MODERN PULP *and* PAPER MAKING

A Practical Treatise

SECOND EDITION

BY

G. S. WITHAM, SR.

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TO MY WIFE

Elizabeth Hurley Witham

"It is one of the curious inconsistencies of human nature to despise paper because of its cheapness and also because of an idea that it is a frail thing easily destructible. This is an unreasoning prejudice against one of the most beautiful and perfect substances ever made by the genius of man. There are so many varieties, and it is, perhaps, more easily adaptable than any other substance known. Thousands of books have been written upon it and the thoughts of men transmitted from generation to generation. With care it is practically indestructible if well made."

E. B. Lintott: *The Art of Water Color Painting*

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Preface: Second Edition

The following notes for a preface to the Second Edition of this book were among the papers of the late George S. Witham, Sr.

"Since the publication of "Modern Pulp and Paper Making" in 1920 there have been momentous changes in the industry in America: for one thing the entire Southern paper industry has come into being. My own experience has greatly broadened. During the past fifteen years I have been connected as an official and as a consultant with mills in the South, on the Pacific Coast, in Wisconsin and in Canada as well as in the regions (New England and New York) where I gained my experience prior to the publication of the first edition of my book.

"I have tried to make the new edition truly "up-to-date" but have not deleted descriptions of older equipment and processes likely to be found in many mills where my readers may be employed.

"The chapters have been completely rearranged in more logical grouping. To save space the Appendix of tables is omitted as data of this kind are now to be found, in much more up-to-date form, in the annual issues of "Paper and Pulp Mill Catalogue" published in Chicago.

"I am indebted to a host of friends throughout the industry for information and illustrations. I have tried to acknowledge all such assistance. If I have inadvertently neglected anyone, I hope they will forgive the omission. I am especially indebted to my son, George S. Witham, Jr., to whom the chapter on the power plant is mainly due, as well as many of the illustrations of Pacific Coast practice; and to Mr. Francis M. Turner, whose combined knowledge of engineering and publishing has been constantly of assistance.

"I can only hope that the new book will serve the industry as well as the first edition seems to have done. My chief motive in writing this book was to give to young men in the paper industry the help that I would have been grateful for in my early days in the mill."

The work on the Second Edition was almost complete when Mr. Witham died in June 1939. With the assistance of his son, Mr. George S. Witham, Jr., himself a well known paper technologist, and many friends, the book has been made available to the technical public and fittingly crowns a lifetime of achievement on the part of its author.

Preface: First Edition

During thirty-seven years of experience in the pulp and paper industry the author has frequently and repeatedly felt the need of a practical work on the manufacture of pulp and paper, as carried on in America, that would not be so abstruse and technical as to be beyond the grasp of the average papermaker, and which at the same time would not merely skim the surface of the various subdivisions of the art.

In the present volume an attempt has been made to describe the equipment and processes actually used in pulp and paper plants on this continent today, giving such practical information as would be of help to men working around these plants from day to day. It is hoped that the present volume will be useful to practical papermakers and, at the same time, that it may possibly be of service to technical men not intimately in touch with the pulp and paper industry and desiring to know the salient facts about it.

No attempt has been made to describe every piece of equipment ever used in the industry. Neither has the author attempted to deal with the historical aspect. Also, while recognizing the great importance of chemistry in connection with papermaking, no chemical considerations have been introduced which would not readily be comprehended by one with no special knowledge of that science.

It may seem strange to some readers of this book that the author has not devoted more space to detailed information concerning bag paper—with which branch of the industry he is particularly identified. In the first place, relatively few of the readers of this book are likely to be especially interested in bag paper, and if overmuch space were devoted to this subject readers interested in other branches might justifiably feel that their interests had been neglected. Of course, this difficulty might have been avoided by giving equally detailed attention to every variety of paper, but such a treatment would have necessitated a much larger book and, consequently, one so expensive as to be beyond the reach of many men actually engaged in the industry. Moreover, the author has felt a certain reluctance to devoting too much space to the particular branch of the industry with which he is commercially identified.

Whenever the author has made use of ideas and experience of others as expressed in the literature serving the pulp and paper field, he has endeavored to give due credit.

Thanks are due to the many manufacturers of equipment, who have so kindly furnished material for illustrations, as well as much important information that is incorporated in this book. The author also is much indebted to the Union Bag and Paper Corporation for permission to use many illustrations taken in the company's plants. He is also duly appreciative of

the assistance rendered by Mr. G. S. Witham, Jr., who has contributed many useful hints, especially concerning the power plant chapter; by Mr. H. S. Ferguson of New York, who kindly checked all the figures on power consumption, and by Mr. William P. Cutter, to whom is due the index at the back of the book.

Finally, the author wishes to express his grateful appreciation of the assistance rendered on behalf of the Publishers by Mr. Francis M. Turner, Jr., Technical Editor of the Chemical Engineering Catalog, who has co-operated with the author throughout the preparation of the manuscript, covering a period of nearly two years.

G. S. WITHAM, SR.

Hudson Falls, New York.

Historical Note

✓ Recent researches in China by Sir Aurel Stein and Dr. Sven Hedin, recorded in R. H. Clapperton's wonderful book on paper, prove beyond a possibility of doubt that the Chinese were not only the inventors of rag paper, raw fiber (mulberry bark and bamboo) paper and paper made from a combination of raw fiber and rags, but also the inventors of loading, sizing and coating of paper. Six centuries before the secret was known to anyone else, in quite the same way as in our modern paper mills, and from the same kind of materials, the Chinese made paper so good it is in existence today. The capture of Chinese prisoners by the Turks and Arabs brought papermaking to Spain in the twelfth century via Bagdad, Egypt and Morocco. In the sixteenth century it was established in England, and by Wm. Rittenhouse in 1690 in Germantown, Pennsylvania.

According to Mr. Louis Le Clert's "Le Papier" published in Paris in 1929 the actual inventor of Chinese paper was a government official named Tsai L'un who lived in the first century of our era.

The name "paper" comes from "papyrus," a sort of rush abundant in the Nile Valley, which the Egyptians flattened and glued together and used to write on for thousands of years before they learned of paper.

1. Processes by Which Pulp is Produced

Cellulose [1] fibers are the basis of paper. They were formerly prepared from linen and cotton rags exclusively; but, although still so prepared for certain fine grades of papers, the main source of cellulose fibers for paper is now wood.

There are two forms of wood pulp, (a) *mechanical* pulp, which is further classified into ordinary mechanical pulp and semi-chemical pulp; (b) *chemical* pulp, which in turn is further classified into *sulphite* pulp, *soda* pulp, and *sulphate* or *kraft* pulp. The preparation of soda pulp and sulphate pulp are today usually treated as two modifications of one process —often spoken of as the "alkaline processes." The equipment and most of the procedure is the same, the chemical reactions being different.[2] Recently a number of other cooking liquors have been experimented with and one large mill is using a modified sulphite as the cooking liquor and making a very superior product.

Mechanical pulp

This pulp is often referred to as groundwood because it consists of wood pulp obtained by grinding wood into a fibrous condition. As already stated there are two types of mechanical pulp, viz.,

Ordinary mechanical pulp: The process is very simple as it merely involves the wet grinding of wood blocks. The composition of the mechanical pulp is practically identical with that of the wood itself. Groundwood made from fresh wood has a distinctive color, bearing on light yellow when it is properly ground and several shades lighter when ground with dull or hot stones. As a matter of fact, by careful observation and practice, one can judge the base of good groundwood, when properly made, from its color. If sap rot wood is ground these fibers can be detected because of the fact that the wood is so soft that it is torn off in fine chunks and will appear as such in the pulp itself. Made from such material, the pulp will invariably be dark, bulky, spongy and lifeless. On the other hand, a lighter colored pulp will result from a wood that is too dry, from which the sap and other life-giving bodies have been dried out.

The first groundwood mill in America was established at Lee, Mass., in 1867 by Steinway, the piano manufacturer.

The pulp produced by the mechanical process is inferior to that produced by the chemical processes, although in the past few years there has been vast improvement in the quality of groundwood as the result of

[1] For details regarding the nature of cellulose see pp. 22-24.

[2] The author has thought it advisable to adopt this mode of treatment, thereby avoiding repetition. Consequently for details refer to Chap. 8, Alkaline Processes, which combines the subject matter of the separate chapters in the First Edition of this book on Soda Process and Sulphate Process.

intensive research, and therefore it is used only in making those kinds of paper where the highest quality is not demanded and price is the chief consideration, e.g., in newsprint; or else in judicious combination with chemical pulp, as in the manufacture of certain wall, bag and wrapping papers. The relative inferiority of paper containing mechanical pulp is due to the shortness and weakness of the fibers, together with the fact that such paper will deteriorate and turn yellow owing to the action of sunlight and the atmosphere on the lignins [1] contained in the wood pulp.

Mechanical pulp is, however, much cheaper to make than any other form of paper pulp. In the first place, only about two per cent of the raw material is lost, as compared to 50 per cent or more in the chemical processes. Secondly, there are no chemicals required. Finally, the equipment necessary for making mechanical pulp is much cheaper, both as regards first cost and maintenance, than that required for making chemical pulp.

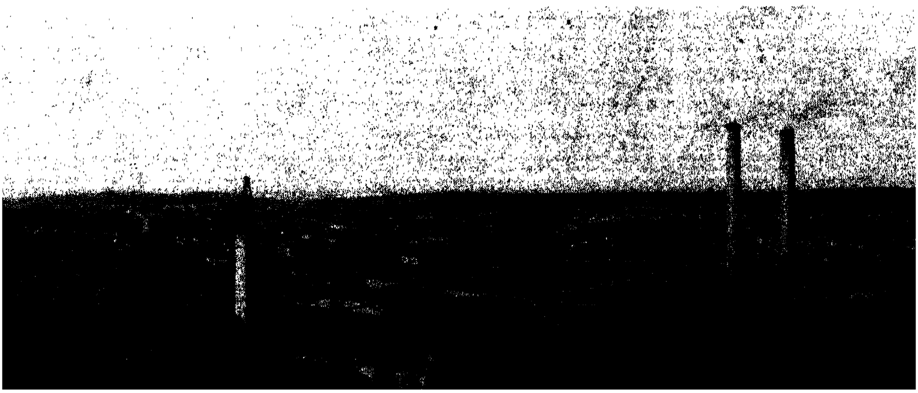
Semi-chemical: This process differs from the "ordinary" only in that the wood is steamed before being ground. As a result of the steaming the pulp loses some of the soluble resinous incrustants of the fiber. The steaming also brings out certain characteristics that make the pulp more suitable for some finished products, stronger and more flexible than that produced by the "ordinary" process. The action of the steam on the wood results in the fibers being colored brown and this limits the application of this kind of pulp to uses, such as the making of brown boards and wrapping paper, where this color is not objectionable.

Chemical pulp

Sulphite: In this process (described in detail in Chap. 6) the pulp is obtained by digesting wood chips with an acid liquor at a high tem-

[1] Lignin is the name given to the complex chief non-cellulose constituent of wood. There is no agreement as to its chemical composition. (See: Hawley, L. F. and Wise, L. E., "Chemistry of Wood," pp. 43-96, New York, Chemical Catalog Co., Inc. (Reinhold Publishing Corp.), 1926, especially p. 43, lines 1-18, and also p. 172.) It is the basis of many useful by-products such as road and core binders.

Great Northern Paper Company's sulphite, groundwood, newsprint, anc



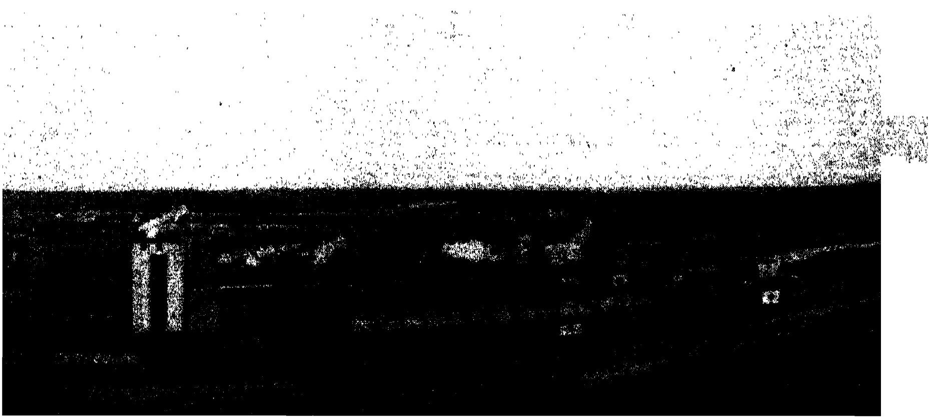
perature and pressure. The acid liquor is chemically known as bisulphite of lime liquor. For details of its preparation see Chap. 7. The liquor dissolves and removes all the constituents of the wood chips except the cellulose, which in impure form constitutes the unbleached sulphite pulp. When bleached this pulp consists of practically pure cellulose. The yield of cellulose will vary from 49 per cent to 53 per cent of the weight of the prepared wood, depending upon the exact process employed. The Mitscherlich process (see below) employing a slow indirect cook will give the highest yield, while the short, direct cook will give the minimum yield.

The invention of the sulphite process is usually credited to Benjamin Tilghman, a Philadelphia chemist who patented the results of experiments at the mills of W. W. Harding & Sons at Manayunk, Pa., about 1866. He used a horizontal rotary digester heated with a steam coil and encountered teriffic mechanical problems. After spending a fortune on experiments he gave up without achieving any commercial success.

A Swedish chemist, C. D. Ekman, has to receive credit for the first actual sulphite pulp mill in the world, started in 1874, using rotary digesters and magnesium bisulphite as a cooking liquor. Apparently he knew nothing of Tilghman's work and patents. An American concern bought a license from Ekman and started a mill at Richmond, Va., under the supervision of Charles Wheelwright, who greatly improved the process. Meanwhile a German chemist called Mitscherlich developed Tilghman's original process and succeeded in making good pulp. August Thilmany introduced the Mitscherlich process into America in 1887 at a mill at Alpena, Mich. The process is still in use at a few mills employing the same acid liquor as the standard sulphite process but a special horizontal digester heated with lead-covered coils.

An Austrian firm named Ritter-Kellner secretly developed a modification of the Ekman process and hit on the important idea of introducing steam directly into the digester. This advance was patented in Austria in 1882 and soon after Russel and Riordon took out a license and erected

wrapping paper mill at Millinocket, Maine; typical of a large eastern plant.



the pioneer plant of the great North American sulphite pulp industry at Merriton, Ont., Canada, in 1885. Today there are hundreds of mills all over the United States, Canada, and abroad.

Sulphite pulp costs considerably more to make than mechanical pulp. In the first place only about 50 per cent of the raw material is retained in the finished product. Moreover, much labor and power must be spent on the preparation of the wood before it reaches the digesting process proper. Also, it involves the upkeep of a large chemical plant for making the acid liquor. Finally, the machinery is expensive both as to first cost and maintenance, the upkeep being high as the acid nature of the process makes for rapid deterioration. The sulphite process requires about 1,300 to 1,500 lbs. of coal per ton of pulp; 232 lbs. of sulphur; 300 lbs. of limestone.. However, the greater length and higher pliability and strength of the sulphite fibers, together with the freedom from deterioration, cause it to be used instead of mechanical pulp for all except the cheapest grades of paper, in spite of its higher cost.

Soda: In this process (described in detail in Chap. 8) the pulp is obtained by digesting wood or other fibers with a solution of caustic soda which combines with the acid constituents of the non-fibrous parts of the wood, leaving in an insoluble state pure cellulose, which is then washed to free it from impurities that may have been formed during the reaction, and subsequently bleached.

The soda process was an outgrowth of the treatment of rags with alkali to make stock for paper. It was developed in England by Watt (of steam engine fame) and a papermaker called Burgess about 1854. The first soda mills in America were near Philadelphia. The oldest mill west of the Alleghenies is that still successfully operated by Mead Corporation at Chillicothe, Ohio.

The soda process is of general application for many woods and fibers that cannot readily be treated by the sulphite process. Ordinarily the soda process is used for the reduction of short fiber woods such as poplar, beech, etc. Unbleached soda pulp is used to some extent in the manufacture of wrapping paper where color is not a consideration. In the bleached state it is used in the manufacture of book, magazine, and envelope papers, especially where soft texture and bulk are the essentials.

Sulphate: The term sulphate pulp was originally used to designate a thoroughly cooked pulp made by digesting wood chips with sodium sulphate and sulphide liquor. This pulp could be bleached with a reasonable amount of bleach. It found application in the manufacture of papers quite different from those made from kraft pulp. The term kraft pulp was originally intended to mean imperfectly cooked sulphate pulp which was further disintegrated by means of a kollergang (a big "edge runner" such as is used in foundries) before being put on the paper machine. Now, however, the two terms sulphate and kraft have in America gradually merged into each other as a result of the decreased output of true sulphate pulp and the increased production of and demand for the kraft pulp. A change has also taken place in the manufacture of kraft. The treatment in kollergangs has been entirely abandoned, at least in America, the disintegration now being completed in beaters and Jordan engines, and more recently in rod mills.

The sulphate process was invented by C. F. Dahl, a Swede, at the free city of Danzig in 1879. He sought to substitute "salt cake," a by-product of chemical manufacture, for soda ash. The industry developed rapidly in Sweden where the product became known as "kraft" from the Swedish word for strength—the dominant characteristic of papers made from sulphate pulp. The first sulphate mill in North America was started at East Angus, Que., Canada, in 1907 by Brompton Pulp & Paper Co. There are today many important mills throughout the United States and Canada. Recently many very large sulphate mills have been erected in the southern states utilizing pine as raw material.

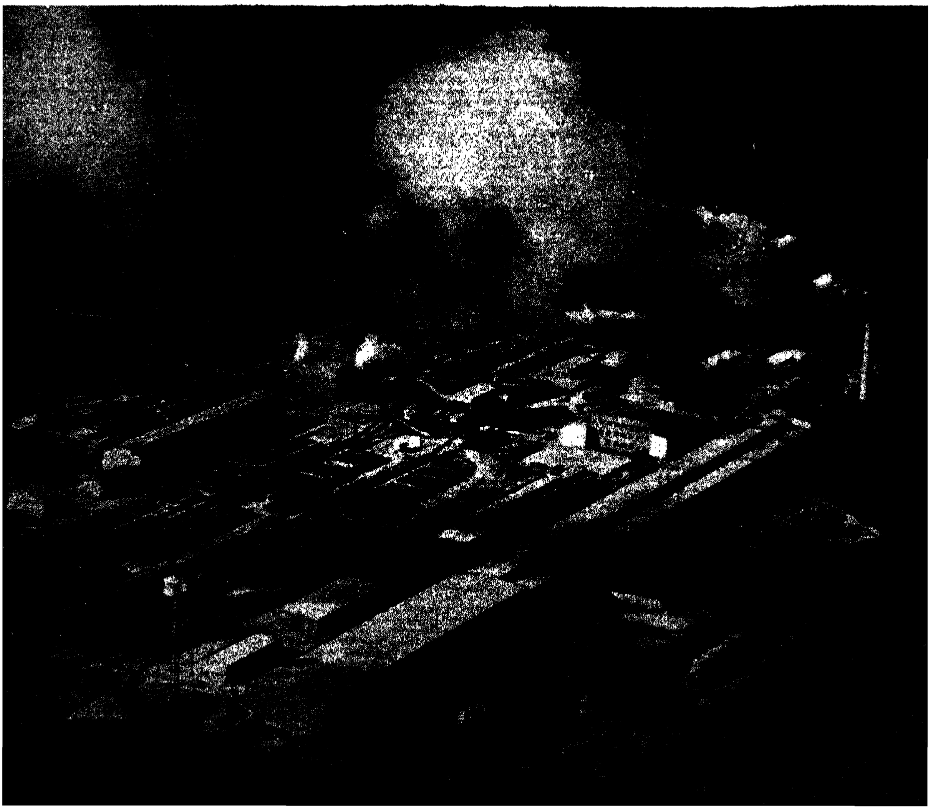
Kraft pulp is of a dull brown shade when unbleached and it is rarely completely bleached, since the process would require an immense amount of bleach and under no conditions would the bleached pulp have quite the purity and brilliancy of bleached sulphite pulp. Consequently it is used for the manufacture of products where color is not a consideration and where strength and ability to resist all kinds of wear and tear are desired,

Crown Zellerbach Corporation's Crown Willamette mill at Camas, Washington, typical of a modern Pacific Coast pulp and paper plant: This mill makes groundwood, sulphite and sulphate pulp and a variety of papers ranging from heavy wrappings to book papers and tissues.

as for instance in wrappings and bag papers. Recently partially bleached kraft has attained an increasing market due to greatly improved bleaching processes. (See Chap. 10.) The kraft process is especially adaptable to the pulping of long fibered resinous and non-resinous woods. Certain kinds of wood that are useless in the manufacture of sulphite pulp are adaptable to the kraft process. This fact, together with the fact that kraft pulp is ideal for certain much used kinds of paper has given a great impetus to the kraft branch of the industry, especially on the Pacific Coast and in the South.

In the kraft process several valuable by-products are formed which have found commercial use. The recovery of methyl alcohol, oil of turpentine and various resins is being carried out on a commercial scale. The lime sludge obtained in the causticizing of the lime liquor has been successfully worked up into a satisfactory coating material. It is only of late that attention has been paid to the utilization of these various by-products, but with the increasing cost of raw materials, labor, etc., such economies

International Paper Company's Springhill, Louisiana mill (the largest in the world) typical of the great new paper plants of the South. Sulphate pulp and kraft boards, milk-bottle stock, tags and paper for business forms are among its products.



are rapidly becoming essential in all branches of the industry in order to meet the figures of the competitor.

So far we have merely enumerated and briefly described the general processes of mechanical and chemical treatment of wood, the raw material ordinarily used for making pulp in America. Each of these processes will be the subject of further and much more detailed treatment in subsequent individual chapters.

Besides the above main branches of pulp manufacture there are numerous special modifications, such as treatment of straw, esparto, bamboo, cotton linters, ramie, bagasse, etc. In addition to the varying chemical treatments of the above and other fibers, we have the chemical treatments of rag, rope, jute and waste paper stocks, which are more of the nature of cleaning and purifying processes. The de-inking and re-pulping of waste papers on a large scale has recently assumed a position of great importance and introduced many new problems into the industry. Descriptions of these processes are incorporated in Chap. 2 on Materials of Pulp.

2. Materials of Pulp

For the manufacture of paper, vegetable substances have come to be of the greatest importance and the commercial value of any one vegetable substance is governed by the following:

1. The quantity of cellulose that the fibers contain.
2. The quality of this cellulose.
3. The facility with which the cellulose can be extracted from the fibers.

Cellulose

Cellulose [1] is a definite chemical compound first isolated by the French chemist Payen in 1838 with a formula which is some large multiple of $C_6H_{10}O_5$, always of vegetable origin and always existing in an organized condition, i.e., formed into fibers of definite form as the result of some special plant organism. However, it must be borne in mind that whatever the form in which cellulose occurs it is for all practical purposes of the papermaker chemically the same.

One of the purest forms of cellulose of natural occurrence is ordinary cotton fiber, the analysis of which according to Müller [2] is:

Cellulose	91.35 per cent.
Water	7.00 per cent.
Fatty substances	0.40 per cent.
Nitrogenous	0.50 per cent.
Ash (mineral)	0.12 per cent.
Cuticular matter	0.63 per cent.

Cellulose in its purest form (e.g., the alpha-cellulose of industry) is a white substance, the form varying according to the substance from which it has been prepared. It is prepared, when desired pure, by washing some natural cellulose-containing material with various chemical reagents which wash away all the other bodies present except the cellulose. As could be inferred from the above remarks regarding its method of preparation, cellulose is a very inert substance, hardly being affected at all by chemicals. An ordinary laboratory filter paper, which resists most chemical solutions, is almost pure cellulose.

The term *"alpha-cellulose"* or, using the Greek letter, "α-cellulose," constantly met with in modern literature on paper, rayon and other cellulose, refers to the residuary product left after treating commercially pure

[1] The author makes no attempt to deal with the chemistry of cellulose—one of the most difficult branches of organic chemistry and one where the leading experts, even today (1941), frequently disagree. A brief digest by C. F. Cross, eminent British paper chemist, will be found at the end of this chapter for the benefit of those of my readers who have no chemical library available and yet are curious as to the chemistry of cellulose. For more complete information, see: Hawley, L. F., and Wise, L. E., "Chemistry of Wood," New York, Chemical Catalog Co., Inc. (Reinhold Publishing Corp.), 1926; Schorger, A. W., "Chemistry of Cellulose and Wood," New York, McGraw-Hill Book Co., Inc., 1926; Sutermeister, E., "Chemistry of Pulp and Paper Making," 2nd ed., New York, John Wiley & Sons, Inc., 1929.

[2] Die Pflanzenfaser.

bleached chemical pulp (for instance spruce sulphite bleached by chlorination) in accordance with a set system of chemical extractions and washings. The small fractions washed away are known to chemists as beta (β) and gamma (γ) cellulose, and are of no direct interest to papermakers. Alpha-cellulose prepared from wood is practically identical with pure cotton cellulose. Since 1915 its manufacture has developed into a big industry in the United States, Canada and Finland. It is used for rayon, lacquers, plastics and chemical compounds.

Almost the only chemical reagent that will dissolve cellulose is Schweitzer's Reagent, which consists of copper hydroxide dissolved in ammonia. This reaction is made use of in the preparation of artificial silk and also in numerous tests for cellulose. However, alkali rapidly hydrolyzes pure cellulose.

Apart from the role it plays in paper technology, cellulose is important as being the basic material of gun-cotton, many military and industrial explosives, Celluloid, Cellophane, collodion, artificial silk, cellulose acetate products, airplane dopes, etc.

According to Griffin and Little,[1] spruce groundwood contains about 53 per cent cellulose. Read [2] reports poplar wood as yielding 41 per cent cellulose. Griffin and Little [3] state that unbleached sulphite pulp made from spruce contains 80.8 per cent cellulose and the same authors mention [4] experiments in which poplar wood yielded by the sulphite process 55.18 per cent cellulose.

According to Müller,[5] the following are the percentages of cellulose contained in a number of European woods:

Poplar	62.77 per cent.
Fir	56.99 per cent.
Birch	55.52 per cent.
Willow	55.72 per cent.
Scotch Pine	53.27 per cent.
Chestnut	52.64 per cent.
Linden	53.09 per cent.
Beech	45.47 per cent.
Ebony	29.99 per cent.

The following table [6] gives the composition of some of the more important Canadian woods:

Material	Age by annual rings	Diam. without bark	Cellulose %	Lignin %	Soluble in boiling water %
Black spruce	74	9½	50.64	27.59	7.24
Red spruce	69	10½	51.80	28.45	5.08
White spruce	83	10⅜	56.48	27.58	3.00
Balsam	54	6¾	50.98	32.75	4.80
Jack pine	61	8⅞	49.24	30.43	6.73
Hemlock	120	12	47.70	26.34	...

[1] The Chemistry of Paper Making, p. 120.
[2] Jl. Soc. Chem. Ind. 5 (1886), 273.
[3] The Chemistry of Paper Making, p. 267.
[4] The Chemistry of Paper Making, p. 269.
[5] Die Pflanzenfaser.
[6] Dr. Bjarne Johnsen, "Paper," XX, No. 8, p. 16 (1917).

Of the materials other than woods, linen (the fibers of the flax plant) contains from 70 to 80 per cent cellulose; jute, from 60 to 64 per cent cellulose; various straws from 48 to 53 per cent cellulose; esparto grass from 46 to 59 per cent cellulose; manila hemp about 50 per cent.

Such figures are the result of laboratory experiments where analytical means were adopted leading to the separation and estimation of all the cellulose present. It should be emphasized that they do not necessarily have any definite relation to the amount of pulp that could be produced from such substances under practical working conditions. The above results by Johnsen, however, were by a method yielding a cellulose indistinguishable from mill-made pulp.

In this connection the following table[1] giving the yields of pulp on a manufacturing scale may be of interest:

YIELDS OF PULP ON A MANUFACTURING SCALE

Rags	70-80 per cent pulp
Esparto	40-45 per cent pulp
Straw	40-50 per cent pulp
Wood (by sulphite process)	40-50 per cent pulp
Waste fibers, waste paper, bagging, etc.	75-90 per cent pulp
Bamboo	40 per cent pulp
Jute	50 per cent pulp

It should be remembered that in general the percentage yield varies with the quality of the pulp being produced and as a rule the higher the quality of the pulp the lower the percentage yield owing to the greater severity of the processes to which the raw material is submitted.

Almost all vegetable structures contain cellulose in some form and to some extent and consequently a great variety of materials have been suggested from time to time as raw materials for paper. It is not possible in this book to deal with all these materials, and attention will be directed only to those that are the basis of large actual manufacturing operations. It should not be inferred, however, that study and research concerning new materials for paper is not worthy of constant attention, as it indeed is, owing to the strain the modern demand for paper is putting on the ordinary present-day sources of pulp.

As stated above, almost any vegetable material of fibrous nature can conceivably be used as a source of pulp. The determining factors as to whether such a line of manufacture is attractive or not are the value of the product and the cost of manufacture. Scientific researches will indicate whether a usable paper can be made from a given material, but they will not yield an answer to the problem as to whether it can be made profitably. The locality has a considerable bearing on this. There are, undoubtedly, places where, on account of the distance of sources of supply of the usual raw materials, extraordinary materials can be profitably used to supply the local demand.

It is impossible here to submit a detailed analysis of the cost of making paper from different materials, but in general it might be said that the

[1] F. P. Veitch, U. S. Dept. of Agriculture, Bur. of Chem., Cir. 41.

cost of chemicals is greater per ton of product for paper made from wood than from most other materials. Also the time required for cooking is greater. However, wood yields a desirable product—long, strong fibers—and when the whole cost of treatment—the subsequent operations as well as the cooking—is taken into consideration the result will be found to favor the use of wood.

A new paper material has little chance of success in ordinary localities unless it will give an equal amount of as good a quality of paper as the present materials.

Fibers Used in Papermaking.

F. C. Clark[1] divides the fibers commonly used in papermaking into the following classes:

1. Seed-hairs, of which cotton and bombax wool are the only representatives.
2. Stem-fibers, such as linen, jute, manila, etc.
3. Leaf fibers, such as straw, esparto, pineapple, palm, etc.
4. Fruit fibers such as coconut.
5. Those derived from wood.

The first two classes find their way into practical papermaking, chiefly as rags and jute materials; the third class is used in straw boards, papers made from esparto, etc., while the fifth is by far the greatest in importance in modern papermaking, especially in America, being the raw material of most of our paper—newsprint, book papers, bag and wrapping paper, and all but the finest writings.

Wood.[2]

Different characteristics are required of woods according to whether they are to be used for chemical pulps or for mechanical pulp. There are, however, many types of wood which are suitable for both branches of pulp making, and this is especially true of spruce, at present the most important raw material of the papermaking industry.

In the manufacture of wood pulps the chief woods used are as follows:

For the manufacture of mechanical pulp: spruce, hemlock, balsam, fir, aspen, poplar and willow.

For the manufacture of sulphite pulp: spruce, hemlock, balsam and fir.[3]

For the manufacture of soda, sulphate and kraft pulps: spruce, tamarack, larch, hemlock, redwood, cypress, balsam, jack pine, southern pine, poplar and aspen.

The best white pulps are obtained from spruce. From a chemical stand-

[1] Paper, (New York) Vol. 23 (1919).

[2] For more complete information on various woods and their availability for papermaking see: Newlin and Wilson, "Mechanical Properties of U. S. Woods," Bull. U. S. Dept. Agric. No. 556, Washington (1917); McElhanney, "Canadian Woods." Patenaude, Ottawa, 1905; Rochester, "Canadian Woods," Can. Forest Service Bull., No. 82, Ottawa, 1933; Wells and Rue, "Suitability of American Woods for Paper Pulp," Washington, U. S. Dept. Agric. Bull. No. 1485 (1927). Also write U. S. Dept. Agric., Washington; Can. Forest Service, Ottawa; and N. Y. State Col. Forestry, Syracuse, N. Y., for information as to latest literature on this subject.

[3] One important mill in the Adirondack region has long been making hardwood sulphite pulp which is of excellent quality for book and magazine paper. As far as the writer knows this mill is unique in America.

point it is desirable as it contains a maximum percentage of cellulose. The fibers are longer, more flexible and stronger than most other woods. Moreover, abundant supplies of spruce are obtainable in the United States and Canada, as well as in other countries, although well regulated plans of forest conservation will need to be carried out if this supply is to be maintained indefinitely.

From a microscopical standpoint the cells from different trees present different appearances, and those of the conifers, such as spruce, pine, fir, hemlock, balsam, etc., closely resemble one another. By the use of a microscope and careful training along that line, the different fibers can be recognized and the different types of wood that have been used to make up a sheet of paper can be detected. This subject will be more fully dealt with in the chapter on the testing of paper.

PULPWOOD CONSUMPTION BY QUANTITY AND COST, AND BY KIND OF WOOD, FOR THE UNITED STATES IN 1938.*

Kind of wood	Cords	Cost
Yellow pine, Southern	3,261,404	$17,570,346
Spruce:		
Domestic	1,447,457	17,249,767
Imported	832,295	11,822,410
Hemlock:		
Domestic	1,677,181	11,124,455
Imported	37,243	212,852
Poplar:		
Domestic	324,868	2,947,023
Imported	95,758	1,111,224
Balsam fir:		
Domestic	321,984	3,446,131
Imported	65,392	731,128
Jack pine, domestic and imported	258,570	2,460,539
Beech, birch, and maple, domestic and imported	168,796	1,667,233
White fir, domestic	98,878	608,238
Gum	47,967	324,086
Cottonwood	40,996	257,069
Tamarack (larch)	9,937	80,735
Other woods	274,105	2,006,656
Slabs and mill waste	231,160	813,289
Total	9,193,991	$74,433,181

PULPWOOD CONSUMPTION, BY PROCESS OF MANUFACTURE, FOR THE UNITED STATES, IN 1938.*

Process	Cords	% of total
Mechanical	1,219,306	13.3
Sulphite	3,090,046	33.6
Sulphate	4,025,540	43.8
Soda	718,172	7.8
Semi-chemical	140,927	1.5
Total	9,193,991	100.0

* Forest Products, 1938: Pulpwood Consumption and Wood-Pulp Production, Bulletin, U. S. Dept. of Commerce, Bureau of the Census.

Spruce: This is the most important wood for the manufacture of both mechanical pulp and chemical pulp. There are several species such as black spruce and white spruce which, from the papermaker's point of

WOOD-PULP PRODUCTION, BY PROCESS OF MANUFACTURE, FOR THE UNITED STATES IN 1938.*

Process	Short tons	% of total
Mechanical [1]	1,337,523	22.5
Sulphite [1]	1,630,110	27.5
Sulphate [1]	2,452,076	41.3
Soda	395,307	6.7
Semi-chemical and other wood pulp	118,544	2.0
Total [1]	5,933,560	100.0

[1] Includes data for screenings as follows: 1938, mechanical, 4,215 tons; sulphite, 23,634 tons; and sulphate, 9,025 tons.

* Forest Products, 1938: Pulpwood Consumption and Wood-Pulp Production, Bulletin, U. S. Dept. of Commerce, Bureau of the Census.

PULPWOOD CONSUMPTION, BY QUANTITY AND COST, AND WOOD-PULP PRODUCTION, BY QUANTITY AND VALUE, BY STATES IN 1938.*

[Statistics are presented in this table for each State for which separate figures can be published without disclosing the exact or approximate production reported by individual establishments. Larger quantities of pulpwood and wood pulp were, however, reported from certain other States than from some of the States for which separate figures are given.]

State	Wood Consumed		Pulp Produced	
	Cords	Cost	Short Tons	Value
United States	9.193,991	$74,433,181	5,933,560	$180,394,204
Northeastern and Central States,[1] total	2,376,534	27,948,652	1,732,011	59,981,771
Maine	1,058,076	11,681,607	847,317	23,349,032
New Hampshire	262,233	2,783,853	133,188	8,908,094
New York	526,484	7,539,303	427,024	14.233,120
Pennsylvania	283,886	3,756,020	165,098	8,028,415
Vermont	15,921	184,523	16,552	345,970
Other Northeastern and Central States [2]	229,934	2,003,346	142,832	5,117,140
Lake States, total	1,496,478	16.455,744	934,510	35,897,850
Michigan	270,690	2,886,391	177,870	6,454,374
Minnesota	255,399	2,595,416	170,748	5,521,572
Wisconsin	970,389	10,973,937	585,892	23,921,904
Southern States,[3] total	3,528,734	19,057,888	2.179,292	48,601,980
Florida	487,235	2,796,397	316,754	5,564,742
Louisiana	722,559	3,209,529	454,211	9,571,845
North Carolina	366,144	2,336,806	199,342	6 503,908
Virginia	559,277	3,455,709	334,869	8.829,734
Other Southern States [4]	1,393,519	7,259,447	874,116	18,131,751
North Pacific States, total	1,792,245	10,970,897	1,087,747	35,912,603
Oregon	342,229	2,382,005	250,788	5,759,628
Washington	1,450,016	8,588,892	836,959	30,152,975

[1] Including Tennessee and West Virginia.
[2] Maryland, Massachusetts, Ohio, Tennessee, West Virginia.
[3] Not including Tennessee or West Virginia.
[4] Alabama, Arkansas, Georgia, Mississippi, South Carolina, Texas.
* Forest Products, 1938: Pulpwood Consumption and Wood-Pulp Production, Bulletin, U. S. Dept. of Commerce, Bureau of the Census.

Some Properties of Certain Woods Grown in the United States [1]

(Average Values—Considerable Variation on Either Side May Be Encountered)[2]

	Spec. Grav.[3]	Shrinkage[4] %	Bark[5] %	Hardness[6] Side	Hardness[6] End	Cellulose %	Lignin %	Solubility in— Hot Water %	Solubility in— Ether %
CONIFERS									
Spruce									
Engelmann	0.31	10.4		240	250				
Red	0.38	11.8		350	410				
Sitka	0.37	11.5		350	430	60.5	29.6	5.0	0.8
White	0.37	13.7	12.4	320	350	60.4	29.0	2.9	1.2
Fir									
Alpine	0.31	9.0		220	280				
Balsam	0.34	10.8		290	290				
Lowland White	0.37	10.6	9.1	360	420	63.0	27.0	2.3	0.9
Noble	0.35	12.5		290	330				
Silver	0.35	14.1	15.9	310	360	60.8	28.2	3.2	0.9
White	0.35	9.4		330	380				
Douglas Fir									
Coast Type	0.45	11.8	10.6	480	510	59.7	30.3	5.6	0.9
Pine									
Jack	0.39	10.4	9.8	370	380	58.7	28.5	3.7	2.2
Loblolly	0.47	12.3	10.5	450	420	58.7	28.3	1.8	1.9
Lodgepole	0.38	11.5		330	320				
Longleaf[8]	0.54	12.2	11.6	590	550	58.6	30.8	3.1	2.1
Ponderosa	0.38	9.6		310	300	58.0	27.2	4.8	6.8
Red (Resinosa)	0.44	11.5		340	360				
Shortleaf	0.46	12.3	11.9	440	410	58.8	29.0	2.6	2.0
Slash	0.56	12.2	15.6	630	600	59.8	27.6	3.6	3.3
Sugar	0.35	7.9		310	320				
White Northern	0.34	8.2	12.5	310	310	60.0	27.5	4.6	3.0
White Western	0.36	11.8		310	310	59.7	26.4	4.5	4.3
Hemlock									
Eastern	0.38	9.7	18.9	400	500	54.4	34.1	3.7	0.6
Western	0.38	11.9	9.7	430	520	59.6	30.2	3.0	0.7
Larch									
Tamarack	0.49	13.6		380	400				
Western	0.48	13.2		450	470	57.8[7]		12.6[7]	0.81[7]
Cypress									
Southern	0.42	10.5		390	440				
HARDWOODS									
Ash									
White	0.55	13.3		960	1010				
Basswood	0.32	15.8		250	290	61.2[7]		4.1[7]	1.9[7]
Beech	0.56	16.3		850	970				
Birch									
White	0.48	16.2	13.2	560	470	60.6	25.7	2.7	1.0
Yellow	0.55	16.7		780	810	61.3[7]		4.0[7]	0.6[7]
Butternut	0.36	10.2		390	410				
Chestnut	0.40	11.6		420	530				
Cucumber	0.44	13.6		520	600				
Elm									
American	0.46	14.6		620	680				
Gum									
Black	0.46	13.9	12.4	640	790	56.7	28.4	4.0	0.4
Red	0.44	15.0		520	630				
Maple									
Red	0.49	13.1		700	780				
Silver	0.44	12.0		590	670				
Sugar	0.56	14.9	13.7	970	1070	60.8[7]	23.2[8]	4.4[7]	0.3[7]
Poplar									
Aspen	0.35	11.5	18.4	300	280	65.5	23.4	3.0	1.1
Balsam	0.30	10.5		230	240				
Cottonwood	0.37	14.1		340	380				
Large-toothed	0.35	11.8		370	400				
Yellow	0.38	12.3		340	390				
Sycamore	0.46	14.2		610	700				

[1] This table has been completely revised by the Staff of the Forest Products Laboratory, Madison, Wisc.

