acid-resisting parts	American Hard Rubber Co., New York, N.Y.
Ace-Ite	Rubber composition	Storage-battery containers	American Hard Rubber Co., New York, N.Y.
Aceloid	Cellulose nitrate (sheets, rods, tubes, and soluble flakes)	Base for molding powders, plastics, solutions, and finished plastics	American Cellulose Co., Indianapolis, Ind.
Aceplus	Cellulose acetate (sheets, rods, tubes, molding powder, soluble flakes)	Base for molding powders, plastics, solutions, and finished plastics	American Cellulose Co., Indianapolis, Ind.
Ace-Sil	Microporous rubber	Battery separators and filters	American Hard Rubber Co., New York, N.Y.
Acrawax **Acrawax B** **Acrawax C**	Synthetic wax	For blending with other waxes, resins, etc., to increase lubrication and melting point	Glyco Products Co., Inc., New York, N.Y.
Acryloid	Acrylic	Clear and pigmented coatings where color and chemical resistance are desired for textiles	Resinous Products & Chemical Co., Philadelphia, Pa.
Acrysol	Acrylic	Clear and pigmented coatings for rubber and rubberized surfaces	Resinous Products & Chemical Co., Philadelphia, Pa.
Adheso Wax	Modified polymerized terpene hydrocarbon (synthetic wax)	For increasing flexibility	Glyco Products Co., Inc., New York, N.Y.
Aero Brand Ester Gum	Resin-glycerol (coatings)	Interior varnish lacquers and enamels	American Cynamid Co., New York, N. Y.
Aico	Cold molded	Radiator valve handles, knobs for cooking utensils, electrical insulating parts, gear-shift balls	American Insulator Corp., New Freedom, Pa.
Akco	Phenolic (coatings)	Quick drying waterproof varnishes and varnish vehicles for enamels, printing inks	American Cynamid Co., New York, N. Y.
Albacer	Synthetic wax	For increasing hardness and melting point	Glyco Products Co., Inc., New York, N.Y.
Alvar	Vinyl acetal	Injection molded articles	Shawinigan Products Corp., New York, N. Y.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Amberlac	Alkyd (coatings)	Industrial air drying and baking finishes	Resinous Products & Chemical Co., Philadelphia, Pa.
Amberlite I R	Synthetic resin Ion exchangers	Removal of salts from aqueous media	Resinous Products & Chemical Co., Philadelphia, Pa.
Amberlite P R	Phenolic (laminating)	Heat-hardening adhesives and coatings, laminating and impregnating	Resinous Products & Chemical Co., Philadelphia, Pa.
Amberol	Phenolic (coatings)	Four-hour enamels, rubbing and baking finishes, nitrocellulose lacquers	Resinous Products & Chemical Co., Philadelphia, Pa.
Amer-glo	Cellulose acetate and cellulose nitrate	Metal surfaced plastics sheet for toilet ware, radio instrument dial panels	Celanese Celluloid Corp., New York, N. Y.
Amerine	Cold molded	For electrical insulating parts	American Insulator Corp., New Freedom, Pa.
Ameripol	Butadiene copolymer (synthetic rubber)	Oil-resistant type suitable for oil-handling hose, belting, packing, gaskets, engraving and printing gums, molded and extruded goods	B. F. Goodrich Co., Akron, Ohio
Amerite	Aqueous synthetic rubber dispersions	Rubber substitutes	American Anode, Inc., Akron, Ohio
Ameroid	Casein	Buttons, trimmings, articles made on screw machines for electrical purposes	American Plastics Corp., New York, N. Y.
Amphenol	Polystyrene	Electrical purposes	American Phenolic Corp., Chicago, Ill.
Amron	Vinylite base	Coatings	The United States Stoneware Co., New York, N. Y.
Aqualite	Phenolic (laminated)	Bearings	National Vulcanized Fibre Co., Wilmington, Del.
Aqualube	Plasticizer	For plasticizing water-soluble materials	Glyco Products Co., Inc., New York, N. Y.
Aquapearl	Phenol-formaldehyde (case resin with pearl effect)	Jewelry, buttons, dress accessories, novelties	Catalin Corp., New York, N. Y.
Aquaplex	Alkyd	Emulsion paint, vehicle for stucco, concrete, brick and other masonry surfaces	Resinous Products & Chemical Co., Philadelphia, Pa.
Aquaresin	Glycol bori-borate	Plasticizer; also for increasing adhesion	Glyco Products Co., Inc., New York, N. Y.
Arcolite	Phenolic	Buttons, knobs, handles, camera, switchbases, boxes, compacts, dials	Consolidated Molded Products Corp., Scranton, Pa.
Arochem	Modified phenolics and maleics	Paints, varnishes, lacquers and allied coatings	Stroock & Wittenberg Corp., New York, N. Y.
Aroclor	Chlorinated diphenyl (coatings)	Lacquers, waxes, brake linings, printing inks, special adhesives, heat transfer work	Monsanto Chemical Co., Everett, Mass.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Arodure	Ureas	Printing inks, surface coatings	Stroock & Wittenberg Corp., New York, N. Y.
Arofene	Phenolics	Varnish and oleoresinous enamels	Stroock & Wittenberg Corp., New York, N. Y.
Aroplaz	Alkyd	Surface coatings in general	Stroock & Wittenberg Corp., New York, N. Y.
Bakelite	Cellulose acetate	Builders' hardware, spectacle and goggle frames, display devices, automotive parts	Bakelite Corp., New York, N. Y.
	Phenol-formaldehyde (adhesives)	Plywoods, veneers, aircraft fuselages and wing structures	
	Phenol-formaldehyde (bonding materials)	Gears, glass wool, abrasives, plastic woods for tabletops, wall paneling and insulation; resistors, coils	
	Phenol-formaldehyde (cast resinoids)	Plates, rods, and tubes for chemical resistant and photo-elastic uses	
	Phenol-formaldehyde (coatings)	Tanks, food processing equipment, chemical apparatus	
	Phenol-formaldehyde (thermosetting molding materials)	Radio cabinets, telephone hand sets, closures, electrical and mechanical parts, buttons, tube bases	
	Polybasic acid (coatings)	Blended with resins to improve quality	
	Polystyrene (coatings)	Paper, fabrics, electrical insulation	
	Polystyrene (films)	Electrical insulation	
	Polystyrene (thermoplastic molding materials)	Flashlight housings, radio parts, wiring devices, closures, combs, refrigerator parts	
	Urea-formaldehyde (coatings)	Architectural and decorative applications	
	Urea-formaldehyde (thermosetting molding materials)	Radio cabinets, buttons, closures, novelties	
	Urea-formaldehyde (miscellaneous materials)	Saturants for creaseproofing and waterproofing fabrics	
Bakelite Resin Blanks	Phenolic molding boards and blanks	Handles, parts requiring reinforcement	Bakelite Corp., New York, N. Y.
BCA	Casein and urea	Buttons, buckles, slides	Button Corp. of America, Newark, N. J.
Banner	Hard rubber (rods, tubes)	Pipe bits	American Hard Rubber Co., New York, N.Y.