[2] The data given in this table, unless otherwise marked, were obtained as follows:

(a) Data on Specific Gravity, Shrinkage and Hardness from "Strength and Related Properties of Woods Grown in the United States" by L. J. Markwardt and T. R. C. Wilson, Technical Bulletin No. 479, U. S. Department of Agriculture, Washington, D. C., 1935.

SOME PROPERTIES OF CERTAIN WOODS GROWN IN CANADA[9]

	Spec. Grav.[3]	Shrinkage[4] %	Hardness[6] Side[10]	Hardness[6] End	Solubility[12] in— Hot Water %	Solubility[12] in— Ether %
CONIFERS						
Spruce						
Black	0.40	11.6	355	410	2.2	0.6
Engelmann	0.37	11.5	340	340	2.1	0.7
Red	0.38	11.9	365	440	2.2	0.7
Sitka	0.35	11.7	325	400		
White	0.35[11]	10.8	280	340	2.6	0.4
Fir						
Balsam	0.32[11]	10.9	275	320	1.8	0.6
Silver	0.35	12.4	335	400		
Douglas Fir						
Coast Type	0.47	12.3	525	610	6.33	1.43
Mountain Type	0.43	11.5	440	520		
Pine						
Jack	0.43	9.8	405	420	5.98	1.91
Lodgepole	0.40	11.4	360	340		
Red	0.39	10.0	340	330		
White	0.34	8.0	265	270		
White, Western	0.37	11.6	300	300		
Yellow, Western	0.44	10.5	420	400		
Hemlock						
Eastern	0.38	10.1	425	570	3.88	0.27
Western	0.41	12.9	460	560	4.16	0.41
Larch						
Eastern	0.48	11.3	425	480		
Western	0.53	14.0	585	640		
HARDWOODS						
Ash						
White	0.53	13.1	895	940		
Basswood	0.36	18.4	330	390		
Beech	0.59	17.7	1015	1100		
Birch						
White	0.51	14.4	620	570	1.58	0.51
Yellow	0.57	16.0	885	960		
Butternut	0.37	9.6	415	460		
Chestnut	0.43	10.0	610	710		
Elm						
White	0.52	15.2	795	850		
Maple						
Manitoba	0.41	13.9	520	560		
Red	0.51	12.4	760	890		
Silver	0.46	12.8	590	710		
Sugar	0.60	15.8	1175	1330		
Poplar						
Aspen	0.38	11.6	345	380	2.38	0.68
Balsam	0.37	11.6	280	290		
Cottonwood	0.36	11.8	425	430		
Large-toothed	0.39	11.9	410	380		

(b) Data on Bark, Cellulose, Lignin and Solubility in Hot Water and Ether from the summaries of Physical and Chemical properties of various woods used in pulping experiments at the Forest Products Laboratory, Madison, from 1927-1935. In (b) the averages of figures from complete logs were taken; e.g., in case of loblolly pine, the figures for summerwood, springwood and compression wood only were not considered.

[3] Based on oven-dry weight and green volume. A known volume of green wood is oven-dried, then the oven-dry weight divided by the weight of a volume of water equal to the volume of the green wood gives the specific gravity.

[4] Shrinkage in volume from green to oven-dry condition and calculated on the green volume.

[5] Calculated on the weight of unbarked wood.

[6] This test indicates the weight in lbs. required to embed an 0.444 inch steel sphere to half its diameter, and was made on green wood.

[7] L. F. Hawley and Louis E. Wise. Chemistry of Wood, pp. 176, 177. Chemical Catalog Company.

[8] Mixed second-growth and old growth wood.

[9] The data given in this table, except where otherwise marked, have been obtained from The Mechanical Properties of Canadian Woods by G. H. Rochester. Forest Service Bulletin No. 82, Department of the Interior, Ottawa, 1933.

[10] Average of tangential and radial values.

[11] J. D. Hale and J. B. Prince. A study of variation in density of pulpwood. Paper presented at the Joint Meeting of the Technical and Woodlands Sections of the Canadian Pulp and Paper Association, 1936.

[12] Figures obtained at the Pulp and Paper Division, Forest Products Laboratories of Canada.

view, may be considered as identical. Spruce readily yields a strong, long fiber when treated by the sulphite process. With the mechanical process, when carefully ground with tolerably dull stones at a low temperature, the corrugations of the stones being kept fine and uniform, spruce yields the best class of groundwood, i.e., that which approximates most nearly to sulphite. This involves a high power consumption (e.g., 55 to 100 hp. per ton of product). Spruce will yield about 1,150 lbs. air-dry pulp per cord of wood by the sulphite process.

Balsam: This wood does not equal spruce as raw material for either the sulphite or the mechanical process. It gives a smaller yield of pulp per cord of wood and produces a fiber of an altogether different character. The fiber carries more pitchy material. This causes trouble later on, and is a detriment when the pulp is to be bleached. Although the balsam fibers are of a length about equal to the spruce fibers, they are much softer and more flexible, and when made up into a sheet of paper they are very easily distinguished. Balsam, when pulped by the sulphite process, will yield about 950 lbs. air-dry pulp per cord of wood.

Balsam pulp, mixed with a small percentage of spruce sulphite, is very satisfactory for some bag papers. Such papers have good tearing and cleavage quality, a soft silky feel, and are very flexible. The above results can only be achieved, however, when the stock has been made with great care.

Hemlock: The general character of hemlock sulphite pulp is similar to spruce, but of somewhat inferior quality. Hemlock groundwood has a decided reddish tinge, which is an undesirable feature. The fibers from hemlock are shorter than spruce, but probably sufficiently long for the cheaper sorts of paper.

J. H. Thickens[1] says: "One who is accustomed to handling spruce groundwood will not be favorably impressed with the appearance of either hemlock or jack pine pulp. This is particularly true of the hemlock sheet. Both pulps are somewhat softer in texture than spruce, and, altogether, are not of so pleasing an appearance as the present commercial product."

Hemlock sulphite is highly adaptable to making high water finish papers. It has the property of taking on a high water finish more readily than any other kind of sulphite stock. Hemlock will yield by the sulphite process about 800 lbs. air-dry pulp per cord of wood.

Poplar and Aspen: These woods are very largely used in making soda pulp, although poplar is quite extensively used for sulphite pulp also. It has been found that under careful treatment these woods give a highly characteristic soda pulp that is soft, silky and pliable and well adapted to book and other such papers.

According to H. E. Surface[2] of the U. S. Forest Service, "Soda poplar pulp is the best known substitute for esparto pulp. Its principal use is in the bleached form, in conjunction with other pulps, and it enters into the highest grade of papers for which it is especially adapted. Such papers

[1] Experiments with jack pine and hemlock for mechanical pulp. U. S. Department of Agriculture, Forest Service, 1912.

[2] Paper: xxiii (1919), 23, p. 50.

are book, magazine, antique, coated, lithograph, map, envelope, writing, wood blotting, and the soft bulky papers sometimes required for special purposes. The pulps usually mixed with the soda pulps in making these papers are the longer-fibered pulps, such as rag pulps and sulphite wood pulps; and the proportion in which they enter the product varies from 0 to 80 per cent, depending upon the quality of the product and the uses to which it is to be put."

Poplar soda pulp lacks strength, and consequently it will generally be found with some other pulp which adds the necessary long, strong fiber to give strength and endurance. Poplar soda pulp is also desirable because of its opacity, a sheet made up largely from this pulp being more bulky and opaque than one composed more of sulphite or rag pulp.

Some poplar, aspen and similar woods are worked up by a modification of the sulphate process to form what is known as "American aspen cellulose," or sometimes as "poplar soda pulp." The fibers are shorter than in spruce sulphite, but the pulp bleaches easily and it is extensively used in European papers as a substitute for rag pulp.

Yellow Pine: Considerable work has been done, resulting in at least some cases in commercial operations, on the use of yellow pine chips in the kraft process. The pitch present in this wood prevents its use for the manufacture of sulphite pulp. During the cooking operation in the kraft process, however, the resins and pitch present in the wood are saponified and thus rendered soluble so they can be washed out. The fibers are characterized by unusual strength. Some work has been done in the South on extracting the resins and pitch with solvents and then using the extracted chips as raw material for pulp. Planer shavings have been utilized in this manner with some success.

According to Dr. C. A. Brautlecht of the University of Maine over ten per cent of the kraft pulp produced is now being bleached and this percentage will probably increase rapidly; that at present about one-third of the wood used is yellow pine, the other two-thirds being made up of tamarack, spruce, hemlock, jack pine, white pine and saw mill waste; that there is evidence to show that slash pine will grow to pulpwood size in the South in 20 to 25 years, especially on former cotton land, and can be delivered at $5.00 per cord at the mill; that other raw materials used in quantity can be obtained locally or at low cost in the South.

The series of tables on page 32 and succeeding pages, which record experiments carried out by the U. S. Forest Service in a miniature pulp mill, afford valuable data as to the pulp making properties of a large number of American woods.

Straw and Esparto.

Straw is converted into a bleached pulp for use in newsprint and magazine papers, and is also extensively worked up into pulp for strawboard. The treatment differs, depending on whether bleached pulp for paper manufacture or strawboard pulp is to be made.

The following description of the process whereby the various kinds of

RECORD OF EXPERIMENTAL COOKS USING THE SULPHITE PROCESS

Species	Shipment number	Cook number	Chip charge, bone-dry weight	Water in chips	Cooking liquor charge at start of cook — Concentrations: Total SO_2	Combined SO_2	Free SO_2	Combined MgO	Combined CaO
			Pounds	*Per cent*	*Grams per liter*	*Grams per liter*	*Grams per liter*	*Grams per liter*	*Grams per liter*
Bald cypress..........	S-3	1	36.7	9.1	43.8	15.4	28.4	....	....
		2	40.5	11.1	43.4	15.0	28.4	....	....
		3	29.6	18.2	42.6	14.3	28.3	....	....
Cotton gum...........	S-2	1	34.8	14.9	42.2	14.1	28.1	....	....
		2	39.8	13.1	43.1	14.7	28.4	....	....
		3	22.3	12.2	42.8	14.2	28.6	....	....
		4	22.7	10.2	42.8	14.3	28.5	....	....
Douglas fir...........	S-498	1	16.0	56.4	41.0	10.3	30.7	2.7	5.3
		2	17.0	47.2	38.5	10.4	28.1	2.7	5.4
Engelmann spruce.....	S-502	1	13.9	79.9	41.5	10.8	30.7	2.8	5.6
		2	14.0	78.1	41.3	10.8	30.5	2.8	5.6
		3	13.7	118.4	41.5	10.8	30.7	2.8	5.6
		4	12.7	96.3	41.2	10.5	30.7	2.7	5.4
		5	10.9	128.8	40.7	11.0	29.7	2.9	5.7
		6	18.7	33.6	40.0	10.3	29.5	2.7	5.3
		12	17.0	47.1	39.5	11.7	27.8	3.0	6.0
Grand fir.............	S-39	1	14.6	71.8	41.0	11.0	30.0	2.9	5.7
		2	15.4	62.6	41.0	12.2	28.8	3.2	6.3
		3	16.9	47.7	41.5	10.8	30.7	2.8	5.6
		4	18.8	33.3	40.5	10.8	29.7	2.8	5.6
		5	21.3	17.5	36.1	12.7	23.4	3.3	6.5
Hemlock.............	S-8	1	36.4	9.9	43.3	14.8	28.5	....	....
		2	36.1	10.8	42.5	13.4	29.1	....	....
Incense cedar.........	S-36	1	14.4	38.9	35.5	9.0	26.5	2.3	4.6
		2	15.5	28.9	40.0	9.6	30.4	2.5	4.9
		3	16.7	19.5	38.7	9.7	29.0	2.5	5.0
Jack pine.............	L-26B	6	13.9	80.4	41.0	11.5	29.5	3.7	5.0
		7	14.6	70.8	40.0	11.5	28.5	3.7	5.0
		8	13.7	82.0	40.0	11.0	29.0	3.5	4.7
		9	14.8	78.6	45.3	15.0	30.3	4.8	6.5
Loblolly pine..........	S-5	1	29.5	18.6	41.0	11.5	29.5	....	....
		3	42.0	13.1	43.8	15.2	28.6	....	....
	S-33	1	15.8	58.2	43.2	14.3	28.9	....	....
		2	19.2	30.2	42.2	13.9	28.3	....	....
		3	19.2	30.2	42.6	14.2	28.4	....	....
Lodgepole pine........	S-499	1	15.1	66.1	41.0	9.6	31.4	2.5	4.9
		2	15.2	64.7	39.8	9.6	30.2	2.5	4.9
		3	15.8	57.8	40.6	12.9	27.7	3.3	6.6
		6	17.3	44.3	39.5	10.7	28.8	2.8	5.5
		7	17.1	45.9	40.0	14.1	25.9	3.7	7.3
		8	19.4	28.7	40.7	11.5	29.2	3.0	5.9
		9	20.2	23.8	34.7	12.8	22.4	3.2	6.3
Red spruce...........	S-11	2	30.0	16.7	40.0	12.3	27.9	....	....
		3	28.9	21.1	42.2	11.7	30.5	....	....
		4	29.2	19.8	42.9	15.9	27.0	....	....
		5	17.2	16.3	38.5	10.0	28.5	....	....
Scrub pine............	S-19,21	1	30.3	15.5	43.3	15.2	28.1	....	....
		2	35.0	14.3	42.5	15.2	27.3	....	....
		3	37.3	11.9	43.5	15.1	28.4	....	....
Tamarack............	L-26E	14	23.2	7.6	49.0	18.5	30.5	5.9	8.0
		15	23.2	7.7	50.0	19.0	31.0	6.1	8.2
		16	23.2	7.7	49.0	19.0	30.0	6.1	8.2
		17	23.2	7.7	51.0	19.5	31.5	6.2	8.4
Western hemlock......	S-38	1	15.4	29.9	36.9	9.6	27.3	1.0	7.0
		2	19.0	58.0	38.7	9.2	29.5	2.4	4.7
		3	18.3	36.5	40.0	9.6	30.4	2.5	4.9
		4	45.3	32.5	40.7	11.3	29.4	2.9	5.8
		5	46.7	28.5	38.0	10.2	27.8	2.6	5.3
White fir.............	S-35	1	16.0	24.7	37.0	8.5	28.5	2.2	4.4
		2	16.1	24.1	40.0	9.6	30.4	2.5	4.9
	S-35,37	1	12.6	58.8	43.0	10.0	33.0	2.6	5.1
		4	25.4	57.3	36.3	8.3	28.0	2.2	4.3
		5	26.8	49.1	41.1	8.7	32.4	2.3	4.5
		8	48.9	22.7	40.1	9.6	30.5	2.5	4.9

RECORD OF EXPERIMENTAL COOKS USING THE SULPHITE PROCESS—*Continued*

Species	Shipment number	Cook number	Cooking liquor charge at start of cook: Quantity per pound of chips, bone-dry weight — Total liquor	Total S.	Combined S.	Free S.	Combined MgO	Combined CaO
			Gallons	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Bald cypress	S-3	1	1.09	19.9	7.0	12.9	....	....
		2	.99	17.9	6.2	11.7	....	....
		3	1.52	27.1	9.1	18.0	....	....
Cotton gum	S-2	1	1.15	20.2	6.7	13.5	....	....
		2	1.01	18.2	6.2	12.0	....	....
		3	2.02	36.1	12.0	24.1	....	....
		4	1.98	35.4	11.8	23.6	....	....
Douglas fir	S-498	1	2.82	48.2	12.1	36.1	6.3	12.5
		2	2.65	42.6	11.5	31.1	6.0	11.8
Engelmann spruce	S-502	1	3.24	56.1	14.6	41.5	7.6	15.0
		2	3.20	55.2	14.4	40.8	7.5	14.9
		3	3.28	56.7	14.7	42.0	7.7	15.2
		4	3.53	60.7	15.5	45.2	8.1	15.9
		5	4.11	69.9	18.9	51.0	9.8	19.5
		6	2.41	40.2	10.6	29.6	5.4	10.6
		12	2.65	43.6	12.9	30.7	6.8	13.3
Grand fir	S-39	1	3.09	52.9	14.2	38.7	7.4	14.6
		2	2.92	50.1	14.9	35.2	7.8	15.4
		3	2.66	46.0	12.0	34.0	6.2	12.3
		4	2.40	40.5	10.8	29.7	5.6	11.1
		5	2.11	31.9	11.2	20.7	5.8	11.6
Hemlock	S-8	1	1.10	19.9	6.8	13.1	....	....
		2	1.24	22.1	7.0	15.1	....	....
Incense cedar	S-36	1	3 13	47.3	12.0	35.3	6.1	12.1
		2	2.90	48.4	11.6	36.8	6.0	12.0
Jack pine	L-26B	6	2.89	49.3	13.9	35.5	8.9	11.9
		7	2.73	45.7	13.1	32.6	8.4	11.3
		8	2.91	48.7	13.4	35.3	8.6	11.6
		9	2.70	51.2	16.9	34.2	10.8	14.6
Loblolly pine	S-5	1	1.35	23.1	6.5	16.6	....	....
		3	.95	17.4	6.0	11.4	....	....
	S-33	1	2.85	51.4	17.1	34.2	....	....
		2	2.34	41.3	13.6	27.7	....	....
		3	2.34	41.7	13.9	27.8	....	....
Lodgepole pine	S-499	1	2.99	51.2	12.0	39.2	6.2	12.3
		2	2.96	49.2	11.9	37.3	6.2	12.2
		3	2.84	48.1	15.3	32.8	7.9	15.8
		6	2.60	42.8	11.6	31.2	6.0	12.0
		7	2.63	43.9	15.5	28.4	8.0	15.9
		8	2.32	39.4	11.1	28.3	5.8	11.5
		9	2.23	32.2	11.4	20.8	5.9	11.8
Red spruce	S-11	2	1.33	22.5	7.0	15.5	....	....
		3	1.38	24.4	6.7	17.7	....	....
		4	1.37	24.5	9.1	15.5	....	....
		5	2.62	42.2	11.0	31.2	....	....
Scrub pine	S-19, 21	1	1.32	23.9	8.4	15.5	....	....
		2	1.14	20.2	7.2	13.0	....	....
		3	1.21	22.0	7.6	14.4	....	....
Tamarack	L-26E	14	1.72	35.2	13.3	21.9	8.5	11.4
		15	1.72	35.9	13.6	22.3	8.7	11.7
		16	1.72	35.2	13.6	21.5	8.7	11.7
		17	1.72	36.6	14.0	22.6	8.9	12.1
Western hemlock	S-35	1	2.92	45.0	11.7	33.3	2.4	17.1
		2	2.11	34.0	8.0	26.0	4.2	8.3
		3	2.45	41.0	9.8	31.2	5.1	10.2
		4	.66	11.2	3.1	8.1	1.6	3.2
		5	.94	14.9	4.0	10.9	2.1	4.1
White fir	S-35	1	2.81	43.3	9.9	33.4	5.2	10.2
		2	2.79	46.6	11.2	35.4	5.8	11.5
	S-35, 37	1	2.78	49.8	11.6	38.2	6.1	11.9
		4	1.77	26.8	6.2	20.6	3.2	6.3
		5	1.68	28.7	6.1	22.6	3.2	6.3
		8	.61	10.2	2.4	7.8	1.3	2.5

RECORD OF EXPERIMENTAL COOKS USING THE SULPHITE PROCESS—*Continued*

Species	Shipment number	Cook number	Total	Duration of cooking: At zero gauge pressure	Duration of cooking: At maximum gauge pressure	Duration of cooking: Below zero steam pressure	Duration of cooking: At maximum steam pressure	Maximum pressures: Gauge	Maximum pressures: Steam
			Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Bald cypress	S-3	1	8.0	0.0	4.0	2.0	2.7	85	58
		2	10.0	.0	3.8	2.0	3.8	88	60
		3	11.0	.0	6.0	3.0	4.7	90	60
Cotton gum	S-2	1	8.0	.0	3.0	2.0	3.0	85	60
		2	7.5	.0	2.5	1.2	1.8	84	58
		3	9.0	.0	5.5	3.5	4.0	80	56
		4	9.0	.0	4.0	3.0	4.0	86	56
Douglas fir	S-498	1	8.0	.3	4.5	3.0	2.0	80	60
		2	9.0	.3	5.5	3.3	3.0	80	60
Engelmann spruce	S-502	1	10.0	.3	4.3	3.0	3.0	90	70
		2	10.0	.3	4.0	3.0	3.0	90	70
		3	9.0	.3	4.5	3.0	3.0	80	60
		4	10.0	.3	4.3	3.0	3.0	90	70
		5	10.0	.3	5.5	2.8	4.0	80	60
		6	10.0	.3	4.5	3.3	2.8	90	70
		12	10.0	.3	5.8	3.3	4.0	80	60
Grand fir	S-39	1	8.0	.3	4.0	3.0	2.0	80	60
		2	9.0	.3	3.0	3.5	2,0	80	60
		3	9.0	.3	4.0	3.0	2.0	80	60
		4	9.0	.3	5.0	3.0	3.0	80	60
		5	8.0	.3	4.0	3.0	2.0	80	60
Hemlock	S-8	1	8.5	.0	4.0	1.7	3.0	86	59
		2	9.0	.0	4.0	3.0	2.0	85	60
Incense cedar	S-36	1	8.0	.3	4.0	2.8	2.0	80	60
		2	9.8	.3	3.8	3.0	2.5	88	64
		3	12.5	.3	4.5	3.0	4.0	90	68
Jack pine	L-26B	6	10.0	.8	6.2	3.0	3.2	80	40
		7	10.0	.2	5.8	3.0	3.2	80	46
		8	15.0	.2	12.2	3.0	4.8	73	46
		9	15.0	.2	8.8	3.0	5.0	75	46
Loblolly pine	S-5	1	10.0	.0	2.0	2.7	.1	80	60
		3	8.0	.0	3.0	2.0	2.0	85	60
	S-33	1	10.0	.0	4.5	2.0	4.3	85	60
		2	10.0	.0	5.5	3.0	4.0	85	60
		3	11.0	.0	6.0	2.7	5.3	85	60
Lodgepole pine	S-499	1	8.0	.3	3.8	2.0	2.0	80	60
		2	9.0	.3	3.5	3.0	2.0	90	70
		3	12.0	.3	5.8	3.0	3.0	80	60
		6	10.0	.3	5.3	3.0	3.0	90	70
		7	9.0	.3	4.5	2.5	2.8	80	60
		8	11.0	.3	6.3	3.0	3.0	90	62
		9	12.5	.3	8.8	3.3	1.5	90	60
Red spruce	S-11	2	10.0	.0	7.0	2.5	.1	70-80	50
		3	10.0	.0	7.0	3.0	.1	70-80	60
		4	8.5	.0	4.0	3.0	2.0	85	60
		5	8.0	.0	4.0	3.0	2.0	80	60
Scrub pine	S-19, 21	1	7.7	.0	3.0	3.0	2.5	84	60
		2	9.0	.0	3.0	1.0	3.0	85	59
		3	9.7	.0	4.5	2.3	3.5	90	60
Tamarack	L-26E	14	10.0	.2	5.5	4.5	3.0	80	46
		15	16.0	1.0	9.0	5.0	4.0	80	46
		16	16.0	1.3	9.5	5.0	5.0	80	46
		17	20.0	.8	12.5	5.0	9.0	80	38
Western hemlock	S-38	1	8.0	.3	4.0	1.5	2.0	80	60
		2	10.0	.3	5.0	3.0	2.0	80	60
		3	9.0	.3	4.0	3.0	2.0	80	60
		4	9.0	.3	3.0	3.0	2.0	80	60
		5	9.0	.3	4.0	3.0	2.0	80	60
White fir	S-35	1	9.0	.3	5.3	1.8	4.0	80	60
		2	8.8	.3	4.0	2.6	2.8	80	62
	S-35,37	1	8.0	.3	3.3	2.5	1.5	80	60
		4	8.8	.3	5.5	2.3	4.0	80	60
		5	8.8	.3	4.7	2.8	3.0	80	54-68
		8	9.0	.3	4.5	3.3	2.0	80	60

RECORD OF EXPERIMENTAL COOKS USING THE SULPHITE PROCESS—*Concluded*

Species	Shipment number	Cook number	Yields		Quality of pulps			
			Screened pulp	Screenings	Ash	Cellulose	Bleach required	Loss on bleaching
			Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Bald cypress	S-3	1	43.5	[1]3.9	1.18	72.0	....	....
		2	46.9	[1]2.4	.68	75.6	126.0	12.9
		3	....	[1].5	.52	81.5	52.0	3.8
Cotton gum	S-2	1	43.0	[1]1.8	.99	83.5	35.0	4.6
		2	42.6	[1].3	.78	83.6	17.0	2.1
		3	44.5	[1].9	1.13	81.5	20.5	3.3
		4	43.5	[1].4	.99	82.7	35.0	5.2
Douglas fir	S-498	1	38.8	16.0	1.25	....	70.0	11.9
		2	32.9	25.8	....	....	....	....
Engelmann spruce	S-502	1	34.7	1.9	.89	86.7	15.0	2.9
		2	39.0	.3	.75	87.2	13.5	2.5
		3	45.2	1.2	.89	85.7	22.5	5.1
		4	45.7	.5	1.12	87.7	12.0	2.4
		5	52.5	.5	.98	88.0	12.3	2.2
		6	40.0	.3	.86	85.9	12.5	2.3
		12	40.1	.5	1.35	85.6	21.0	5.1
Grand fir	S-39	1	51.4	1.7	1.71	....	80.0	12.8
		2	24.1	19.4	2.00	72.8	....	....
		3	46.0	.6	.76	....	26.6	1.6
		4	46.9	1.5	.86	....	28.0	5.7
		5	46.4	2.4	2.78	....	40.0	7.8
Hemlock	S-8	1	43.8	[1]1.5	.75	81.2	85.0	10.0
		2	39.2	[1]3.7	.38	85.8	37.0	4.9
Incense cedar	S-36	1	40.8	8.3	2.37	71.3	....	....
		2	37.9	[1].3	1.38	78.6	....	....
		3	16.3	.4	1.35	80.8	....	....
Jack pine	L-26B	6	45.5	4.9	....	....	....	....
		7	34 8	17.2	....	....	....	....
		8	40.7	5.9	....	....	....	....
		9	53.2	3.0	....	....	....	....
Loblolly pine	S-5	1	....	1.3	.83	85.4	35.0	7.7
		3	....	[1]2.1	.57	83.1	39.0	5.7
	S-33	1	....	....	4.50	....	....	....
		2	....	....	1.06	76.6	72.0	9.3
		3	....	....	1.45	....	80.0	12.9
Lodgepole pine	S-499	1	43.6	7.6	1.15	80.3	50.0	8.8
		2	43.1	2.4	1.29	81.6	39.0	7.0
		3	39.9	3.1	2.53	81.2	29.0	6.6
		6	36.8	.5	.60	78.5	22.8	3.8
		7	50.9	5.3	6.84	75.5	43.0	13.7
		8	32.4	5.7	.65	....	23.0	3.6
		9	33.5	.3	.44	....	16.8	2.5
Red spruce	S-11	2	....	....	....	....	....	....
		3	....	[1]8.2	1.96	73.5	98.0	22.0
		4	....	[1].7	.67	86.1	17.0	3.6
		5	53.9	1.7	2.00	84.4	35.0	6.3
Scrub pine	S-19, 21	1	....	[1]6.7	1.13	....	65.0	9.5
		2	....	[1]3.1	.59	....	67.0	7.0
		3	....	[1]1.1	.43	....	20.4	4.1
Tamarack	L-26E	14	42.8	8.4	....	....	....	....
		15	46.0	.8	....	....	....	....
		16	45.8	1.5	....	....	....	....
		17	46.7	1.7	....	....	....	....
Western hemlock	S-38	1	43.6	.8	2.41	85.1	44.8	7.7
		2	45.2	2.5	1.29	83.1	41.0	7.6
		3	47.3	1.1	1.13	84.7	35.0	6.4
		4	28.6	18.1	1.24	80.3	72.0	11.7
		5	42.0	.3	.66	85.9	25.0	4.5
White fir	S-35	1	40.6	1.3	1.03	85.8	20.5	4.0
		2	42.7	.9	1.22	85.1	23.5	4.7
	S-35, 37	1	45 5	.2	1.23	85.6	28.0	4.9
		4	48.3	.8	.66	88.0	19.0	1.8
		5	44.8	.4	.90	83.8	17.0	3.2
		8	41.4	.7	.43	86.0	12.8	1.1

[1] Air-dry screenings. Percentage based on bone-dry weight of chips.

RECORD OF EXPERIMENTAL COOKS USING THE SODA PROCESS

Species	Shipment number	Cook number	Chip charge, bone-dry weight	Water in chips	Cooking liquors at start of cook: Concentrations NaOH	Concentrations Na_2CO_3	Concentrations Total Na_2O	Causticity
			Pounds	*Per cent*	*Grams per liter*	*Grams per liter*	*Grams per liter*	*Per cent*
Aspen	L-19	2	39.4	9.1	80.5	2.2	63.7	97.9
		4	40.3	8.2	80.2	3.1	64.0	97.1
		7	39.9	9.8	71.6	2.7	57.1	97.2
		25	39.0	8.2	70.0	2.1	55.5	97.8
Beech	S-7	5	21.8	14.6	91.0	5.2	73.5	95.9
		6	22.1	13.0	90.0	6.4	73.5	94.9
		7	22.1	13.3	90.0	4.6	72.5	96.2
		8	21.9	14.2	100.0	5.8	80.9	95.8
Cotton gum	S-4	3	22.4	11.8	90.0	5.1	72.7	95.9
		4	22.1	13.0	90.0	8.1	74.5	93.6
Douglas fir	S-498	1	40.4	9.1	90.0	2.7	71.4	97.8
		2	40.4	9.1	90.0	2.4	71.2	98.0
Engelmann spruce	S-502	4	21.4	16.9	90.0	5.0	72.7	96.0
		5	21.3	17.2	90.0	3.0	71.5	97.5
		6	21.1	18.6	80.0	2.7	63.6	97.5
		7	21.2	17.7	90.0	3.4	71.8	97.2
		8	22.1	13.4	80.0	3.2	63.8	97.1
Grand fir	S-39	5	21.9	14.3	90.0	7.6	74.2	94.0
		6	21.8	14.9	90.0	3.4	71.7	97.2
		7	21.9	13.9	90.0	6.1	73.3	95.1
		8	22.1	13.2	90.0	4.2	72.2	96.6
		13	21.4	17.1	80.0	5.7	65.3	94.9
		15	22.7	14.7	90.0	6.7	73.6	94.7
Incense cedar	S-36	3	21.9	14.4	80.0	3.7	64.2	96.0
		4	21.6	15.6	80.0	4.4	64.6	96.0
		5	21.8	14.7	80.0	3.7	64.2	96.5
		6	22.0	13.6	80.0	3.8	64.2	96.5
		7	22.0	13.9	90.0	3.9	72.6	96.0
Jack pine	L-105	1	35.8	39.8	90.0	2.4	71.2	98.0
		2	35.8	39.7	90.0	2.4	71.2	98.0
Loblolly pine	L-2	1	41.0	22.1	90.0	2.7	71.4	97.8
Lodgepole pine	S-469	1	22.2	12.6	90.0	3.4	71.7	97.2
		2	22.4	11.7	90.0	3.2	71.7	97.4
	S-499	4	21.8	14.7	90.0	4.9	72.6	96.0
		5	21.8	15.0	90.0	4.9	72.6	96.0
		7	22.2	12.9	80.0	3.2	63.9	97.1
		8	21.9	14.4	80.0	2.8	63.6	97.4
Longleaf pine	L-3	1	41.9	14.6	90.0	2.7	71.3	97.8
		2	41.9	14.6	90.0	2.4	71.2	98.0
		3	41.9	14.6	90.0	2.4	71.1	98.0
Red alder	S-524	4	21.8	14.7	80.0	4.4	64.5	96.0
		5	21.5	16.4	80.0	3.9	64.3	96.5
		8	22.0	13.8	80.0	2.1	63.2	98.0
		9	21.5	16.3	80.0	4.0	64.3	96.4
		10	21.4	16.8	80.0	4.0	64.3	96.4
		11	21.5	16.1	80.0	3.7	64.2	96.6
Red maple	S-14	2	22.3	12.1	80.0	4.4	64.4	96.0
		3	22.2	12.9	80.0	5.9	65.5	94.7
		4	22.2	12.9	80.0	8.1	66.8	92.8
Sycamore	S-18	1	22.0	13.6	80.0	4.2	64.4	96.2
		2	22.1	13.2	80.0	4.6	64.7	95.8
Tamarack	L-26E	18	40.8	10.4	90.0	2.7	71.4	97.8
		19	40.8	10.4	90.0	2.4	71.2	98.0
Tulip tree	S-16	4	21.7	15.5	80.0	4.6	64.7	95.8
		5	21.7	15.2	80.0	5.7	65.3	94.9
		6	22.0	13.7	89.1	5.4	72.2	95.6
Western hemlock	S-38	8	17.6	13.8	80.0	4.7	64.7	95.9
		9	20.1	14.4	80.0	7.4	66.3	93.6
White fir	S-35	4	11.8	9.3	87.2	2.3	69.0	98.0

RECORD OF EXPERIMENTAL COOKS USING THE SODA PROCESS—*Continued*

Species	Shipment number	Cook number	Cooking liquors at start of cook: Quantity per pound of chips, bone-dry weight: Total liquor	NaOH	Na_2CO_3	Total Na_2O	Duration of cooking: Total	At zero gauge pressures	At maximum gauge pressure
			Gallons	*Per cent*	*Per cent*	*Per cent*	*Hours*	*Hours*	*Hours*
Aspen	L-19	2	0.399	26.8	0.8	21.2	8.0	0.4	7.0
		4	.594	39.7	1.6	31.7	7.0	.2	6.0
		7	.376	22.4	.9	17.9	7.0	.2	6.0
		25	.429	25.0	.8	19.9	8.0	.4	7.0
Beech	S-7	5	.371	28.2	1.6	22.7	8.5	.3	8.0
		6	.370	27.8	2.0	22.7	8.3	.3	8.0
		7	.371	27.9	1.4	22.4	8.3	.3	8.0
		8	.362	30.2	1.8	24.4	8.3	.3	8.0
Cotton gum	S-4	3	.392	29.5	1.67	23.8	8.3	.3	8.0
		4	.405	30.3	2.7	25.2	8.3	.3	8.0
Douglas fir	S-498	1	.333	25.0	.7	19.8	8.0	.3	5.0
		2	.333	25.0	.7	19.8	7.0	.3	6.0
Engelmann spruce	S-502	4	.353	26.5	1.4	21.4	6.5	.3	6.0
		5	.384	28.8	1.0	22.9	6.3	.3	6.0
		6	.428	28.6	1.0	22.7	9.3	.3	9.0
		7	.441	33.1	1.3	26.3	9.5	.3	9.0
		8	.431	28.8	1.1	22.9	9.3	.3	9.0
Grand fir	S-39	5	.398	29.9	2.5	24.6	7.3	.3	7.0
		6	.400	30.0	1.1	23.9	9.3	.3	9.0
		7	.462	34.7	2.4	28.2	7.3	.3	7.0
		8	.462	34.7	1.6	27.8	9.3	.3	9.0
		13	.332	22.2	1.6	18.1	10.3	.3	10.0
		15	.349	26.2	1.9	21.4	8.3	.3	8.0
Incense cedar	S-36	3	477	31.8	1.5	25.6	5.5	.3	5.0
		4	.481	32.1	1.8	25.9	6.5	.3	6.0
		5	.477	31.9	1.5	25.6	9.5	.3	9.0
		6	.326	21.8	1.0	17.4	12.3	.3	12.0
		7	.343	25.8	1.4	20.8	12.3	.3	12.0
Jack pine	L-105	1	.333	25.0	.7	19.8	7.0	.3	6.3
		2	.333	25.0	.7	19.8	8.0	.3	7.0
Loblolly pine	L-2	1	.333	25.0	.7	19.8	7.0	.3	6.0
Lodgepole pine	S-469	1	.390	29.4	1.1	23.3	9.3	.3	9.0
		2	.367	27.5	1.0	21.9	10.3	.3	10.0
	S-499	4	.368	27.6	1.5	22.3	7.5	.3	7.0
		5	.373	28.0	1.5	22.5	10.5	.3	10.0
		7	.442	29.5	1.2	23.6	10.3	.3	10.0
		8	.392	26.2	.9	20.8	12.3	.3	12.0
Longleaf pine	L-3	1	.333	25.0	.8	19.8	7.0	.5	6.0
		2	.266	20.0	.5	15.8	7.0	.3	6.0
		3	.267	20.0	.5	15.8	8.0	.3	7.0
Red alder	S-524	4	.388	25.9	1.4	20.9	8.3	.3	8.0
		5	.403	26.9	1.3	21.6	5.5	.3	5.0
		8	.520	34.7	.9	27.4	4.3	.3	4.3
		9	.534	35.6	1.8	28.6	6.3	.3	6.0
		10	.536	35.8	1.8	28.7	6.3	.3	6.0
		11	.681	45.4	2.1	36.5	6.3	.3	6.0
Red maple	S-14	2	.383	25.6	1.4	20.6	8.3	.3	8.0
		3	.386	25.8	1.9	21.1	10.3	.3	10.0
		4	.402	26.8	2.7	22.4	10.3	.3	10.0
Sycamore	S-18	1	.434	25.9	1.5	23.3	8.3	.3	8.0
		2	.387	25.9	1.5	20.8	10.3	.3	10.0
Tamarack	L-26E	18	.333	25.0	.8	19.9	7.0	.3	6.0
		19	.400	30.0	.8	23.8	7.0	.3	6.0
Tulip tree	S-16	4	.421	28.1	1.6	22.8	7.3	.3	7.0
		5	.427	28.5	2.0	23.3	10.3	.3	10.0
		6	.319	23.7	1.5	19.2	11.3	.3	11.0
Western hemlock	S-38	8	.385	25.7	1.5	20.8	8.3	.3	8.0
		9	.423	28.2	2.6	23.4	10.0	1.0	8.0
White fir	S-35	4	.346	25.2	.7	19.9	7.0	.3	6.0

RECORD OF EXPERIMENTAL COOKS USING THE SODA PROCESS—*Concluded*

Species	Shipment number	Cook number	Maximum gauge pressure	Yields: Screened pulp	Yields: Screenings	Quality of pulps: Ash	Quality of pulps: Bleach required	Quality of pulps: Loss on bleaching
			Pounds per square inch	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Aspen	L-19	2	100	50.3	0.0	0.81	8.0	1.1
		4	98	46.5	.0	.95	6.0	.4
		7	100	52.6	.0	.85	9.0	1.6
		25	100	50.8	.0	.79	9.5	1.4
Beech	S-7	5	110	50.7	.1	.73	13.2	2.1
		6	110	44.7	.2	.76	15.3	1.8
		7	110	45.4	.8	.78	14.7	3.0
		8	110	39.8	1.0	.92	...	...
Cotton gum	S-4	3	110	...	...	1.51	23.2	1.5
		4	110	43.7	.1	1.73	26.5	1.7
Douglas fir	S-498	1	110	45.3	.1	...	...	...
		2	100	46.1	.0	...	...	...
Engelmann spruce	S-502	4	110	46.0	1.0	.71	93.0	...
		5	110	37.8	.9	.82	67.0	7.4
		6	110	39.4	1.0	.69	69.0	8.2
		7	110	36.2	.1	.71	42.5	4.9
		8	110	42.4	.4	...	...	...
Grand fir	S-39	5	110	41.7	.1	.52	63.0	6.1
		6	110	41.5	.1	.60	46.0	4.8
		7	110	41.6	.1	.66	47.5	8.9
		8	110	40.8	.1	.59	44.6	4.4
		13	110	46.0	3.7	...	...	...
		15	110	47.9	.5	...	...	...
Incense cedar	S-36	3	100	38.6	1.3	.96	...	...
		4	110	39.5	.2	.78	90.	...
		5	110	35.2	.1	.73	80.0	9.1
		6	110	41.7	3.3	1.05	...	...
		7	110	36.3	.2	.69	...	...
Jack pine	L-105	1	100	48.1	.0	...	...	...
		2	90	51.8	.1	...	...	...
Loblolly pine	L-2	1	110	45.4	.0	...	...	...
Lodgepole pine	S-469	1	110	38.1	.1	.64	41.0	4.6
		2	110	40.9	.1	.90	51.5	...
	S-499	4	110	44.4	.1	.82	46.0	5.4
		5	110	39.0	.2	.87	41.0	5.4
		7	110	40.4	.1	.73	46.5	5.5
		8	110	42.1	1.1	...	...	...
Longleaf pine	L-3	1	100	48.6	.0	...	...	...
		2	100	46.7	4.4	...	...	...
		3	100	50.4	.0	...	...	...
Red alder	S-524	4	110	45.4	.1	.76	23.8	3.2
		5	110	48.7	.1	.77	25.5	3.5
		8	110	42.7	.1	.69	20.8	2.5
		9	110	38.2	.1	.71	20.1	2.8
		10	110	41.1	.1	.66	18.5	2.8
		11	110	39.1	.1	.87	18.0	2.3
Red maple	S-14	2	110	44.6	.2	.91	15.5	2.6
		3	110	...	...	.63	13.0	...
		4	110	42.6	.3	.78	12.4	...
Sycamore	S-18	1	110	43.4	.1	1.08	13.7	3.2
		2	110	45.4	.2	1.27	15.0	...
Tamarack	L-26E	18	110	35.0	8.7	...	...	...
		19	110	37.8	.0	...	...	...
Tulip tree	S-16	4	110	42.2	.0	.85	15.0	3.0
		5	110	40.7	.1	1.01	14.1	2.4
		6	110	40.5	.1	.98	18.8	3.1
Western hemlock	S-38	8	110	45.7	.8	...	...	...
		9	110	42.6	1.0	...	66.4	...
White fir	S-35	4	100	49.0	4.7	...	...	...

straw are converted into bleached straw pulp will also apply in general to esparto.