Bas-Releef	Injection-molded thermoplastics	Automobile interiors	Cruver Mfg. Co., Chicago, Ill.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Beckacite	Pure phenolic, modified phenolic, and non-phenolic resins	Oleoresinous base used in enamels and lacquers	Reichhold Chemicals, Inc., Detroit, Mich.
Beckamine	Urea-formaldehyde resins	For high-bake refrigerator and store finishes	Reichhold Chemicals, Inc., Detroit, Mich.
Beckolin	Synthetic oil	Oleoresinous base for house paints	Reichhold Chemicals, Inc., Detroit, Mich.
Beckopol	Phenolated copals	Base for rubbing varnishes	Reichhold Chemicals, Inc., Detroit, Mich.
Beckosol	Pure alkyds, alkyds modified with phenol or oils and phenols, and non-phenolic alkyds	Base in automotive finishes and various enamels	Reichhold Chemicals, Inc., Detroit, Mich.
Beetle	Urea-formaldehyde (cements)	For bonding plastics and plywoods	American Cyanamid Co., New York, N.Y.
	Urea-formaldehyde (coatings)	Baking enamels, finishes for speed, hardness, and color retention	
	Urea-formaldehyde (laminating resins)	Displays, wall coverings, refrigerator interiors	
	Urea-formaldehyde (molding compounds)	Housings, packaging, closures, buttons, tableware, hardwares, lighting fixtures	
Beetleware	Urea-formaldehyde (molded materials)	Plates, cups, etc.	American Cyanamid Co., New York, N.Y.
Benalite	Cured lignin sheets		Masonite Corp., Chicago, Ill.
Benaloid	Uncured lignin sheets		Masonite Corp., Chicago, Ill.
Brandywine	Vulcanized fiber (tubes)	Electrical insulation	Brandywine Fibre Products Co., Wilmington, Del.
BuCreA	Urea-formaldehyde	Buttons, slides	Button Corp. of America, Newark, N. J.
Butacite	Polyvinyl acetal	Interlayer sheeting for safety glass	E. I. du Pont de Nemours Co., Plastics Division, Arlington, N. J.
Butvar	Vinyl	Injection-molded articles	Shawinigan Products Corp., New York, N. Y.
Caffelite	Molding compound from coffee beans		Caffelite Corp., New York, N. Y.
Cardolite	Phenol-aldehyde (cashew nut derivative)	Resins and polymers	Irvington Varnish & Insulator Co., Irvington, N. J.
Carterite	Resin molding compound	Preforms for industrial applications	Dispersion Products, Needham Heights, Miss.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Catabond	Phenol-formaldehyde liquid resin	Plywood manufacture, jointing glues for waterproof joints, especially in aircraft, bonding agent for abrasive disks	Catalin Corp., New York, N. Y.
Catalin	Phenol-formaldehyde (cast resinoids)	Radio cabinets, buttons, displays	Catalin Corp., New York, N. Y.
Catavar	Phenol-formaldehyde (laminating varnish)	Display fixtures, dials, tabletops; waterproofing and impregnating	Catalin Corp., New York, N. Y.
Celastic	Stiffened fabric	Box toes and counters of shoes	Celastic Corp., Arlington, N. J.
Celite	Diatomaceous earth	Filler	Johns-Manville New York, N. Y.
Cellophane	Regenerated cellulose film	Wrappings	E. I. du Pont de Nemours & Co., Cellophane Division, Wilmington, Del.
Cell-O-Silver	Vinyl (mirrored plastic)	Plastic mirrors	Gemloid Corp., Elmhurst, L. I,. N. Y.
Cellucraft	Cellulose acetate and cellulose nitrate (coatings)	Spray coatings	Detroit Macoid Corp., Detroit, Mich.
Cellulate	Cellulose acetate (sheets)	Decorative	National Plastic Products Co., Detroit, Mich.
Celluloid	Cellulose nitrate (sheets, rods, and tubes)	Toilet ware, novelties, fountain pen barrels, tool handles, index forms	Celanese Celluloid Corp., New York, N. Y.
Celluvarno	Cellulose nitrate	Covering of bathroom fixtures	Sillcocks-Miller Co., South Orange, N. J.
Cel-O-Glass	Cellulose acetate (coated wire screen)	Hot beds, chicken coops, window and door screens, decorative purposes such as lamp shades, signs	E. I. du Pont de Nemours & Co., Organic Chemicals Dept., Wilmington, Del.
Celoron	Phenolic (molded fabric)	Gears, housings, radio antenna masts, bearings, pipes and fittings	Continental Diamond Fibre Co., Newark, Del.
Charmour	Cellulose acetate (sheets)	Lamp shades	Celanese Celluloid Corp., New York, N. Y.
Cibanite	Aniline formaldehyde (sheets, boards, molded articles, rods, molding powders	High-voltage insulation, switch gear rods, base-boards, bushings	Ciba Co., Inc., New York, N. Y.
Cinelin	Cellulose acetate and cellulose nitrate (sheets, rods, tubes, and molding powder and solutions)	Base for molding powders, plastics, solutions, and finished plastics	Cinelin Co., Indianapolis, Ind.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Clair de Lune	Cellulose acetate (decorative sheet)	Lamp shades	Celanese Celluloid Corp., New York, N. Y.
Clearsite	Cellulose acetate	Containers	Hygienic Tube & Container Co., Newark, N. J.
Cloisonnette	Cellulose acetate	Novelty and toilet ware	Gemloid Corp., Elmhurst, L. I., N. Y.
Cohardite	Hard rubber	Electrical insulation	Connecticut Hard Rubber Co., New Haven, Conn.
Colasta	Phenolic (molding compound)	Circuit-breaker parts, all types of electrical insulation, instrument parts, electrical connections	Specialty Insulation Mfg. Co., Hoosick Falls, N. Y.
Colfite	Graphited laminate	Bearing material	Formica Insulation Co., Cincinnati, Ohio
Coltrock	Phenolic	Moisture and chemical resistant, extra strength for closures, special colorings	Colt's Patent Fire Arms Mfg. Co., Hartford, Conn.
Coltstone	Cold molded	Insulation	Colt's Patent Fire Arms Mfg. Co., Hartford, Conn.
Coltwood	Phenolic	High-impact gun grips, gears, tool handles	Colt's Patent Fire Arms Mfg. Co., Hartford, Conn.
Comet	Hard rubber	Pipe bits	American Hard Rubber Co., New York, N. Y.
Complac	Shellac compound		Poinsettia, Inc., Pitman, N. J.
Compo-Site	Shellac compound	Business machine and instrument knobs, caps, closures, hardware handles, checkers and poker chips	Compo-Site, Inc. Paterson, N. J.
Copene	Polyterpene copolymer resin	Adhesives, paper coatings, textiles, rubber compounding and waterproofing, paints, varnishes, lacquers	The Neville Co., Pittsburgh, Pa.
Coronation	Casein	Buttons	George Morrell Corp. Muskegon Heights, Mich.
Corprene	Synthetic rubber with ground cork		Armstrong Cork Products Co., Lancaster, Pa.
Crystalex	Acrylic compound	Dentures	Detroit Dental Mfg. Co., Detroit, Mich.
Crystalex	Acrylic	Dentures and prosthetic devices in gum pink and clear colors	Röhm and Haas Co. Philadelphia, Pa.
Crystalite	Acrylic (molding powder)	Dials, lenses, gauge glasses, combs, jewelry	Röhm and Haas Co., Philadelphia, Pa.
Cumar	Cumarone-indene	Paint and varnish, rubber compounding adhesives, resin modifier, printing inks	The Barrett Div., Allied Chemical & Dye Corp., New York, N. Y.
Daka-Ware	Urea molded products		Harry Davies Molding Co., Chicago, Ill.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Diamond	Vulcanized fiber	Fabricated and formed sheets, rods, and tubes	Continental Diamond Fibre Co., Newark, Del.
Dicalite 14 Dicalite 14 B Dicalite 14 W	Diatomaceaus silica	Filler for plastics	The Dicalite Co., New York, N. Y.
Dulux	Alkyd (coatings)	Pigmented and clear finishes	E. I. du Pont de Nemours & Co., Arlington, N. J.
Duraloy	Phenolic (sheets)		Detroit Paper Products Corp., Detroit, Mich.
Duraplex	Alkyd (coatings)	Industrial air drying and baking finishes	Resinous Products & Chemical Co., Philadelphia, Pa.
Durez	Phenol-formaldehyde (adhesives)	Weatherproof, waterproof plywood for aircraft, boats, concrete forms	Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.
	Phenol-formaldehyde (bonding resins)	Laminated paper, wood, cloth, grinding wheels, brake linings, resistors	
	Phenol-formaldehyde (coatings)	For wood, metal, cloth, paper, ceramics, leather	
	Phenol-formaldehyde (oil soluble resins)	Paints, varnishes, lacquers, enamels, printing inks	
	Phenol-formaldehyde (thermosetting molding materials)	Automotive electrical parts, communication, radio equipment, business machine housings, closures, packaging chemical equipment, handles, knobs, rayon machine parts	
Durite	Phenol-furfural and phenol-formaldehyde resins and molding compounds	Abrasive wheel and brake lining resins, incandescent lamp basing cements, communication, radio and general electrical and mechanical parts, resins for containers and protective coatings	Durite Plastics, Inc., Philadelphia, Pa.
Eastman acetate sheet	Cellulose acetate	Rigid sheet thermoplastic, packaging	Eastman Kodak Co., Rochester, N. Y.
Ebrok	Bituminous plastic (cold molded)	Storage-battery containers	The Richardson Co., Melrose Park, Ill.
Elasti-glass	Vinyl copolymer	Belts, suspenders, raincoats, wrist-watch bands, tobacco pouches, bill folds	S. Buchsbaum & Co. Chicago, Ill.
Elastolac	Shellac derivative	Water- and alcohol-soluble resinous viscous sirups	Glyco Products Co., Inc., New York, N. Y.
Electrose	Shellac composition		Insulation Mfg. Co., Inc., Brooklyn, N. Y.
Enameloid Cloisonné	Cellulose acetate and methyl methacrylate (engraved plastic)	Toilet sets, compacts	Gemloid Corp. Elmhurst, L. I., N. Y.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Endurance	Hard rubber	Storage-battery jars and parts	American Hard Rubber Co., New York, N. Y.
Esterol	Alkyd resin	Enamels and varnishes	Paramet Chemical Corp., Long Island City, N. Y.
Ethocel	Ethyl cellulose	Injection-molded plastics, extruded forms, lacquers, and varnishes	Dow Chemical Co., Midland, Mich.
Ethofoil	Ethyl cellulose film and sheeting	Rigid transparent packages	Dow Chemical Co., Midland, Mich.
Ethomelt	Ethyl cellulose hot resin	For paper coating	Dow Chemical Co., Midland, Mich.
Ethomulsion	Ethyl cellulose lacquer emulsion	Fabric treating and finishing	Dow Chemical Co., Midland, Mich.
Fibestos	Cellulose acetate (sheets, rods, tubes)	Playing cards, X-ray film, animated cartoon cells and slides, airplane turrets and windows	Monsanto Chemical Co., Springfield, Mass.
	Cellulose acetate (molding compounds)	Automobile parts, bezels, grilles, business machine parts	
Fibronized	Cellulose acetate, cellulose acetate butyrate, vinyl ester resins and vinylidene chloride (extruded)	Extruded shapes	Irvington Varnish & Insulator Co., Irvington, N. J.
Filfloc	Cotton flock	Filler for plastics	Rayon Processing Co. of R. I., Central Falls, R. I.
Flamenol	Vinyl chloride resin	Insulation of wire	General Electric Co., Schenectady, N. Y.
Flexo Wax C	Synthetic wax	For adhesives, lacquers, enamels	Glyco Products Co., Inc., New York, N. Y.
Flexoresin	Polymerized terpenes	Insulation and water resistance	Glyco Products Co., Inc., New York, N. Y.
Forestite	Wood flour	Filler for plastics	The Burnet Co., New York, N. Y.
Formalin	Phenolic resins (cast)	For slush molding	National Plastic Products Co., Detroit, Mich.
Formica	Phenolic and urea (laminated)	Wallboards, decorative surfaces in furniture, fixtures and building	Formica Insulation Co., Cincinnati, Ohio
Formvar	Polyvinyl-aldehyde reaction products	Injection-molded articles	Shawinigan Products Corp., New York, N. Y.
G	Glycerol-phthalic anhydride	Varnishes and lacquers	Makalot Corp., Boston, Mass.
" G " Resin	Cumarone-indene	Adhesives, aluminum paint, paper coatings, floor tile, pipe coatings, paints, varnishes, lacquers, printing inks, rubber compounding and waterproofing	The Neville Co., Pittsburgh, Pa.
Gala	Casein	Buttons	George Morrell Corp., Muskegon Heights, Mich.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Galorn	Casein	Buttons	George Morrell Corp., Muskegon Heights, Mich.
Garit	Bituminous plastic (cold molded)	Wiring device parts, connectors and plugs, instrument mountings	Garfield Mfg. Co., Garfield, N. J.
Gelva	Vinyl acetate	Adhesive purposes	Shawinigan Products Corp., New York, N. Y.
Gemcote	Proprietary formula	Impregnated solvent for coating paper	Gemloid Corp., Elmhurst, L. I., N. Y.
Gemglo	Styrene, methyl methacrylate	Flashlights, numerals	Gemloid Corp., Elmhurst, L. I., N. Y.
Gemlike	Cellulose acetate, cellulose nitrate	Postcards, novelty inserts	Gemloid Corp., Elmhurst, L. I., N. Y.
Gemlite	Cellulose acetate, methyl methacrylate, styrene (injection molded and extruded)	Lamp parts, clocks, radio escutcheons	Gemloid Corp., Elmhurst, L. I., N. Y.
Gemloid	Cellulose acetate and cellulose nitrate	Radio and automobile parts	Gemloid Corp., Elmhurst, L. I., N. Y.