In America, esparto is of less importance than in Great Britain and on the continent of Europe, where it is a very important raw material. It is a grass which grows wild in Spain and the north of Africa. Spanish esparto is the better grade. The fibers are shorter than straw fibers, but tougher. The following analyses of esparto are those made by Müller:[1]

	Spanish	African
Cellulose	48.25	45.80
Fat and wax	2.07	2.62
Aqueous extract	10.19	9.81
Pectous substances	26.39	29.30
Water	9.38	8.80
Ash	3.72	3.67

The esparto is shipped in bales, from which the ropes and hoops have first to be removed. The bundles are then treated in a machine like a rag duster which breaks them up and frees them from dirt.

According to Clapperton[2] from 4,000 to 5,000 pounds of esparto can be boiled in from 2½ to 3 hours, under a pressure of from 30 to 40 pounds, using 14 to 16 per cent of 70 per cent caustic soda on the raw material.

Preparing Straw for Bleached Pulp.

The straw is digested with caustic soda under pressure, yielding, when bleached, a white paper pulp which is nearly pure cellulose. The fibers are very fine and shorter than those obtained from wood, but very strong. Such material imparts to paper a certain hardness and "rattle" that is distinctive of fine writing papers.

The following is the composition of various straws, according to Müller:

	Winter Rye %	Winter Wheat %	Summer Barley %	Winter Barley %	Oats %
Water	14.3	14.3	14.3	14.3	14.3
[1]Total organic material	82.5	80.2	79.7	80.2	80.7
Ash	3.2	5.5	...	5.5	5.0
Cellulose	54.0	48.0	43.0	48.4	40.0

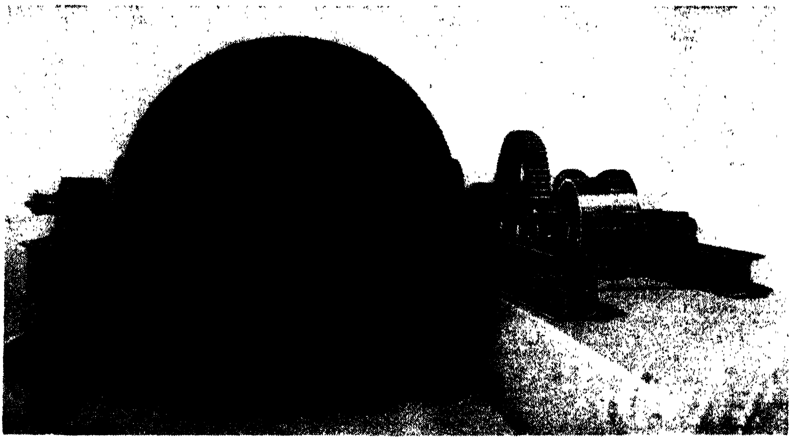
[1] Includes cellulose.

Rye straw is the first choice, then wheat and lastly oat straw. The straw is carefully picked over for the removal of all impurities, such as weeds, roots, etc. This picking is done by hand, the straw being spread on a long table at which are seated the workers. When the picking is completed the straw is cut into pieces from two-fifths of an inch to one inch in length by means of a straw cutter which, according to the extent of the operations at the mill, is capable of turning out from 600 to 2,500 pounds hourly. The cut straw is freed from any grain, nodes or sand it may contain by means of a gentle current of air produced by a fan. The nodes of the straw do not contain any fibers and are very hard, being

[1] Die Pflanzenfaser.
[2] Practical Paper Making, London, 1917.

composed chiefly of insoluble siliceous matter. Consequently it is necessary to remove them so they cannot pass into the digesters as they absorb a good deal of soda, render bleaching difficult, stain the pulp and reduce its value. In some mills handling esparto and straw the material is charged into the digesters without being cut, but this is older and less efficient practice.

For boiling it is customary to use rotary horizontal or spherical digesters. Sometimes stationary vertical digesters are used. The spherical digesters are better than the cylindrical ones, as in the latter there is danger of the straw forming a compact mass unless special interior arrangements are provided, and these are troublesome. One of these devices is a system of bars riveted to the wall, but repairs to these bars are difficult, and moreover they interfere with loading and unloading the digester.



Courtesy: Biggs Boiler Works Co., Akron, Ohio.

FIG. 1.—Type of rotary digester used in strawboard industry: also used for rags and for digesting dyewood chips.

The usual capacity of the digesters is 2,000 pounds of cut straw. The straw is introduced through a manhole by manual labor, or else by means of a blower. The mass is then treated with caustic soda solution of from 10 to 15 per cent strength at a temperature of from 140°F. to 150°F. In the English mills the usual practice is to use 16 pounds of caustic per 112 pounds of raw material and to digest from one and a half to two hours at 40 pounds pressure. In American mills the pressures vary from 10 to 50 pounds, and the duration of the operation from one and one-half to five hours. The heat and pressure are supplied by the injection of direct steam.

When the boiling is complete, the digester is emptied. Sometimes this is done through a manhole and sometimes the pulp is blown into a washing machine similar to a beater where it is both beaten and freed from chemicals.

The further treatment of the pulp is practically the same as in the manufacture of soda pulp from wood, which is described fully in a subsequent chapter. The soda liquor is also recovered in the same way.

Esparto is sometimes pulped by a modified sulphate process, instead of by the soda process above described. In this way a pulp is made the value of which for high class printing and medium quality writing papers is well known. This material has qualities that cannot readily be obtained from other fibers such as rag and wood pulp. It is chiefly used in papers intended for lithographic printing, books, etc., and other purposes where a sheet is demanded which must have a good surface and yet be soft and pliable.

Strawboard.

The following is a description of the treatment of straw to make pulp for strawboard:

The straw is subjected to a cooking process with steam and milk-of-lime in large ellipsoidal rotary digesters. The digester is filled with straw and liquor, steam admitted, the mass cooked down and then more straw and liquor put in until the maximum capacity of the digester is reached. The final charge consists of about 6 tons of straw and 2,100 pounds of lime in the form of milk-of-lime. The mixture is then rotated under 40 pounds steam pressure for 12 hours. By this process the straw is reduced to a dark-yellow, pulpy mass. The yield of pulp is from 75 to 80 per cent of the original material. The stock from the digesters is stacked in pits and allowed to drain for 24 hours or more. It contains practically all the lime and about 50 per cent of water.

The stock is then placed in a washing machine, similar to that used in making rag pulp, only somewhat cruder in design. It contains a beater roll and bed plate and a revolving brass screen through which the water escapes carrying the lime in solution together with the finer particles of fiber.

After the washing is complete the stock is conducted to a kind of cylinder machine, similar to the cylinder paper machine described in another chapter, and formed into strawboard or pasteboard.

Bamboo.

The British have displayed great interest in bamboo, because there are in the British Isles no forests suitable for supplying wood for wood pulp, and consequently British papermakers have been somewhat more inclined than others to investigate new materials. In the British tropical possessions there are unlimited supplies of bamboo.

These investigations are of some interest in this country, as in the southern Atlantic states there are quantities of canes very similar to the bamboo that may have to be used for paper in the future.

As long ago as 1875 Rutledge[1] (who introduced esparto into England) advocated the use of bamboo. About 1906 R. W. Sindall made a

[1] Rutledge had his original pamphlet printed on paper made from bamboo.

very thorough investigation of the subject for the British Government. Since then actual manufacturing operations have been carried on in India and in the Philippines.

The stems are cut in such a manner that the nodes are rejected. In India the cook is carried out at 60 pounds pressure for 10 hours with 30 pounds of 76 per cent caustic per 100 pounds of dry bamboo. Bleach is used in the proportion of 20 pounds per 100 pounds of pulp.

The bamboo has also been worked up in Burmah by the sulphite process at a cost of about $24.00 per ton, the yield being over 50 per cent and less bleach being required than with the soda process described above.

In the Philippines the soda process has been used, from 40 to 43 per cent of bleached fiber being obtained.

Paper made from bamboo is excellent for book and writing purposes. An interesting point about bamboo is the fact that once cut it grows again very rapidly. On a conservative estimate only about 16 square miles would be required to supply a 100-ton mill indefinitely. The chief reason bamboo has not been used more is that the lands where it is indigenous are so far from the great paper markets and also great difficulty has been encountered in the recovery process because of the high silica content of the bamboo stems even when the nodes are rejected.

Jute.

Jute is received in the paper industry in the form of old gunny sacks and rope and also as jute cuttings, which are the parts of the plant rejected in making jute fabrics.

According to Müller [1] raw jute fiber contains 63.76 per cent cellulose and the jute cuttings contain about 60.89 per cent.

Jute fiber is strong and suitable for many kinds of paper. It cannot be used in fine papers on account of the great difficulty in bleaching it. So much bleach has to be used to render it white that all advantage gained through cheapness in the original material is lost and also the strength of the fibers is weakened by the large amount of bleach.

Jute materials are generally boiled with lime, sometimes some caustic soda being added. The equipment used and the general conduct of the process are the same as described for rags.

Manila Hemp, Etc.

Manila hemp is a fiber produced in the Philippines, which is of interest as being the original source of the class of papers known as Manilas, which are very desirable for wrapping and for other purposes, being very smooth, clean, soft and flexible, taking an excellent and characteristic finish, and being quite strong at the same time.

According to Müller [2] Manila contains 64.07 per cent cellulose. Many of the Manila papers on the market today contain none of this fiber at all, being clever imitations.

[1] Die Pflanzenfaser.
[2] ibid.

Other varieties of hemp, such as Italian hemp, Sunn hemp, etc., are sometimes used as raw materials for paper, generally in the form of discarded fabrics or cordage. When hemp is spoken of, Italian hemp (Cannabis) is usually meant.

Agave fiber, of which Sisal hemp is one well known form, is largely used in rope and cord, and in this form it reaches certain types of paper mill. This plant is a native of tropical America.

At one time rags formed the only raw material of paper. Of recent years the importance of this kind of paper stock[1] has steadily been

Commercial Grades of Rags

From "The Paper Industry and Paper World," December, 1939

Domestic Rags, f. o. b. New York

New Rags	per cwt.	Old Rags	per cwt.
Blue Overalls	5.50 to 5.75	Roofing—	
Corduroy	3.00 to 3.25	No. 1	1.75 to 1.85
Cottons—		No. 2	1.60 to 1.70
Washables, No. 1	2.25 to 2.50	No. 3	1.50 to 1.60
Fancy Percales	3.75 to 4.00	Twos and Blues—	
New Soft Blacks	4.00 to 4.25	Repacked	2.25 to 2.50
New Light Seconds	2.00 to 2.25	Thirds and Blues—	
New Dark Seconds	1.75 to 2.00	Repacked	2.00 to 2.25
Khaki Cuttings—		Miscellaneous	1.75 to 1.90
Mixed	3.25 to 3.75	White, No. 1—	
O. D.	3.75 to 4.00	Repacked	3.50 to 4.00
New Canvas	8.00 to 8.50	Miscellaneous	3.00 to 3.25
New Mixed Blacks	2.75 to 3.00	White, No. 2—	
Shirt Cuttings—		Repacked	2.75 to 3.00
New White No. 1	8.00 to 8.25	Miscellaneous	2.00 to 2.25
Silesias No. 1	5.25 to 5.50		
New Unbleached	7.75 to 8.00		
Fancy	2.50 to 2.75		

Rags (Foreign), ex dock New York City

New Rags	per cwt.	Old Rags	per cwt.
New Dark Cuttings	Nominal	No. 1 White Linens	Nominal
New Mixed Cuttings	Nominal	No. 2 White Linens	Nominal
New Light Silesias	Nominal	No. 3 White Linens	Nominal
Light Flannelettes	Nominal	No. 4 White Linens	Nominal
Unbleached Cuttings	Nominal	No. 1 White Cottons	Nominal
New White Cuttings	Nominal	No. 2 White Cottons	Nominal
New Light Oxfords	Nominal	No. 3 White Cottons	Nominal
New Light Prints	Nominal	No. 4 White Cottons	Nominal
		Extra Light Prints	Nominal
		Ord. Light Prints	Nominal
		Med. Light Prints	Nominal
		Dutch Blue Cottons	Nominal
		French Blue Cottons	Nominal
		French Blue Linens	Nominal
		Checks and Blues	Nominal
		Linsey Garments	Nominal
		Dark Cottons	Nominal
		Old Shopperies	Nominal

[1] The term "paper stock" is applied in the trade to a large variety of materials used for making paper. It applies generally to waste material, whether paper, rags, cotton, linen, jute, hemp, flax or Manila. It may come in the form of new clippings from the fabrics made of the various fibers or old pieces of the same, or may come in the form of threads, strings, twines or ropes, or in the form of waste of various qualities, such as card waste, rove waste, washed flax waste, etc. Manufacturers of roofing and felt paper use many thousands of tons of such miscellaneous material each year, much of it being of foreign origin.

decreasing, and with the more extensive use of other kinds of pulp only minor importance is attached to the preparation of rag pulp, in America, at least. However, at the present time rags to the value of about $20,000,000 annually are used for papermaking, chiefly in the more expensive grades of paper, such as paper used for fine writing purposes, fine books, the printing of stock certificates, bonds, money and legal documents, etc., where fine finish and permanency are the object and where expense is not an objection, and (in the case of cheap rags) in such specialties as roofing paper, and consequently the subject merits some discussion.

The word "rag" is used to designate a very wide range of raw material for conversion into paper. The prices which various kinds of rags bring vary very widely according to their suitability for various kinds of paper. Naturally those rags which, with the minimum of treatment, constitute suitable raw material for the highest grades of writing paper, bring the best prices. The preceding table, taken from one of the trade papers, shows how carefully this class of material is graded and the range of prices. It will be noted that white rags bring considerably more than colored ones, and clean

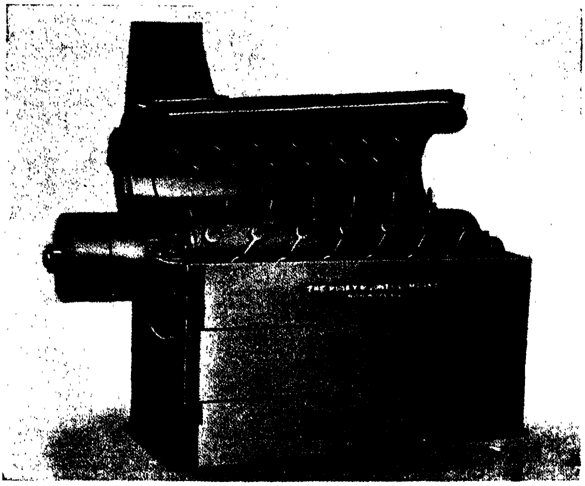


FIG. 2.—Typical rag willow.

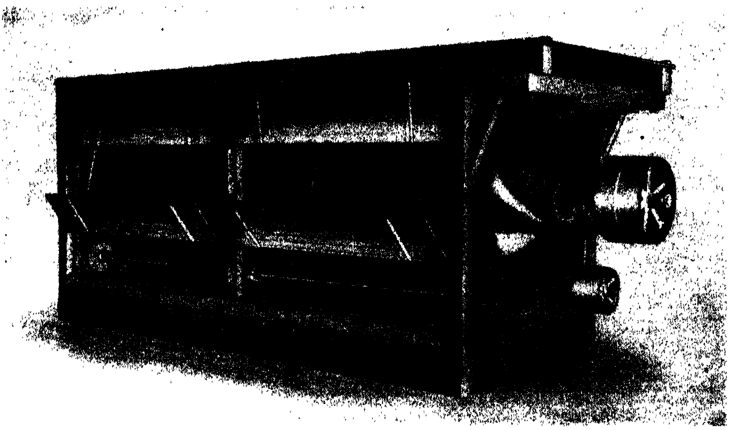
Courtesy: Pusey and Jones Corp., Wilmington, Del.

rags more than soiled. Unsorted rags bring much lower prices than sorted rags because the papermaker does not want a mixture of old and new rags, clean and dirty, or white and colored in the same lot. They also must be sorted by materials. Cotton rags must not be mixed with linen or hemp, etc.

In the case of high class writing papers, only the best qualities are considered, such as new linen and cotton cuttings, or well sorted rags of domestic origin. However, the majority of rags used in the paper industry are more or less foul and require somewhat drastic treatment.

Sorting: The first operation involved is that of sorting, either done by hand or mechanically. Different materials are sorted from each other. Different colors are sorted out. Buttons, pins, etc., are removed. Notwithstanding the increased cost of sorting by hand, and the objection to it on account of the danger to the health of the workers, this plan is generally conceded to be the best in the end, especially for the better grades of paper, as more thorough sorting and removal of impurities result.

Dusting: Following this operation of sorting and cutting, is that of dusting, which is done mechanically. One machine for doing this is a rag "willow," which takes the material to be treated through a hopper into a compartment where a revolving cast-iron cone, armed with spiral flanges bearing pins, passes it rapidly and regularly to the discharge opening. This process opens up the material, separates the dust from it and does this without such violent treatment as to cause injury to the fibers.



Courtesy: Pusey and Jones Corp., Wilmington, Del.

FIG. 3.—Typical rag duster.

The case is of wood, with cast-iron ends containing the bearings. Tight and loose pulleys comprise the drive, which turns the cone at 300 revolutions per minute. Over the ends of the cone are the cast-iron collars of the lid, neatly fitting in order to prevent the escape of dust. In the center of the lid at the top is a steel plate containing pins which permit those on the cone to pass between, thus opening up the stock. Below the cone is a bottom of wire through which the dust sifts and is removed by swinging doors at the side. The floor space occupied by such a machine is about 3 feet by 6 feet.

Rag thrashers are similar in effect to willows. One type of thrasher consists of a wooden case in which a horizontal octagonal drum revolves at a speed of about 120 revolutions a minute. This drum is armed on two opposite sides with heavy teeth bound by iron and filled with wood. These play between corresponding teeth which are planted in a beam fastened to the top of the case. Below the drum is a wire cloth, through which the dust falls as a combined result of thrashing the rags between the two sets of teeth and vigorously moving them over the wire itself. The drive consists of two loose pulleys, between which is run a tight one. Belts, giving right and left rotation, run upon the loose pulleys until either belt is moved to the tight pulley. One manufacturer of such machines states that, when attended by one man, one of them will thrash from 800 to 1,000 pounds of cotton rags per hour, and that the actual loss of weight from the time the rags are taken from the bale until they have passed through the rag cutters is 15 per cent.

Rag dusters are generally built of hardwood boards firmly bolted together and reinforced at points of wear by iron castings. In the center is a wooden drum 15 inches in diameter, bolted to cast-iron spiders, which are in turn keyed to a shaft, designed to turn, by means of tight and loose pulleys, at 100 revolutions a minute. Fastened to the drum is a series of steel plates set at such an angle as to insure the traveling of the rags from the inlet to the discharge end. In doing so they are thrown open and blown free from dust.

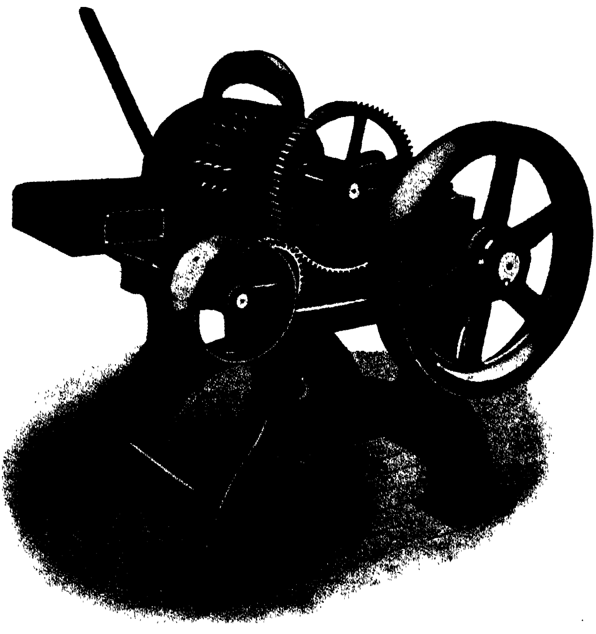


FIG. 4.—One type of rag cutter.

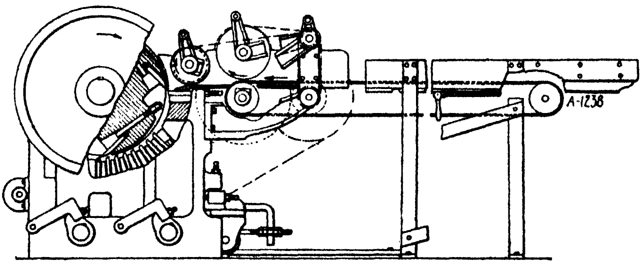
Courtesy: Pusey and Jones Corp., Wilmington, Del.

Cutting: A rag cutter consists of an iron table bolted on the top of a heavy cast-iron stand. This table supports the bearings of the two driving shafts. To one of these shafts, driven by a tight and loose pulley, a cutter head is attached, which carries three fly knives firmly bolted within heavy cast-steel shoulders. At the other end of this shaft is a fly wheel to relieve the shock when cutting. The bed knife is contained in the table and is held by both adjusting and tightening bolts.

A separate belt, on a small pulley to the right of the operator, propels a series of gears which drive a drum studded with projections set in rows and staggered. This drum spreads the feed of rags to the knives and serves as a protection to the operator. It is carried on a curved frame, which may be lifted by the operator by means of a lever to ease the passage of rags, should they get choked in the feed trough.

The length of the rag cut may be controlled by a difference of speed imparted to the two belts.

A magnetic pulley to remove metal such as pins, buttons, etc., from the cut rags is advisable.



Courtesy: Socony-Vacuum Oil Co., Inc., New York

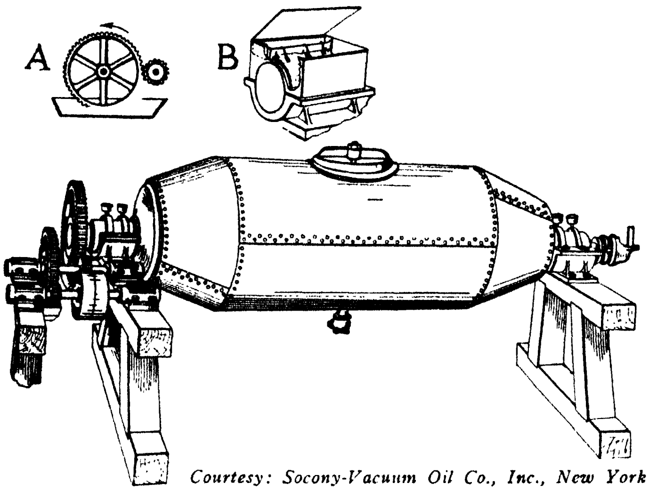
FIG. 4a.—Diagram showing operation of rag cutter.

Boiling: After all this mechanical treatment, the rags are ready to be boiled. The boiling is usually done in vessels of steel plate which may be of spherical, cylindrical or vomiting types. The object of the boiling is to remove the grease and dirt and by means of the high temperature, the agitation and the chemicals used, bring the rags into such condition that the impurities can readily be removed by washing, leaving fiber suitable for paper.

The rotary boilers commonly employed are of cylindrical shape, now usually of welded construction. The trunnions are of cast iron or steel and are firmly attached to the boiler by large flanges, in some cases these flanges serving as the head of the boiler. The trunnions are hollow for the admission of steam. Manholes are provided for filling and emptying.

In some cases ribs or projections are arranged around the inside to prevent the stock packing against the sides. The boilers are supported on steel, masonry or wooden supports, as may be required and are driven by means of worm gearing countergeared to suit conditions. The usual speed at which they rotate is from $\frac{1}{3}$ to 3 revolutions per minute. The usual sizes are from 6 by 10 feet (capacity 270 cu. ft.) to 8 by 24 feet (capacity 995 cu. ft.). The internal pressures used vary from 60 to 120 pounds.

The chemical usually added in America is milk of lime. In England caustic soda is chiefly used. The lime forms soaps with the grease in the rags and is not a sufficiently strong alkali to damage the fiber as soda is prone to do. Sometimes a little soda is added to increase causticity of the solution. In some cases, rags are boiled with soda alone, but this is unusual. The usual practice is to fill the rotary about two-thirds full with rags and milk of lime and run for from twenty minutes to half an hour before steam is admitted. The lime used for this purpose should be ascertained to be free from iron before being used as iron will discolor the stock, and should also be free from gritty material such as sand and coal dust. The amount of lime used varies. About 15 per cent of lime based on the dry weight of the rags is quite a usual proportion but as high as 20 per cent and sometimes as low as 4 per cent are used. The higher grades of rags require less lime and also lower temperature and pressure and a shorter boiling period. However, this also depends largely on the kind of paper being made. Conditions have to be determined by experiment at each mill.



Courtesy: Socony-Vacuum Oil Co., Inc., New York

Fig. 5.—Typical horizontal boiler.

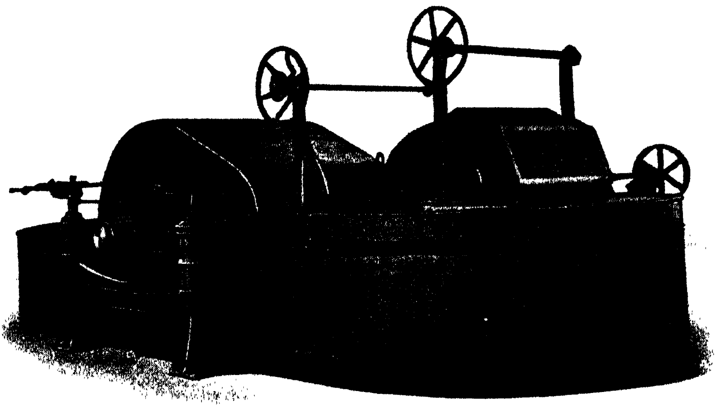
Various practices prevail with regard to emptying the rotaries. Some operators relieve all the pressure before removing the stock. Others blow off under pressure just as in a sulphite digester. This latter procedure is hard on the stock, but it is claimed it gets rid of more dirt.

The rags are generally drained on draining floors or in shallow pits. Sometimes they are let stand some days after boiling to soften.

A device known as a Mather Kier is frequently used for rag boiling, especially in England, instead of a rotary boiler. It consists of a sort of tank into which cars containing the rags can be run. There is a device for spraying the hot liquid over the rags. The advantages claimed are saving in steam and floor space, improved quality of fiber and saving in quantity of water used for washing.

Vomiting boilers are sometimes used. These are cylindrical stationary tanks in which the steam is conducted to the bottom through a pipe which enters through the top of the boiler. This steam forces the liquid which has collected beneath a false bottom upwards, through a vomit pipe surrounding the steam inlet, and it is sprayed over the stock by a spreader. There are manholes for filling and emptying and a safety valve. This is quite like the ordinary domestic coffee percolator.

Washing: Following the boiling of the rags comes the washing to remove all alkali used in the cooking, as well as all dirt and greases that were loosened during the chemical treatment. This washing is usually performed in a rag engine or Hollander. This machine is similar to the beater or beating engine (which is described in detail in Chapter 12) except that on the side of the midfeather opposite the beater roll is a revolving cylinder or octagon covered with wire cloth. This permits the wash water to run through but keeps the fibers in the machine. There



Courtesy: Downingtown Mfg. Co., Downingtown, Pa.

FIG. 6.—Hollander or washing engine, as used in manufacture of rag paper, showing cylinder washer.

may be more than one of these cylinder washers; in some machines as many as four or five are used. Sand catchers are usually inserted in the base of the engine in front of the roll to catch dirt, buttons, etc., in the stuff. In this way the machine serves not only the purpose of a beater, breaking up the bundles of fibers and drawing them out, but also permits all alkali and impurities to be carried away with the wash water. In some mills machines are used having a paddle in place of a beater roll. This propels the stock around the machine but does not break up the fiber bundles or brush out the fibers, all of this work being left for the regular beaters in which the stock is placed after bleaching.

The clean, washed and disintegrated rag stock is now bleached, either by means of bleaching powder or electrolytic bleach (bleaching will be dealt with fully in Chapter 11), after which it is thoroughly washed to remove any excess of bleach remaining.

The rag stock at this point is known as "half stuff," and, in order to convert this half stuff into paper, it must be further treated in beaters or beating engines to obtain a complete separation of the fibers into single units and to stroke out the fibers so they will felt and form paper, as explained in detail in Chapter 12.

Bagasse.

Of all the different materials investigated during the last few years, during which period millions of dollars have been spent to advance the art of cellulose utilization, few materials have received more attention than bagasse, the residue of sugar cane after the juice has been pressed from it.

Before the introduction of a process whereby this waste could be utilized for paper pulp it was piled and burned in the furnaces of the sugar mills. It has been found that the bagasse contains fibers of a high quality suitable for many grades of paper. The sugar cane stalk is largely composed of two constituents, fibrous cellulose and non-fibrous cellulose in about equal parts. A process is now being investigated whereby these two consituent parts can be separated mechanically and the fiber treated chemically either by the soda or the sulphite process. Bagasse boards are manufactured in Louisiana by the Lee process in which the bagasse is digested with a liquor prepared by treating low grade molasses from the sugar mills with lime, its principal constituent being saccharate of lime. The boiling causes a hydration of the non-fibrous cellulose which toughens it and thus makes it possible to make pulp out of material that really contains hardly any fibers at all, the cells of the non-fibrous cellulose being too short to correctly be called fibers.

Interesting experiments have also been carried out on making semi-transparent, glassine and parchment papers from bagasse by utilization of this hydration effect.

Waste Flax Fiber.

Some work has been done on the utilization of this material for paper. The fiber would be of excellent quality for making high grade papers, provided that it could be obtained entirely free of seeds which make grease spots in the stock and defects in the paper. Up to date this has been the chief obstacle. It has been estimated by the U. S. Government that sufficient of this material is now wasted annually in the Northwestern States to make 480,000 tons of good paper.

In connection with the above remarks on various of the new materials proposed for paper, the following table[1] may be of interest:

ESTIMATES OF WASTES SUITABLE FOR PAPERMAKING PRODUCED ANNUALLY

Material	Waste Quantity (Tons)	Waste Value $	Yield of Paper (Tons)
Waste textiles suitable for papers of the highest quality and strength	1,000,000	20,000,000	800,000
Flax fiber suitable for the best and strongest paper	600,000	18,000,000	480,000
Forest waste from lumber industry suitable for medium and low grade paper	* 12,000,000	60,000,000	5,000,000
Waste paper suitable for high quality and lowest quality	1,000,000	10,000,000	900,000
Cereal straws suitable for medium quality paper and boards	70,000,000	350,000,000	28,000,000

* Cords.

[1] U. S. Department of Agriculture, Bureau of Chemistry. Circular No. 41.

Waste Paper.

According to U. S. Government statistics more than 11,000,000 tons of paper are now made annually in this country, of which fully 80 per cent, or 8,800,000 tons, becomes waste material in three or four years. Of this, about 25 per cent, or 2,200,000 tons, is again used in the form of cuttings and trimmings and old paper for making new. While there must always be some waste impossible to recover, with proper precautions a much larger percentage could be recovered than is now the case. The first World War gave a considerable impetus to the saving and utilization of waste paper.

Not all waste paper is suitable for the manufacture of high grade papers, such as book, but almost all of it can be worked up into some kind of wrapping, cover or blotting paper, building paper, boards, etc.

The principal difficulty in getting satisfactory results in an attempt to substitute waste paper for chemical or mechanical wood pulp consists in the fact that the equipment of the average mill does not lend itself readily to such substitution. Beaters which are most efficient in treating rags, bagging, rope, sulphite, etc., are not well adapted to the treatment of waste paper. It must be borne in mind that waste papers have all been once, at least, through the process of manufacture of paper. Hence, it is only reasonable to assume that such grinding, beating and brushing as may have been necessary to produce the best results have already been applied to the fibers and that a repetition of the process cannot help but have a tendency to unduly shorten the fibers and weaken the resultant sheet.

Treatment of Waste Paper.

The papers when received at the mill have to be sorted. This should be done in a light, well ventilated room; light being necessary if the papers are to be properly sorted and all dust having to be carried off by exhaust fans to preserve the health of the workers. The paper is received in bales. The foreman who receives should be an experienced man who can tell at a glance if the bale is not up to grade so it can be rejected before it is distributed in the sorting room. The sorters are usually paid at the rate of so much per hundred pounds, which makes for efficiency, and with practice they become wonderfully adept at this work. If the grades of bales received contain mixtures of a great many kinds of paper, it is generally necessary to pay the sorters by the day, as sorting of this kind of stock goes very slowly.

A simple test with phloroglucinol will reveal mechanical pulp which this reagent colors deep red instantaneously.

There are certain standard classifications for waste paper stock which have been decided on by the biggest firms in the business of handling this material. These grades are:

No. 1 Book and Magazine Stock: Such stock must be free from groundwood paper, parchment paper, leather or cloth book covers, magazine covers of highly colored paper, school paper, paper shavings, photogravure paper and books with burnt edges. Certain of the cheaper magazines will not be accepted as No. 1 stock, such as "Popular," "All Story," etc. Cheap novels, telephone directories, mail order catalogs, are all excluded from this class. Thick books, like Dun's Agency books, must be ripped apart into sections the size of an ordinary magazine.

Ledger Stock: Consists of high class writing paper, account books, ledgers, letters, checks, bonds, insurance policies, legal documents, etc., but such material must not be torn into little pieces. Ledgers, etc., must be free from covers. Postal cards, school books, telegrams, envelopes, tissue paper, copying paper, manila, highly colored paper, bills of lading, etc., will not be accepted in this class.

Mixed Paper Stock: Consists of all kinds of clean, dry paper from office, schools, etc. For instance, wrapping paper, cardboard boxes, pamphlets, telephone books, magazines not good enough for No. 1, envelopes, paper torn into little pieces, crumpled newspapers, etc. Must be free from rubbish, string, leather, rags, cloth book covers, wire, wood, etc.

Newspaper Stock: Clean, folded newspapers. No crumpled newspapers, pamphlets, etc.

These grades are further subdivided by speaking of "Extra No. 1," etc.

Prices of such material fluctuate very rapidly. The following table, taken from "The Paper Industry," will indicate how this material is quoted on and roughly what is the range of prices. The prices are in cents and fractions thereof per pound.

WASTE PAPER, F. O. B. NEW YORK CITY

	per cwt.
Shavings—	
White Envp. Cuttings	2.75 to 3.00
Ord. Hard White No. 1	2.25 to 2.50
Ord. Soft White No. 1	2.00 to 2.25
Soft White, Extra	2.50 to 2.75
Flat Stock—	
Stitchless	1.10 to 1.15
Overissue Mags	1.00 to 1.05
Solid Flat Book	.95 to 1.00
Crumpled No. 1	.85 to .90
Solid Ledger Books	1.75 to 1.90
Ledger Stock—	
White	1.50 to 1.65
Colored	1.10 to 1.20
New B. B. Chips	.55 to .65
Manilas—	
New Env. Cuts	1.80 to 1.90
New Cuttings	1.50 to 1.60
Sulphite Wrappers	.55 to .65
Bogus Wrappers	
No. 1 Old Kraft	1.00 to 1.15
News—	
No. 1 Wh. News Cuttings	1.35 to 1.45
Strictly Overissue	.85 to .90
Strictly Folded	.60 to .70
No. 1 Mixed Paper	.55 to .65

The old process of working up waste paper consisted in pulping the paper in a beating engine, after which the stock was placed in agitators where it was treated with caustic soda and finally thoroughly washed, drained and furnished to the beaters along with other grades of stock to form new paper.

Many mills use rotary boilers of the type described earlier in this chapter for rags.

Another process used what were known as "bleach tanks" although such equipment was never used for what could properly be called bleaching. These tanks were large, cylindrical, steel plate tanks, provided with a false bottom perforated with small holes. In the center is a vomit pipe, the top of which is equipped with a baffle plate, to spray the cooking liquor over the papers. The papers were charged into the tank through a chute. The liquor consisted of caustic soda solution about 2.1° Be. at 180°F., that being the temperature at which the cook is conducted. The liquor sprays over the papers in an intermittent manner, like an ordinary coffee percolator. With this process it is stated that 1,750 pounds of caustic soda will cook 6,000 pounds of waste paper stock. The cook requires from 5 to 15 hours, according to conditions. The charging of the tank requires from 1½ to 2 hours. Longer cooks produce better results, about 10 hours being generally very satisfactory. This system is very wasteful of steam. Covered tanks have been tried, but without much success. When the cook is completed the papers are removed by a hoisting device, operated by a motor. The cooked paper is forked into cars or onto a conveyor. This work requires the services of two men for two hours for each tank. The work is very unhealthy and disagreeable. From the cooking tank, or "bleach tank" as it is called, the papers are taken to washers, which may be either chests with agitators, or else Hollanders fitted with paddles instead of beater rolls. Sometimes the papers go first, by means of a conveyor to an agitator, in which they are pulped sufficiently fine that they can be pumped with a fan pump to the washers. The pipe leading to the washers is arranged in a continuous loop so that the stock will always be in circulation and no clogging will result, the feeders to the washers being led off from this system at intervals.

The above methods are wasteful of steam, floor space, labor and chemicals. Moreover, they tend to disintegrate the stock much more than is necessary for stock which has already once been through the process of paper making. They are gradually giving way to more modern, efficient and economical methods.

Improvements in Treatment of Waste Paper.

Efforts towards improvements in the treatment of waste papers might be classified into three general divisions, which are, in what seems to us to be the order of their importance:

(1) New pulping or de-fibering devices.

(2) Improved washing devices designed particularly for the treatment of pulp made from waste papers.

(3) New chemicals to be used as detergents to take the place of caustic or soda ash.

During the last few years several machines have been placed on the market for working up waste papers, for which the inventors make various claims. Some of these machines are designed to be used merely to give the papers what might be called preliminary treatment. Such machines break up the books, or large bundles of paper which are fed into them, and thus prepare the material for further mechanical refinement and complete defibering.

Another class of pulpers consists of those which, while designed to pulp the papers so that they are ready for the Jordan, or possibly for the paper machine, are not intended to do more than this. In other words, it is not claimed that they are designed to liberate the ink or color, both of which remain in the pulp and are not capable of being liberated except by special treatment.

Still another type is on the market for which the inventors claim not only pulping and de-fibering qualities, but also that the action of the machine in connection with the use of a suitable detergent will liberate the ink and color during, and coincident with, the process of de-fibering.

Winestock De-Fibering and De-Inking Process.

It is claimed for the Winestock de-fibering and de-inking machine and process that, in addition to reducing the papers to a single fiber unit without appreciable shortening or weakening of the fibers, the same operation also liberates the ink and color from the fibers, so that by thorough washing the fibers are restored to the color of the original pulp before coloring matter ever was added. It is also claimed that this result can be obtained whether the papers contain groundwood, or are completely free from it.

Most black printing ink consists of a suspension of finely divided carbon (lampblack, carbon black, etc.) in some oil such as pine oil or linseed oil. After the type has transferred the ink to the paper, some of the oil evaporates and the remainder is absorbed by the paper, holding the carbon with it. As carbon is not affected by any bleaching agents, the only way to get rid of the black color is to loosen the mixture of oil and carbon from the fibers so the carbon will fall off during the washing. Alkaline material, such as soda ash, will break up the oil and free the carbon and will also attack the rosin with which the paper is sized, which also helps in the removal of the ink.

Consequently, the de-inking and de-fibering of waste paper is a process which combines chemical and mechanical effects.

The principle involved in the Winestock machine is novel, being what the inventor terms "an Inertia Process."

The de-fibering action is performed by two propellers revolving rapidly —about 2,000 revolutions per minute—so that the water is unable to take up the rotary speed of the propellers and in consequence there are always two opposing factors—the speed of the propeller and the inertia of the liquid stock.

A simple illustration of this principle could be obtained by floating a flat sheet of paper in a vat of water and then striking the floating paper a sharp, quick blow with a wooden lath, a switch or a straight piece of wire. The inertia of the floating paper could not be overcome quickly enough for it to follow the course of the striking object and the result would be a *cleavage*—not a *cutting*—of the paper.