Gemstone	Phenolic (cast)	Rods, tubes, cabinets	A. Knoedler Co., Lancaster, Pa.
Glaseal	Adhesive	Adhesive	American Hard Rubber Co., New York, N. Y.
Glaurin	Diethylene glycol mono laurate	Plasticizer	Glyco Products Co., Inc., New York, N. Y.
Glucarine B	Polyhydric alcohol	Plasticizer (water-soluble)	Glyco Products Co., Inc., New York, N. Y.
Glyceryl Laurate S	Lauric acid ester of glycerin	Plasticizer (water-dispersible)	Glyco Products Co., Inc., New York, N. Y.
Glyceryl Monostearate S	Stearic acid ester of glycerin	Wax lubricant (water-dispersible)	Glyco Products Co., Inc., New York, N. Y.
Glyceryl Phthalate S	Phthalic acid ester of glycerin	Used either by itself as a synthetic resin or in combination with fatty acids for special purposes	Glyco Products Co., Inc., New York, N. Y.
Glyptal	Alkyd	Formulating of paints	General Electric Co., Bridgeport, Conn.
Golden Rule	Cellulose acetate, ethyl cellulose, cellulose nitrate (sheets, rods, tubes, molding powders and solutions)	Base for molding powders, plastics, solutions and finished plastics	Cinelin Co., Indianapolis, Ind.
Gummon	Bituminous plastic (cold molded)	Switch bases, handles, knobs	Garfield Mfg. Co., Garfield, N. J.
H-Scale	Synthetic pearl essence	Lacquers, plastics	Celanese Celluloid Corp., New York, N. Y.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Halowax	Chlorinated hydrocarbons	Wire insulation, sealing compounds, fabric saturants, dielectrics	Halowax Corp., New York, N. Y.
Harvite	Shellac compound	Poker chips	Siemon Co., Bridgeport, Conn.
Haskelite	Plastics bonded plywood (phenolic)	Aircraft structures	Haskelite Mfg. Co., Chicago, Ill.
Haveg	Asbestos-filled phenolic	Chemical equipment, storage tanks, kettles, pump and fin parts	Haveg Corp., E. Newark, Del.
Hemcoware	Cellulose acetate, cellulose acetate butyrate, melamine, methyl methacrylate, styrene, urea	Tableware, scoops, funnels, children's dishes	Bryant Electric Co., Bridgeport, Conn.
Hemit	Cold molded	Arc shields and barriers, third-rail insulators, heavy-duty switch bases	Garfield Mfg. Co., Garfield, N. J.
Hercolyn	Solvent and plasticizer	For alkyds, nitrocellulose, cellulose acetates, cellulose acetate butyrates, ethyl cellulose, chlorinated rubber, polycyclo rubber, polyvinyl acetate-chloride, polyvinyl halides	Hercules Powder Co., Wilmington, Del.
Hercose AP	Cellulose acetate propionate	Base for metals and cloth finishes, airplane dopes, thermoplastic finishes	Hercules Powder Co., Wilmington, Del.
Hercules Cellulose Acetate	Cellulose acetate (flake)	Molding powders, lacquers and films	Hercules Powder Co., Wilmington, Del.
Hercules Ethyl Cellulose	Ethyl cellulose	Molding powders, varnishes, lacquers, resins	Hercules Powder Co., Wilmington, Del.
Herculoid	Cellulose nitrate	Raw material for crystal rods and transparent sheets	Hercules Powder Co., Wilmington, Del.
Heresite	Phenol-formaldehyde (coatings)	Rayon-machine parts, storage tanks, cars, fume hoods and ducts, and shipping containers	Heresite & Chemical Co., Manitowoc, Wis.
Heresite M66	Phenol-formaldehyde (molding compound)	Closures, electric switches and insulating radio parts, laboratory utensils and rayon-machine parts	Heresite & Chemical Co., Manitowoc, Wis.
Hycoloid	Cellulose nitrate	Containers	Hygienic Tube & Container Co., Newark, N. J.
Hydroresin A	Water-soluble resin	Plasticizer for cellulose nitrate resins, shellac, adhesive for water and alcohol-soluble resins	Glyco Products Co., Inc., New York, N. Y.
Imperial Ester	Resin glycerol	Varnishes and lacquers	Hercules Powder Co., Wilmington, Del.
Inceloid	Cellulose acetate, ethyl cellulose	Packaging material	American Products Mfg. Co., New Orleans, La.
Indur	Phenol-formaldehyde (molding compound)	Electrical appliances, gears, closures, decorative pieces	Reilly Tar & Chemical Corp., New York, N. Y.
Insulate	Shellac composition		Insulation Mfg Co., Inc., Brooklyn, N. Y.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Insurok	Phenolic and urea molded and laminated plastics (sheets, rods, tubes, fabricated parts)	Aircraft accessories, bearings, dials, gears, electrical insulation	The Richardson Co., Melrose Park, Ill.
Interlox	Cellulose acetate butyrate, polyvinyl butyral	Wallboard trim, counter and table edging	Extruded Plastics, Inc., Norwalk, Conn.
Irv-O-Lite	Extruded plastic tubing	Varnishes and lacquers	Irvington Varnish & Insulator Co., Irvington, N. J.
Kapsol	Methoxy ethyl oleate (plasticizer)	Vinyl chloride-acetate, vinyl resins, and chlorinated rubber	Ohio-Apex, Inc., Nitro, W. Va.
Kellite	Phenol-formaldehyde (molded)	Telephones and other molded products	Kellogg Switchboard & Supply Co., Chicago, Ill.
Ketonone	Benzoic acid derivatives (plasticizer)	Cellulose acetate and cellulose nitrate	American Cyanamid Co., New York, N. Y.
Kodaloid	Cellulose nitrate (sheets)	Rigid sheet, thermoplastic	Eastman Kodak Co., Rochester, N. Y.
Kodapak	Cellulose acetate	Pliable sheet, thermoplastic	Eastman Kodak Co., Rochester, N. Y.
Kopol	Esterified, fused and modified copals	Oleoresinous base for metal primers and surfaces	Reichhold Chemicals, Inc., Detroit, Mich.
Koroseal	Polyvinyl chloride elastomers	Tank linings, cable and wire coatings, molded and extruded parts, coating fabrics	B. F. Goodrich Co., Akron, Ohio
KP 23	Butoxy ethyl stearate (plasticizer)	Ethyl cellulose, cellulose nitrate, and chlorinated rubber	Ohio-Apex, Inc., Nitro, W. Va.
Kronisol	Dibutoxy ethyl phthalate (plasticizer)	Cellulose acetate, cellulose nitrate, ethyl cellulose, vinyl chloride-acetate, chlorinated rubber	Ohio-Apex, Inc., Nitro, W. Va.
Kronitex	Tricresyl phosphate	Cellulose acetate, cellulose nitrate, ethyl cellulose, vinyl resins, chlorinated rubber	Ohio-Apex, Inc., Nitro, W. Va.
Kys-ite	Phenolic impregnated fiber	Housings, trays, electrical equipment	Keyes Fibre Co., Waterville, Maine
Lacanite	Shellac compound	Buttons, insulators, poker chips, knobs, ear caps, switch bases, checkers	Consolidated Molded Products Corp., Scranton, Pa.
Lamicoid	Phenol-formaldehyde and urea-formaldehyde (laminated)	Electrical and mechanical insulation, lighting fixtures and decorative uses	Mica Insulator Co., New York, N. Y.
Lamitex	Phenol-formaldehyde (laminated)	Instrument panels, gears, mechanical and electrical purposes	Franklin Fibre-Lamitex Corp., Wilmington, Del.
Lauxite	Urea-formaldehyde and zinc chloride (plywood resin adhesive)	Waterproof plywood panels, furniture, boats	Lauxite Corp., Lockport, N. Y.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Level Check	Hard rubber	Battery covers	American Hard Rubber Co., New York, N. Y.
Lewisol	Modified maleates, phenolics	Protective coatings	Hercules Powder Co., Wilmington, Del.
Limaca	Laminated sheet	Decorative wall panels	National Plastic Products Co., Detroit, Mich.
Lindol	Tricresyl phosphate (plasticizer)	Cellulose acetate, cellulose nitrate, ethyl cellulose	Celanese Celluloid Corp., New York, N. Y.
Loalin	Polystyrene (molding compound)	Electrical insulation, containers, imitation jewels, brushes	Catalin Corp., New York, N. Y.
Louvreglas	Louvered cellulose acetate (sheet)	Decorative lighting	Ivan T. Johnson Co., Inc., New York, N. Y.
Lucite	Methyl methacrylate (sheets, rods, tubes, molding powder)	Airplane windshields, enclosures, jewelry, display fixtures and outdoor applications	E. I. du Pont de Nemours & Co., Inc. Plastics Dept., Arlington, N. J.
Lucitone	Methyl methacrylate	Dentures	The L. D. Caulk Co., Milford, Del.
Lumapane	Cellulose acetate coated wire screen	Partitions	Celanese Celluloid Corp., New York, N. Y.
Lumarith	Cellulose acetate (molding powder, films, sheets, rods, tubes)	Automobile hardware, airplane cockpit enclosures, lamp shades, telephone bases, electrical appliances	Celanese Celluloid Corp., New York, N. Y.
Lumarith Protectoid	Cellulose acetate (films and foils)	Wrapping materials, laminated paper and cardboard, electrical wire and slot insulation, transparent containers	Celanese Celluloid Corp., New York, N. Y.
Lusteroid	Cellulose nitrate	Vials, tubes	Lusteroid Container Co., South Orange, N. J.
Lustron	Polystyrene (molding compound)	Refrigerator parts, television and radio set parts, buttons, combs and artificial gems, lenses, magnifying glasses, caps and closures	Monsanto Chemical Co., Springfield, Mass.
Luxene	Phenolics, polyvinyl chloride-acetate and acrylic	Dentures	Luxene, Inc., New York, N. Y.
Luzerne	Hard rubber (sheets, rods, tubes)	Special molded articles, pipe fittings, pumps, tanks, buckets, funnels	Luzerne Rubber Co., Trenton, N. J.
Maco	Casein	Clay coating of paper, adhesives	Prolamine Products, Inc., New York, N. Y.
Macoid	Cellulose acetate, cellulose nitrate (coatings)	Dip coatings	Detroit Macoid Corp., Detroit, Mich.
Maizite	Alcohol-soluble protein	Lacquer paper coating	Prolamine Products, Inc., New York, N. Y.
Makalot	Phenolic (coatings)	For laminating and heat-bonding of plywood	Makalot Corp., Boston, Mass.
	Phenolic (liquid resins)	Emulsions with liquid latex coil insulations, thermosetting coatings and adhesives	

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
	Phenolic (press powders)	Electrical insulators, cabinets, boxes, trays, handles, closures	
	Urea (creams and sirups)	Textiles, leather and paper coatings	
	Urea	Resins for laminating wood	
Marblette	Phenolic (cast)	Brush backs, gear shift knobs, picture frames, radio cabinets	Marblette Corp., Long Island City, N. Y.
Marbon	Rubber hydrochloride cyclo rubber	Paper coatings to resist acids and alkalies, adhesives, lacquers and enamels, wire insulation, special purpose plastics	Marbon Corp., Gary, Ind.
Melmac	Melamine-formaldehyde (resins and molding compounds)	Lacquers, enamels, varnishes, molded tableware, and electrical insulation	American Cyanamid Co., New York, N. Y.
Melocol	Polyamide formaldehyde (synthetic glue)	For furniture, veneers, plywood	Ciba Co., Inc., New York, N. Y.
Melopas	Polyamide formaldehyde	Laminated sheet material for decorative purposes, wall panels, table tops, furniture, electric lighting, accessories, motor car parts	Ciba Co., Inc., New York, N. Y.
Mercury	Hard rubber	Storage-battery jars and parts	American Hard Rubber Co., New York, N. Y.
Metalite	Mirrored foil plastic	Displays	Gemloid Corp., Elmhurst, L. I., N. Y.
Methocel	Methyl cellulose	Emulsifying and thickening agent, paper sizing for improving gloss, ink printing, and greaseproofing	Dow Chemical Co., Midland, Mich.
Methox	Dimethoxy ethyl phthalate (plasticizer)	For cellulose acetate, cellulose ethers, alkyds, ethyl cellulose, cellulose nitrate, vinyl chloride-acetate, vinyl resins, chlorinated rubber	Ohio-Apex, Inc., Nitro, W. Va.
MIC	Phenolic (laminated)	Electrical insulation, aircraft	Molded Insulation Co., Inc., Philadelphia, Pa.
Micabond	Bonded mica	Commutator rings and segments, insulation of electrical heating apparatus, induction coils, commutation sleeves, rheostat rods	Continental Diamond Fibre Co., Newark, Del.
Micanite	Mica	Electrical insulators	Mica Insulator Co., New York, N. Y.
Micarok	Sheet mica	Electric motors	The Richardson Co., Melrose Park, Ill.
Micarta	Phenolic (laminated)	Electrical insulation, industrial gears, rolling-mill bearings, rayon-spinning buckets	Westinghouse Electric & Mfg. Co., Trafford, Pa.
Micoid	Phenol-formaldehyde (laminated)	Electrical and mechanical insulators	Mica Insulator Co., New York, N. Y.
Mirasol	Alkyd	Varnishes and lacquers	Carbogen Chemical Co., Garwood, N. J.
Mir-Con	Phenolic (laminated—paper base)	Decorative, architectural	Detroit Paper Products Corp., Detroit, Mich.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Moldarta	Phenol-formaldehyde	Traverse reels, switch blocks, knobs and handles	Westinghouse Electric & Mfg. Co., Trafford, Pa.
National Vulcanized Fibre	Converted cotton cellulose	Grommets, bushings, spools, motor insulation, top sticks, coil forms, fuse cartridges, protective guards, helmet crowns, abrasive disk backing, trunks, bobbin heads, gears, cams, washers	National Vulcanized Fibre Co., Wilmington, Del.