This describes the action of the propeller blades on the paper floating in the liquid. This action is facilitated by the soda ash or other detergent used, which softens the size in the paper as well as the binder in the ink. The rapidly moving propeller blades, while disintegrating the paper into single fiber units are, at the same time, knocking the loosened ink and color from the fibers themselves, thus accomplishing the de-fibering and de-inking at the same time, as before mentioned.

A novel and effective method of circulation is provided, whereby the pulp, after passing through the propeller tube, is discharged tangentially into a large circulating tank, entering the tank at the bottom and working to the top with a spiral motion. At the top it cascades over into an upright cylindrical tank which, in turn, leads the stock again to the propeller tube. The circulation is very active and continues until the paper is thoroughly de-fibered.

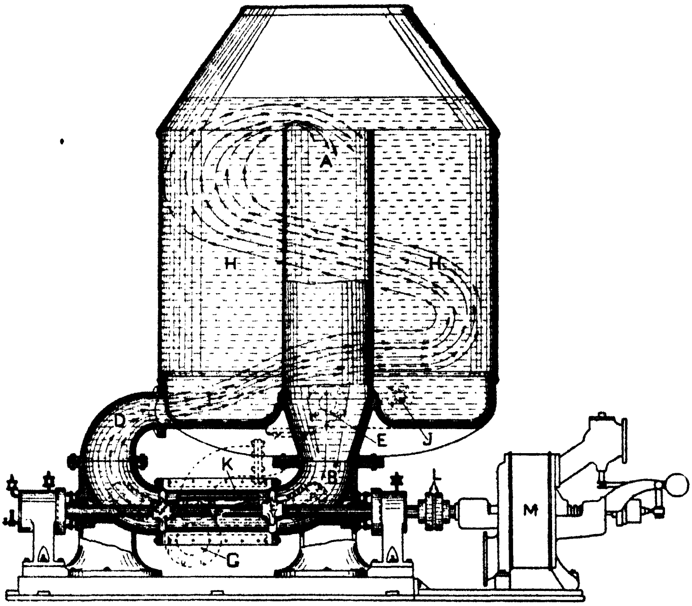


FIG. 7a.—Vertical cross-section of Winestock de-fibering and de-inking machine, showing circulation of stock.

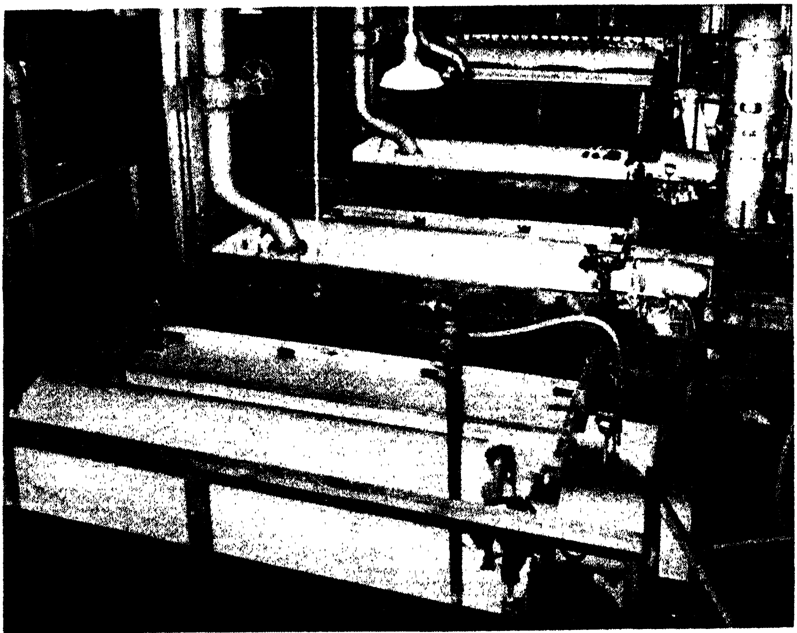
Softening tanks should always be used in connection with this machine, as they enable the machine to complete its work in appreciably shorter time. A type of softening tank that has been found to work very satisfactorily consists of an upright chest with a perpendicular shaft running through the center. In place of the ordinary agitators two sets of fans are bolted to the shaft with the blades so pitched that the mass is thrown upwards. One set of fans (there are two blades to each set) operates at the bottom of the tank with just room enough for clearance, and the second set is located midway between the top and the bottom. The speed of the shaft is 25 revolutions per minute.

In some cases "breaking up" engines are being used with excellent results and this method is especially good where solid stock is used such as solid ledgers, telephone books, etc., which may be fed into such a machine without first tearing the books apart.

Books and magazines to be manufactured into white paper require from 35 to 40 minutes of treatment, while hard-sized paper containing writing, printing, engraving, etc., requires a somewhat lengthier treatment to obtain most satisfactory results.

The machine holds from 700 pounds to 900 pounds of dry papers at a charge, and the average production ranges from 12 to 15 tons per 24 hours. From the Winestock machine the papers go to a washer and then follow the usual process of manufacture.

Owing to the fact that the paper is completely de-fibered and the color and ink thrown into a solution or emulsion in the water, the pulp washes more quickly than stock treated by rotary or open bleach. The mass as it comes from the Winestock machine has an entirely different and more satisfactory appearance than the product of the rotary or open bleach.



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 7b.—Multiple-stage washer specially designed for washing de-inked magazine stock, with complete removal of suspended solids.

Book papers, for example, instead of being brown or nearly black, give a grayish colored pulp. If this pulp be thoroughly washed on a small hand screen, the individual fibers will be found to be as white as the original paper from which the pulp was made. Under actual mill conditions the ordinary washing engine does not give the stock the proportionate amount of flushing and agitation that is obtainable by hand washing, and it may be found necessary to use a small amount of bleach to tone up the color. This is, however, more a limitation of the washing engine than of the de-fibering machine itself, for the hand washing shows conclusively that the fibers are in no way discolored. It is asserted that this result is obtained because the mechanical action of the machine, and the principle involved, enables it to accomplish its work in the shortest possible time, with a minimum amount of chemicals, and at a low temperature—from 160 degrees to 190 degrees Fahrenheit.

It seems only reasonable to assume that, inasmuch as the ink and the color are actually knocked off the fibers and into the water, the result would be a pulp that would require less washing than would be the case if the ink and color were cooked into the fiber during a treatment lasting several hours, or kneaded in by the action of an ordinary pulper. In addition, the violent scrubbing to which the fibers are subjected in the soapy, alkaline liquor is a big factor in producing bright, clean pulp.

Digester Process for Waste Paper.

Recently there has been much interest in working up waste paper, especially old magazines and books, especially telephone books, in digesters such as are used in the soda pulp process. A new kind of ink has been invented especially for the use of the telephone company which readily washes out of the waste paper in this process. Soda is used as a cooking agent, about 75 lb. being required for a 1200 lb. charge of paper. The stock is circulated with a large open impeller centrifugal pump. This pump also acts as a beating and de-inking engine. Live steam is admitted directly to the digester. The cook requires about 3 hours. Overheating or undue prolongation of the cook injures the paper. Considerable care must be exercised in charging the digester so as not to clog the pump. Some mills pulp the paper first in a beater and feed the stock to the digester. This system eliminates much of the labor needed for treatment of waste paper in rotary boilers but uses a lot of steam. However this can be avoided if hot water from a waste heat system elsewhere in the plant is used for charging the digester. This system makes a very nice quality of pulp and avoids the excessive de-fibering action often unavoidable in using rotaries. Also it is more sanitary for the workers.

3. Varieties of Paper

The art of papermaking having been known for over 1,800 years, naturally paper has come to be used for a great variety of purposes, and as the uses for paper have broadened, there has come to be a corresponding specialization in the kinds of paper manufactured for these various uses.

Writing and Book Paper.

The different kinds of paper are made by using different kinds of raw stock and varying the process to which this raw stock is subjected.

One of the oldest and most important branches of the paper industry is that involving the manufacture of writing, book and high grade printing papers. The properties of papers of this type are such as to exhibit the following main characteristics:

(1) An even, uniformly closed sheet.
(2) A soft, strong, pliable sheet.
(3) A high finish with an even bulk.

High opacity or lack of "show-through" is also absolutely necessary for a good book paper. This is especially true of thin papers for encyclopedias, dictionaries, Bibles, etc. Severe eye-strain results from lack of opacity, and advertisers complain of "show-through" which is also very undesirable in papers used for envelopes. In the past decade great improvement has been made, especially by more accurate control of the particle size of clay and by the use of improved fillers containing titanium dioxide and barium sulphate. Modern offset printing has greatly increased the importance of these factors, also the development of "all purpose" bonds dealt with under "Writing Paper" below.

To obtain the above characteristics, specially prepared pulp must be used. The ideal fiber is one which retains its original length, strength and elasticity as completely as possible after having been prepared into "half stuff," *i.e.*, after the cooking and bleaching processes are completed. The pulp must be an easy bleaching stock, or otherwise a hard, brittle fiber will be produced with very poor felting qualities and the resulting sheet will be unsatisfactory no matter what precautions are taken later on in the beater room and machine room.

Book paper is chiefly made from rag (cotton and linen) pulp, sulphite and soda wood pulp and, in the cheaper grades, some groundwood, all of which are bleached. Esparto pulp has also found a wide application in the manufacture of medium quality book papers and writings. Large quantities of high-grade waste paper are also re-worked for incorporation in book paper.

In addition to the various combinations of stock that may be used in the making of book paper, loading materials must be added to the extent

PRODUCTION OF PAPER AND PAPERBOARD—BY KIND, QUANTITY, AND VALUE FOR THE UNITED STATES FOR 1937.

Kind	Quantity (Short Tons)	Value
Paper industry, all products, total value		$957,939,764
Paper and paperboard, aggregate	12,837,003	887,920,461
Newsprint, total *	975,854†	37,086,644
Groundwood printing and specialty papers total	518,332	32,617,672
Hanging	126,890	7,785,201
Catalog	100,974	7,399,405
Novel-news and news-tablet	64,342	2,999,972
Poster and lining	27,249	1,898,647
Printing	54,433	3,735,004
Other groundwood papers (including rotogravure)	144,444	8,799,443
Book paper, total	1,520,523	147,342,602
Machine-finished, sized and super-calendered	1,028,183	98,262,075
Converting paper	343,502	30,038,086
Lithograph	50,618	5,683,482
Offset	60,460	8,232,638
Text paper	10,512	1,753,572
Other book paper	27,248	3,372,777
Cover paper	24,437	4,435,204
Writing paper (fine)	578,147	87,271,592
Unbleached sulphite and semibleached sulphate:		
Butchers' and grocers' paper	147,293	11,346,439
Bag	103,680	7,608,148
Machine-glazed wrapping	4,908	526,685
Other grades	43,550	4,246,640
Bleached sulphite and bleached sulphate:		
Waxing paper (18 lbs. and up)	123,896	14,334,946
Bag	13,470	1,591,422
Machine-glazed wrapping	35,657	3,782,642
Other grades	93,531	9,203,074
Wrapping and envelope manila	36,897	2,632,978
Grease proof	14,876	2,807,746
Glassine	46,833	9,920,864
Vegetable and other imitation parchment	13,738	1,962,140
Kraft wrapping	1,130,033	86,142,532
Bogus and screenings	26,212	1,290,073
Heavy (mill wrappers, etc.)	32,409	1,509,963
Rope and jute	16,983	3,132,715
Tagboard, light manila board, and pattern	59,820	6,125,243
Other wrapping paper	109,601	11,570,243

* Imports of newsprint in the U. S. for 1939:

Canada	2,899,708 tons
Overseas	293,953 tons
Newfoundland	123,344 tons
Total	3,317,005 tons

† The total newsprint figure given by the Association of Newsprint Manufacturers of the United States is 945,721 tons.

PRODUCTION OF PAPER AND PAPERBOARD—*Continued*

Kind	Quantity (Short Tons)	Value
Tissue paper total	540,152	55,914,224
High-grade tissue (cigarette, condenser, carbon, etc.)	37,618	10,031,827
Waxing (up to 18 pounds)	26,808	3,465,195
Wrapping tissue (up to 18 pounds)	60,634	7,776,345
Toweling	93,284	6,390,818
Toilet tissue	254,221	20,720,440
Napkin stock	55,576	5,739,376
Pattern tissue	6,237	928,767
Sales book tissue	2,395	336,862
Carpet twisting	3,379	524,594
Absorbent paper, total	138,064	22,120,473
Blotting	11,794	2,185,230
Filter	1,435	385,804
Matrix paper and board	3,739	1,658,771
For vulcanized fiber	17,971	3,029,374
Other absorbent paper (including paper for parchmentizing)	103,125	14,861,294
Building paper, total	608,086	32,630,126
Other paper	77,985	11,427,872
Boards total	5,802,036	277,339,535
Container boards		
Liners:		
Kraft	977,561	45,678,709
Jute	1,019,995	43,207,483
Other	147,012	6,739,921
Chip (plain and test)	506,013	18,457,834
Straw (for corrugated-container use)	441,312	16,895,781
Other container boards	75,657	3,423,586
Folding boxboards (bending):		
Manila-lined (all-lined boards)	798,220	41,128,607
Patent-coated	244,591	12,472,244
Other folding boxboards	246,213	11,597,891
Set-up boxboards (non-bending):		
Chip and straw	332,034	13,936,028
Newsboard	251,458	9,864,394
Other (including tube, egg-case, etc.)	136,818	5,953,517
Binders' Board	51,913	3,620,887
Cardboard:		
Blanks and miscellaneous	21,181	1,544,434
Clay-coated cardboard	25,618	2,153,118
Photomounts	944	165,319
Other cardboard	3,575	304,660
Bristol board:		
Index	20,455	2,592,804
Mill (including specialties)	46,273	5,239,750
Uncoated postcard	6,821	612,039
Leatherboard	27,174	2,238,888
Pressboard	8,623	1,521,648
Other boards	412,585	25,989,993

of from 10 to 15 per cent, so as to make the paper more absorbent and opaque, and to enable a clear print to be made. Such materials also lessen to a large extent the friction when the paper and type come in contact during the printing. In selecting the loading materials a number of considerations have to be kept constantly in mind.

First: The chemical nature of the substance itself must be examined. Any substance containing free acid or chlorine compounds cannot be used.

Second: A finely graded material, of uniform consistency, free from sand and grit is necessary.

Third: The material must be of such a color that it will not interfere with the shade of the finished paper.

Kaolin, or clay,[1] is the chief substance used for loading book paper, although of recent years titanium dioxide has demonstrated its usefulness for high grade book papers. It fills up the pores of the paper, giving a sheet of closer texture that will take up ink rapidly and it enables a high finish to be obtained in the calenders.[2] Papers requiring a higher finish than is possible to achieve with the machine calenders are generally finished in supercalenders,[3] where the high pressure and the contact between the upper metal and the bottom paper-covered rolls has the effect of imparting a velvety surface necessary for illustrated work where halftones are used and for the finer sorts of printing.

Coated Paper.

The highly surfaced papers on which some books are printed, especially when fine half-tones have to be brought out, are known as coated papers. The preparation of such papers is a line of industry really separate from the manufacture of paper and will be dealt with in detail in Chapter 15.

Grades of Book Paper.

According to the U. S. Government Report on the Book Paper Industry,[4] book paper is a general term designating roughly all of the grades of printing paper except newsprint. The chief distinction between book paper and newsprint is that the former is made chiefly of chemical pulp while the latter consists mainly of mechanical pulp. Book paper stock is carefully refined in a beater: newsprint stock usually is refined by Jordans alone in modern mills. Standard newsprint consists usually of about 80 per cent mechanical pulp and 20 per cent sulphite. Very recently excellent newsprint has been made both in Finland and in the United States entirely from groundwood due to great improvements in the art of grinding wood and the design of the grinders.[5] Between standard newsprint and book paper there are various intermediate grades containing more or less groundwood and known as half-tone news, special news, novel news, catalog news, etc.

The principal grades of book paper are antique (or "bulking") machine

[1] See Chapter 12 for full discussion of use of clay and other fillers.
[2] See Chapter 13 for construction and operation of calenders.
[3] See Chapter 14 for construction and operation of supercalenders.
[4] Senate Document No. 79, 1917.
[5] For details of these improvements see Chap. 9, The Groundwood Mill.

finish (M.F.), English Finish (E.F.), supercalendered (S.C.), coated, and cover. The difference in the first four grades lies mainly in the finish given the paper. This book, for instance, is printed on English Finish paper. Cover paper is a strong, heavy grade, and is usually coated. It is used mainly for the covers of magazines, catalogs, etc. Within each of these grades there are numerous variations in the specifications for size, weight, color, etc.

Book papers are made from various proportions of bleached sulphite, soda and waste paper stock, the latter being necessarily high-grade magazine or book stock, usually publishers' over-runs. Also some high-grade book papers contain rag stock. For a usual high-grade book paper 40% bleached sulphite, the balance soda pulp or bleached waste paper stock, would be typical. To increase bulk the proportion of soda pulp is increased. So-called "bulking paper" or "feather-weight" may be 80% soda pulp. In England esparto is also much used. Book paper is usually very thoroughly refined (with the exception of "bulking paper" which is beaten as little as possible) in both beaters and Jordans or other refining engines; made at a speed of not more than 600 F.p.m. (usually much less) and put through two stacks of machine calenders and finally supercalenders, and usually nowadays packed in reams on skids or in cases.

Machine finish book paper goes through practically the same manufacturing process as newsprint. It receives no finish but that given by the calender rolls at the dry end of the paper machine. Some variation in finish is possible, however. A complete summary of paper finishes will be found in Chapter 14. These different finishes are made by watermarking, by rollers of different design which press on the paper while it is still moist, and by variations in the pressure applied at the calenders. Machine finish paper is used largely by publishers of books and for trade catalogs, etc.

Sized and supercalendered paper is machine finished paper which has undergone an additional process of sizing and calendering to give it a high finish. This is the paper most used for the higher grade of illustrated magazines and also for trade catalogs, advertising literature and many books.

The uses of book paper are not confined to the printing of books, magazines and catalogs, etc. It is also used for cheap writing pads and school exercise books, for wrappings for soap and pharmaceutical products, and for lining and covering paper boxes. Very fine papers for money, stock certificates, etc., are made in mills where the most extreme precautions as to boiling, washing, bleaching and beating are exercised. Quantity production is no object, small size equipment is used, and time and attention lavished on each process.

Writing Paper.

The manufacture of bond and other writing paper calls for about the same requirements as book paper. Bleached sulphite and rag stock are used exclusively. However, in writing paper special watermarks, engravings and finishes are more generally applied. The one usually called for is linen finish. For details on other finishes see Chapter 14.

Linen Finish: This effect is made only on high class work. The paper is taken from the machine in a moist condition in the form of sheets. It is then hung up on poles to dry in a drying loft, where it is usually kept for about 24 to 30 hours. When taken from the loft the paper must still be a trifle damp in order that the impression of the linen may be more easily taken. The paper is now ready to receive the linen finish, which operation is conducted on plate rolls operated under great pressure. A sheet of the best grade of linen is placed upon a sheet of heavy tin. Then a sheet of paper is placed on the linen, followed by another sheet of linen, and so on until a pack of sheets of tin, linen and paper is made about 4 inches thick. This pack is then run through the plate rolls and the paper receives the imprint of the linen.

Recently "all purpose" bonds have become greatly in demand for printing display letterheads, advertising folders and booklets, etc. They combine the qualities of writing and printing papers, *i.e.*, take halftones and color plates well and yet have a good surface to write on. These papers are also much used for maps and for insurance policies and similar forms. In addition to great care in the preparation and refining of the bleached sulphite stock these papers call for the use of relatively expensive but very efficient fillers compounded of oxides of one or both of the elements barium and titanium.

Bond papers also require a definite "crackle" or "rattle" which, however, should not be exaggerated. This is attained by prolonged beating of the stock and the use of silicate of soda and/or starch in the sizing process in addition to rosin size and alum.

Pure rag paper is little in demand today except for money, legal documents and de luxe writing papers and artists' papers. It is made on small, slow machines and usually vat sized with animal size or glue subsequent to the engine sizing and dried very carefully in a loft to prevent curling.

The above applies also to hand-made paper, the ancient art of making which has been revived by Mr. Dard Hunter in this country, and has always been pursued to a small extent in Italy and other European countries. It should be emphasized that, contrary to popular impression in some quarters, hand-made paper is not superior to paper made in modern mills—quite the contrary. Much imitation hand-made paper is made in America on specially equipped cylinder machines and used for advertising announcements, de luxe books and stationery.

Wrapping and Bag Papers.

Wrapping papers are made from various combinations of kraft, sulphite, groundwood and waste paper. Frequently sulphite screening stock[1] is used in conjunction with the above materials. Jute and various combinations of jute and inferior stocks have had a wide application in the past but such materials are now being supplanted by kraft wrappers.

Kraft wrapping, although a variety of paper still in its infancy, is leading all the other combinations for wrapping heavy bundles. As a result of the

[1] For origin of sulphite screenings see Chapter 6.

great strength of its fibers and their flexibility and compactness, a wonderful sheet can be made for this kind of service.

Depending upon the specific service that is to be required of a wrapping paper, there are many modifications that can be made in the finish used to make up a desirable paper. It is not desirable to incorporate mechanical wood pulp in a wrapper of heavy weight that is going to encounter hard usage. As a result of the shortness of the fibers in such paper, and their weakness, it is devoid of all flexibility and strength. However, such combinations (colored up to resemble the true kraft color) are often sold as kraft wrappers.

A variety of pulp that at one time made a very good imitation of kraft is the so-called "brown wrapper." This was made from pulp obtained by steaming the wood at a high temperature, thus softening the fiber to a certain extent, and then grinding by the regular mechanical process. The wood is thus easily ground and yields a pulp containing long fibers, which, in their physical properties, closely resemble those of pure wood cellulose. However, all the original constituents of the wood besides cellulose are present, chiefly lignins, and these are almost unchanged, as in the mechanical pulp. Such paper has been almost entirely replaced by kraft, and mixtures of kraft and sulphite and other combinations.

Another well known form of wrapping paper is the so-called *"Butchers."* The prime requisite for such papers is sizing quality. They must be so sized as to stand what is known as the "blood test." This is a test devised to determine the resistance of the paper to blood, as such papers are intended for the use of butchers in wrapping meats. These papers are ordinarily made by using 60 per cent sulphite or kraft and 40 per cent groundwood in the unbleached state. Nearly all these grades are given a slight water finish which tends to raise the sizing of the sheet. Silicate of soda is often added to the size. The standard weight on such sheets has been taken at 40 pounds, 24×36 inches, 480 sheets to the ream. There are, however, some manufacturers making weights both above and under the above weight.

Manila papers have also obtained considerable importance in the wrapping paper field and also for electrical insulation, and for sandpaper. Such papers were originally made from pulp prepared from manila rope,[1] but the term is now also applied to papers made from sulphite and groundwood and colored to imitate the characteristic manila shade. One of the essential features of a good manila sheet is cleanliness. In order to obtain this quality many manufacturers apply special screening devices so as to get good stock quite free from dirt specks and uncooked shieves. A careful examination of manila sheets made throughout the country would lead one to the opinion that there are many different ideas as to what kind of finish is suitable for a first class manila sheet. It is generally conceded, however, that a high steam finish is mainly to be desired. This gives a soft, flexible sheet, which, when crumpled up, will give one the impression of a silky feel.

Cutlery papers are required to show complete freedom from chemical

[1] See Chapter 2.

residues which would tarnish the polished metal goods which are wrapped in them. The residues most likely to be present are sulphur compounds and these may easily be tested for by warming the paper with dilute acid in a test tube, holding a slip of filter paper dipped in lead acetate across the mouth of the test tube and noting whether or not the paper saturated with the lead acetate solution is blackened. If it is blackened it indicates the presence of sulphur in the paper being tested. Acidity in cutlery wrapping papers is also highly undesirable.

The papers used for packing small goods, such as silverware and other delicate articles, are generally tissues, the better qualities of which are made from sulphite and rag stock. Such papers must also be entirely free from sulphur and acidity which would have a damaging effect on silver and other fine metal articles.

Bogus wrapping is a very cheap paper made from screenings, poor waste paper, etc., on a cylinder machine, useful where covering is desired and no strength required.

Tissue and Cigarette Papers.

These papers constitute a distinct class on account of their extreme thinness. They cannot well be made on ordinary paper machines as the web of paper has not the necessary strength to carry across from one part of the machine to another, and must, at all times, be supported on a felt. Also, being very thin, they do not need as much pressing and drying as ordinary paper, one set of press rolls usually being sufficient. The Harper Fourdrinier machine is excellent for such papers. This machine will be described in detail in the chapter on the machine room. The drying part of the machine is frequently equipped with a Yankee dryer, which will also be described in the chapter on the machine room. Special devices are used in many mills for imparting crêpe finish to tissue papers. These are like calenders with corrugated rolls. The extended use of paper towels has led to the development of special papers resembling both tissue and blotting in qualities.

Cigarette Paper: Cigarette paper is best made from very carefully refined stock on a Harper Fourdrinier or a Flying Dutchman or Yankee machine (known in England as an M. G. machine) with a 120-mesh wire. Only recently the best cigarette paper has been made chiefly in France, Germany, Italy and Austria, but now very satisfactory grades are being made in America.

A good cigarette paper should be absolutely neutral in flavor and aroma while the cigarette is burning. As very few vegetable fibers possess these properties, the selection of material is most important in making this kind of paper. Pure flax, or linen fiber, hemp fiber and ramie, are usually used. Rice straw was formerly extensively used for making cigarette paper but this stock does not possess strength to satisfy the requirements of modern cigarette making machinery. Chemical wood pulp is only used for the cheapest grades of cigarette papers. It is deficient in tensile strength unless it is too thick. Straw papers usually contain silicic acid, which is undesirable in cigarette papers as it imparts disagreeable burning properties to the paper. Excessive use of cotton fiber gives the lamp wick odor found in some of the cheaper grades of cigarette paper.

According to Stroud Jordan the analysis of samples from reels of paper actually running on cigarette machines revealed that these papers were made up chiefly of linen fiber slightly sized with starch or dextrine and filled with calcium carbonate in the form of a specially prepared chalk which promotes slow, even burning. The filler in three of the samples (Austrian) averaged 24.05 per cent and in two other samples (French) averaged 9.13 per cent.

According to French patent 798,186 stearic acid, in proportion about 0.8% and a white pigment, preferably titanium dioxide, about 2% is added in the beater to give the highest possible whiteness, softness, opacity and even rate of combustion.

A good cigarette paper should weigh from 10 to 20 grams per square meter. With the former weight the paper should be 0.014 mm. thick and a 20 gram paper should be 0.037 mm. thick.

Porosity is necessary to admit air for the proper combustion of the paper. Cigarette papers are being made somewhat thicker today than formerly on account of the necessity for strength in paper to be used on cigarette machines and the manufacture of paper of the proper thickness and strength with sufficient porosity is quite a problem. Opaqueness is also necessary in order to give a good appearance to the finished cigarette. If the paper is not sufficiently opaque, the tobacco will show through the paper giving the cigarette a grayish or mottled appearance when packed which is undesirable from the cigarette manufacturers' point of view. Securing the necessary opaqueness without making the paper too thick is one of the nice points in the manufacture of this variety of paper. Titanium dioxide filler has recently proved useful for this purpose.

The boiling of the stock is very important. The slightest variation in the cooking process, whether in time, temperature, pressure or chemicals employed, may disastrously affect the character of the material, interfering with beating to the proper consistency and causing a great deal of trouble through tearing on the machine. Cigarette paper should be beaten with very dull knives. After beating, it is bleached, very thoroughly washed and then drained and stored for several months to ripen. This ripening process is necessary to give the paper the desired opaqueness and soft, silklike feel.

The operation of the machine in manufacturing cigarette paper is a very delicate problem. With no paper is exactness in regulating the flow of stuff on to the wire so necessary. The machine must be very carefully cared for as very fine wires are used which easily become filled up with slime and dirt. Such paper is usually made at a speed of about 130 feet per minute on a machine giving a web 58 inches wide.

In making very thin papers on fast running machines, there is always a danger of the paper sticking to the upper press roll. In order to avoid this trouble, most careful attention must be given to the condition of the stock. If this is not right, that is, if the stock has not been cooked and beaten in just the proper manner, no amount of adjustment of the machine will give satisfactory results.

In making very thin papers in which groundwood is used, careful attention must be paid to the selection of the groundwood, that prepared by the hot grinding process being most suitable. If sulphite pulp is used, it must be entirely free from pitch and sticky resinous matter and must possess a soft but sound fiber. If the original quality of the pulp is not right, it cannot be made right by any treatment in the beater or on the machine. If a sulphite pulp has been cooked too quickly, or with an unsuitable acid, or an unsuitable pressure, or if a mechanical pulp has been ground from old wood or with the wrong kind of stones, the pulp will never do for tissue or any other kind of unusually thin paper.

This term covers a great variety of papers such as citrus tissues (used for wrapping oranges, etc.) candy wrappings, cutlery tissue, toilet tissue, cigarette paper, carbon tissue (the basis of stenographers' carbon paper) and fancy Japanese paper (often known as "Yoshino" or "mulberry" paper) and imitations thereof. All of these "tissues" have little in common except that they are all lighter in weight than 12 lb. per ream 24×36—500. It is usually made on either a Harper Fourdrinier or a cylinder machine equipped with a Yankee dryer and from a great variety of stocks, in America bleached sulphite predominating.

Bag Paper.[1]

The required qualities in bag paper are: tensile strength, pliability, tearing and bending qualities, a certain resistance to moisture, a smooth printing surface and, in some lines, a considerable bulkiness (*e.g.* in sugar bags, sacks, etc.).

The materials and the method of manufacture must both be chosen with a specific view to the fact that the paper is to be used for bag purposes. Paper does not become *bag paper* merely by virtue of having been run through a bag machine and made into a bag. Conversely, there are several uses for bag paper other than the manufacture of bags.

Bags serve not only as *containers*, but also as *carriers*, and the stock must be sufficiently strong and pliable to permit of the bag being twisted, folded and gathered into improvised "handles." This feature of the use of paper bags submits the bag to a strain unique in paper usage. The strain applied to a paper bag in carrying home, say, a few pounds of nails, is only under other circumstances applied to materials much stronger than paper.

Good bag paper must be soft and pliable; must not be harsh or brittle; and must have good folding qualities to survive unimpaired the sharp creasing it receives in use. Moreover, since not all the strain the paper bag receives is tensile, one of the strains being the potential rupture of the sheet due to pressure of merchandise (individual *pieces* of merchandise in many cases, such as apples, vegetables and the like) we see that

[1] The following remarks on bag paper apply equally to wrapping papers in general.

the fibers must not run too definitely in any one direction, *i.e.*, they must not form a distinct "grain" running lengthwise of the bag. That would invite easy splitting of the sheet. Consequently, it is necessary to exert every effort to make a sheet that will have equal tearing-strength in all directions. From the very beginning of the art of making paper, this has been regarded as very difficult. In addition to eliminating a definite "grain" the sheet must be properly "closed," which will be more completely understood after the chapter on the paper machine has been studied. If the sheet is exclusively formed of long fibers, it will be all the better if it is properly closed and the fibers properly criss-crossed on the paper machine, avoiding variation of strength in one square inch of the sheet compared to the next inch. Hence the fibers must always be long enough so that the edge of the sheet will present a ragged and truly fibrous appearance when torn in any direction. A sheet of bag paper will frequently, against the light, appear to be relatively "wild" (that is when compared with varieties of paper other than bag and wrapping) and yet with splendid bag qualities in general, and without appreciable variation of strength inch by inch. Further, just enough size and alum must be used. There must be enough size to enable the bag to withstand quite a little moisture in the course of its use, and also to prevent too great penetration of moist materials. Only enough alum must be used to precipitate the sizing material; otherwise the sheet will be made too brittle.

Bag papers for the most severe service can best be made of kraft pulp, and with lessening severity of service, larger percentages of sulphite can be intermixed, until a point is reached where the bag is intended for uses where very little stress is ever applied to its surface, when combinations of sulphite and groundwood will suffice. The above remarks refer to the regular grades of bag paper. There are many specialties on the market which call for specially prepared paper consisting of jute, bleached soda pulp, bleached sulphite pulp, heavily loaded papers, parchment, etc.

Strict adherence to the many specifications required in the making of a commercial sheet of bag paper requires special skill and experience. The pulp from which it is made must be given preference for strong long fiber washed clean and free from odors, dirt, shives and chemicals. The stock must be prepared in beaters, Jordans and other refiners with continued effort to obtain long, strong fibers carefully hydrated in the beaters and refined with the same care. There must be no chemicals used in the beaters that might create odors in the finished paper. Nothing but clean pure size in liquid form carefully strained and pure iron-free alum must be used in the beaters; always bearing in mind that the finished paper is used for bags in which to carry food from grocer to consumer. The following list of tests is given in the order of their relative importance, as they apply to bag papers:

Punch Test: Punch or Mullen Test pertains to the breaking strength or a localized rupture of a paper bag, for instance one filled with oranges or similar contents—some one thing pressing from the inside of the bag and breaking through.

Tear Test: Tear test pertains to the splitting of the bag grainwise of the paper caused by lack of proper crossing of fibers when the paper is formed on the Fourdrinier wire or cylinder mold.

Bending Test: Bending test pertains to the pliability of the bag paper, the lack of which is caused by improper cooking of the kraft or sulphite pulp and the lack of proper hydration of the pulp in the beaters and refiners. Paper bags must be pliable, easy to fold and twist into convenient hand holds for carrying when full of vegetables, fruit, etc.

Durability Test: The durability test of bag paper is measured by the number of times that a strip of paper may be bent, rebent, folded and refolded, rubbed together, etc., without rupturing the paper.

Porosity Test: A sheet of bag paper that leaks air is undesirable. The paper must be as near air tight as possible for obvious reasons. If it leaks air it will leak moisture regardless of the sizing it contains. Moist and sometimes wet vegetables are carried home from the grocer in bags made from this paper. Porous bag paper is an indication of poor workmanship. It is easy to avoid. If well prepared stock yields porous paper, the machine tender is at fault. Cutting the stock shorter in the Jordan will help close the sheet but will sacrifice fiber length which is very essential in bag papers.

Size Test: The size testing of paper is to determine its moisture resisting qualities. The standard test for moisture varies in different papers. The gradations are determined from the paper and its use.

Finish Test: The surface of all grades of paper usually requires a different finish depending on what the paper is used for and is usually matched with samples furnished by the purchaser. Newsprint paper is very much the same on all daily papers and has become standardized. Most writing and bond papers and various other commercial papers have a machine finish. Special high finish must be made on supercalenders. Any of these finishes may be demanded on modern bag papers that are to have lettering or illustrations printed on them, frequently in several colors, or with metallic inks as in coffee bags.

Fiber Length Test: The length of fiber in a sheet of bag paper is determined by the quality of paper to be made. It influences nearly all other qualifications in paper, viz. testing, bending, durability, finish, formation, bulk, elasticity, cockling, curling and the general appearance of the paper. The construction of any sheet of paper depends on the fiber length of the stock.

Formation Test: The formation of bag paper is very important. One of the first things a dealer will look for is good formation. The outstanding evidence of poor workmanship is always on exhibition in a shabbily made paper caused by uneven and poor formation and will disqualify paper that may be good in all other respects.

Moisture Content Test: The moisture content in paper varies in all grades and kinds. It also varies in different weights of paper and is one of the most delicate and exacting requirements: 25 pound paper made from all chemical pulp may test 4 or 5 per cent retention of moisture, while a 50 pound sheet will retain 8 or 9 per cent. More care must be exercised in making paper from a large percentage of mechanical pulp or groundwood—wallpaper with 15 per cent of sulphite and 85 per cent of groundwood is very exacting in the drying. Too much moisture renders the paper useless for bag paper especially for printing; also, paper that is too dry becomes so brittle that it cannot be used for bags. The drying of bag paper is very exacting and one of its most important requirements.

Bulk Test: The thickness of paper, meaning bulk, applies to all papers to a more or less degree and is very exacting in bag and wrapping papers. The bulking of paper begins with the preparation of the stuff in the beaters and Jordans and continues through the paper machine presses and calenders. It is allowed to bulk on the wire. No dandy roll is used and very little pressing. Calenders are used very lightly, the weight of three intermediate rolls being used to level unevenly distributed fibers on the surface of the sheet.

Parchment and Vulcanized Papers.

Genuine vegetable parchment paper consists of unsized rag, or bleached sulphite paper called "waterleaf" which has been treated in a bath of dilute sulphuric acid. After treatment with the acid the paper is washed with water and then with dilute alkali to neutralize any trace of acid remaining and finally with pure water again to remove the alkali. This is done on a special machine where the web of paper passes into a vat for treatment with the acid and then between rolls to remove surplus liquid after which it passes into the vats containing the dilute alkali and water. This treatment increases the tensile strength of the paper to a remarkable degree and gives it many of the properties of animal parchment. The acid transposes the surface fibers into a tough, gelatinous mass called "amyloid" which forms a protective coating for the unaltered fibers beneath. Such paper is impervious to air, moisture, fat or oil and stronger wet than dry. In some instances zinc chloride is substituted for the sulphuric acid. Its action is quite similar.

In the manufacture of *vulcanized fiber*, used for trunks, tubs, waste baskets, trucks, etc., sheets of "waterleaf" paper which have been treated with zinc chloride are pressed together and then thoroughly washed to remove the chemicals.

Another modification of parchment paper is the *Willesden Paper* obtained by saturating a sheet of "waterleaf" paper with Schweitzer's reagent (an ammoniacal solution of copper oxide) thus causing a gelatinization to take place on the outside of the paper. Then when the sheet is dried it is impregnated with a green varnish consisting of a compound of the reagent with the cellulose, which is waterproof and very strong. Sometimes several sheets are pressed together, making a board. The reagent is prepared on a commercial scale by allowing concentrated ammonia liquor to trickle down towers packed with copper scrap, air being blown up the towers at the same time. The same treatment is applied to textiles.

In the manufacture of these different forms of parchment paper it is advisable to use a thoroughly bleached stock. Unbleached stock, when treated with these chemicals, takes on a dirty, brown color. The presence of any mechanical wood pulp is apt to give a charred effect. Formerly an unsized cotton rag stock was entirely used for making these special grades, but this is now supplanted almost entirely by the use of bleached sulphite stock. Mitscherlich process sulphite is favored by some leading manufacturers of parchment.

Glassine Paper.

This is a translucent or semi-transparent greaseproof paper used for wrapping paper, bags, window envelopes and occasionally for stationery. It is often finished with embossed rolls to yield attractive cobweb and watered effects for book jackets, package wrappers, etc. It should not be confused with vegetable parchment since, unlike the latter, it loses strength on wetting. It is sometimes, however, called imitation parchment or parchmoid.

Glassine paper should not have more than 3% or 4% moisture content when it is finished on the paper machine before supercalendering. *This paper must not be calendered to a glossy finish on the paper machine.* One or three nips of the stack will level the surface and condition the paper preparatory to receiving the surface moisture as it is being wound into rolls for the supercalenders, the moisture being applied to the surface of the paper by the use of a stray-dampening device. Steam sprays are too fugitive, the vapor being too light, not damp enough and floating away before reaching the surface of the paper. The principle used in the manufacture of an effective paper dampener is compressed air combined with water. By the use of compressed air, water is forced through minute orifices and the water becomes a spray of vapor.

After the paper is conditioned and made into rolls as above described, it is best to permit the rolls to remain in storage for a few hours, permitting the moisture to become evenly distributed through the entire roll. The paper may then be run through supercalenders and converted into a beautiful transparent sheet of glassine paper. The pulp from which this paper is made must be carefully selected clean bleached sulphite.

Beating Glassine Stock: In preparing for a run of Glassine Paper all stuff chests, pipes, pumps, screens and head box must be made absolutely clean. Next, furnish the beaters with clean fresh water and clean bleached sulphite pulp until a density is reached that will circulate in a Hollander type beater about 4 complete circulations per minute. Do not lower the beater roll until the stock is mixed and running smooth. Next, lower the beater roll to a light brush. Continue this for about one hour. Then, lower the beater roll to a medium hard brushing. Continue this for about two hours. Next, lower the beater roll to a hard brushing and continue this position for three hours. The roll bars and bed plate bars must be dull. Sharp tackle will not do. Lava rolls are successfully used in some mills. Glassine Stock must be *well hydrated and not cut in the beaters.* The cutting should be done in the Jordan or other refining engine, where the long well-hydrated slow fibers may be reduced to the proper length for a well-closed sheet of paper. Well-hydrated stock will sink in water; therefore, do not attempt a trial run on a paper machine equipped to make 50 or 75 tons of paper per day for it would have too much screening capacity, too deep and too large head box and would be generally disproportionate. Fourdrinier wires should not be elevated at the breast roll. Wire should be a fine mesh at least 70 or 80 mesh. Use all white water. After the first furnish for starting the machine, use only screens enough properly to screen the stock, the head box shallow enough to prevent the stock from settling and becoming sluggish. Boiling and extreme agitation must be avoided. A gentle and smooth delivery from the screens to the wire must be provided, at the same time the stock must be thoroughly mixed. The proper speed is about 250 F.p.m.

All colors and tints of Glassine papers may be made. Colors should be used in liquid form and put into the beater of stock about one hour before the stock is emptied into the stuff chest. The order in which the color, size and alum are put into a beater of stock is: first, color which should be allowed to become thoroughly mixed with the pulp, which will take less than one-half hour; then the size is put in, and allowed to mix thoroughly with the stock. Alum is next put in. Alum and size should be used in liquid form, never thick size or dry alum. They should all be added to the stock in the order given above and about 15 or 20 minutes apart to allow for thorough mixing.

Newsprint.

The uses of newsprint are by no means confined to the printing of newspapers. Large amounts are used for catalogs, telephone directories, railway guides, school tablets, scratch pads, handbills, wrapping paper, etc.

Most newsprint is made entirely of groundwood, or groundwood with about 20 per cent of sulphite added. In all cases unbleached stock is used. In the manufacture of this paper it is necessary to run the machine at high speed, and since a sheet of newsprint is comparatively light, it necessitates the use of comparatively slow stock. The explanation of this will become apparent after the chapter on the machine room has been studied. Some modern newsprint machines run at a speed as high as 1200 f.p.m. and seldom less than 800 f.p.m. The wire frequently has a high pitch—sometimes as much as 18 inches to increase the speed of the stock and make a sheet more than 150 inches wide—in some cases as wide as 199 inches.

No beaters are used for newsprint. The pulp is "dissolved" or made into slush in chests fitted with agitators, to which the output of the "broke" beaters are added. In a few mills Jordans or other similar refiners are employed. No sizing is used. Clear white newsprint is obtained by the judicious use of blue and red aniline dyestuff color, with a little alum to "set" the color. The above comments are characteristic of the vast bulk of newsprint production in the United States, Canada and Newfoundland. Some special grades of newsprint are made on a relatively small scale which approximate to book paper, as described on page 61. Very recently by means of the Minton vacuum dryer a sheet of newsprint has been made from groundwood that in printing results will approximate magazine paper except for the grayish color.

Blotting Paper, Paper Towels and Toilet Paper.

By reason of the physical properties of cotton fiber which has the greatest capacity for sucking up liquids of any of the fibers used in the manufacture of paper, the best blotting papers are invariably composed of cotton rag stock. Before treating the stock in the beaters it is essential to allow it to become well matured and it is frequent practice to allow the rag stock to sour after boiling in order that any lime salts that have been left may become decomposed. For this process a pure, soft water is essential, since calcium salts have a tendency to harden the fiber and render it less absorbent.

Just as in other grades of paper there are many gradations in quality from the best blotters made of pure cotton rag stock to cheap blotters made almost entirely of mechanical wood pulp. In the medium grades soft soda pulp, either alone or with an admixture of cotton rag pulp, is extensively used. Blotting stock is beaten quickly, the beater being of ample capacity so the circulation will be rapid and thorough. Usually one hour in the beater is enough.

The principal requirements of good blotting paper are: absorbency, freedom from hairiness and a good printing surface. Hairiness gives rise to fluff that tends to cause smudging of the ink. A good blotting paper should only yield a slight quantity of ash on being incinerated.

A huge business has developed in paper towels. Requirements are much as for blotting paper. However, for towels more strength is required so the stock is held much longer in the beater and otherwise refined. One important mill uses Claflin refiners and Jordans are quite suitable if skilfully supervised to avoid too much "cutting up." In making towel paper kraft is also useful where cream or brown color is not objectionable. The dryers are run low so as not to seal the surface of the paper and disturb its absorbency. Special sanitary precautions are of course mandatory in a mill making such a product. Mild impregnation with disinfectants and odors—such as pine—have recently been experimented with. The above remarks also apply to toilet tissue except that a cylinder machine or Harper Fourdrinier is usually employed.

Filter Paper.

Filter paper is in many respects similar to blotting paper. Just as in blotting paper, the fundamental requirement is marked ability to absorb water and other liquids. The manufacture of filter paper for scientific purposes is a branch of paper manufacture which has received most expert attention and forms an art in itself. There are a number of firms in England, France, Germany and Sweden that have given special study to this subject and produced a wide variety of filter papers suitable to the various requirements of the chemist. For some purposes a very fast filtering paper is required, *i.e.*, one that will let the liquid run through in a minimum of time, and this effect is sometimes secured at the expense of making the paper so loose and open in structure as to allow some of the finer particles of the precipitate to pass through. For other purposes papers are required which will make as near a 100 per cent retention of the precipitate as possible, even if the filtering operation is very slow.

A good filter should possess sufficient mechanical strength, even when wet, not to be broken by the weight of the liquid in the filter or by a moderate amount of suction. Filter papers intended to be used with suction naturally have to be stronger than others. A good filter paper should have a smooth surface free from hair or down or fluff of any kind that will detach itself from the surface of the paper and come off when a precipitate has been dried in it.

The best filter papers consist of stock made from the best qualities of cotton rags, sometimes with a little wool fiber mixed in. In order to extract any mineral matter in the fiber (silica, etc.), the stock is treated with hydrochloric and hydrofluoric acids, dilute alkalis and frequent washings with the purest water. The extent of this treatment depends, naturally, on the ultimate quality desired. For rough qualitative work and industrial purposes such treatment is not necessary. For filters for accurate quantitative analytical work (*e.g.*, the ashless filters), such treatment is necessary. Such filter paper is almost perfectly pure cellulose.

After being made into sheets, filter paper is ordinarily stamped out in disks of various diameters, which are packaged together in bundles for sale. A good deal, however, is sold in sheet form. The heavier grades are sold in large sheets for filter presses and other industrial work.

Considerable quantities of filter paper stock are never made into paper at all, being dried and sold in bulk form for "filter mass" which is packed into various forms of stoneware and metallic filtering apparatus. For this sort of filtering medium sulphite wood pulp has been found to be an effective and cheaper substitute for cotton rag pulp in some lines of manufacture.

Swedish filter paper manufacturers frequently freeze the wet sheets of paper. The crystals of ice force apart the fibers leaving the paper with a porous structure when it is thawed and dried.

Hangings and Wallpaper.

Wallpaper stock is made usually from a mixture of 85 per cent groundwood and 15 per cent sulphite, both being used in the unbleached state. About 10 per cent of clay is added to the combination in order to render it opaque and give a suitable surface. The surface must be capable of receiving a good impression.

Hanging paper must be sufficiently well sized that when it is applied to a wall it will stand the application of the paste without breaking. Undersized hangings are very objectionable. Like all other classes of paper, special attention must be given to the moisture content of the finished paper. If it is over-dried, it will become brittle and practically worthless.

The prime feature to look for in hangings is softness combined with pliability, resistance to water and a certain bulk.

No. 1 Hangings: Used for expensive wallpaper, especially the new so-called waterproof wallpapers. Made from bleached sulphite, bleached soda and not more than 20% very high grade groundwood, with talc as filler, high rosin sizing and frequently silicate of soda.

No. 2 Hangings: The standard grade of wallpaper. Made from 72% to 90% high grade groundwood, the balance being unbleached sulphite and very occasionally some unbleached soda pulp. Little filler is added as maximum bulk and minimum weight is required.

The quality of the product of a mill making hangings depends largely on its groundwood department. Good hangings are made in the groundwood mill. Without properly made stock it is impossible to manufacture a good product, no matter how much care is exercised in subsequent operations. In no branch of paper making is this more true.

Since this is necessarily a comparatively cheap grade of paper, and thus it is necessary to run the machine at a high rate of speed (in order to have an output of finished paper that will yield sufficient dividends) groundwood stock of a very free nature must be employed since the paper is a comparatively heavy sheet. If slow stock is used, the machine must be slowed down to get the water out of the sheet. This results in a loss in production serious in the case of an inexpensive product. It is therefore essential that the groundwood stock should be prepared in a free state as closely resembling sulphite fibers as possible. The details of accomplishing this effect will be explained in the chapter dealing with the groundwood mill.

The users of hangings, or wallpaper stock, have adopted as standard certain weights of paper, as follows:

Weight in Ounces	Basis Weight 24 in. × 36 in.—500 sheets
9	38½
10	42½
11	46¾
12	57
14	59
16	68
18	77
29	125

Surface of Paper: 24 ft. long × 21½ inches wide.

Roofing and Building Papers.

These papers are made from very coarse and cheap materials such as low grade rags, old gunny sacks, coarse jute wastes, sulphite screenings, etc. The principal points aimed at are cheapness and bulkiness, together with a certain absorbency, which is necessary when the papers are to be impregnated with asphalt, etc.

In addition to ordinary building and roofing papers, a large number of specialties containing asbestos, etc., and impregnated with various chemicals and asphaltic substances have been developed. In some cases the papers are marketed in rolls and in other cases handled as boards.

The machines for making these boards are very highly specialized and are generally of the cylinder type. The principle and operation of such equipment will be described in the chapter on the machine room.

Asbestos Papers: Building papers made from asbestos mineral fiber beaten (after preparation in crushers) in an ordinary paper beater and formed into board, with or without admixture of other fiber, on a cylinder machine, and sold for use for heat insulation.

Tracing Paper.

This engineer's specialty is thin, transparent, tough and with a good hard surface for drawing on with ink. Its preparation is almost identical with glassine (see p. 71) except that it is much more *highly sized* and is calendered *very lightly.*

Waxing Paper.

Requirements for waxing papers are much the same as to stock and method of beating as for high grade bag papers (see pp. 63, 64) except that the adaptation of the surface to the waxing process is all important. There are two principal waxing processes: (1) *self-sealing* process in which the paper is highly impregnated with hot wax and, when used on an automatic machine, seals under the heat and pressure of the machines, and (2) *dry wax process* in which wax is applied and then "ironed in" by heated rolls, and the waxed paper thus produced used in a packaging machine requiring an adhesive other than the wax.

From the papermakers' viewpoint the two processes differ greatly. Paper for *self-sealing* should be highly machine finished or even supercalendered: for *dry waxing* they should have a low finish and maximum absorbency.

Very exact control of weight across the machine is also extremely important, as otherwise one would get uneven waxing on the waxing machine and much trouble on the packaging machines.

For details of automatic equipment for regulating weight across the machine see Chap. 13, The Machine Room.

A special grade of waxed paper is made with a considerable percentage of kraft and used on the automatic confectionery wrapping machines which subject the paper to a severe twisting strain. Another special product of great utility is the opaque waxed tissue used for bread wrapping and similar purposes in making which titanium dioxide filler is used. At the other extreme we have waxed boards used for cartons and other containers.

4. The Saw Mill

The papermaker's interest in wood must necessarily start long before the wood reaches his plant, for the economy of his mill and the quality of its product depend largely on the quality and uniformity of his pulpwood. However the author deems it neither necessary nor desirable to attempt to deal exhaustively with the subject of harvesting pulpwood, cutting it up and delivering it to the paper mill.

There are, however, some general observations that should be given careful consideration.

In such a huge area as North America extremely different conditions[1] are met with in various regions where papermaking prevails. The following are some general classifications:

1. Northeastern U.S.A. and older parts of Ontario and Quebec where pulpwood is usually received at the mill by rail or truck (or in the case of seaboard and lakeshore mills by ship) in the form of 2-foot or 4-foot blocks.
2. In many locations in Maine, Michigan, Wisconsin, Northern New York, Ontario and Quebec, etc., pulpwood is floated down streams to the mill, or towed in booms when the mill is on a lake or large river. Many of the mills now receiving pulpwood by rail were originally in this class, as will readily be surmised from their locations.
3. In Oregon, Washington and British Columbia huge logs 3 to 5 feet in diameter and 18 feet or more long are brought out of the woods by logging railroads; transported to the mill by main-line railroads; held there in a floating reservoir of raw material until needed to feed the "breakdown mill" in which they are slit lengthwise into 4-inch thick logs or "cants," stripped of bark, freed from knots, and made ready for chipping which follows immediately.
4. In the South, where many huge papermills have recently been erected, it is customary for the mill to maintain a graded woodyard at least 1000 ft. × 250 ft. in area. Here pulpwood is received by rail, highway truck and in some cases by barge. These new Southern mills usually get their wood from a number of sources such as their own stumpage contracts; individual private contractors; farmers, etc. The wood is usually in 4-foot blocks and less uniform than Northern pulpwood. From this woodyard it goes direct by conveyor to an outdoor installation of barking drums and thence by conveyor to the chippers.

Contrast in size of wood from West to East is amazing. For instance, a 13-foot log of Adirondack or Eastern Canadian spruce 5 inches in diam-

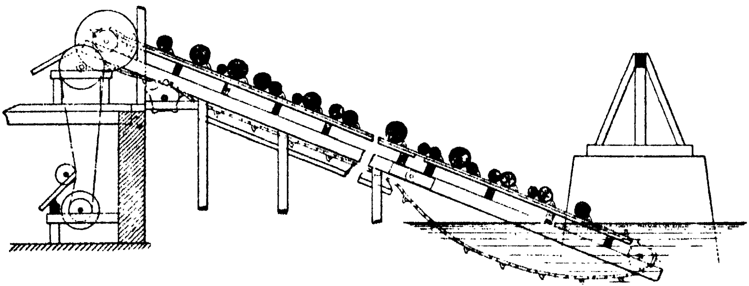
[1] The illustrations accompanying this chapter and the next will show examples of all these different conditions and should be carefully studied and compared.

eter would require 34 logs to a cord, whereas with West Coast hemlock a tree 4 feet in diameter at breast height will yield 18 cords of wood!

I. Northeastern Papermaking Regions

Log Haul-Ups, or Jack Ladders.

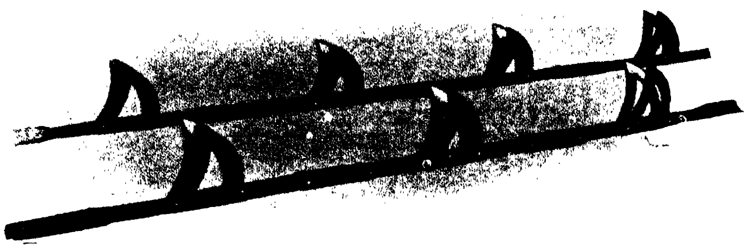
Whenever possible, it is advisable to use parallel chain haul-ups, which bring the logs up sideways, instead of end for end. This form of hauling is especially advisable when the logs are of uniform length and are to be cut into blocks with a multiple saw slasher.



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 8.—Parallel chain log haul-up.

The diagram shows the arrangement of such a system. Two or more chains are used, running parallel to one another. The logs are floated into such a position that they will be pulled up by the chains as these emerge from the water. The incline should not be more than 30° if 24-inch logs or larger are to be handled. Smaller logs can safely be handled at a greater angle. In fact, 24-inch logs can be handled at angles exceeding

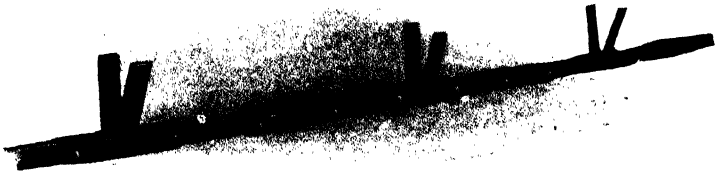


Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 9a.—Steel wing link chain.

30° if specially designed chains are provided. The above remarks refer to the usual forms of chains, two typical kinds of which are illustrated.

The logs discharge automatically from the head end of the haul-up onto an inclined deck, and roll onto the slasher. Automatic counting devices are sometimes installed which record the number of logs passing, and thus afford accurate records of the numbers of logs brought into the mill from day to day.

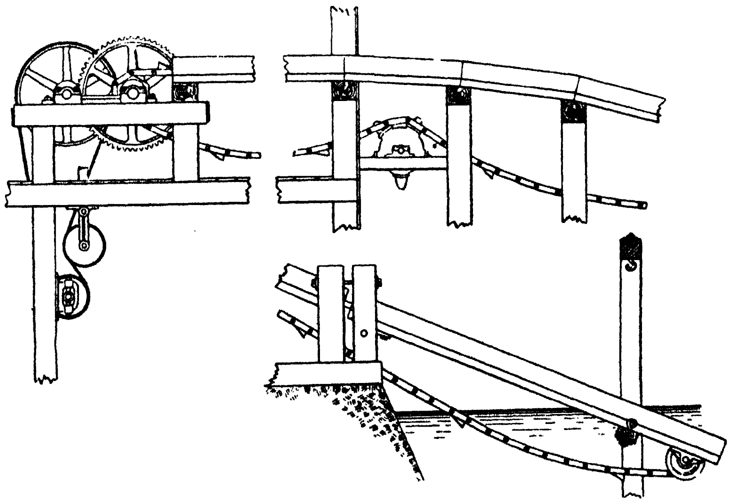


Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 9b.—Iron wing link chain.

When it is found more convenient to bring the logs up end to end, an endless chain haul-up is installed, as shown in the illustration. Several types of chain are used on such conveyors, three of which we illustrate.

The lower end of the haul-up should be so arranged that it can be raised and lowered, thus accommodating the chain to various levels of water met with during a season's operations.



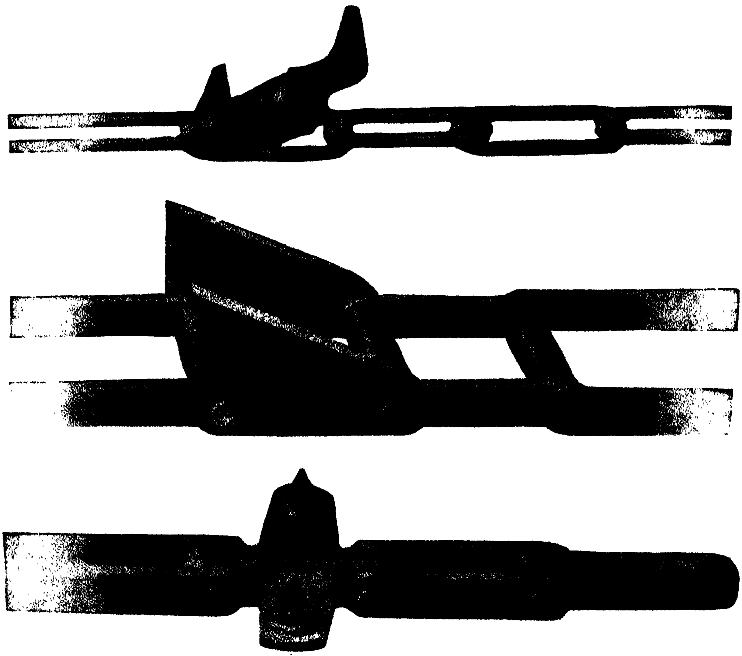
Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 10.—Endless chain log haul-up.

The illustration shows the drive for this haul-up located above the floor. This is not imperative. It can very conveniently be located below the floor. The drive can be either spur or bevel gear, and starting and stopping is usually provided for by means of iron and leather frictions, or by means of a belt tightener.

Log Kickers.

When logs are brought into the mill end to end, a kicker must be used to expel them from the log haul trough. The usual form of this machine is a rocker shaft, to which as many cast iron arms are attached as may be required (this depending on the length of the logs being handled). To these arms are attached shover arms, which are made up of two castings with heavy wrought iron riveted sides, working through cast iron guide troughs, located at the side of the log haul trough. The rocker shaft



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

FIG. 11.—Typical chains used with endless chain log haul-up.

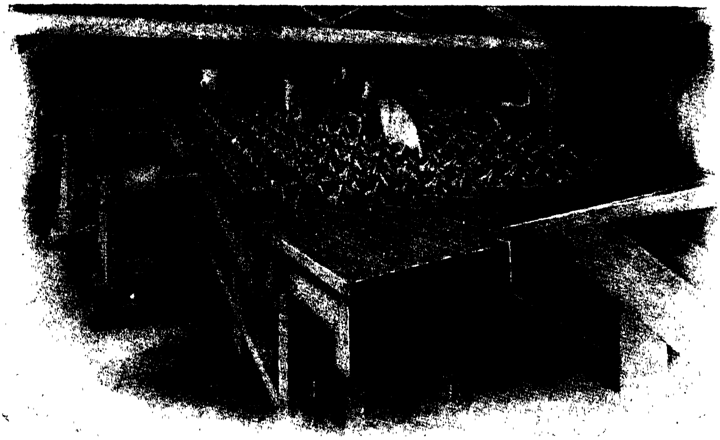
and arms are in turn operated by means of a steam cylinder, attached to the shaft by a connecting rod or pitman. This machine may be operated by means of a foot tread or lever. In most cases the former device is used and the tread placed on one side of the log way. The operator by stepping on the tread admits steam to the cylinder, and throws the logs out of the trough onto the inclined deck leading to the live rolls. The shover arms pass up through the guide troughs in such a manner as to strike the log at the easiest point to set it rolling. The cylinder is stationary, steam piping rigid and all possibility of leaky cylinders thereby avoided.

Saws.

There are two chief types of saws used in saw mills in the paper industry. These are: (1) *Slashers*, which are intended for the economical reduction of long logs of nearly uniform length to blocks of a short uniform length in large quantities. (2) *Swing Saws*, which are intended for use in mills where the logs are of extreme length, or where the lengths vary to such a degree as to render a slasher impracticable. In many saw mills both slashers and swing saws are required.

Slashers.

These machines consist of an arrangement of one or more stationary saw arbors equipped with the ordinary type of circular saw, revolving at a high rate of speed and mounted upon a slightly inclined table. This table is provided with a number of feed chains, so arranged as to receive the logs automatically from an inclined deck, carry them to and through the saws, and deliver them at the upper end to a conveyor or whatever other means may be provided for removing them.



Courtesy: Kyther & Pringle Co., Carthage, N. Y.

FIG. 12.—Typical five-saw slasher installed in wood preparing plant.

The arbors should be made of the best quality of cold rolled, open hearth steel, of superior quality and temper, combining both strength and stiffness. The arbors themselves should be accurately turned and keystead, and the saw collars fitted with the utmost care. The diameter of the arbors should be exactly the same throughout the entire length.

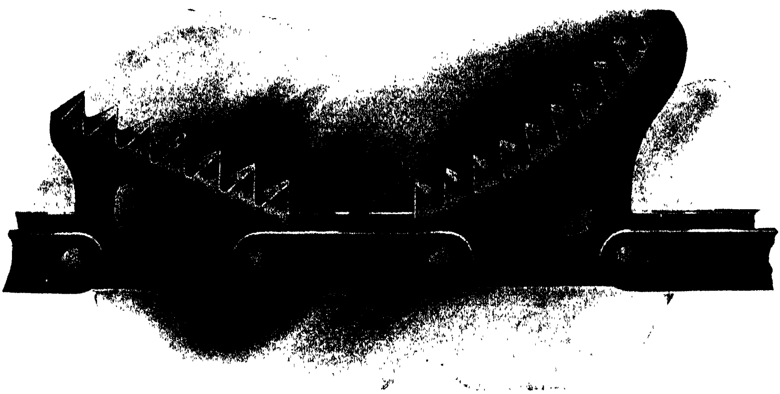
Each arbor should be equipped with three self-oiling bearings of liberal strength. Two of these bearings should be attached to the framework of the slasher, and one bearing should be mounted in an adjustable floor stand and arranged to be placed outside of the arbor pulley, thus insuring a perfect and permanent alignment of the arbor.

The arbor pulleys should be all made extra heavy and solid, turned and perfectly balanced, keyed and fitted to the arbors.

The saw collars should be made of cast iron, and when fitted for 60-inch saws should be 10 inches in diameter, with a 2-inch arbor hole and two lug pins, ⅝ inch diameter and 3½ inches center to center. The tight collar is fitted against a slight shoulder turned on the arbor and then shrunk on. The loose collar, which clamps the saw against the tight collar, is secured by means of a 2-inch hexagon nut, fitted with a special thread to permit of securely clamping the saw. The above arrangements are necessary to guard against any danger of the saws working loose while in operation.

The saw arbors are arranged in such a manner relative to the feed chains and other parts of the slasher that, by merely removing the nut and the loose collar, the saws may be changed very quickly, without removing the arbors or any other part of the machine.

The feed chains are a very important part of the slasher. They run parallel with the saws, pick up the logs at the receiving end of the machine, carry them to and through the saws, and deliver them sawed to length at the discharge end of the machine.



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

FIG. 12a.—Detail of slasher chain.

The nature of these chains will readily be seen from the illustration. The shape of the pockets formed by the link is such that a log of any diameter from 4 inches to 24 inches is firmly held in position while being sawed, thus avoiding any possible cramping of the saws. There are two lines of chain for each sawed piece resulting from the sawing of the log, thus providing for securely holding in position each block of wood throughout the cut and until the blocks are released at the head end of the machine.

When passing the sprockets at the delivery end, the chains free the blocks of sawed wood automatically, and they are delivered onto the conveyor, or whatever means may have been provided for removing them. The chains should run in steel trough irons, to which are riveted cast iron chains, by which they are secured to the frame of the machine. The chains must be accurately built to template, so that when there are a number of chains used, the alignment of the chain pockets will be perfect, thus bringing the logs squarely against each saw.

The sprocket wheels which drive the feed chains should be of cast iron with chilled teeth surfaces to insure long life. The head, or driving sprockets, should be keyed to the head shaft, particular care being used to preserve a perfect alignment of the spockets, and, in consequence, the chains themselves.

The head shaft, to which the driving sprockets are keyed, should be back-geared through a pinion countershaft, from a belt countershaft, which, in turn, is driven from a pulley keyed to one of the arbors. In this manner, the speed of the feed chains is reduced to about 25 feet per minute. This feed should be self-contained and capable of being started or stopped instantly, independently of the saws by a hand lever.

In large slashers, where the chains are of great length, it is advisable to provide bottom idlers to relieve the driving sprocket of the weight of the chains.

One prominent manufacturer of this class of equipment states that, as the result of a number of observations taken from different slashers working under varying conditions, the following definite statement can be made as to the power required to operate the same successfully:

"Eighteen hp. should be figured for each 60-inch saw operated to full capacity. This amount of power will also operate the necessary log haul, or jack ladder, required to bring the logs to the slasher. For saws less than 60 inches diameter, the power required will be proportionately less."

According to the writer's experience, the above figure is correct. The power required for the log haul, or jack ladder, depends on the length and pitch of the ladder. Under ordinary conditions a 15 hp. motor will take care of a jack ladder 75 feet from center to center of sprockets.

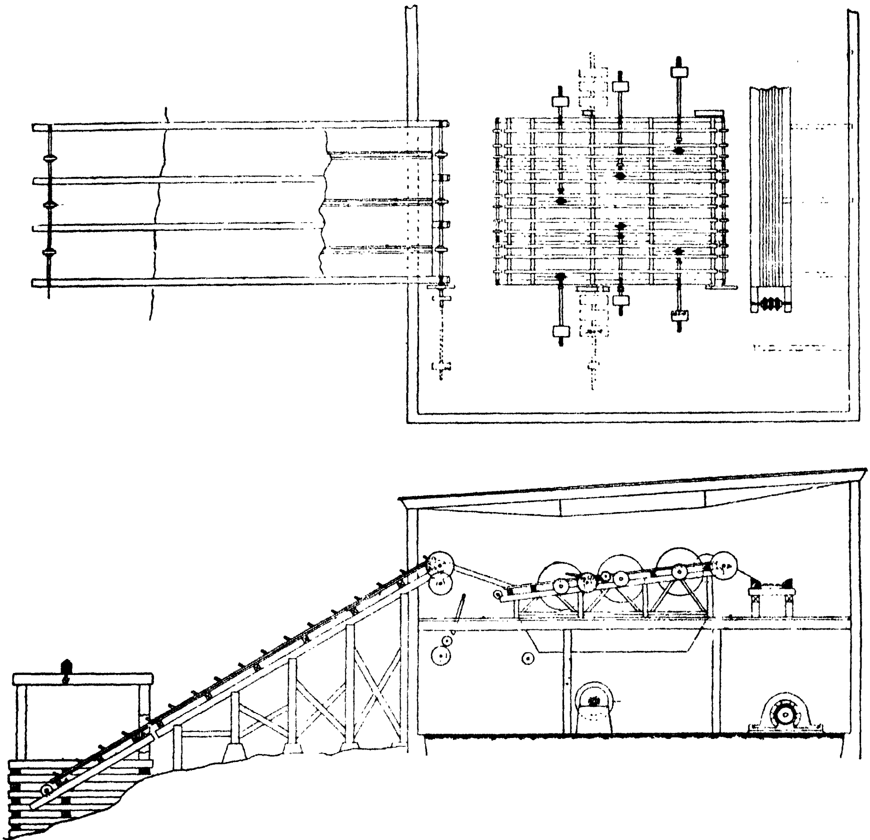
The following two descriptions of the saw mill equipment installed in two well known pulp mills by Messrs. Ryther & Pringle Company, of Carthage, N. Y., are typical:

At a plant in New York, the logs, which are 12 feet long, are brought into the mill by a parallel chain log haul and delivered automatically to the slasher which is equipped with five 60-inch saws so arranged as to cut the 12-foot logs into six 24-inch pieces. The sawn blocks are delivered automatically from the head end of the slasher to a cable conveyor, which in turn carries them to a storage pile outside the mill.

This machine (Fig. 13) is operated with a crew of eleven men, distributed as follows: Seven men are stationed at the foot of the log haul to guide the logs onto the elevator chains, two men are on the slasher itself, and the other two men are on the cable conveyor which carries the sawn wood away from the slasher.

During four seasons this machine handled 163,000 cords of wood, the daily average being about 500 cords per ten hours. The total amount of repairs and replacements for that period averaged less than $5.00 per season. The saws did not have to be changed in four years, during which time they wore from 60-inch diameter to 55¾-inch diameter.

Indicator diagrams taken at the above plant at various intervals during the operations showed a total power consumption of not to exceed 90 hp. which included the power necessary to operate the entire combination of log haul and slasher.



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

FIG. 13.—Plan and elevation of wood preparing installation consisting of five-saw slasher, parallel chain log haul-up and distributing conveyor. This is the same installation shown in Fig. 12.

A similar machine installed at a Canadian plant exceeded the record of the above machine, owing to more favorable river conditions. The average at the Canadian mill was over 600 cords per ten hours. On one day as high as 16,815 logs were put over, this being more than 800 cords per ten hours.

At another Canadian plant a seven-saw slasher is installed. Owing to the location of the wood room relative to the pond from which the logs were drawn it was necessary in this instance to take the logs from the water endwise, by means of a single strand log haul, instead of broadside by a parallel chain log haul, as is ordinarily done. Operating in this manner it was not possible to cut as large a number of logs per hour as is done where the parallel chain log haul is used.

One man, stationed at the table where the log haul delivered the logs from the pond, commanded a view of the entire operation from the water to the conveyor for sawn blocks and controlled the log chain and the kicker to the slasher and counted the logs. The kicker throws the logs from the log haul trough to the slasher table, and at the same time, lines up the logs, so that the head ends follow a regular line through the saws. The last end of the logs is trimmed first to 16 feet, plus a slight allowance for sawdust loss. The first saw cuts the 16-foot logs once in two and spreads the logs sufficiently to prevent any possibility of cramping the saw ahead. Next, the two 8-foot blocks are each cut into two 4-foot pieces, and finally another pair of saws cut each 4-foot block once more in two, thus resulting in eight 24-inch pieces. From 5,000 to 6,000 logs can be handled from the water, sawed and piled in 10 hours. The handling, sawing and piling of the logs in 24-inch lengths is done at a cost for labor of 10 cents per cord.

It should be taken into consideration that a great variety of factors. apart from the efficiency of the machinery, influence the operation of such an installation.

It is not always possible, for a variety of reasons, to install the machinery in the position and arrangement ideal from a mechanical point of view. The case of the Canadian Mill, described above, is an illustration of this. In such cases the best has to be made of the conditions at hand.

River conditions will have a great effect on the problems of the saw mill, and these will not be the same at any two plants, and will vary at one and the same plant from time to time.

The labor available at different points will vary. The operation of this kind of equipment requires both physical strength and intelligence, as well as ingenuity. It will be found to pay to have this department overmanned, if anything, rather than undermanned.

Swing Saws.

Where logs of varying lengths and diameters have to be reduced to short blocks of uniform length, a swing saw system is generally used.

The logs are brought into the mill end for end, by means of a single strand conveyor chain fitted with spurred links at intervals. The log haul drive is so arranged as to be under the control of an operator stationed at the head of the log deck, and may be stopped, or started, as required. A log having been brought to the head of the deck, the drive is stopped by means of a lever, the operator admits steam to the kicker cylinder, and the log is kicked, or rather rolled, from the trough onto the inclined deck. This deck is of sufficient size to hold in reserve a supply of logs. From the deck, as required, logs are released by means of a steam trip, or loader, and roll onto the live rolls. The live rolls are arranged to operate, in series—the length of the train over all being sufficient to accommodate the longest logs being cut. The operation of these live rolls is under the control of the sawyer, who engages, by means of a lever, the frictions which drive the rolls, and advances the log or logs as the case may be to the gauge block. The gauge block is located at a distance beyond the saw to correspond with the required length to be cut, and as soon as the log is brought in contact with the gauge block and stopped, the block disappears. The sawyer then, by means of a lever, admits steam to the cylinder, which operates the saw frame, bringing the saw through the log until the cut is completed. The sawn block is then kicked onto the conveyors.

Care of Saws.[1]

It is very important that the saws should be kept in the best of condition. If too much sawdust is produced and if it is allowed to adhere to the ends of the blocks it will cause trouble later on. Holes and defects in the paper can sometimes be traced right back to the saw mill.

The following are some of the causes which give rise to unsatisfactory conditions in saw mills. Frequently the saw or the saw maker is blamed when actually one or more of the following circumstances is the cause of the unsatisfactory operation:

Insufficient power to maintain regular speed.
Too thin a saw for the class of work required.
Not enough or too many teeth for the amount of feed carried.
Weak and imperfect collars.
Collars not large enough in diameter.
Ill-fitting mandrel and pin holes.
Uneven setting and filing.
Not enough set for proper clearance.
Too much pitch or hook of teeth.
Irregular and shallow gullets.
Out of round and consequently out of balance.
A sprung mandrel, or lost motion in mandrel boxes.
A carriage track neither level nor straight.
Carriage not properly aligned with saw.
Lost motion in carriage trucks.
Heating of journal next to saw.
Guide-pins too tight or not properly adjusted.
Backs of teeth too high for clearance.
Attempting to run too long without sharpening.

Setting the Carriage Track and Husk or Saw Frame: It is very essential to good work that the foundation of the mill should be amply strong to withstand the shocks it is subjected to in turning logs; the track stringers should be good sound heart lumber, preferably yellow pine, as this is a firm wood and will resist moisture. The size of the stringers should not be less than 8 inches by 8 inches and as few pieces as possible to make up the necessary length. The stringers should be set perfectly level and parallel with the mill house and gained into the girders and joists of the mill floor or foundation timbers, and secured by keys and bolts so that they will not change position when logs are rolled against the head blocks. The track irons, particularly the V side, should be firmly bolted to the stringer and when finished be perfectly straight and level.

[1] Adapted from Lumberman's Handbook: Henry Disston & Sons, Inc.

It is quite as important that the saw frame should be firmly secured to its place as that it should be level and solid, for the vibration and strain are of such a nature that the frame would quickly change position unless very firmly secured. The slightest change would make a vast difference in the running of the saw and necessitate relining. When putting in the husk stringers, use well seasoned wood and put them down in such a manner that they cannot possibly change their position, then find the position of the husk on the stringers and fasten down securely with through bolts.

Lining the Saw with the Carriage: The amount of lead required for circular saws should be the least amount that will keep the saw in the cut and prevent it heating at the center. If the lead into the cut is too much, the saw will heat on the rim; if the lead out of the cut is too much, the saw will heat at the center, it is therefore advisable to give the least amount that is used, which is one-eighth of an inch in twenty feet.

Of the various methods used for lining a saw with the carriage, the following is the one that we think will be the most easily understood: First, see that the mandrel is set perfectly level, so that the saw hangs plumb and true when screwed between the collars, and is flat on the log side. Draw a line running ten feet each way from center of mandrel and parallel with the V track, fasten a stick to the head-block, so that it comes up to the line at the end in front of saw; run carriage forward the twenty feet, move the rear end of line one-eighth of an inch away from former parallel position, then slew the end of mandrel either forward or backward until it is exactly at right angles to the new position of line, and the saw parallel with same.

All end play must be taken out of the mandrel and carriage trucks when lining a saw to the carriage, and the truck must be laid solid, level and true, so that the carriage will run straight and smooth.

Collars for Saws: For a perfect running saw it is indispensable to have the collars and stem of mandrel true and well fitting; any imperfection in these points is multiplied as many times as the saw is larger than the collars; they should fit exactly.

Large saws should have collars that have a perfect bearing of three-quarters of an inch on the outer rim, the other part clear, as they hold tighter than a solid flat collar. Examine the collars carefully to see if they are true, if not, have them made so; also be sure that stem of mandrel fits the hole nicely and offers no obstruction to the saw slipping easily up to and against the fast collar. The use of six-inch collars for portable and semi-portable mills is advocated. Collars for steam feed mills should be larger.

Test the saw with a straight edge, and if it is found true, place it on the mandrel, tighten up the collars with the wrench, test again with a straight edge and see if the position of the blade has been altered, observing whether it shows true; if not, the fault is sure to lie in the collars and will be likely to ruin the saw. The best results cannot be obtained from the mill until the defects are remedied.

The best circular saws are finished by a process which insures each side of the saw plate being perfectly true throughout its entire surface; by this invaluable process, every particle of unevenness is removed; the saw never requires packing (providing the collars are true) and all the trouble which has hitherto perplexed the sawyer in this particular is removed.

Adjusting Saw to Mill: See that the saw slips up freely to fast collar and hangs straight and plumb when tightened up; that the mandrel is level, in proper line with the carriage, and that it fits in its boxes as neatly as possible without heating, for when the mandrel heats, by transmission, the saw will heat also and thus expand in the center, which will make it work badly, injure, and perhaps ruin it. A saw cannot be expected to run on a mandrel that heats, although if it were known exactly to what degree it heats a saw could be made that would admit of that much expansion. However. a heating mandrel will always give more or less trouble. To get the best results from a saw this must be overcome.

Take up all end play or lateral motion in mandrel as the grain of the wood will draw or push the mandrel endwise, no matter how well the saw is kept. See that the carriage track is level, straight, solid and in proper line. also that rolls or trucks have no end play. Keep all gum or sawdust off the tracks.

Speed of Saws: This is a very important point of consideration, since a hundred revolutions, more or less, will always make a great difference in the running of the saw. The tension of saws can be adjusted to overcome a slight variation in speed provided full instructions are given when ordering the saw though we would advise a regular speed at all times. Our experience has been that saws work better when run at a regular speed even if it is necessary to reduce the number of revolutions one hundred below that given in the table, than to have a variable speed. If the power is too light to maintain the standard speed, run the engine at a higher regular speed, put a larger diameter receiving pulley on the mandrel, and the results will be better both as to quality and capacity. This will be much better than the throttle plan, even if the speed does fall below that given in the table; the regularity is the most desirable point to look after. Following is a table of speeds:

Speed of Saws Running 10,000 ft. per Minute on the Rim

72 in., 530 revolutions per min.	36 in., 1080 revolutions per min.
68 in., 560 revolutions per min.	32 in., 1225 revolutions per min.
64 in., 600 revolutions per min.	28 in., 1400 revolutions per min.
60 in., 640 revolutions per min.	24 in., 1630 revolutions per min.
56 in., 700 revolutions per min.	20 in., 1960 revolutions per min.
52 in., 750 revolutions per min.	16 in., 2450 revolutions per min.
48 in., 815 revolutions per min.	12 in., 3260 revolutions per min.
44 in., 890 revolutions per min.	10 in., 3920 revolutions per min.
40 in., 980 revolutions per min.	8 in., 4600 revolutions per min.

Portable mills, of limited capacity, are usually run at a speed about one-third less than given above.

Rules for Calculating Speed, etc.

PROBLEM 1. The diameter of driving and driven pulleys and the speed of driver being given, find the speed of driven pulley.

RULE. Multiply the diameter of driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions of driven pulley.

PROBLEM 2. The diameter and revolutions of the driven pulley being given, find the diameter of the driver.

RULE. Multiply the revolutions of driven by its diameter and divide the product by the revolutions of the driving shaft; the quotient will be the diameter of driver.

Splitters.