Navy	Hard rubber	Storage-battery jars and parts	American Hard Rubber Co., New York, N. Y.
Neillite	Phenolic (molding material)	Electrical insulation, mechanical industrial moldings, novelties, automotive accessories	Watertown Mfg. Co., Watertown, Conn.
Neoprene (generic term)	Chloroprene rubber	Wire, belting, clothing, footwear, gloves, and molded goods	E. I. du Pont de Nemours & Co., Wilmington, Del.
Nevillac	Phenol indene cumarone	Oil varnishes, spirit varnishes, nitrocellulose lacquers	The Neville Co., Pittsburgh, Pa.
Neville Resin	Cumarone-indene resins	Adhesives, aluminum paint, paper coatings, floor tile, pipe coatings, printing inks, rubber compounding and waterproofing, paints, varnishes, lacquers	The Neville Co., Pittsburgh, Pa.
Nevillite	Hydrocarbon	Adhesives, lacquers, inks, varnishes and paper coatings	The Neville Co., Pittsburgh, Pa.
Nevindene	Cumarone-indene resins	Adhesives, lacquers, inks, varnishes, paper coatings	The Neville Co., Pittsburgh, Pa.
Nipocer	Synthetic wax	To replace Japan wax	Glyco Products Co., Inc., New York, N.Y.
Nitron	Cellulose nitrate (sheets, rods, tubes)	Fountain pens, drawing instruments, advertising novelties, optical frames, heel coverings, clock and watch crystals, cutlery handles	Monsanto Chemical Co., Springfield, Mass.
Nixonite	Cellulose acetate	Airplane windshields, automotive accessories, slide fasteners, fountain pens, optical goods, novelties	Nixon Nitration Works, Nixon, N. J.
Nixonoid	Cellulose nitrate	Umbrella handles, musical instruments, buttons, hair brushes, toilet seat covering	Nixon Nitration Works, Nixon, N. J.
Nuba	Cumarone-indene	Adhesives, aluminum paint, paper coatings, floor tile, paints, varnishes, lacquers, rubber compounding and waterproofing	The Neville Co., Pittsburgh, Pa.
Nylon (generic term)	Polyamide	Bristles, fibers, sutures, molded products	E. I. du Pont de Nemours & Co., Inc., Plastics Dept., Arlington, N. J.
Nypene	Polyterpene resin	Adhesives, paper coatings, paints, varnishes, inks, textiles, rubber compounding, waterproofing	The Neville Co., Pittsburgh, Pa.
Ohmoid	Phenolic (laminated)	Electrical insulation	Wilmington Fibre Specialty Co., East Wilmington, Del.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Okon	Cold molded (non-refractory)	Insulating equipment	American Hard Rubber Co., New York, N. Y.
Opalite	Phenol-formaldehyde (cast resin with opal effect)	Jewelry, novelties, buttons	Catalin Corp., New York, N. Y.
Opalon	Phenolic (cast)	Radio cabinets, clock cases, dice, automatic coin machines, decorative fixtures	Monsanto Chemical Co., Springfield, Mass.
Ozowax	Synthetic wax	Used in place of mineral or fossil wax	Glyco Products Co., Inc., New York, N. Y.
Panelyte	Phenolic (laminated — sheets, rods, tubes)	Used in thermal insulation, refrigeration, and in paper mill industry	Panelyte Div., St. Regis Paper Co., New York, N. Y.
Paradene	Cumarone-indene	Rubber compounding, mastic floor tile, paints, varnishes, lacquers	The Neville Co., Pittsburgh, Pa.
Paradura	Phenolic (pure resin)	For enamels and varnishes	Paramet Chemical Corp., Long Island City, N. Y.
Paranol	Phenolic (modified phenolic resin)	For enamels and varnishes	Paramet Chemical Corp., Long Island City, N. Y.
Paraplex	Alkyd	Resin plasticizer for permanently flexible nitrocellulose lacquers	Resinous Products & Chemical Co., Philadelphia, Pa.
Parkwood	Acetate impregnated woven veneer		Parkwood Corp., Wakefield, Mass.
Parkwood Textolite	Phenolic or urea	Impregnated woven veneer	General Electric Co., Plastics Dept., Pittsfield, Mass.
Parlon	Chlorinated rubber	Base for concrete paint, alkyd enamels	Hercules Powder Co., Wilmington, Del.
Peerless	Converted cotton cellulose	Formed top sticks, slot insulation	National Vulcanized Fibre Co., Wilmington, Del.
Pentek	Pentaerythritol	Paints and varnishes	Heyden Chemical Corp., New York, N. Y.
Petrex	Terpinene maleic anhydride	For manufacture of synthetic resins of the alkyd type. Partial substitute for shellac and tannic acid in aniline inks	Hercules Powder Co., Wilmington, Del.
Phenac	Phenolic (coatings)	Quick drying waterproof varnishes and varnish vehicles for enamels, printing inks	American Cyanamid Co., New York, N. Y.
Phenester	Cumarone	Special varnishes and enamels	The Neville Co., Pittsburgh, Pa.
Phenolite	Phenolic (laminated — sheets, rods, tubes, fabricated shapes)	Electrical and radio insulation, bearings, silent gears, pump valves, breaker strips, refrigerator equipment, bobbins	National Vulcanized Fibre Co., Wilmington, Del.
Picco Di Polymer Oil	Plasticizer	For synthetic rubber	Pennsylvania Industrial Chemical Co., Clairton, Pa.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Piccolyte	Terpene resin	Paint and varnish manufacture, printing inks, paper coatings, textile waterproofing	Pennsylvania Industrial Chemical Co., Clairton, Pa.
Piccoumaron	Indene (and cumarone)	Used in paints, varnishes, lacquers, adhesives, cements, flooring	Pennsylvania Industrial Chemical Co., Clairton, Pa.
Plaskon	Urea-formaldehyde (molding compound)	Housings, buttons, displays, hardware, tableware, novelties, packaging, electrical parts, lighting fixtures	Plaskon Co., Inc., Toledo, Ohio
	Urea-formaldehyde resin	Adhesive for plywood	
Plastacele	Cellulose acetate (sheets, rods, tubes, molding powder)	Airplane windshields, automobile accessories, buttons, novelties, handles, radio parts	E. I. du Pont de Nemours & Co., Plastics Dept., Arlington, N. J.
Plasterez	Synthetic resin plastic paint	For plywood, wallboard, plaster interiors	I. F. Laucks, Inc., Seattle, Wash.
Plasticoil	Cellulose acetate and cellulose acetate butyrate (coiled — extruded)	Fluorescent lighting and decorative applications	Schwab & Frank, Inc., Detroit, Mich.
Plastiktrim	Cellulose acetate, cellulose acetate butyrate, etc. (extruded)	Architectural molding	R. D. Werner Co., Inc., New York, N. Y.
Plastilite	Cellulose acetate and cellulose acetate butyrate, etc. (extruded)	Architectural molding, furniture webbing	Wilson Metal Products Co., Columbus, Ohio
Plastine	Cellulose nitrate	Signs, house numbers	Sillcocks-Miller Co., South Orange, N. J.