Sometimes when very large wood is being handled, which would not be capable of being put into the chipper spout, or into a pulp grinder, a device known as a splitter is employed to separate the large blocks into

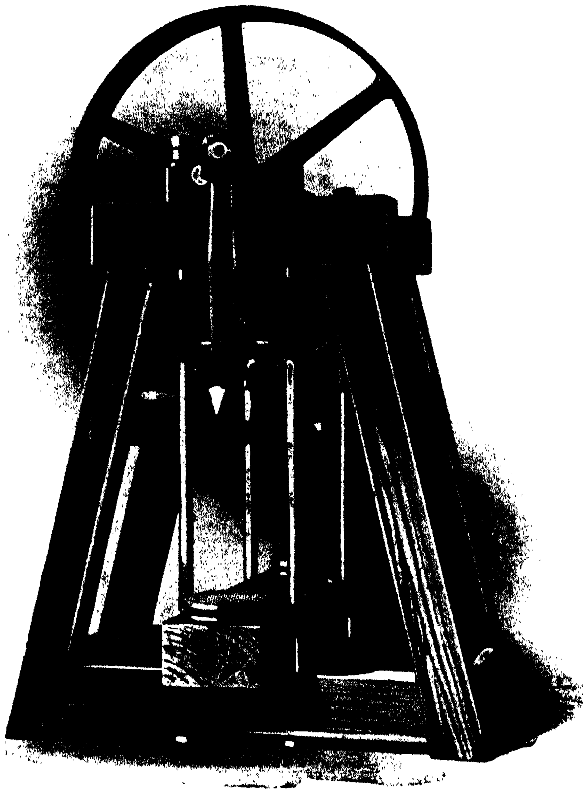


FIG. 14.—Vertical type of splitter.

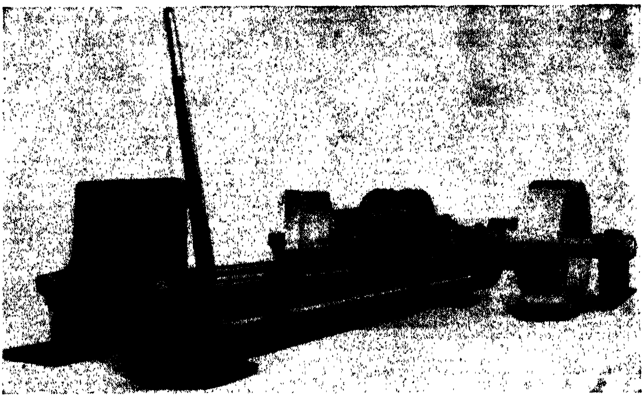
Courtesy: Ryther & Pringle Co., Carthage, N. Y.

two or more smaller ones. This machine is simply a mechanically operated axe of powerful construction, standing about 10 or 12 feet high. The nature of the machine will be readily understood from the illustration.

Another excellent type of splitter is of a horizontal design. This splitter is run by an electric motor, belted to a pulley. Motor drive is convenient and economical because it is in use only when wanted and does not require an extra attendant. The motor runs continuously during the splitting process, and if for any reason the operator wishes to stop the axe he merely shifts a hand lever which operates a clutch connecting the driving pulley with the axe mechanism.

Power tests have shown that 7½ hp. furnishes ample power for splitting 4-foot wood. When operating normally splitters will sometimes consume no more than 3½ to 4 horsepower. In cases of this kind, however, it is always well to be safe and furnish too large a motor with the splitter rather than one that is too small. A 10 hp. motor should be all right. The cost of the power is a very small matter compared with the increased output developed by a good splitter.

The base of the horizontal splitter is made of two channels securely bolted to heavy cast iron cross bars. Heavy cast iron double gear shaft-bearings are mounted on the channels and are made to receive both gear and pinion shafts.



Courtesy: Appleton Machine Co., Appleton, Wis.

FIG. 15.—Horizontal type of splitter.

A heavy cast iron splitting block is mounted on the channels securely bolted to them, thus forming part of the base. This block is slightly rounded and has a corrugated face to prevent the wood from slipping when the machine is in operation. It is obvious that should slipping occur in any way the operator would be in danger. The double shaft bearings and splitting block are connected by steel tie rods. The axe guides are mounted on the base very rigidly and consist of two steel slides so arranged and fitted that the axe has a bearing on the under side as well as on the steel sides. Experience has shown that it pays to use plenty of bearing surface for the axe in order that there will be no appreciable wear and to reduce power consumption to the minimum. This design also affords a simple and excellent means for thorough lubrication.

The axe is provided with a first-class steel cutting edge and is also carefully machined to fit the slides and bottom bearing as above explained. By increasing the size of the gears and the radius of the crank pin it is possible to give a splitter a stroke of almost any length. Generally, however, this type has a stroke of 15 inches for splitting 4-foot wood.

There are two crank gears on the machine. They each have thirty-six teeth, are made of cast iron, and are shrouded on both sides of the teeth. These gears are driven by two cast steel pinions each having twelve teeth. The pulley, therefore, makes three times as many revolutions a minute as is made by the crank gears. In other words, to find the number of strokes made by a given splitter of this type, multiply the r.p.m. of the driving pulley by the number of teeth in the pinions and divide by the number of teeth in the crank gears.

The connecting rod is usually made of cast steel and is of great strength.

For splitting 4-foot wood a 40-inch pulley is usually recommended as the proper size, this to run at a speed of about 110 r.p.m. If this pulley is 11 inches in width it is sufficiently large to transmit the power through a 10-inch belt.

NUMBERS OF 13-FT. LOGS OF VARIOUS DIAMETERS IN 1 CORD OF 128 CU. FT.[1]

34 logs	5"	diameter	10 logs	12"	diameter
27 logs	6"	diameter	9 logs	13"	diameter
22 logs	7"	diameter	7 logs	14"	diameter
18 logs	8"	diameter	6 logs	15"	diameter
17 logs	9"	diameter	5½ logs	16"	diameter
15 logs	10"	diameter	5 logs	17"	diameter
12 logs	11"	diameter			

[1] Courtesy of Ryther & Pringle Company.

Measurement of Pulpwood.

Pulpwood is usually measured by the *cord*. The cord is an orderly pile of wood blocks 8 ft. long × 4 ft. wide × 4 ft. high, the long dimensions of the blocks being parallel. The cord is inaccurate but is so established in general use it continues to be quoted.

Engineers often use the *cubic foot* as a measure of pulpwood meaning the solid wood content of a log calculated by mensuration. It is handy to note that an ideal cord contains just 100 cu. ft. In practice a cord usually runs from 80 to 90 cu. ft. due to crooked logs, carelessness in piling, etc.

Board foot measure is sometimes used, especially on the West Coast where paper mills are run in conjunction with lumbering, meaning a board 1 ft. square and 1 in. thick. Very approximately 500 bd. ft. is equivalent to a cord of pulpwood, and obviously 1 bd. ft. equals 1/12 cu. ft.

A new unit called the *"Cunit"* has been proposed and, while logical and convenient is not yet much used. It represents 100 cu. ft. solid unbarked pulpwood. It is necessarily always the same and avoids dispute and also happens to be equivalent to an *ideal* cord.

In mill calculations it is frequently convenient to use the *ton* (2000 lb.) in speaking of pulpwood as this is the unit used for pulp, paper, fuel, etc. Naturally, due to the high water content of pulpwood in using the ton one must define that either *air dry* (90% fiber and 10% water) or *bone dry* (100% fiber) is meant.

Loose piled pulp wood in blocks 24 inches long as dropped from a Cable Conveyor or loose piled in a car, occupies 163 cubic feet for every cord of 128 cubic feet close piled. For 48-inch blocks the equivalent is 183 cu. ft.

One cord of 128 cubic feet of close piled rossed wood contains approximately 96 cubic feet of actual wood.

A log 19 inches in diameter at butt and 13 feet long equals one market.

3 markets equal 1 Cord.

5 markets equal 1,000 feet B. M.

Average Adirondack Spruce runs 15 to 20 markets to the acre.

Hardy S. Ferguson, Consulting Engineer, New York, estimates the approximate amount of wood required to one ton of newsprint in the following manner.

Assumptions

1. 1.08 cords of rough wood will yield 1 ton Air Dry Ground Wood Pulp.
2. 2 cords of rough wood will yield 1 ton Air Dry Sulphite Pulp.
3. In the Paper Mill 2 per cent of the Sulphite is wasted.
4. In the Paper Mill 8 per cent of the Ground Wood is wasted.

(A) Paper containing 25 per cent Sulphite (neglecting fillers).

$$1 \text{ ton Paper requires } \frac{2 \times 25}{98} + \frac{1.08 \times 75}{92} = 1.39 \text{ cords.}$$

(B) Paper containing 22½ per cent Sulphite (neglecting fillers).

$$1 \text{ ton Paper requires } \frac{2 \times 22.5}{98} + \frac{1.08 \times 77.5}{92} = 1.37 \text{ cords.}$$

(C) Paper containing 20 per cent Sulphite (neglecting fillers).

$$1 \text{ ton Paper requires } \frac{2 \times 20}{98} + \frac{1.08 \times 80}{92} = 1.35 \text{ cords.}$$

Courtesy: Pulp Div., Weyerhaeuser Timber Co.

FIG. 16.—Typical Douglas pine log used for pulp making on Pacific Coast.

The following table taken from "The Woodman's Handbook," published by the U. S. Department of Agriculture, gives the volume of unpeeled pulpwood in cubic feet of trees of varying heights and diameters as determined by measurements obtained in southern New Hampshire.

Diameter breast-high	Height of Tree (Feet)						Basis
	40	50	60	70	80	90	
	Volume (Cubic Feet)						
Inches							Trees
5	1.9	2.5	3.0	....	....	....	29
6	3.5	4.2	5.2	6.4	....	....	98
7	5.0	6.2	7.5	9.0	....	....	128
8	6.6	8.4	10.0	11.7	....	....	165
9	8.5	10.8	12.7	14.8	....	....	161
10	....	13.5	15.6	18.0	....	....	113
11	....	16.5	18.8	21.5	....	....	78
12	....	19.5	22.3	25.4	....	....	63
13	....	....	26.0	29.5	34.5	....	42
14	....	....	30.0	34.0	39.5	....	55
15	....	....	34.5	38.5	44.0	....	56
16	....	....	39.0	43.5	49.0	....	49
17	....	....	43.5	49.0	55.0	63.5	38
18	....	....	48.0	54.5	61.0	70.0	44
19	....	....	53.0	60.5	67.5	77.0	30
20	....	....	58.0	67.0	74.5	83.5	21
21	....	....	....	74.0	82.0	90.5	18
22	....	....	....	81.5	89.0	98.0	16
23	....	....	....	88.5	96.5	106.0	10
24	....	....	....	95.5	104.5	114.0	5
25	....	....	....	102.0	112.0	123.0	2
26	....	....	....	109.0	120.0	131.5	2
27	....	....	....	....	128.0	140.0	2
28	....	....	....	....	135.5	148.5	1
							1,226

Stumps varying from ½ to 1½ feet and tops above 4-inch diameter point are excluded.
To reduce to cords divide by 100 or point off two places. Some use 95 cubic feet per cord.
Bark = 11 per cent of volume.

II. Pacific Coast Papermaking Region.[1]

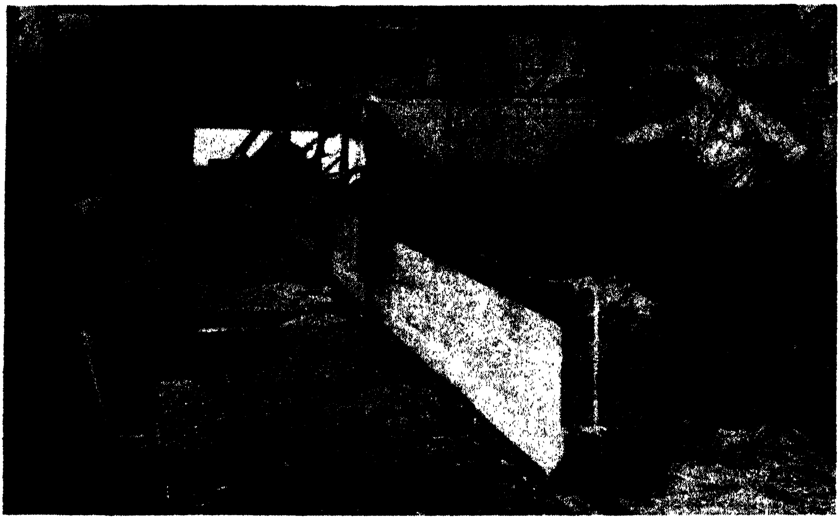
At Vail, Washington, trees are harvested to supply the Weyerhaeuser mills in Everett. Logs leave the woods by rail and are drawn to South Bay on Puget Sound. Dumped into the water, they are segregated according to species by boom men, who make up huge rafts of West Coast hemlock destined for the pulp mill. More than eight hundred logs, representing half a million board feet, log scale, go into a single raft. After a water-haul up Puget Sound, pulpwood arrives at the mill and is delivered to a log pond adjacent to the breakdown plant. In each raft is enough

[1] For this description of typical saw mill operations in one of the most important Pacific Coast paper mills the author is indebted to the Pulp Division of the Weyerhaeuser Timber Company, Longview, Washington.

wood to keep the saws busy for two to three days, so rafts arrive at the rate of about three a week.

Special emphasis is placed upon the cleaning of pulpwood preparatory to the making of chips that later are cooked in the digesters. It is the function of the breakdown plant to reduce the thick logs to cants, or planks, so that a thorough inspection of all the contained wood is made possible. Bringing all natural defects to light is essential before the cleaning processes of the chipping plant can be carried forward—before the careful removal of dirt sources can become effective.

Logs entering the breakdown plant are hoisted single file from the pond by means of a haul-up, an inclined chain conveyor fitted with sharp hooks that catch logs under water and put them within reach of the head-rig. This high-speed sawing mechanism, so arranged that a power-driven carriage forces a log at a time back and forth through a band saw, reduces the log to cants in a succession of lengthwise cuts. As a result of the practice of making these cants four inches thick, all natural defects are revealed. As the cants move along on a chain conveyor, additional saws cut them into pieces that measure no more than twelve feet in length and sixteen



Courtesy: Pulp Div., Weyerhaeuser Timber Co

FIG. 16a.—Douglas pine "cant" ready for barking.

inches in width. Continuing, the cants move on automatically to the chipping plant.

The sawyer, the man who runs the head-rig, takes off a thin strip with his first cut below the curved, bark-covered surface of the log. Known as slabs, these pieces have considerable bark and only one sawn surface. By-passing the main-line conveyor, they are directed to the slab-cleaning department. Once freed of bark and cleaned of knots, the slabs are reduced to chips by means of their own chipper.

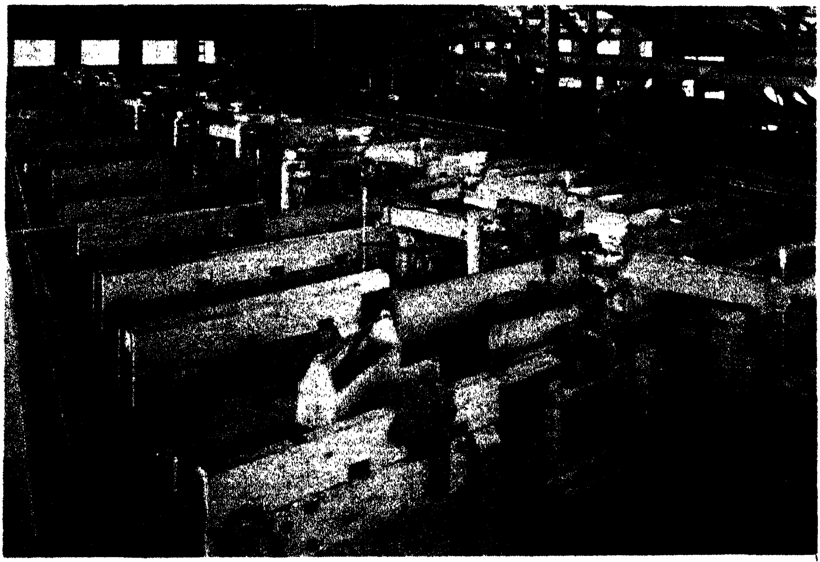
The large cants, comprising by far the bulk of the wood used for chip-making, arrive at the wood-cleaning plant to be distributed to four reserve or storage tables.

Courtesy: Pulp. Div., Weyerhaeuser Timber Co.

FIG. 17.—Barking machine removing bark at Pacific Coast mill.

Chief sources of wood dirt in pulp are surface bark, ingrown or enclosed bark, knots, and seams of defective wood. In layout and equipment, the wood-cleaning room at Everett is prepared to remove effectively those particles likely to detract from the quality of the product. Rather than send all wood through the cooking process and then rely on the supplementary pulp-cleaning procedure, it is the practice to prevent undesirable wood from entering the system. Such prevention entails inspection of every plank and is reflected in the number of men at work in the chipping plant. There, for one shift a day, more workers are engaged in wood-cleaning operations than are required to maintain production in all the other operating departments combined.

Drawing from each section of the cant storage table is a power barker, or "buzzer," a massive machine fitted with rotating curved knives that plane away all bark in a high-speed operation. These machines are adapted for thorough removal of bark from various-sized cants, since the knives within the cutter head are so arranged that rapid adjustment on the part of the operator sets them for any curvature within a generous range. Each power barker is controlled by a single operator, who has full visibility of the cants just ahead of the machine as well as those from which the bark has been cut. Push buttons and levers enable him to handle the heavy pieces conveniently and to reverse a cant for a second cut whenever he sees that his original adjustment did not entirely free it of bark. Under the eyes of the barkermen, the first step in the wood-cleaning operation takes place.



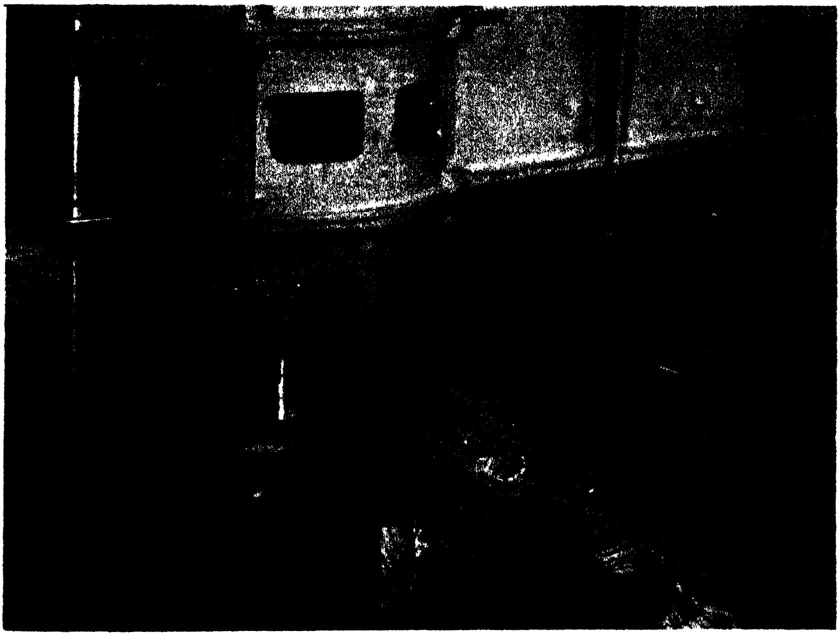
Courtesy: Sumner Iron Works, Everett, Wash.

FIG. 18.—Knot-boring machines at typical Pacific Coast mill.

Thoroughly barked cants move on automatically to a table from which they slide into position for the knot-borers. West Coast hemlock logs contain knots large enough to be removed effectively. The wood room is equipped with 24 knot-boring machines, 6 to each power barker, to insure the removal of all knots. Individually operated, every machine is fitted with a drill which, in addition to boring out the knots, can be used for removing seams of undesirable wood. Mechanical arms hold the cant rigid during operations of boring and routing.

Stripped of bark, then freed of objectionable defects by the knot-borers, cants move in a steady stream to either of two inspectors who examine every section of wood to make sure that elimination of undesired material has been thorough. Should any defect appear, the inspector directs the cant in which it occurs to men who give that piece another going-over.

The intensive wood-cleaning operations carried on at Everett make certain that only the acceptable portion of the wood enters into the production of pulp. Following the removal of natural defects visible in the thin cants, wood is prepared for the cooking process by being cut up into small chips of uniform length. This is accomplished by three chippers, each placed at the bottom of a long steel chute down which cleaned cants are dropped. Heavy knives, set into a steel disc, cross the butt of the cant with tremendous force and rapidity. Since the feeding chute is long, several cants go down at once, one after the other in single file. This holds the bottom piece firmly against the face of the revolving disc, keeps the cant from bouncing around during cutting, and results in chips of great uniformity.



Courtesy: Pulp Div., Weyerhaeuser Timber Co.

FIG. 19.—Close-up showing operation of knot-boring machines as illustrated in Fig. 18.

To eliminate over-sized pieces and remove sawdust, chips are run onto oscillating screens. Pieces larger than the uniform holes of the top screen slide off the bottom of the slope and go to a crusher, where they are broken down prior to making another trip over the screens. Accepted chips fall through the perforations, landing on a fine mesh screen that allows sawdust to drop to a refuse conveyor.

As might be expected, such careful selection of wood for chip-making results in the accumulation of quantities of rejected material. Throughout the mill, from saws, barkers, borers and so on, discarded wood substance is collected automatically and then used as fuel in "Dutch" ovens of the boiler house. Roughly, it satisfies half the fuel requirements of the pulp mill.

A belt conveyor, carrying accepted chips to the storage building, passes over a weightometer that records and totals the weight of prepared wood leaving the chipping plant. Operators know the rate of chip-making, as well as the exact amount of wood held in reserve within the storage building. Filled to capacity, this building holds enough chips to maintain regular production for more than 4 days. One advantage of a large reserve is that cooking is not dependent upon constant operation of the chipping plant. Also, this method of storing chips makes for uniformity in the moisture content of wood going into the digesters. Wood cleaning fits into the production schedule in such a way that by running the chip plant eight hours a day, the rest of the mill is kept going continuously.

III. Southern Papermaking Region.

The following two installations are typical of arrangements in the large new Southern mills :[1]

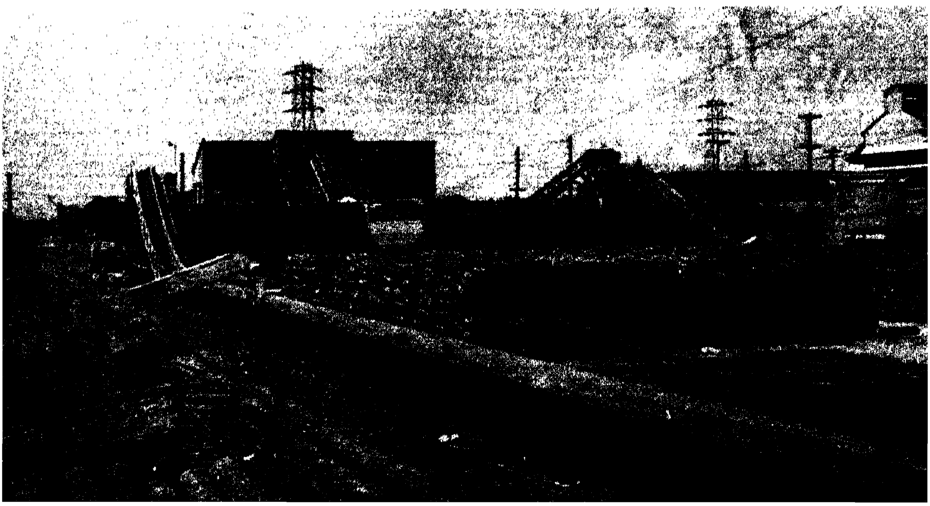
Champion Paper and Fiber Company, Pasadena, Texas.

This mill has been designed for a daily productive capacity of 175 to 200 tons of bleached sulphate pine pulp, which, when added to the combined capacity of the other two plants, gives a total daily productive capacity for the complete operations of 250 tons of coated paper, 600 tons of uncoated paper, 620 tons of pulp, 120 tons of board, 110 tons of 25-per cent liquid chestnut tannin extract, 40 tons of caustic soda, 35 tons of adhesive extract, 10 tons of sodium resinate, and 600 gallons of refined turpentine.

Wood for the mill is to be obtained from the pine forests of east and

[1] Described in articles by Harry E. Weston in "Paper Industry."

ood storage and handling facilities at a typical, large Southern mill showing conveyors, portabl



south Texas. It may be delivered by truck, rail or barge. A stumpage contract on nearly one million acres of land in southeast Texas assures a long time supply.

Two Jeffrey wood conveyors, each with a total length of about 450 feet, a little over 300 feet of which is horizontal, deliver the wood from the woodyard to the barking drums. The operating speed of these conveyors is 100 f.p.m. and the individual capacity 20 cords per hour.

Wood may be fed to either of these conveyors direct from railroad cars or delivered to them from storage over Jeffrey portable units. There are two portable units for each main conveyor and each set is a duplicate of the other. One of the two in a set is approximately 50 feet long, while the other is nearly 70 feet in length. The shorter unit handles wood from storage piles inside two parallel railroad spurs. Wood also is piled on the outside of both of these spurs and it is to reach this wood that the longer units are used—one over each track and each designed with a 15-foot boom at the discharge end to permit elevation when railroad cars are to be passed.

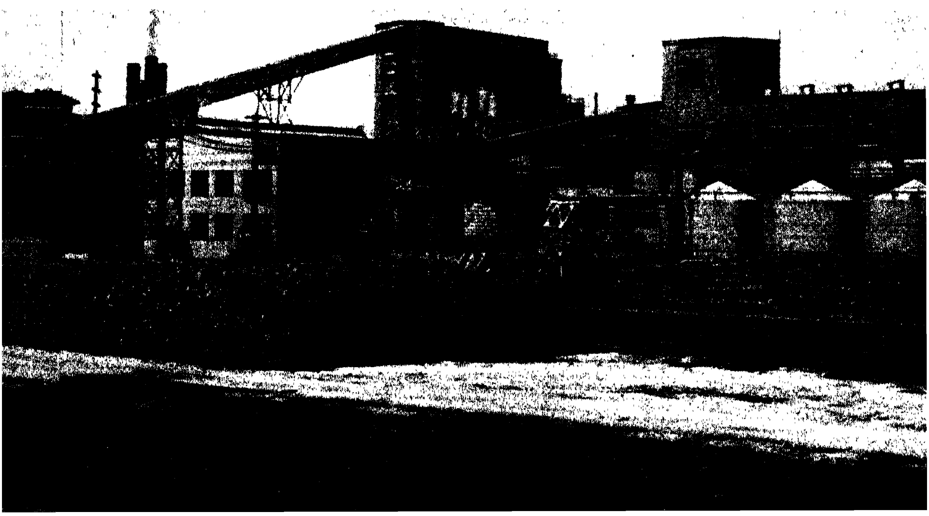
The barking drums, two of them, are D. J. Murray-Branch type units. Each drum has a diameter of 12 feet and a length of 50 feet, and is driven through a belt drive by a 150-H.P. motor.

Three additional Jeffrey conveyors handle the wood that is discharged from the barking drums. The first of them is an inspection conveyor from which the unsatisfactorily barked wood is removed. The second unit, a return wood conveyor, receives the wood and returns it to one of the barking drums for another passage through it. The third unit receives the selected wood and conveys it to one of two chippers.

Another system of Jeffrey conveyors delivers the bark from the barking drums to a Hofft bark furnace, which is attached to an 870-H.P. Vogt four-drum water-tube boiler. The system includes a double strand drag

conveyors, and barking drums. Also, note chip conveyor and digester house in backgroun

Courtesy: Jeffrey Mfg. Co., Columbus,



scraper conveyor to remove the bark from the drums, three intermediate 24-inch rubber belt conveyors that connect this unit with a storage bin and three single strand drag type units that convey the bark from the bin to the furnace.

Courtesy: Jeffrey Mfg. Co., Columbus, Ohio

Fig. 19A.—Barking drum and conveyors at Florida mill where wood is received from barges.

Union Bag and Paper Corporation, Savannah, Georgia.

The mill is the first of at least two units that are planned for this project. It alone is designed for a daily production of 135 tons or more of sulphate pulp, and 125 tons of kraft bag and wrapping paper, and for the conversion of this paper into as many as 12 million bags daily.

Close to the wood room is a graded and surfaced yard, approximately 1000 ft. by 300 ft., for wood storage. This yard permits wood to be delivered to it by highway, or rail. Its facilities permitting this delivery include two parallel side tracks and a woodyard road extending in from the main highway fronting the property.

A system of Stephens-Adamson conveyors permits the delivery of this wood to two 10 ft. by 30 ft. American barking drums.

This system of conveyors includes two portable yard conveyors, two main conveyors, one transfer conveyor, and an inclined conveyor. The portable yard conveyors are each 74 ft. 6 in. long and operate at right angles to the main conveyors. One of these traveling cross conveyors serves one main conveyor, while the other serves the second.

The main conveyors, as is the case of the portable conveyors, are horizontal in design. One of them is 409 ft. long. The other is 400 ft. long.

These conveyors receive their wood either from the portable conveyors, or from cars or trucks direct.

The transfer conveyor delivers the wood from one of the main conveyors to the inclined conveyor which in turn conveys the wood direct to the barking drums. This transfer conveyor is 100 ft. long.

Wood from the second main conveyor discharges directly to the inclined conveyor.

The inclined conveyor is 164 ft. long and has a 36 ft. rise.

Another conveyor, likewise with a 36 ft. rise, a combination horizontal and inclined unit, delivers wood from barges directly to the barking drums. This latter conveyor is 300 ft. long.

Each of these wood handling conveyors utilizes a U-shaped steel trough in the bottom of which is a channel section with the channel side up to take the wear of the loaded chain above it. The chain runs in the trough formed by the channel. Steel framework supports the trough and the framework in turn is supported by a foundation of concrete piling set level with the surface of the ground.

These conveyors have a capacity of approximately 30 cords per hour and are designed to operate at a speed of about 125 ft. per minute.

5. The Wood Room

The wood from the saw mill is either carried directly on conveyors to the wood room, or else stored in large piles until it can be used. The extent to which piles of wood are accumulated is governed by a number of factors. It is advisable to use wood as fresh as possible, both in the chemical and the mechanical processes of pulp manufacture but, on account of the distance of most mills from the source of wood supply, it is generally necessary to have some wood stored in piles.

Wood Piles.

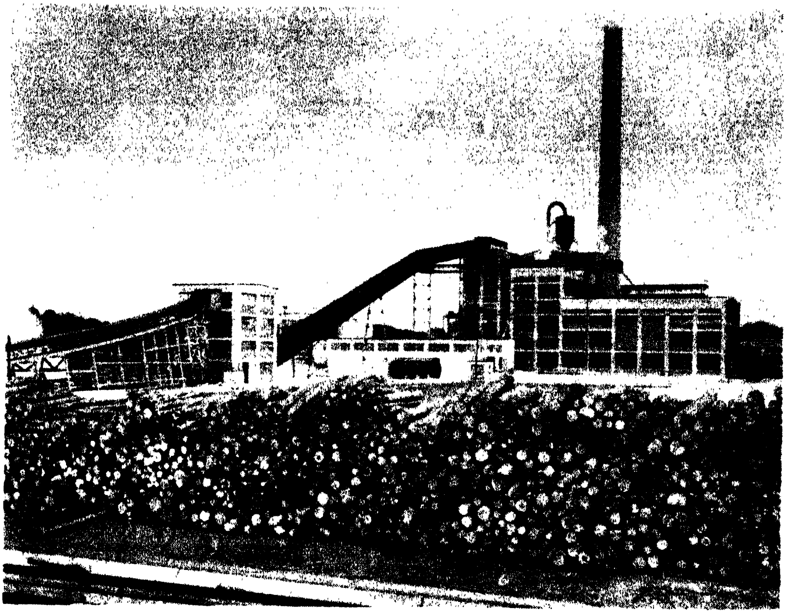
The number of cords the piles should contain and the distance from the mill buildings, or from each other, if insurance on the property is to be obtained at minimum rates, depends on the rulings of the insurance companies. Disregard of these stipulations will cost many thousands of dollars each year in the case of a large mill in addition to presenting a constant menace of fire. The value of the wood in these piles running into many thousands of dollars, it pays well to take every precaution against fire and to have fire hydrants located conveniently to all the piles of wood and in winter to make sure they are not frozen up. Conditions vary in every mill. It is best to get local advice from your insurance company.

The wood should be carefully piled. Piles which lean outward, are irregular in shape and faulty in general arrangement frequently are the cause of serious accidents to employees. In freezing weather dynamite is frequently used for loosening piles of wood. This work should only be trusted to a careful and experienced person, who should be held responsible for the receiving, storage, handling and firing of the explosive. If possible this work should be done at the beginning of the working day and precautions should be taken to see that all persons are out of the way of possible danger.

Fire Hazard: Greasy sawdust, fine chips, bark, etc., deposited by conveying machinery!

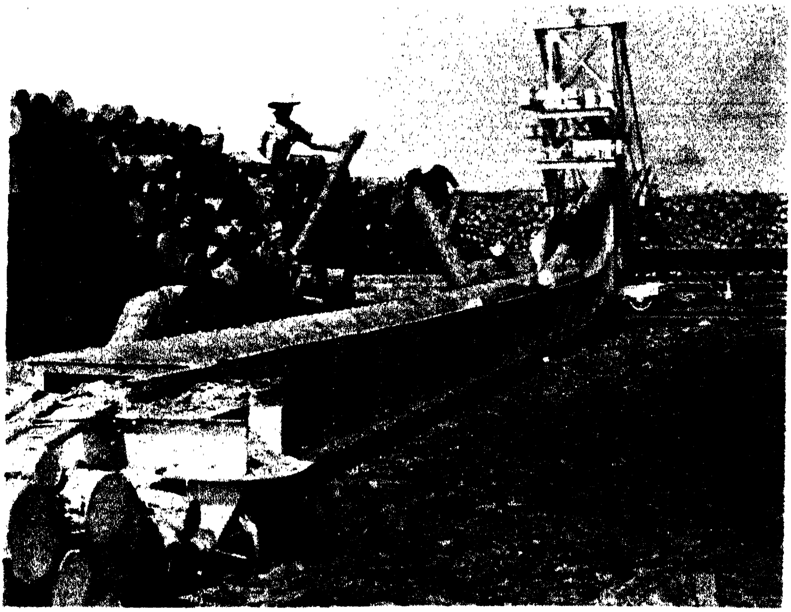
Wood Storage.

The usual manner of storing wood is to have a conveyor supported on a rigid structure either of wood or of structural steel. This is built as high as may be necessary, in the case of wooden construction the height being limited by the length of timber it is possible to procure for the legs of the structure. The higher the structure the greater the storage capacity in a given space. Of course, the structure should not be too high. This will be regulated by considerations of strength and of expense. The wood is conveyed by a wire rope cable to which are attached at intervals iron



Courtesy: Jeffrey Mfg. Co., Columbus, Ohio.

FIG. 20.—Log pile, log conveyor, wood room, chip conveyor and digester house at typical Southern mill.



Courtesy: Jeffrey Mfg. Co., Columbus, Ohio.

FIG. 21.—Close-up of receiving end of log conveyor.

discs or blocks. The cable travels in a wooden trough lined with iron strips. The iron discs are so spaced as to accommodate 2 foot or 4 foot blocks and to fit the teeth of the driving sprockets at the ends of the conveyor. The drive is usually furnished by an electric motor. This motor should be in an accessible position and it is wise to have a hydrant located at this point, as this is one of the most likely places for fires to start in the wood storage, the motor being the cause. If a hydrant is not possible a good fire extinguisher should be kept convenient to the motor. The motor should be kept clean and in good order and inspected regularly and every precaution should be taken against fires at this point. Make sure the hydrant is not frozen up in winter.

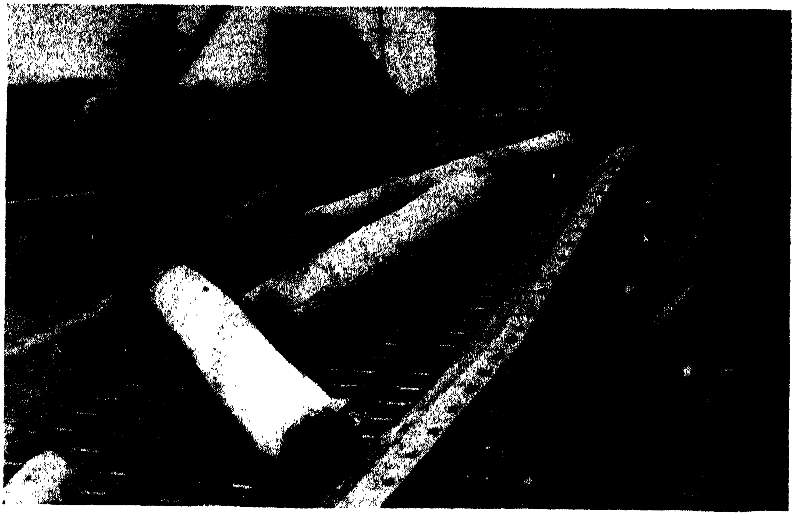
FIG. 22.—

Conveyor for barked logs showing barking drums in background.

Courtesy:
Jeffrey Mfg. Co., Columbus, Ohio.

The wood is delivered to the pile by the upper run of the conveyor and sent to the mill by the lower or return run. The lower run is placed in a trench or trough beneath the surface of the ground and this trench is roofed in with heavy planks when the wood is being stored. When the pile is being depleted and sent to the mill the covering is removed.

Another more modern system of storage is to have a structural steel stacker, the base of which rides on a truck running on rails. This stacker is built like a section of a cantilever bridge. An endless belt carries the wood up to the tip of the stacker where it falls off onto the pile. The wood is fed to the stacker from a short conveyor. This scheme has the advantages that several cars can be unloaded at once, no long conveyor is



Courtesy: Jeffrey Mfg. Co., Columbus, Ohio.

FIG. 23.—Inspecting barked logs as they travel from barking drum on conveyor.

necessary and the track on which the stacker moves can be taken up and moved along as the pile develops.

A third system is to have two or more tall towers of structural steel, concrete or wooden construction, with a conveyor running between them. A runway extends the length of the conveyor and wood can be dumped off it at any point.

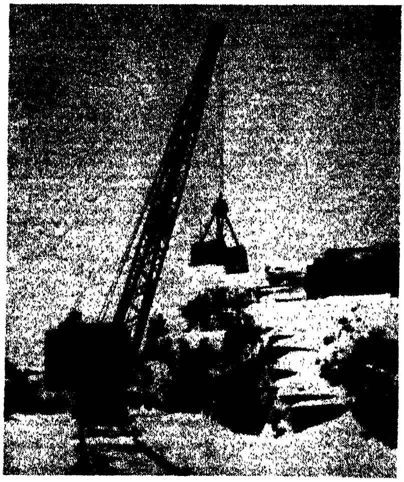


FIG. 24.—

Locomotive crane used for handling pulpwood at Wisconsin mill.

Courtesy: Industrial Brownhoist Corp., Bay City, Mich.

The usual type of conveyor will handle 250 cords in 10 hours and requires $1\frac{1}{2}$ hp. per 100 feet of conveyor, travelling at 100 feet per minute.

Since too dry wood is not desirable raw material because, while it enables production to be increased and lowers the sulphur bill (because stronger acid is needed with green wood), it decreases the strength of the paper, it is obvious that there must be a certain degree of flexibility in the arrangements for utilizing the wood. A large mill storing from 50,000 to 80,000 cords of wood, some of which is rough, some peeled, some fresh from the forest, will have to be so organized that when a bad pile is struck the wood from it can be gradually worked in with better grades; otherwise the quality of the paper would be immediately and noticeably affected.

Special portable conveyors for reclaiming the wood are available, obviating sending men on the dangerous task of going to the top of the pile.

Courtesy: Jeffrey Mfg. Co., Columbus, Ohio.

FIG. 25.—Portable pulpwood stacker showing barked wood stored, and unbarked wood waiting to be barked.

The Work of the Wood Room.

The wood room is a system of machines, conveyors, etc., for cleaning wood, for removing bark and, in those mills where the pulp is to be manufactured by a chemical process (sulphite, sulphate or soda process) for chipping and screening the wood into designated sizes for the digesters. In the case of mills making groundwood or mechanical pulp the blocks are delivered direct to the grinders from the wood room.

Removing the Bark: It is essential that every trace of bark should be removed from wood that is to be used for making pulp. The bark colors the pulp and fills the paper with dirt specks. Bark seems to hold its original state unaffected by the chemicals used in either the sulphite or the kraft processes of pulp manufacture. It is equally necessary to have the wood free from bark if it is to be used for groundwood.

In some mills the bark is removed in tumbling drums and in others by means of "barkers" or barking-machines. The latter are less efficient both from the standpoint of labor and waste. Tumbling drums will save sometimes fifty per cent of the labor and ten per cent of good wood which the barking-machine wastes. However, the first cost of the equipment is much higher.

The two-foot or four-foot blocks are delivered to the wood room by means of a chain or cable conveyor. This device possesses the following advantages for this purpose:

FIG. 26.—View of typical woodroom pond showing barker in left foreground.

It is cheaper than teams; the blocks of wood may be singly and easily inspected as they pass a given point along the conveyor; two or three different qualities of wood may be conveniently mixed in exact proportions, as is often desirable from necessity on account of having a variety of kinds on hand which it is always best to mix; finally, the blocks can be counted to determine the number of cords used in a given time. The number of two-foot blocks contained in a cord varies according to the diameter of the logs from which they are cut—ranging from seventy-five to one hundred and twenty-five blocks per cord. The average number is generally determined by piling several cords, counting the blocks and taking the average. This method, while not absolutely correct, is a convenient way of checking other measurements. All wood is "scaled" (measured) several times before it is finally reduced to pulp. One cord of green, peeled wood weighs (approximately) 3,000 lbs.

Arriving at the wood room,[1] the wood is usually dumped from the conveyor into a pond or tank of water. There is usually a centrifugal pump which takes water out of the lower end of the tank and delivers it to the head end, thus causing a continuous current which floats the logs towards the tumbling drums or barking-machines. There are several reasons why this floating process is preferable to mechanical conveyors. First, the maintenance of the floating process is very small compared with other methods; second, the wood in winter time is freed from ice, and the dirt attached to the ice, by heating the water with exhaust steam; third, all dirt adhering to the wood is pretty sure to be removed during its progress through the pond; fourth, it serves as a storage reservoir holding a surplus of wood so that there will always be the needed supply on hand for the chippers or grinders. This pond is usually from 3 ft. to 4 ft. deep, made of pine or concrete. A pond 80 ft. × 12 ft. × 4 ft. deep requires

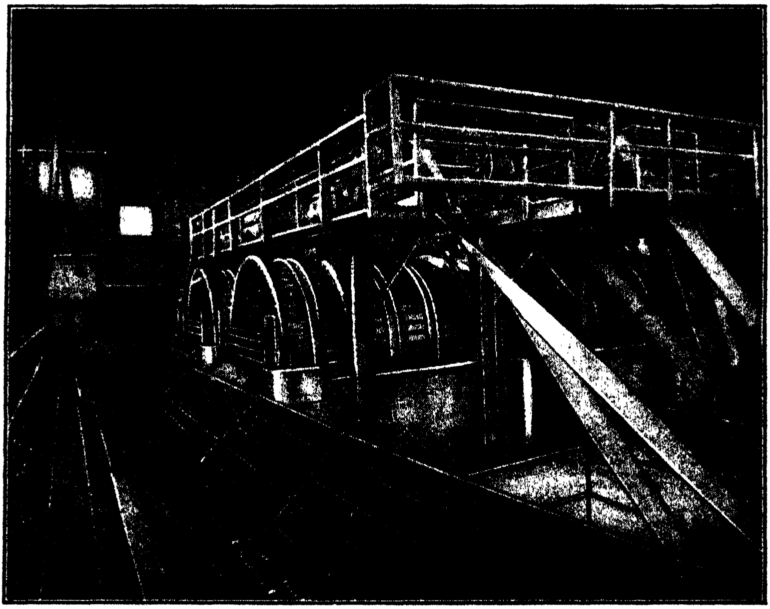


FIG. 27.—Barking drum installation showing conveyor in foreground for removing barked logs.

21,000 board feet of lumber. An 8 inch slow speed centrifugal pump, capacity 600 to 800 g. p. m. requiring 6 hp. and running at 450 r.p.m. will provide for the water circulation.

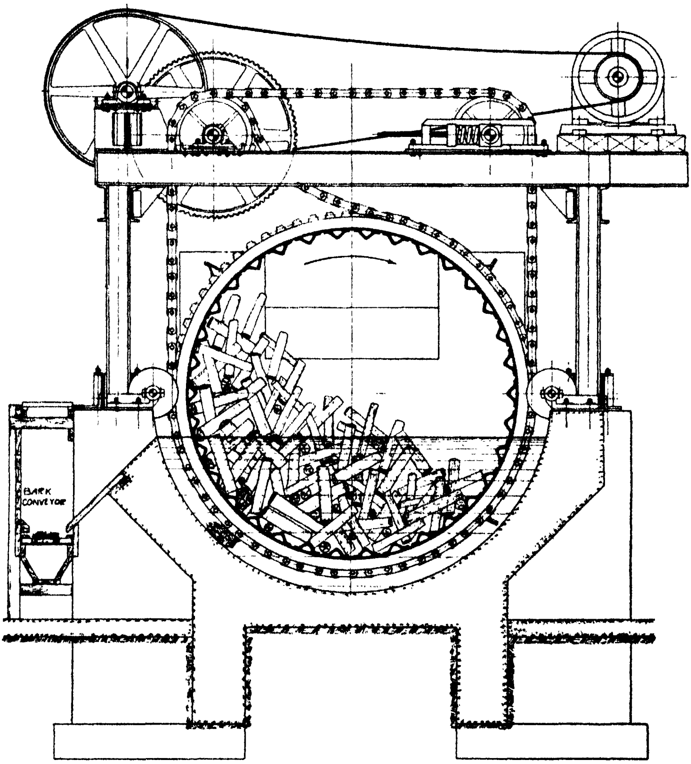
Where a pond is not thought necessary a powerful spray or a washing

[1] The following remarks relate to typical Northeastern or Canadian mills using unbarked pulpwood delivered by rail, truck or ship. Obviously there is no need for a wood room pond in a Pacific Coast mill where barked "cants" go direct to the chipper, nor in a Southern mill where the barking drums are out in the open near the storage piles.

drum is sometimes used to clean the wood. This gives an opportunity to inspect the wood and remove shreds of bark, knots and rot spots.

Barking Drums.

The use of tumbling drums for removing bark in the paper industry was first introduced into this country by Bache Wiig. His equipment took the form of closed cylinders of steel plate, into which were packed



Courtesy: Fibre Making Processes, Inc., Chicago, Ill.

FIG. 28.—Diagram showing operation of chain-suspended barking drum.

four-foot blocks parallel with each other and the sides of the cylinder. Water was injected through an opening at the center of the ends. When the machine had rotated long enough the logs were removed and another batch put in. The cylinder rested on trunnions. In some cases there was a large girth gear by means of which the cylinder was rotated.

These drums have since given way to drums made of steel channel or tubular sections (nowadays usually welded) and open at each end and operating continuously, the logs being fed into one end of the slightly inclined drums and after having all the bark rubbed off by jostling against one another and the drum, gradually working out of the other end. Some barking drums run on rollers and others are slung in heavy chains. Drive may be either by a girth gear, or by a heavy chain and sprocket. The drums dip in a pond of water which is scooped up by the channel irons. Water pours over the logs constantly while in the drums and washes away the bark, which accumulates in a waste pile and is generally burned. From the lower end of the tumbling drums the blocks fall onto a conveyor which takes them to the chippers, in the case of sulphite mills, etc., or to the grinders in the case of groundwood mills. A man is stationed at a convenient point who transfers to a conveyor, leading back to the pond in the wood room and back through the drum for rebarking, all logs from which the bark has not been completely removed. The usual size for these drums is 8 to 12 ft. diameter by 30 to 45 feet long and the capacity is 4 to 25 cords per hour of 4-foot wood depending on the wetness of the wood mainly. A drum 8 ft. by 30 ft. requires about 50 hp. to drive and one 12 ft. by 45 ft. requires 150 hp.

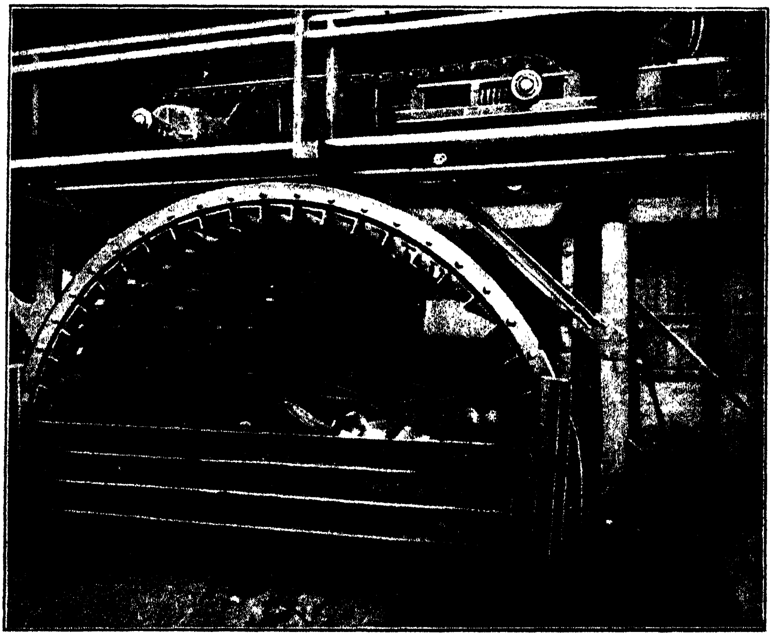
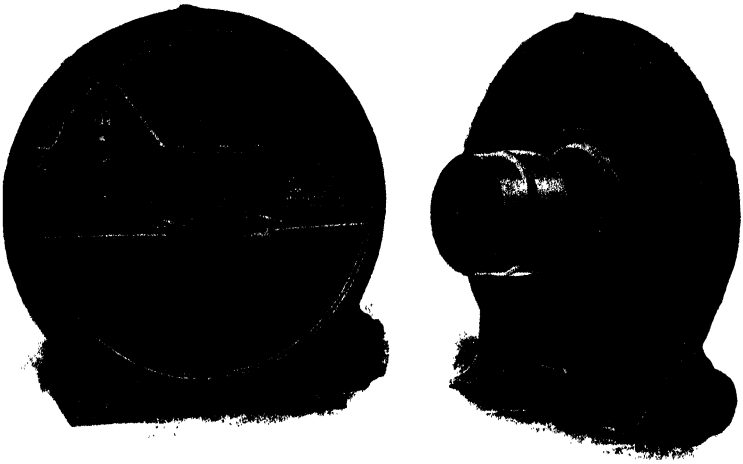


FIG. 29.—End view of barking drum showing drive and supporting chain.

Barking Machines.

Although barking-machines are more wasteful of wood than barking drums, and although it requires more labor to operate them, they are still frequently found in American mills. The first drum installations in this country were not conspicuously successful and the fact that improved equipment has removed the causes of the early failures has not yet become quite as universally appreciated as might be desired.

A barking-machine works on the same principle as a carpenter's plane. Four knives, analogous to the blades of the plane, are set in a round, flat-faced disc. The knives are set in the disc an equal distance apart. If a block of wood is held against these revolving plane-knives the wood or bark will be shaved from the block. Turning the block will thus cause the bark to be removed from the entire circumference.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 30.—Two views of a typical disc barker.

Barking machines differ very little in general construction and style. A barker, to produce good results, should have a disc at least 42 inches in diameter (60 inches is better) and should contain 4 knives. The discs must be in perfect balance so that in revolving they may run true, as any extra weight on either side imparts an eccentric motion to the revolving disc. They are properly balanced before leaving the shop and every reasonable effort should be made to keep them so. This is a very important matter, as the discs run at a high rate of speed—from 750 to 950 revolutions per minute, and when out of balance, cause the machine to jump and pound, quickly destroying the bearings, and affecting the proper running of the machine. It may be said that some discs are run so thoroughly out of balance as to be really dangerous to life and property.

The discs should be equipped with proper clearing irons, or clips, which serve to keep bark and refuse from binding and lodging between the disc and shell or hood of the barker, causing undue friction and waste of power.

In a supply of knives for these machines, there may be some which have been worn considerably narrower than others; in many cases these knives of various widths are put into the same barker, no attention being given as to whether or not the wide knives are all on the same side of the disc. The result is that the disc is thrown out of balance to a dangerous extent. If it is necessary to use various widths of knives, they should be carefully gauged or weighed, and heavy and light knives placed opposite heavy and light ones respectively, so that the disc will retain its proper balance.

The barker must be equipped with tight and loose pulleys so it may be stopped at will for the purpose of re-setting the knives. If driven by belt a 6 hp. motor is satisfactory. Direct drive requires a larger motor and is a menace to both machine and operator.

Barker knives should be of the best quality of steel, tempered to stand hard usage, as wood is very gritty, containing many hard and dry knots. They should never be allowed to run after they become dulled, but should be kept in proper condition, even if it becomes necessary to change them three or four times a day. They should be ground with an automatic emery grinder with water running on them to prevent drawing the temper. Care should be taken to grind them in sets, all the knives in a set being of the same width and thickness; they should be set in the grinder carriage so that the back or blunt edges are lined up against a straight edge, so that in grinding, they shall be kept of the same width.

It very often happens that barker-men put in a set of knives of various widths and line up the cutting edges with the emery wheel; the first time the carriage runs across, if the emery wheel does not touch all the knives, they are promptly rapped into line with no regard as to variations in width. The result of a continual operation of this kind is that there are no two knives of the same width and weight in the entire supply.

After removal from the grinder, the knives should not be placed in the barker disc until finished with an oil-stone to remove the burr or wire edge left by the emery wheel.

Knives should always be set by a gauge—never left to the judgment of the barker-man, as it is known to be more laborious to properly bark wood when the knives protrude but slightly; while knives set rank (or protruding noticeably), will usually remove the bark and considerable good wood. However, they should be set out not farther than $\frac{1}{8}$ of an inch beyond the surface of the disc, to avoid wasting wood.

The shell, or casing, of the barker is designed to carry off the bark and shavings. The high speed of the disc inside the case produces a blast similar to that resulting from the use of an air-blast fan, sufficient to blow the shavings to a considerable distance. Sometimes small wings are bolted to the disc to increase the velocity of the shavings. These shavings are blown into cone-shaped receptacles, called cyclones, which are supposed to give vent to the air-pressure made by the revolving disc, and retard the velocity to a speed suitable for the conveyors. They then pass, by means of the conveyors, to the boiler house for fuel.

The barker should always be equipped with a suitable table, adjustable to large and small wood. The end of this table should always be equipped with a stop to prevent the wood from sliding endwise as the knives strike it; or, in other words, to counteract the force.

Most barkers are equipped with an automatic attachment for turning the wood. Some manufacturers prefer not to use this attachment, as it is claimed to be rather wasteful. There is no doubt that by its use more wood can be barked per day than when this work is done by hand; it is a question of figuring the loss of wood against the low production.

A good workman can bark approximately ten cords of wood per day without this attachment, provided such wood is of reasonable size and good quality—that is, does not contain too many gum seams and knots, the best sizes ranging from 8 inches to 12 inches. The wood should be thoroughly cleaned of all bark, gum and knots, to prevent the entry of dirt into the pulp or groundwood.

Extreme care must be taken to protect employees against accidents on these machines. The floor must be kept free from bark and never allowed to become wet and slippery. Suitable guards should be provided and there should be ample room around the barkers. All attachments must be kept in proper repair.

The barkers must be kept carefully oiled. Loose pulleys must be oiled. Special care must be taken never to allow the belt to run on the loose pulley any longer than is absolutely necessary. If, for any reason, the supply of wood to the barkers is stopped for any length of time, it is better to shut off the power than to shift the belts to the loose pulleys.

Pacific Coast Barkers.

Mills on the Pacific Coast usually send to the chippers "cants" which are lateral sections of a tree 3 ft. or more in diameter. These "cants" are 18 ft. or more long. A machine known as a "buzzer" is used to remove the bark from these cants. The operation of these is described in Chap. 4, p. 94.

Chippers.

Two-foot or four-foot blocks free from bark are brought, by a mechanical conveyor, or by means of another pond, from the tumbling drums or barking machines to the chippers. These are powerful machines which slice the blocks crosswise of the grain into sections seven-eighths of an inch thick, at the rate of eight hundred slices per minute.

Before explaining the construction and operation of this machine, it might be well to explain why the blocks are not sawed into sections of the right thickness. This method has been tried, but has been found too wasteful and too slow. It is wasteful because any saw suitable for this work will make a "scarf" (wood turned into sawdust) at least a quarter of an inch wide. In sawing sixty thousand cords of wood—a fair year's supply—into sections seven-eighths of an inch thick there would be a loss of about 14,000 cords of wood, worth about $280,000. Moreover, the sawdust would be objectionable in the digesters, as will be explained later. Wood for soda pulp is chipped a little shorter than for sulphite or kraft.

The modern "Four-Knife Chipper" consists of a flat-faced disc of solid cast iron on the rim of which a steel ring is shrunk for safety. The disc is usually about 84 in. in diameter, 4 in. thick and weighs about 3 tons; but the huge chippers used on the Pacific Coast often have discs 110 in. in diameter. It is run at a speed of from 300 to 600 r.p.m. This disc is firmly keyed to a shaft which passes through its center. On either end of this shaft are journals supported in journal-bearings. Keyed to this same shaft is a driving-pulley of suitable dimensions, by which the disc is driven in a vertical position—similar to a car wheel.

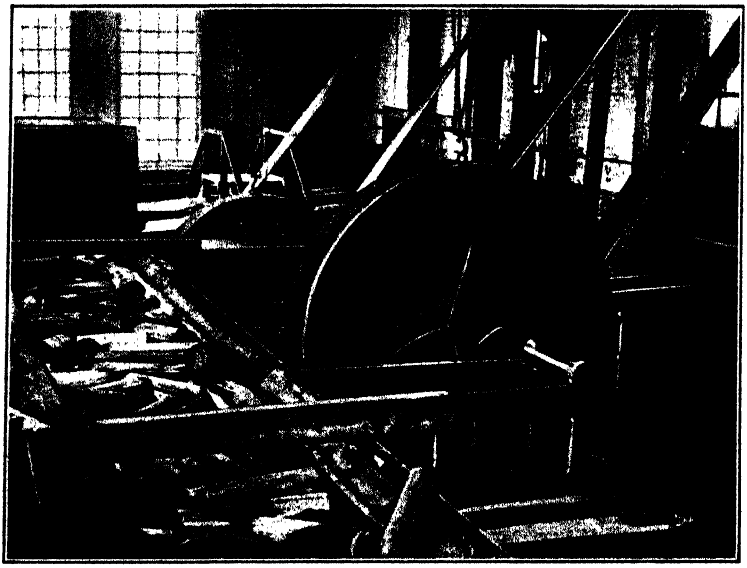
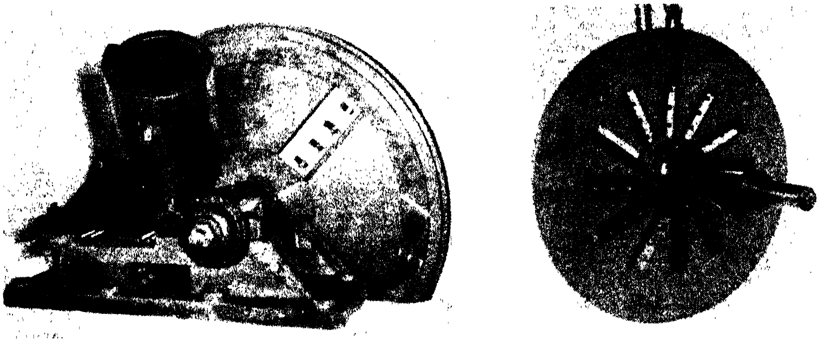


Fig. 31.—Chipper installation at northern New York mill showing end of pond and platform for feeding chipper.

The disc-shaft and pulley, thus assembled, are all mounted in a very substantial cast-iron frame, designed to stand the violent hammering and strain. This disc, like the barking-machine, has three or four knives placed in a circle. The knives are much stronger than the knives on the barking-machine and are ground at an angle varying with the make of the knife and regulated by the quality (whether wet or dry, etc.) of the wood to be chipped. By multiplying the revolutions per minute by the number of blades (4) we arrive at the number of cuts per minute, and knowing that the chips are always $\frac{5}{8}$ inch thick, and knowing the number of sticks to a cord we can calculate the theoretical capacity of a chipper. Allowance should be made, of course, for the efficiency of the feeding system.

Chippers are built in the extremely strong fashion explained above on account of the *terrific* violence of the strains to which they are subjected. The centrifugal force on the rim of such a disc, running at the required number of revolutions per minute, together with the force with which the knives strike a 12-inch block of sound spruce wood hard enough to cut a clean slice seven-eighths of an inch thick, across the full diameter, demands the sturdiest construction of every portion of the machine.



Courtesy: Carthage Machine Co., Carthage, N. Y.

FIG. 32.—Typical chipper with hood removed showing knife. At right, disc of twelve-knife chipper in use at Pacific Coast mill.

The spout of the chipper is of cast iron, generally square, but sometimes round, and inclined at an angle of forty-five degrees to the disc. The reason for this angle is to feed the blocks against the disc so that the knives will strike in an oblique manner. This may be likened to whittling with a knife, which is held at an angle of about forty-five degrees instead of holding it straight. Moreover, if the chip is cut at right angles the area at the end, and consequently the number of pores exposed, is less. It has been found that the acid penetration in the digesters takes place through the ends of the chip; consequently it is desirable to have the end area as large as possible.

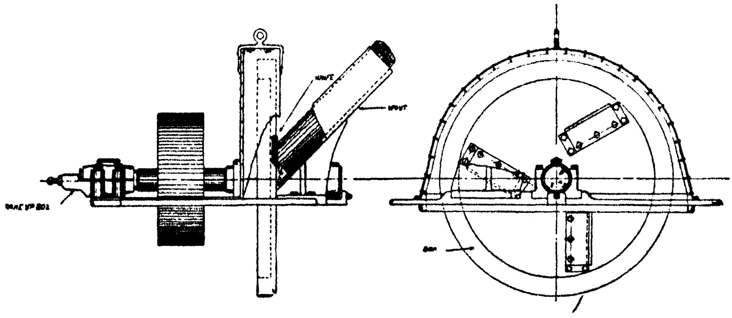


FIG. 33.—Diagram showing construction and operation of standard chipper.

At the base of the spout is a hardened steel bed plate, intended to prevent undue wear in the spout, and to make the chipper cut clean chips. This bed plate must be renewed frequently. In modern chippers the bed plate is usually made of alloy steel or stellite. If worn and rounded bed plates are used they have a tendency to allow the wood in direct contact to turn over, yielding a ragged chip. A good hardened steel bed plate ought to last during the chipping of a large number of cords of spruce under normal conditions.

It is very important that the knives should be kept sharp and in perfect condition. The chips must be *sliced* off clean, without bruising. Dull knives will *pinch* off the chips, bruising them, closing the pores and thus rendering them impermeable to the acid when they reach the digesters.

It is, of course, imperative that the disc should be run in perfect balance. With the great weight and high speed of the disc it will rapidly injure the journal bearings, which, apart from the damage to the machine, is very dangerous.

Given proper attention and sufficient driving-power the chipper will handle from 5 to 30 cords of wood per hour. About 150 hp. is usually required to drive a standard 84 in. round spout chipper. Pacific Coast square spout 110 in. chippers require 300 hp.[1]

The chippers have an endwise adjustment controlled by a screw so the disc can always be kept snug up against the bed plate. The chippers discharge through a hopper into the crusher, placed immediately below.

Crusher.

The crusher is a machine for disintegrating the chips into specified weights and thicknesses directly after passing through the chipper. One

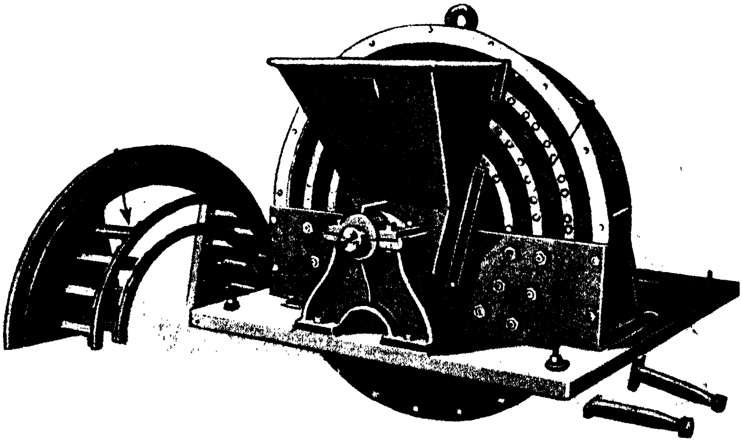


FIG. 34.—Cage type of chip crusher.

type of crusher consists of a rotor to which are attached swinging pins, held reasonably positive by the action of centrifugal force. These pins are held on pivots of lignum vitæ or oak, thereby preventing undue binding and protecting the fingers, which throw back in case a spike or bolt accidentally passes through the crusher, thus saving the machine from being wrecked. The pins should be maintained complete and in good con-

[1] For illustration of chipper drive see Chap. 17, page 578.

dition. Operating the crusher with missing pins permits coarse chips and knots to be delivered to the belt, and while the screens will reject these to the refiner, the efficiency of the whole installation will be lowered on account of the excessive amount of waste of poorly prepared chips, etc., rejected by the screens. The usual speed of the crusher is about 1500 r.p.m. At that speed it will handle about 250 cords of chips a day and requires a 30 hp. motor. Another type of crusher is designed on the cage principle. The chips are fed to the center by a worm and forced to the periphery by centrifugal force, passing between rotating and stationary rods as they do so. This type of crusher run at about 750 r.p.m., requires a 30 hp. motor and will handle the oversize from 250 cords chips a day.

Screens.

The chips must be screened very carefully, not only to eliminate large chips that have failed to be disintegrated in the crusher, knots, etc., but also to separate too finely divided particles, sawdust, etc. Chips usually contain about 3.5 per cent sawdust and about 2.5 per cent slivers, shieves, etc.

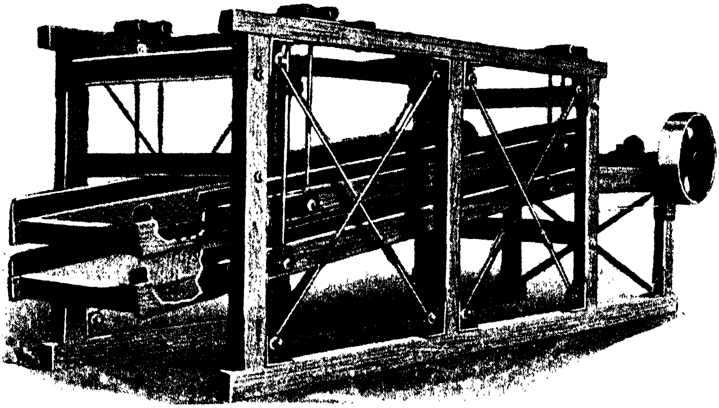
Many theories have been advanced as to the undesirability of sawdust in the chips. One of these is that sawdust will not cook in the digesters. This has been disproved by suspending a copper basket filled with sawdust in the digester. It will cook. However, it is very apt to be overcooked. In other words, if a $\frac{7}{8}$-inch chip predominates, it takes a specified time for the acid to penetrate and if the digester contains 95 per cent of these $\frac{7}{8}$-inch chips, this 95 per cent of the digester will be properly cooked, and the other 5 per cent consisting of sawdust will be overcooked. Moreover, any attempt to cook the sawdust would result in poor circulation. There are some conditions when the digester is first started off, where the sawdust would plug the strainer. As a result of poor circulation a large part of the sawdust might remain undercooked and appear in the sheet as dirt.

The chips from the crushers are elevated to the screens by means of a scraper or drag conveyor which passes beneath the crusher and receives the chips from the crusher through a hopper.

Several types of screens are in use. The Lombard, or rotary type, resembles a tumbling drum. The first section consists of a fine sawdust section, fitted with $\frac{1}{8}$-in. or $\frac{1}{4}$-in. perforated metal, removing all sawdust and particles smaller than the standard chips. The second section consists of a coarse mesh screen with perforations approximately 1 in. in diameter, permitting the standard chips to fall through and ultimately go to the digester, and rejecting the balance. Such a screen 36 ft. by 6 ft. handles 24 cords per hour and requires a 12 hp. motor to revolve it through a speed reducer at 18 r.p.m. The chief objection to this type of screen is that long slim chips which should go to the re-chipper stand on end and go through.

Shaker Screens.

The Shaker Type Screen is preferable and works more efficiently. The shaking motion has a tendency to hold the long slivers parallel to the

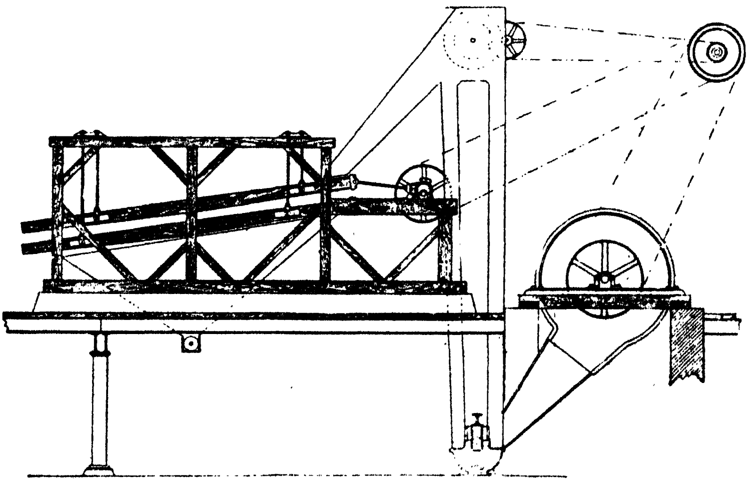


Courtesy: Ryther & Pringle Co., Carthage, N. Y.

FIG. 35.—Standard type of shaker chip screen.

screen and sift them off. In the rotary type these slivers sometimes are stood on end and fall through the openings, thus finding their way to the digester.

The Shaker Screen consists of two large, flat trays, one directly above the other. The top tray is covered with perforated metal or wire with openings (about 1 in. by 1¾ in. in size), which let out the chips, but retain the large knots and slivers. The motion of the screen moves these rejected particles to the discharge end, where they fall into a tank of water. The slivers and large pieces of sound wood float and are skimmed from the



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

FIG. 36.—Typical screening installation showing chipper, elevator, and chip screen.

top of the water by a conveyor chain, passing into the re-chipper. The chips from the re-chipper then pass back to the screens. The knots, being heavier than water, sink in the tank and are removed from the bottom at intervals. Knots are useless as material for pulp.

The bottom tray of the screen is covered with perforated metal having openings only large enough for sawdust and fine particles of dirt to fall through. This waste is automatically conveyed to the boiler house for fuel.

The standard sized chips, freed from those particles that are either too large or too small, fall from the screen to a belt conveyor by which they are carried to the chip bins.

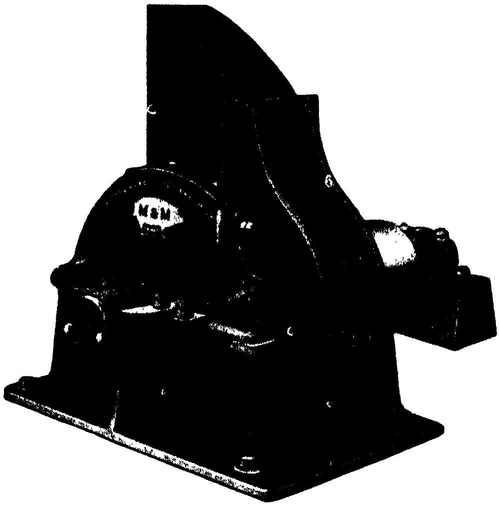


FIG. 37.—Re-chipper.

Courtesy: Mitts & Merrill, Saginaw, Mich.

Re-Chipper.

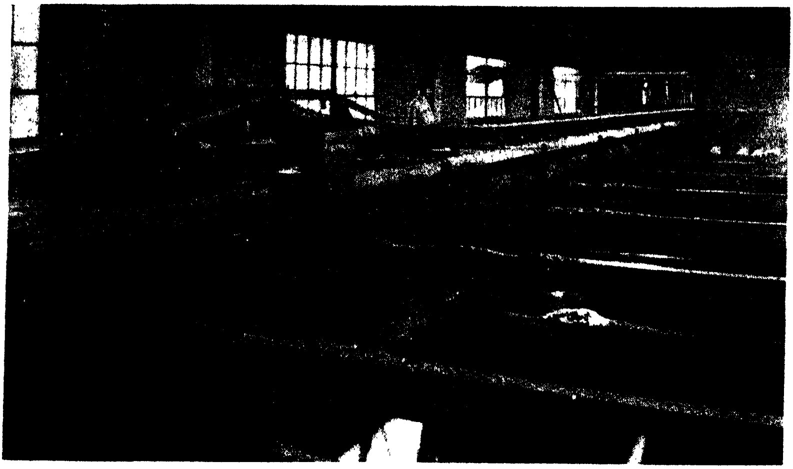
This machine consists of a disc or cylinder with sharp knives on its periphery. It is not at all like the chipper, being a sort of cutter similar to those used for scrap leather, etc. It requires about 2 hp. per cord per hour. Its usual speed is from 500 to 600 r.p.m.

Chip Bins.

The chip bins are large steel plate or concrete storage bins, the bottoms of which are wedge shaped to permit the chips to flow freely from the openings at the base.

The chip bins are located just above the digesters. The opening at the base is closed by a sliding gate operated by a hand-wheel. A portable hopper, suspended to rails, can be placed to coincide with the openings in the chip bins and the digester-head, serving as a "funnel" for chips when filling the digester.

The chip bin capacity should be so planned that it will not only serve to accumulate the desired charge of the digesters, but will also act as a reservoir to take care of the fluctuation in chip requirements and in the chip production of the wood room. It is customary to regulate the chip bin capacity so as to be able to charge each digester every eight to ten hours on running schedule in wood room of ten hours; also to enable the digester to be charged Sunday nights and the cooking process started without running the wood room overtime. Conditions vary, but as a general rule, a cord of wood when put into chip form will occupy from 175 to 210 cu. ft.



Courtesy: Jeffrey Mfg. Co., Columbus, Ohio.

FIG. 38.—Chip bin showing conveyor passing over weight recording device.

Chip Conveyors.

The chip conveyor from the chip screen in the wood room to the chip loft is quite a large piece of conveying equipment, owing to the fact that the chip bins are located at the extreme top of the digester building, which is itself necessarily a tall structure, and the wood room frequently has to be some distance away. In many cases, this conveyor passes over several other buildings on a trestle. The conveyor is usually of either the dished belt type or the drag type with maple flights. The width of the belt conveyor is usually about 30 inches; and of the drag conveyor usually 18 inches and spacing 24 inches. The hp. required to drive this conveyor depends on the layout and the length and pitch of the conveyor. A drag conveyor 100 feet, center to center, with 25 to 30° pitch, requires 18 hp. for a speed of approximately 125 feet per minute. The above specifications give a carrying capacity of 12 to 15 cords of chips per hour. Sometimes the flight conveyor does not reach to the chip bins, discharging into a hopper at one of the lower floors of the digester building, from which point the chips are elevated by a bootleg (bucket) elevator. Belt conveyors for chips usually operate at an angle of 20° or less from hori-

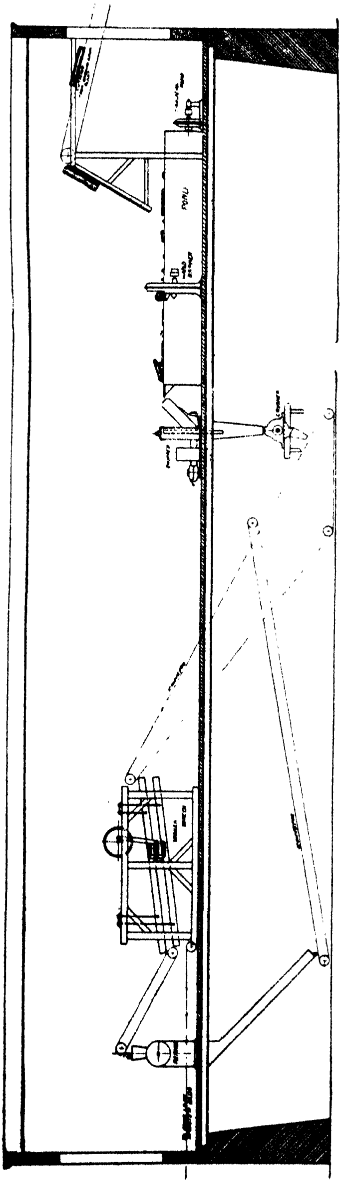
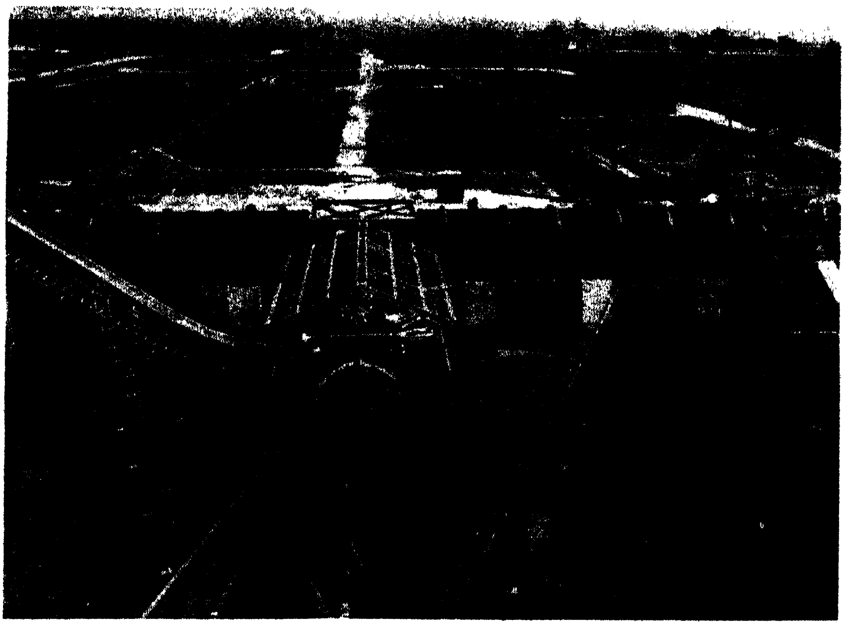


FIG. 39.—Diagram showing typical chipping and screening plant designed so as to simplify the conveyor installation as much as possible. In order from right to left are shown the conveyor from the barking drums, the pond, the chipper, crusher, shaker screen and re-chipper together with the necessary conveyors and a hand barker for removing bark from any logs failing to receive proper treatment in the barking drum.

Courtesy: Jeffrey Mfg. Co., Columbus, Ohio.

FIG. 40.—Typical chip conveyor.



Courtesy: Jeffrey Mfg. Co., Columbus, Ohio.

FIG. 41.—Outdoor barking installation in typical kraft mill in the South.

zontal. A weightometer or continuous recording scale is frequently installed in connection with the belt conveyor leading to the bins.

Inspection of Chips.

Chip tests are made on this material going to the bins by passing the chips through standard mesh sieves, the "Ro-Tap" machine being excellent for this purpose. Two analyses are given below to show how these results may be interpreted. (See also chapter on testing.)

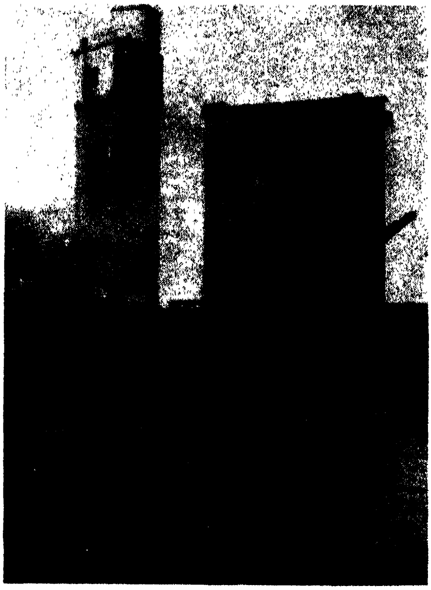


Fig. 42.—Log pile and crane at western mill showing digester house and acid towers in background.

Fraction	Size	Percent	
(1)	Over ¾" Square	18.38	21.63
(2)	½" to ¾" Square	74.77	54.50
(3)	¼" to ½" Square	5.08	12.33
(4)	Thru ¼" Square	1.77	11.53
		100.00	99.99

Fraction 1 is very coarse, 2 is good material, 3 is irregular and 4 is sawdust. Test No. 1, although showing an abnormal amount of coarse stuff, is nevertheless a very good test while No. 2 is very poor for fractions one and four are large and two is small. The season of the year affects the size of chips, as frozen wood is much more friable than dry material.

6. Sulphite Mill

In this chapter we will consider the processes and equipment required for the manufacture of chemical pulp by the sulphite process. The acid plant, which is the part of the pulp mill devoted to preparing the acid liquor used in the sulphite digesters, will not be considered in this chapter, but will be dealt with in a separate chapter immediately following this one.

Sulphite Process.[1]

The sulphite process is today the most important method of making chemical wood pulp. Its invention is usually ascribed to B. C. Tilghman of Philadelphia, although numerous chemists and engineers have subsequently made important contributions to its theory and practice which have led to the present efficient and valuable process. Tilghman's original patent was taken out in 1867, but it was not till considerably later that the sulphite process became a real working proposition.

Tilghman originally proposed digesting the wood in lead lined iron cylinders, but this proved impractical for large-scale operations. A few years later Swedish engineers introduced changes in the process that made it commercially practical, using digesters similar to the modern digester, only much smaller, and using an indirect cook, *i.e.*, not letting the steam come immediately in contact with the wood and acid, but having the heat applied by means of a jacket and coils.