Plastrim	Cellulose acetate and cellulose acetate butyrate, etc. (extruded)	Architectural molding, automobile interior trim	Michigan Molded Plastics, Inc., Dexter, Mich.
Plexiglas	Methyl methacrylate (sheets, rods, tubes)	Airplane windows, cockpit covers, gun turrets, transparent displays, jewelry	Röhm and Haas Co., Inc., Philadelphia, Pa.
Plexigum	Acrylic (solution)	Interlayer for safety glass	Röhm and Haas Co., Inc., Philadelphia, Pa.
Pliofilm	Rubber hydrochloride	Packaging, waterproof clothing, shower curtains	Goodyear Tire & Rubber Co., Akron, Ohio
Plioform	Modified isomerized rubber (thermoplastic molding material)	Hose, conveyors, and transmission belting	Goodyear Tire & Rubber Co., Akron, Ohio
Pliolite	Modified isomerized rubber	Paint vehicle, moisture- and vaporproof coating for cellulosic products, rubber compounding ingredient	Goodyear Tire & Rubber Co., Akron, Ohio
Pregwood	Phenolic (impregnated wood laminations)	Propellers for airplanes, golf club inserts, electrical insulation	Formica Insulation Co., Cincinnati, Ohio

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Primal	Acrylic (emulsion)	Leather finishes for upholstery, shoes, garments	Röhm and Haas Co., Inc., Philadelphia, Pa.
Protoflex	Casein derivative	Water-dispersible casein product	Glyco Products Co., Inc., New York, N.Y.
Prystal	Phenol-formaldehyde (sheets, rods, tubes, special castings)	Phonograph and radio cabinets, buttons, displays, novelties	Catalin Corp., New York, N. Y.
PVA	Polyvinyl alcohol	Tubing, rubber substitute (see Resistoflex)	E. I. du Pont de Nemours & Co., Wilmington, Del.
Pyraheel	Cellulose nitrate (embossed plastic)	Covering wooden heels	E. I. du Pont de Nemours & Co., Wilmington, Del.
Pyralin	Cellulose nitrate (sheets, rods, tubes)	Covering for toilet seats, slide fasteners, fountain pens, novelties	E. I. du Pont de Nemours & Co., Wilmington, Del.
Raytellics	Metal powder and flake	Decorative filler for plastics	Rayon Processing Co. of R. I., Central Falls, R. I.
Realwood	Phenolic laminating wood	Decorative surfaces in furniture, fixtures, and building construction	Formica Insulation Co., Cincinnati, Ohio
Resinox	Phenol-formaldehyde (molding compound)	Caps and closures, molded radio cabinets, electrical equipment, large housing, novelties, games, handles, knobs and pulls	Monsanto Chemical Co., Springfield, Mass.
Resinprest	Resin bonded plywood	Boat planking, signs, house exteriors, farm uses, industrial buildings	M & M Woodworking Co., Portland, Ore.
Resistoflex PVA	Polyvinyl alcohol (flexible tubing, sheets, solvent)	Automotive, aviation, and industrial hose assemblies, protective clothing, molded products such as washers	Resistoflex Corp., Belleville, N. J.
Resiston	Hard rubber (sheet)	Sheet insulation	American Hard Rubber Co., New York, N. Y.
Resovin	Vinyl	Dentures	S. S. White Dental Mfg. Co., Philadelphia, Pa.
Resproid	Vinyl copolymer (sheets, rods and tubes)	Shoe fabrics, tapes	Respro, Inc., Cranston, R. I.
Revolite	Phenolic (impregnated cloth)	Laundry-roll covers, covering for ironers	Atlas Powder Co., Zapon Div., Stamford, Conn.
	Synthetic resins	Decorative fabrics	
Rexenite	Cellulose acetate and cellulose acetate butyrate, etc. (extruded thread)	Wearing apparel, decorative fabrics	The Rex Co., Inc., Cambridge, Mass.
Rez	Liquid sealer and primer	For plywood, floors, wood trim	I. F. Laucks, Inc., Seattle, Wash.
Rezite	Liquid sealer and primer	For plywood and millwork, machine and dip application	I. F. Laucks, Inc., Seattle, Wash.
Rezitex		For plywood, stucco and brick exteriors	I. F. Laucks, Inc., Seattle, Wash.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Reziwood	Phenolic (laminated wood)	Treated plywood	I. F. Laucks, Inc., Seattle, Wash.
Rezyl	Alkyd (coatings)	Auto and furniture lacquers, exterior enamels and industrial finishes	American Cyanamid Co., New York, N. Y.
RHonite	Urea (emulsion)	Textile finishes for crush-resistant fabrics	Röhm and Haas Co., Inc., Philadelphia, Pa.
RHoplex	Acrylic (emulsion)	For textile finishes, permanent wash-fast finishes for dress and other fabrics	Röhm and Haas Co., Inc., Philadelphia, Pa.
Richelain	Phenolic and urea	Molded plastics, specialties, custom-made	The Richardson Co., Melrose Park, Ill.
Rub-Erok	Special rubber sheet composition for stabilized insulation	Radio and electrical insulation parts for short-wave switches, radio tube sockets, terminal posts	The Richardson Co., Melrose Park, Ill.
Rub-Tex	Molded hard rubber	Electrical insulation, refrigerator insulation, door frames, door tracks	The Richardson Co., Melrose Park, Ill.
RX 39	Acrylic	Denture material	Iteco Dental Mfg. Co., Portland, Ore.
Ryercite	Phenolic (molded)	Bearing material for bushings	Jos. T. Ryerson & Son, Chicago, Ill.
Ryertex	Phenolic (laminated)	Heavy-duty bearings	Jos. T. Ryerson & Son, Chicago, Ill.
Safety Samson	Cellulose acetate (film base)	Photographic film, movie and X-ray film, graphic arts	Celanese Celluloid Corp., New York, N. Y.
Safetyware	Phenolic (molded)	Novelties and smokers' supplies	The Bryant Electric Co., Bridgeport, Conn.
Saflex	Vinyl acetal (sheet plastics)	For safety glass	Monsanto Chemical Co., Springfield, Mass.
Samson	Cellulose nitrate (film base)	Photographic movie and X-ray film, graphic arts	Celanese Celluloid Corp., New York, N. Y.
Santolite	Toluene sulfonamide formaldehyde	Lacquers, coatings	Monsanto Chemical Co., St. Louis, Mo.
Saran	Vinylidene chloride derivatives	Extruded monofilaments, rods, tubes, tapes, injection moldings for chemical resistance and non-inflammability	The Dow Chemical Co,. Midland, Mich.
Sicapon	Binder	Water-soluble material	Glyco Products Co., Inc., New York, N.Y.
Simco	Cellulose nitrate	Signs, bathroom fixtures	Sillcocks-Miller Co., South Orange, N. J.
Spauldite	Phenolic (laminated — sheets, rods, tubes, fabricated parts)	Machine parts, gear stock, valve disks, washers, gaskets	Spaulding Fibre Co., Tonawanda, N. Y.
Stacol	Sodium borophosphate	Water-soluble resinous material	Glyco Products Co., Inc., New York, N.Y.
Staybelite	Hyrogenated rosin	Coatings	Hercules Powder Co., Wilmington, Del.

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Styramic	Polystyrene base insulating material	Electrical insulation in radio and television fields	Monsanto Chemical Co., Springfield, Mass.
Styron	Polystyrene	Injection moldings used in unlimited fields, wire coatings, paints, and lacquers	Dow Chemical Co., Midland, Mich.
Sundora	Cellulose acetate	Sheeting for lamp shades	E. I. du Pont de Nemours & Co., Arlington, N. J.
Super-Ace	Hard rubber	Sheet materials	American Hard Rubber Co., New York, N. Y.
Super-Beckacite	Phenolic	Oleoresinous base used in spar and marine finishes	Reichhold Chemicals, Inc., Detroit, Mich.
Super-Floss	Diatomaceous earth	Filler for plastics	Johns-Manville, New York, N. Y.
Sylphrap Cellophane	Regenerated cellulose	Wrappings	Sylvania Industrial Corp., New York, N. Y.
Syntex	Alkyd	Varnishes, lacquers, paints	Jones-Dabney Co., Div. of Devoe & Raynolds, Inc., Louisville, Ky.
Synthane	Phenol formaldehyde (laminated)	Radio insulation, gear material, textile machinery	Synthane Corp., Oaks, Pa.
Taylor	Phenolic (laminated)	Insulation	Taylor Fibre Co., Norristown, Pa.
Tec	Cellulose acetate	Costume jewelry, buttons, buckles, pens, radio grilles	Tennessee Eastman Corp., Kingsport, Tenn.
Tegit	Cold molded	Relay bases and covers, conduit outlets, heavy duty connector plugs	Garfield Mfg. Co., Garfield, N. J.
Teglac	Alkyd (coatings)	Clear and pigmented wood lacquers, sanding sealers and other lacquers not subjected to severe outdoor exposure	American Cyanamid Co., New York, N. Y.
Tego	Phenolic	Hot press bonding of plywood, veneers, radios, organs, paneling, aircraft, boats	Resinous Products & Chemicals Co., Philadelphia, Pa.
Templus	Phenolic (molded)	Electric wiring devices and specialties	The Bryant Electric Co., Bridgeport, Conn.
Tenite I	Cellulose acetate	Automobile steering wheels, interior hardware, costume jewelry, novelties	Tennessee Eastman Corp., Kingsport, Tenn.
Tenite II	Cellulose acetate butyrate	Toothbrush handles, continuously extruded forms	Tennessee Eastman Corp., Kingsport, Tenn.
Textac	Thermoplastic resin	For textile finishing	Hercules Powder Co., Wilmington, Del.
Textolite	Cellulose acetate	Flashlight cases, cosmetic containers	General Electric Co., Plastics Dept., Pittsfield, Mass.
	Cellulose acetate butyrate	Flashlight cases, radio bezels	

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Textolite (*Continued*)	Cold molded (nonrefractory)	Heaters, bases, knobs, wiring device parts, indoor roller-skate wheels	
	Cold molded (refractory)	Rheostat bases, arc chute deflectors	
	Methyl methacrylate	Lenses, dials	
	Phenolic (laminated)	Switchgear panels, fabricated parts, gears, bearings, cams	
	Phenolic (molded)	Decorative uses, wood flour and rag filler	
	Polystyrene	Refrigerator control knobs and handles	
	Urea-formaldehyde	Lamp reflectors, housings in color	
Thermoplax	Cold molded	Heatproof handles, electrical switch bases and parts, arc shields for electrical devices, conduit fittings, terminal blocks	Cutler-Hammer, Inc., Milwaukee, Wis.
Thiokol	Organic polysulfide (synthetic rubber) Crude sheeting, molding powder and liquid dispersions	Valve disks, gaskets, oil seals, gasoline and oil hose, oilproof synthetic rubber products	Thiokol Corp., Trenton, N. J.
Ucinite	Phenolic (laminated)	Electrical insulation	The Ucinite Co., Newtonville, Mass.
Uformite	Urea-formaldehyde	Protective coatings, laminating, plywood adhesive	Resinous Products and Chemical Co., Philadelphia, Pa.
Varcum	Phenolic resin	Paints, varnishes	Varcum Chemical Corp., Niagara Falls, N. Y.
Vermont	Asbestos fibers	Fillers for plastics	Vermont Talc Co., Chester, Vt.
Vernonite	Acrylic	Dentures and prosthetic devices in gum pink and clear colors	Röhm and Haas Co., Inc., Philadelphia, Pa.
Vimlite	Cellulose acetate coated wire screen	Windows, partitions	Celanese Celluloid Corp., New York, N. Y.
Vinal	Vinyl acetal	For safety glass	Pittsburgh Plate Glass Co., Pittsburgh, Pa.
Vinsol	Modified rosin	Binder for fiber-board products	Hercules Powder Co., Wilmington, Del.
Vinylite	Copolymer of vinyl acetate and vinyl chloride	Coated paper used as liners for bottle caps, containers. Used in preparation of baked surface coatings, molding material for pipe bits and lens frames, dials, crystals	Carbide and Carbon Chemicals Corp., New York, N. Y.
	Polyvinyl acetate	For preparation of both solvent and heat-sealing types of adhesives for paper, plastics, wood, plastic wood, artistic novelties	
	Polyvinyl chloride	Tubing for food products, wire insulation, extruded rods and fabricated shapes, coatings	

Trade Name	*Type*	*Typical Applications*	*Manufacturer*
Vinylite (*Continued*)	Polyvinyl acetate modified in methyl acetate	Adhesive solution for bonding metal to metal, metal to wood	
	Polyvinyl acetal	Interlayer for safety glass	
	Polyvinyl acetate modified in toluol	Adhesive solution for bonding metal to metal, metal to wood	
Vinylseal	Polyvinyl acetate (in solution)	General adhesive for paper, wood, plastics films	Carbide and Carbon Chemicals Corp., New York, N. Y.
Vinyon	Copolymer vinyl chloride and vinyl acetate	Used in production of synthetic yarn, filament, fabrics	Carbide and Carbon Chemicals Corp., New York, N. Y.
Vistanex	Polybutene (rubbery hydrocarbon)	Adhesives, fabric coatings, plasticizers, rubber compounding, gaskets, wire insulation	Advance Solvents & Chemical Corp., New York, N. Y.
Vuepak	Cellulose acetate	Packaging material, rigid transparent packages, containers, displays, book and brochure covers	Monsanto Chemical Co., Springfield, Mass.
Vue-Lite	Embossed cellulose acetate (translucent sheets)	Fluorescent lighting fixture panels	Monsanto Chemical Co., Springfield, Mass.
Vulcoid	Phenolic (laminated vulcanized fiber)	Arc chutes in air circuit breaker, formed insulating parts	Continental Diamond Fibre Co., Newark, Del.
X 2 B	Hard rubber	Radio insulation	American Hard Rubber Co., New York, N. Y.

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BIBLIOGRAPHY

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NAME INDEX

GENERAL INDEX