About ten years after Tilghman's patent, Mitscherlich began experimenting with the process in Germany and used a digester lined with brick, a form of equipment which has since become almost universally adopted. The original Mitscherlich boilers were from 10 to 12 feet in diameter and about 36 feet long. These digesters were heated indirectly by means of coils of lead covered pipe. The Mitscherlich process is still used for certain classes of pulp and will be described in greater detail later in this chapter; however, the apparatus used for the modern Mitscherlich cook has been altered a good deal and the digesters are larger.

The first practical working sulphite mill in America used the Partington process, which called for spherical digesters of the rotary type.

Larger scale manufacturing operations were commenced by Wheelwright, who overcame great difficulties and succeeded in producing pulp of

[1] It is not the intention of the author to deal at great length with the historical development of the sulphite process, which, although of great interest, would take up too much space in a book intended for practical papermakers. But for convenience in reference we have included in this chapter a copy of Tilghman's original patent. There is also a brief summary of the history in Chapter 1, p. 17.

Moreover, no attempt has been made to discuss in detail the chemical aspects of the process. We refer the reader to "Chemistry of Pulp and Paper Making" by Edwin Sutermeister, and to Bjarne Johnsen's comprehensive article in "Pulp and Paper Manufacture," vol. 3 (1937) and to the technical journals in English and German dealing with the paper industry, as well as to numerous articles that have appeared in the publications of the various chemical societies.

Finally, we have tried to confine the discussion to types of equipment and variations of the process now in actual use so as to avoid confusing the practical reader.

excellent quality cheaper than it had ever been made before. Wheelwright devoted great attention to the form of the digester and the nature of the lining and, according to Griffin and Little [1] succeeded in reducing the cost of repairs on linings from $10.00 per ton of product to about $1.50 per ton of product in three years.

Tilghman's Patent.

"The process of treating vegetable substances which contain fibers with a solution of sulphurous acid in water, either with or without the addition of sulphites or other salts of equivalent chemical properties as above explained, heated in a close vessel under pressure, to a temperature sufficient to cause it to dissolve the intercellular incrusting or cementing constituents of said vegetable substances, so as to leave the undissolved produce in a fibrous state, suitable for the manufacture of paper, paper-pulp, cellulose, or fibers, or for other purposes, according to the nature of the material employed.

"I also claim as new articles of manufacture the two products obtained by treating vegetable substances which contain fibers with a solution of sulphurous acid in water, either with or without the addition of sulphites or other salts of equivalent chemical properties as above explained, heated in a close vessel, under pressure, to a temperature sufficient to cause it to dissolve the intercellular or incrusting constituents of said vegetable substances, one of said products being soluble in water, and containing the elements of the starchy, gummy, and saline constituents of the plants, and the other product being an insoluble fibrous material, applicable to the manufacture of paper, cellulose, or fibers, or to other purposes, according to the nature of the material employed.

"I also claim the use and application, in the manufacture of paper, paper-pulp, cellulose, and fibers, of the fibrous material produced by treating vegetable substances which contain fibers with a solution of sulphurous acid in. water, either with or without the addition of sulphites or other salts of equivalent chemical properties as above explained, heated in a closed vessel, under pressure, to a temperature sufficient to cause it to dissolve the incrusting or intercellular constituents of said vegetable substances.

"I also claim the use and application of sulphites of other salts of equivalent chemical properties as above explained, in combination with a solution of sulphurous acid in water, as an agent in treating vegetable substances which contain fibers, when heated therewith in a closed vessel, under pressure, to a temperature sufficient to cause said acid solution to dissolve the intercellular or incrusting constituents of said vegetable substances.

"I also claim the recovery and re-use of sulphurous acid and sulphite from the acid liquids which have been digested on the vegetable fibrous substances, by boiling said liquids or neutralizing them with hydrate of lime."

Chemistry of the Sulphite Process.

The following outline of the chemistry of the sulphite process is adapted from Griffin and Little [1]:

"It is well known that many of the more complex members of the carbohydrate group, to which cellulose belongs, undergo more or less pronounced changes upon being boiled with water, especially if the boiling is conducted at the higher temperatures obtained under pressure in a closed vessel. Sugar, which is the typical member of the group, becomes inverted: that is, the sugar combines to a limited extent with the elements of water, and the more complex molecule thus formed breaks down into the two simple ones of dextrose and levulose. Such an action in which, as a result of taking up the elements of water, a molecule is broken down, is called a hydrolytic

[1] The Chemistry of Paper Making.

action, and the decomposition itself is called hydrolysis. Similar changes are brought about through the action of water alone upon cellulose and its incrusting matters, but these changes proceed far more rapidly and completely in the presence of dilute acids. Cellulose itself is comparatively stable under these conditions, unless the temperature is considerably raised, but lignin, probably from its greater complexity, is broken down with considerable rapidity at temperatures not much higher than that of the boiling-point of water. The products of the decomposition are largely organic acids, and the direction of the decomposition is toward the production of these acids, but among the earlier products there undoubtedly occur a considerable proportion of substances having, at least, the general character of the aldehydes. When the ordinary mineral acids, as sulphuric or hydrochloric acid, act in the dilute form, and at moderately high temperatures, upon wood, the decomposition products rapidly accumulate in the liquor, and undergo further secondary decompositions, the course of which tends toward the production of insoluble, dark-colored, and tarry matters. It is obviously impossible under these conditions to look for the production of cellulose in any condition of purity.

The reaction undoubtedly takes a somewhat similar course when sulphurous acid without any base is used; indeed, this acid is well known to have a decomposing action upon many groups of organic compounds.

The primary action of a bisulphite liquor in resolving wood proceeds upon the same lines as that of a solution of sulphurous acid, but the presence of the base in this combination materially modifies the subsequent course of the reactions. The bisulphides possess the remarkable property of forming, with the aldehydic products of the first stage of the decomposition, true double compounds which are soluble and comparatively stable. Compounds of this class have been found in the waste liquors. It is characteristic of the aldehydes that they pass by oxidation into organic acids, and in spite of the presence of sulphurous acid, which tends to prevent oxidation, there is some formation of these acids. Once formed, they displace the sulphurous acid from an equivalent portion of the base, and form soluble organic salts. By these two actions the bisulphites take up the products of the resolution of the wood, and prevent for the most part the extreme degradation of the products which is characteristic of the water treatment or of the soda process. The combination of the acid products with the base is shown by the steady rise in the gas pressure observed during the last part of a sulphite cook, and which is avoided by blowing off. It is also shown by the composition of the waste liquors. A. Ihl finds that the resinous matter obtained by evaporating liquors consists mainly of the calcium salts of acids similar to arabic acid, and that these acids, as indicated above, decompose carbonates, sulphites, and sulphides.

An incidental advantage of considerable importance is obtained by the use of sulphurous acid in connection with a base, and is due to the power of this acid to form with various coloring-matters compounds which are themselves colorless. The practical effect of this latter action is the production of a fiber which may be at first of a color as good as that of well-bleached pulp, although, as in the case of all sulphurous acid bleaching, this high color does not persist for any considerable length of time.

Although all the bisulphites act in general in the manner specified above, the character of the liquor is modified in several important particulars, according as one base or another is in combination with the acid. Bisulphite of lime is a very unstable salt which upon being merely heated decomposes, one-half of the acid being set free. The resulting monosulphite is practically insoluble, so that when this decomposition occurs in the boiler, this latter salt is precipitated throughout the pulp, from which it is difficult to remove it by washing. When lime liquor is used, there is therefore more gas pressure in the digester, and the resulting pulp is comparatively harsh, hard and transparent. It is also more difficult to make a straight lime liquor of high test than it is to prepare similar liquors from magnesia or soda, but on account of the insolubility of sulphate of lime the former liquors never contain more than three-tenths per cent of sulphuric acid, while soda or magnesia liquors may contain an indefinite amount. In the case of lime liquors, any excess of sulphate over the amount given is precipitated and may be settled out.

Bisulphite of magnesia is somewhat more stable than the corresponding lime salt, and its action on the incrusting matter is milder, but even more effectual. The sulphates or monosulphites which may be present in magnesia liquors remain in solution, and are easily washed out from the pulp. The resulting product is much softer and whiter than any which is ordinarily made with lime without some subsequent treatment. These desirable qualities of magnesia are possessed in a still higher degree by soda. Sodium bisulphite is so permanent that it may be easily obtained and preserved in the crystalline form. The gas has so strong an affinity for the base that liquors of 35° Be. may be made without difficulty. Both the sulphite and sulphate of soda are very soluble, and there is therefore no precipitation either in the liquor apparatus or in the digester. Pulp made with soda liquor is white and soft, and almost entirely free from the last portions of incrusting matter.

It has been held in some quarters that sulphuric acid in considerable amount is formed in the digester during boiling, but numerous experiments show that in reality this oxidation of the sulphurous acid is very slight; it is obviously so when we consider that making no allowance for the chips and liquor in the digester, but supposing the whole interior to be filled with air at the ordinary temperature and pressure, the total amount of oxygen contained therein only amounts to 22 pounds in a digester of a capacity of 1,200 cubic feet, a quantity so small when compared to the weight of sulphurous acid in the liquor that it may be disregarded."

Digesters.

The typical form of digester used in the sulphite process today is a tall cylindrical vessel of steel plate construction with a dome-shaped top and a conical bottom, as shown in the drawing. The size of the digester depends on the method of cooking the wood. The steel plate is usually

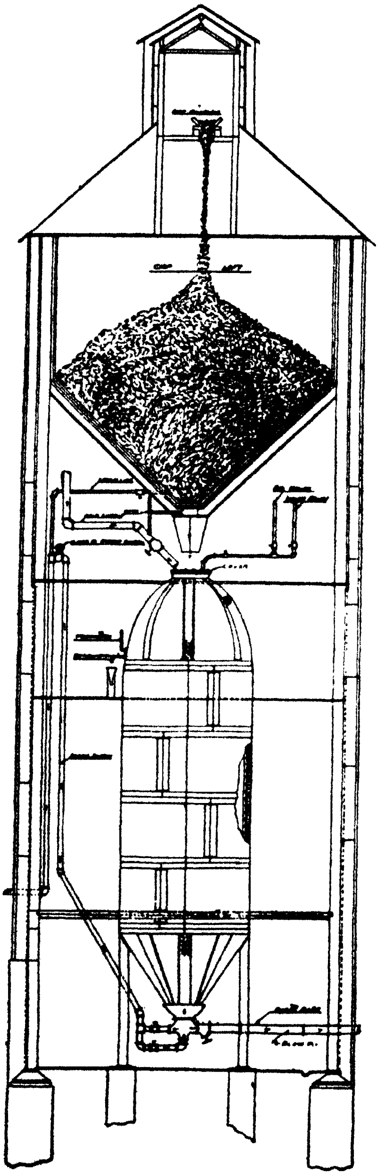


FIG. 43.—Cross-section of digester house showing chip conveyor, chip bins, digester, blow-pipe, and steam and acid connections.

CAPACITY OF STANDARD SULPHITE DIGESTERS WITH STANDARD LININGS*

Size of digester		Thickness of lining, inches	Contents, cubic feet	Capacity contents, tons fiber	Gallons of acid	Cords of wood
Diameter, feet	Height, feet					
8	24	8	610	1.33	3,000	2.48
8	30	8	840	1.75	3,787	3.24
10	28	8	1,319	2.66	6,000	4.96
10	30	8	1,397	2.90	6,525	5.34
10	37	8	1,850	3.85	8,663	7.16
10	40	8	2,024	4.50	9,450	7.81
11	30	8	1,672	3.48	7,330	6.47
11	37	8	2,896	4.60	10,125	8.37
11	40	8	2,416	5.00	11,250	9.30
11	42	8	2,563	5.33	12,000	9.92
11	45	8	2,784	5.75	12,937	10.69
12	30	9	2,015	4.13	9,292	7.67
12	35	9	2,457	5.10	11,470	9.48
12	40	9	2,879	6.00	13,500	11.16
12	45	9	3,272	6.80	15,300	11.64
12	48	9	3,572	7.40	16,650	13.76
14	38	9	3,819	7.90	17,775	14.64
14	42	9	4,320	9.00	20,250	16.74
14	45	9	4,678	9.75	21,934	18.13
14	47	9	4,924	10.50	22,950	18.97
14	48	9	5,046	10.64	23,625	19.53
14	50	9	5,392	11.20	25,000	20.83
15	40	10	4,682	9.75	21,934	18.13
15	42	10	4,964	10.33	23,250	19.22
15	45	10	5,388	11.20	25,200	20.83
15	47	10	5,671	11.80	26,550	21.31
15	50	10	6,096	12.40	27,900	22.06
15	54	10	6,652	13.75	30,937	25.57
16	45	10	6,146	12.80	28,800	24.80
16	48	10	6,680	13.75	30,937	25.57
16	50	10	6,952	14.40	32,400	26.78
16	54	10	7,598	15.80	35,550	29.38
16	60	10	8,565	17.80	40,050	33.10
16	64	10	9,210	19.00	42,750	35.34
17	56	10	9,074	18.80	42,300	34.96
17	60	10	9,814	20.25	45,900	37.94
17	64	10	10,552	21.80	49,050	40.44
17	70	10	11,660	23.00	51,750	42.78

The figures in the above table are for average operation; those in the last three columns will necessarily vary with local conditions. Dimensions also vary, but capacities can be approximated by comparing cubic contents.

*Corcoran.

$\frac{7}{8}$ to $1\frac{1}{4}$ inches in thickness. The joints are triple riveted. Several firms are offering welded digesters instead of riveted ones. These should be good if the welding is well done, which is a matter of great difficulty with such huge pieces of apparatus. The welded digesters have hardly been in use long enough to say how this development will succeed.

The riveting must be done with the utmost care and faithfulness and the whole construction must be of the strongest and most thorough type on account of the great pressure and high temperature prevailing at certain stages of the operation. The outside of the digester should be kept neatly painted and clean so incipient defects can be detected before they go so far as to become dangerous. The surrounding building should be well lighted. Windows and doors should not be allowed to stand open in cold weather so as to chill the sides of the digesters as this produces periodical local contractions and expansions that strain the digester, often causing cracks.

The digesters are located in a tall structure which supports the chip bins over the digesters. The digesters rise through two floors, one being placed just where the cylindrical portion begins and the other being located so that the digesters' heads just rise through it. The digesters should stand alone, no floors coming in contact with them. The digester house should be strongly constructed, well illuminated and accessible at all levels by good stairways. It should also be provided with a good system of ventilation to carry off fumes.

A digester of the shape described 15 feet in diameter and 50 feet high will hold approximately 22 cords of chipped wood and 28,000 gallons of acid.

Essential Parts of the Digester:

1. Shell.
2. Lining.
3. Opening provided with cover at top for receiving chips.
4. System for filling the digester with the acid.
5. System of pipes for supplying the steam for cooking.
6. System of relief lines for getting rid of steam and acid gas.
7. Thermometers to record the temperature.
8. Gauges for recording the steam pressure.
9. The blow valve and blow pipe through which the pulp is discharged under pressure when the cook is completed.

The shell has already been discussed above. We will now pass on to a discussion of digester linings, one of the points which gave the most trouble in the early days of the sulphite process and which required much patient experiment on the part of Mitscherlich, Partington, Wheelwright and others. The present method of lining is largely the result of work by G. F. Russell.

Lining: The acid used in the sulphite process will rapidly disintegrate naked iron. Therefore, some kind of lining is necessary. Lead is chemically the material best adapted to resist this acid, but after years of experiment with lead lined digesters, they have largely been abandoned. This is because the coefficient of expansion of lead is so different from that of iron that the two metals will pull away from each other when subjected to alterations in temperature. Lead, however, when once expanded, does not contract to its original shape and size when the temperature is lowered as do most metals. It tends to remain in the expanded form. This has the result that lead will "crawl" or pull away in one direction from any point where it is held, thus making a round bolt hole gradually into an ellipse and permitting leakage.

We will not dwell on the immense amount of ingenuity that was expended in attempts to overcome the fatal faults of lead before lead linings were finally given up in favor of brick ones. Digesters built of bronze were also tried. This bronze, however, did not perfectly resist the action of the acid, as was proved by chemical tests, and did not possess the necessary mechanical strength at the temperatures encountered in the digester. No bronze has been found that will overcome these defects. Numerous kinds of enamels and cements have also been tried. Although all of these have their advocates, the brick lining has come to be almost universally used.

There are generally two layers of brick, the first separated from the shell by a 1½- or 2-inch layer of cement. The best formula for this cement is 1 part Portland cement; ½ part fireclay; ½ part crushed quartz mixed with enough 4° Be. solution of silicate of soda to render it workable. The bricks are laid with a cement made as follows: one part of sand or crushed quartz, and one quart of litharge are mixed dry and then glycerine added to form a thick paste. The glycerine should be slightly warmed before it is used. Sometimes a little silicate of soda is added to the glycerine. This helps the cement to set well. After the glycerine is added the cement is kneaded like bread till it is of an even consistency. The glycerine should be added to small portions of the dry ingredients at a time, the cement thus being prepared about as fast as it can be used. A ball which a man can nicely hold in both hands will lay about five bricks. The first layer of brick may be common red brick and the inner layer special vitrified acid resisting brick. The two layers are separated by a thin layer of cement, either a special cement or ordinary cement mortar mixed 1 to 2. The inner layer of vitrified brick is laid with great care in the special cement described above.

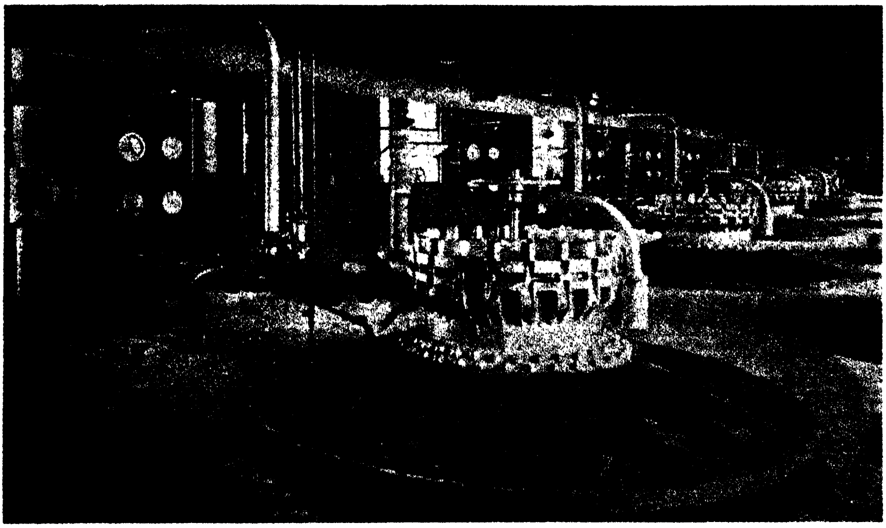
A number of manufacturers produce bricks specially adapted to digester linings. In general such bricks should be hard, homogeneous and non-absorbent to water. They should be thoroughly baked and well annealed so as to resist temperature changes. They should be free from iron and similar metals. The best bricks will split and crack to some extent under the action of acid, temperature change and the mechanical agitation of the liquid, but careful selection of brick can do much to reduce the quantity of such waste matter getting into the pulp and also delay the necessity of relining the digester.

When a digester has been shut down to be relined, or for any other cause, or is being started for the first time, so that it is cold, it should not be heated up to a high temperature suddenly. The brick should be allowed thoroughly to dry out and then the digester should be gradually brought up to cooking temperature. The digester should be at least 24 to 36 hours in warming up from cold to ordinary cooking temperature.

Disregard of these precautions will crack and disintegrate the brick lining, strain the shell and may result in a disastrous explosion.

Insurance inspectors should never be misled and no attempt should be made to conceal anything from them. Their advice as to safe pressures, repairs, etc., should be regarded as these men are selected for their practical knowledge and have a wide experience from inspecting mills throughout the country.

Head: The "head" or cover of the digester is removable. It is fastened to a casting which forms the top rim of the digester proper by means of clamps which hold it securely in position against the internal pressure of the digester. The head is a steel casting lined with a sheet of acid-resisting metal. Between the head and the rim on which it sits is inserted a gasket, which it has usually been found economical and efficient to make out of a lap of sulphite pulp.



Courtesy: Foxboro Co., Foxboro, Mass.

FIG. 44.—Charging floor of digester house showing digester heads, acid and relief connections, recording instruments, and hoppers for charging chips into digesters.

A chain hoist is provided for removing and replacing the digester heads, which have to be removed every time the digester is filled with chips and acid.

The head is fitted for the connection to the relief line. This is usually a 2½-inch bronze pipe. It relieves the pressure in the digester after the steam has been turned on and allows the gas that forms in the top or neck of the digester to escape to the recovery system, which will be described later. After leaving the digester this line divides into two separate lines. One is a liquor relief line and one a gas relief line. These lines are controlled by valves and the attendant can tell by the sound whether liquor or gas is coming off from the digester and thus direct it into the proper line. Both these lines are of bronze and usually 2½-inch diameter.

Strainers should be provided to prevent pulp getting into the relief lines, thus plugging them up. These are usually hard lead or bronze globes or hemispheres provided with numerous holes about $\frac{3}{16}$ of an inch in diameter.

Steam Supply: At the base of the digester are the inlets for the steam. The connections between the boilers and the digesters should be as short as possible to prevent condensation of the steam and reduction of the steam pressure. Suitable traps should be provided and all lines should be covered with an efficient heat insulating substance such as magnesia.

Where a number of digesters are used, as is usually the case, the piping system should be designed so that all the digesters will receive steam at the same pressure, which will not be the case unless the main line leading from the boilers is adequate in size.

The steam pipe for the digester is usually carried up to a point near the top of the digester and then down again, entering the digester at the bottom.

FIG. 45.—Bottom floor of digester house showing conical base of digesters, and blow-pipe.

This forms a trap which prevents anything being forced from the digesters back into the boiler system should the steam pressure through any cause become less than the pressure in the digesters. This arrangement permits of the reducing valve being located on the working floor, i.e., the floor where are the digester heads, gauges, etc., and thus being under the eye of the operator at all times. Frequently an automatic pressure regulator is installed in this line to shut off the steam at a predetermined top cooking pressure. This line should be provided with one or more suitable check valves, one in the horizontal section of the pipe accessible to the working floor. The location of the second, if such is installed, is between the first check valve and the digester.

To the bottom of the digester is fastened a bronze[1] tee, the side outlet being attached to the digester. To one end of the tee the 4-inch bronze steam line is connected. It is of bronze in case any acid from the digester should by any chance get into it. To the other end of the tee is fastened

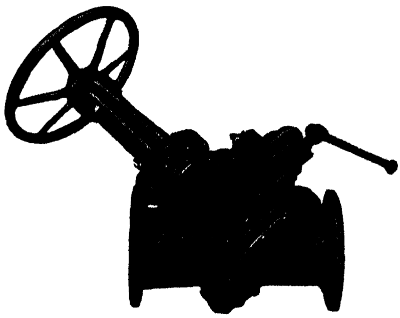


FIG. 46.—Typical valve used for blowing digester.

a bronze blow-off valve and to this a 10-inch cast iron pipe increasing in diameter to 12 inches at the farther end and passing through the side of the blow pit.

A digester such as has been described will require a maximum of about 1,200 boiler hp, the average being about 300 hp per hour. In modern mills steam flow meters are installed on each digester.

Temperature and Pressure Recording Instruments: Thermometer wells of acid resisting bronze or steel are located in the side of the digester about one-third down from the top. These wells should extend through the brick lining and project into the contents of the digester at least 6 inches. Indicating and recording pressure gauges should be provided at the operating level. The author is partial to an instrument where both pressure and temperature are recorded on a single chart. There should also be a draw-off cock for taking samples of the cooking acid.

Cooking.

There are in general three methods of cooking sulphite pulp. The oldest, which is still used for certain grades of pulp, is the Mitscherlich process, which is an indirect cook, the steam never coming in direct contact with the pulp and which requires a special form of digester, which has already been described. The second method, which is that in general use, is the Direct Cook, sometimes known as the Ritter-Kellner Process (after the men who first introduced it in Europe) using the vertical digester we have already described. The third method is known as the

[1] Of recent years acid resisting low-carbon chromium-nickel-molybdenum steel has largely superseded bronze for digester castings.

Indirect or Morterud System, the latter designation being derived from the name of the Norwegian who first experimented with it. This is an indirect system with forced circulation, i.e., the acid is heated in a heater separate from the digester and forced through the digester by means of a pump. All of these methods have their advantages and their drawbacks.

Mitscherlich Process.

The pulp produced by the Mitscherlich process is of excellent quality, but the process has been largely abandoned on account of the following disadvantages. This is a very slow process to operate, the cooking time being very long, usually 35 to 40 hours and in some cases upwards of 60 hours. The pressure rarely exceeds 45 pounds. The digester has from 250 to 500 feet of lead pipe coil in it for heating purposes which is constantly leaking and in need of repair. When the heating coils have to be repaired the digester has to be shut down. On account of leaks, the acid liquor gets into the condensate from the steam used for heating, thus making it impossible to use this condensate in the boiler plant and thus increasing the consumption of coal. Calcium monosulphite collects on the lead pipes and has to be removed and will frequently drop into the pulp during the cooking, where it is very undesirable. The chips are brought into direct contact with the heating surface, frequently causing overcooked pulp and lower yield from the wood. On account of uneven circulation and the fact that the heating coils are entirely in the lower part of the digester, the bottom part of the pulp will be digested first. The pulp is not blown out of the digester, as in the case with the direct cook, but is removed by shovels and rakes through a large manhole near the bottom of the digester after the pressure has been relieved. The chips have to be blown in with a steam injector.

In spite of all drawbacks the Mitscherlich process is found advisable in some cases. It makes a very strong pulp ideal for certain purposes, which cannot be exactly imitated with a direct cook. It is also economical of sulphur. A much weaker acid can be used than is customary with the direct cook. When rotating digesters are used (which is the general practice today) there is great uniformity of temperature and also mechanical decomposition of the chips. However, it will be seen from the above remarks that the process is a very troublesome one.

Direct Cooking Process.

The first great advantage of this process is the fact that it is quick, the time varying in different mills, but never being anything like as long as for the Mitscherlich process. The second great advantage is the comparative simplicity of the equipment, leaks and other causes of stoppage being cut down to a minimum and repairs being as low as possible.

In charging the digester it is filled as completely as possible with chips which, before the cooking operation has proceeded very far, will have settled enough to be entirely covered with the liquor.

A digester 15 feet in diameter by 50 feet high will hold approximately

22 cords of chips and requires about 28,850 gallons of liquor. Such a digester will produce about 12 or 13 tons air-dry pulp.

The liquor should be run in as quickly as possible. The pipe for this purpose should be at least 6-inch and maybe larger. Like all other connections with which the acid comes in contact, it is of hard lead or bronze. An 8-inch centrifugal pump of hard bronze is satisfactory for pumping the acid into such a digester. Running at approximately 850 r.p.m. it will fill the digester in 25 minutes. It requires 24 hp against a 60-foot head. All connections from the tank to this pump and from the pump to the digester can best be made of hard lead, containing 8 per cent antimony in its composition.

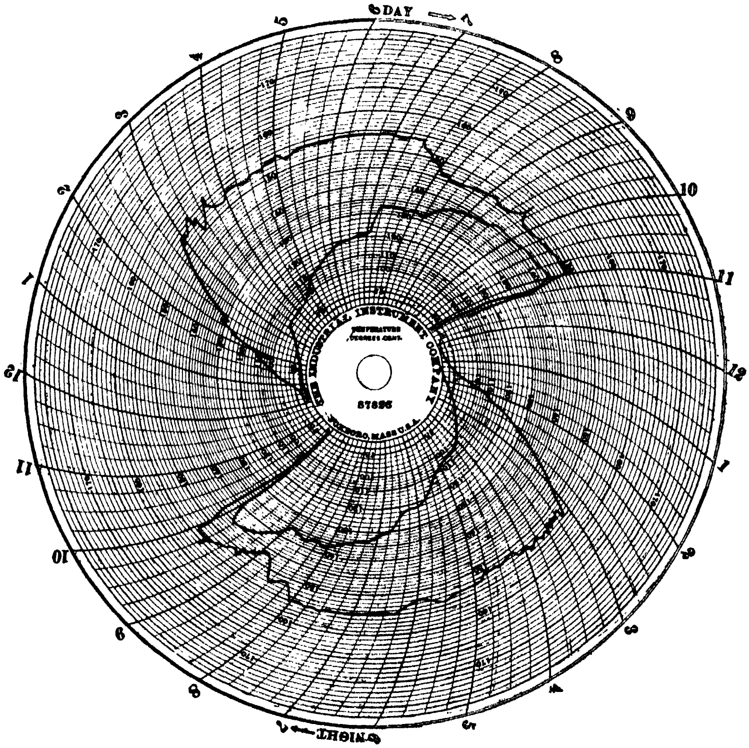


FIG. 47a.—Temperature diagram for typical sulphite cooks. The inner curve is a pressure curve plotted on the temperature diagram for purposes of comparison.

In some mills the acid is pumped into the bottom of the digester, a check valve being inserted to prevent the acid running back in case of accident to the pump, this valve being closed before stopping the pump. In this way the acid rises gradually through the chips. This method does away with fumes. However, this method is not to be recommended, as the chips float and do not become thoroughly saturated with acid and it is hard to tell when the digester is full.

When the digester is filled with chips and acid, the cover is securely bolted on and the pressure and temperature recording instruments noted, and at times calibrated. The relief valve is slightly adjusted to let out the air. The steam valve is then opened and the digester allowed to come gradually to 65 or 70 pounds pressure. It is very important that the pressure should not be applied too suddenly. The acid should be allowed to thoroughly saturate the chips and penetrate every particle of them before any notable increase in temperature takes place. This is necessary to produce the proper chemical changes in the material and to prevent charring and overcooking of the chips.

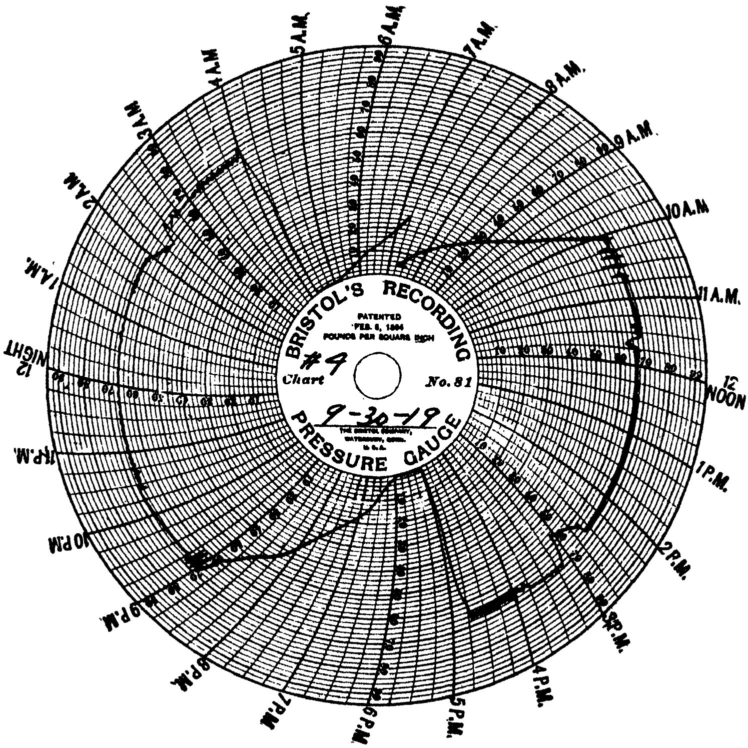


FIG. 47b.—Pressure diagram for typical sulphite cooks.

Moreover, if the heating is forced at the beginning of the cook, the steam striking the cold liquid will hammer, which is hard on the digester. However, the chief reason for raising the temperature slowly is the effect on the chips mentioned above. If reddish or brown bundles of fiber are found in the pulp it is an indication that the pressure has been applied too early before the acid had a chance to thoroughly saturate the chips.

The pressure carried throughout the main portion of the cook depends on the grade of stock required, physical conditions of the digester, maximum pressure allowed by the insurance companies, etc.

In general the temperature should not be allowed to exceed 110°C. until after 2½ hours have elapsed.

When the steam pressure has been brought up to standard the relief valves are opened sufficiently to shake up the contents and bring the acid up over the top of the chips.

It is impossible to give any general directions for cooking. The cook varies in every mill, depending on the materials being used, the grade of pulp being produced and the personal ideas of the man in charge of operations. In most modern mills very elaborate records are kept of the temperature and pressure throughout the cooking operation, as well as of the chemical composition of the samples drawn off at various stages, and careful deductions are made from these facts and the digesters operated accordingly. In some mills, however, rule of thumb methods still prevail and the operation of the digesters depends entirely on the idiosyncrasies of some one man.

The methods of relieving, in particular, vary greatly, and many mills attach peculiar importance to keeping their method of performing this operation a secret. Many times after the digester is started, particularly within the second and third hour before the final blowing time, the cook will note a wet or dry relief, sometimes detected by the sound or sing of the relief valve. With proper cooking conditions, the digester relieves 100 per cent gas almost continuously for two or three hours before the end of the cook. The cook tries to hold the gas as long as possible and take it all out of the digester just before the blowing point. He must do this as far as possible, and yet not have the temperature exceed the predetermined maximum at the time of blowing.

Authorities vary as to the proper temperature. The writer finds a temperature of 145°C. at the time of blowing desirable.

Certainly the temperature should not exceed 155°C. and it is better to have it, especially if strong acid is being used. When weaker acid is used the time of cooking has to be prolonged also. In this case the blow is much darker in color.

For strong pulp which will have a low bleach consumption, strong acid, a short cook and a low temperature is the proper combination. Such a cook produces high screenings, uses a great deal of sulphur, and makes repairs heavy, owing to the action of the strong acid on the bronze castings. This is minimized by the use of acid resisting chrome-nickel steel instead of bronze.

With weaker acid satisfactory pulp can also be obtained with lower percentage of screenings, lower sulphur consumption and decreased repair cost. However, the cook must be prolonged and the temperature maintained high.

The pressure is not an accurate indication of the temperature, especially in the later stages of the cook, as this pressure may be largely due to gas set free by the process proceeding in the digester. The temperature should be judged by an accurate thermometer placed about one-third of the way down on the digester.

The reader may wonder why, if the grade of pulp to be produced has been settled, the strength of the acid, the temperature, the pressure at every stage of the cook and the duration of the cook cannot be absolutely standardized and the operation made to conform to these standards. Acid concentration and chip moisture are the two variables in sulphite cooking. Acid concentration can be closely controlled (see Chapter 7, The Acid Plant) but the wood will always vary in moisture content and in other respects. This variable factor makes it necessary for the cooking operation to be in charge of a capable and experienced man who can exercise judgment.

However, much can be done to simplify the operation by making sure that the acid is of constant strength and that the condensed water and consequent dilution of the liquor is kept steady by preventing radiation as far as possible and by keeping the pressure of the steam constant.

Testing.

During the cooking operation the cook draws samples which he analyzes for total, free and combined SO_2. Combined SO_2 is that in chemical combination with lime or lime and magnesia, free SO_2 is that in solution in the liquid, total SO_2 is the sum of the two preceding amounts.

The cook also tests the smell of the cooking liquor and an experienced man can frequently be guided by this more perfectly than by the most extensive system of chemical control. The appearance of the liquor is also of importance.

The method usually employed for determining the end of the cook is that of drawing off a portion of the cooking liquor from time to time and determining the total, free and combined SO_2, smelling it and noting its appearance. Other means are employed such as blowing a small sample of stock from the digester through a plug cock against a small target. After examining this a very small portion of the sample should be diluted in a clear glass bottle filled with clear water. By holding this up to the light every fiber stands out prominently. If there is any uncooked wood these particles will appear in a strong contrast to the cooked fibers. When a digester which meets all the requirements has been blown, a sample of this stock should be saved and diluted in a bottle as above for future reference. It is surprising how uniform the stock can be blown from time to time when the operation is in charge of an experienced cook.

It has not seemed to the author desirable to take space in this book to give details of the chemical methods by which acid, liquor from the digesters, etc., are analyzed. Such details would consume much space and are of interest only to the chemist, who already knows where to find such information. The technical publications serving the pulp and paper industry go into this matter in great detail and describe all the standard methods which have been worked out, together with all the many improvements and criticisms that develop from time to time.

Indirect Process.

The Morterud and other similar processes embody an attempt to get away from the disadvantages of the Mitscherlich Process, at the same time retaining the advantages of that method of cooking. It is in extensive use in Europe and modifications of Morterud's original process have been introduced with considerable success into many mills in America. Up to date it has been applied to a greater extent in connection with the sulphate and soda processes than the sulphite.

The system originally called for a specially constructed heater with bronze pipes in which the acid is heated by steam passing through the pipes. A special circulating pump was used for pumping the acid from the heater into the digester. Another pump removed the condensate from the heating tubes and returned it to the boilers. It was claimed that the amount of acid required for a cook by this process is 30 per cent less than by the direct cooking process, and also that a weaker acid can be used, on account of the perfect transfusion of the acid provided for

The disadvantages, as compared with direct cooking, were: power required for operating pumps; the pumps and the heating apparatus require repairs; the possibility of acid from the heater getting into the boiler system should the heater tubes be leaking at a time when the pressure in the digester is greater than the steam pressure in the heater.

All this has been changed with the availability of trustworthy acid resisting steels from which to fabricate the equipment, the heat exchangers and the pumps. Several firms specialize in equipment for this purpose and a typical indirect cooking installation (differing in no essential respect from those in use in sulphite pulp mills) is described in Chapter 9, The Alkaline Processes.

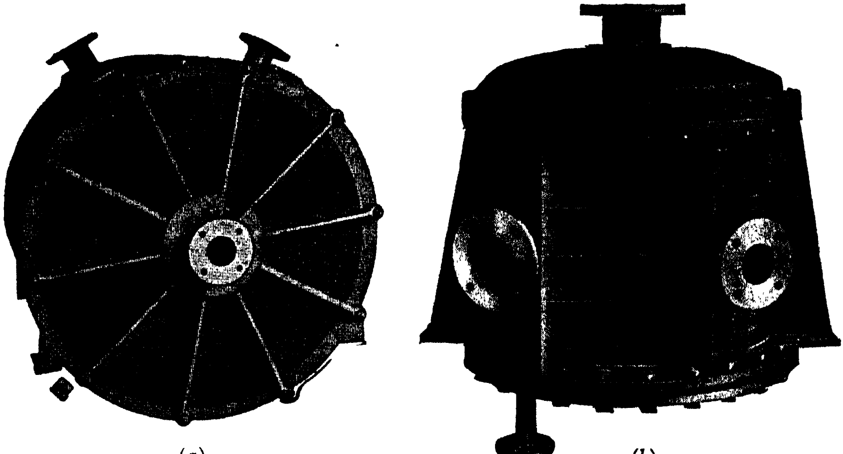
Forced Circulation.

While forced circulation by means of centrifugal pumps which draw liquor from the bottom of the digester and return it to the top has been developed mainly in connection with the indirect cooking systems, there are installations where forced circulation is successfully applied to direct cook digesters. Most of these are in mills where the Chemipulp[1] system of hot-acid recovery is also in use. Forced circulation alone yields no economy of steam but promotes efficiency in heat distribution. Forced circulation with indirect cooking adds to all the advantages of that procedure (see p. 142) the additional advantage of even distribution of heat at all times in the digester. To Chemipulp installations forced circulation contributes additional efficiency in *maintaining* even heat distribution.

Granted the certainty of trouble-proof equipment, the indirect cooking systems offer the following advantages: recovers much of the heat in relief by the use of heat exchangers; condensate from heaters can be used for boiler feed; gets rid of dilution of the cooking acid due to condensation of steam and thus promotes uniformity of acid strength.

[1] See page 142 for description of Chemipulp system.

Fig. 49 shows the general arrangement of a Fiber Making Process circulating system and heat exchanger. The strainer, which is located below the minimum acid level, is connected to the suction pipe and pump by means of a sleeve through the digester shell and an angle valve. The pump is directly connected to the top of the heat exchanger. A discharge pipe connects the bottom of the heat exchanger with the bottom casting of the digester, where a gate valve is provided for shutting off the line. This makes a simple layout with pump, heat exchanger and valves easily accessible.



(a) (b)

Courtesy: American Heat Reclaiming Corp., New York

FIG. 48.—Two views of special heat exchanger used for reclaiming heat units in modern digester operation.

The heat exchanger can be opened without disconnecting any pipes. The steam condensate from the heat exchanger is returned through a trap to the boiler plant for makeup.

The Fibre Making Process heat exchanger is of the single pass design. The principal advantage of this type is that there can be no leakage between the acid and steam chamber due to leaks in the packing. There is also less friction drop in the single pass heat exchanger than in the double pass and less piping is necessary. The end covers are hinged, making it possible to inspect the tubes without removing the tube bundle. Scale formation in the tubes is minimized by the high velocity of the liquor and the highly polished surface of the tubes.

The Fibre Making Process circulating pump is of the split casing and bearing type, making the inspection of shaft and impeller very simple. The packing box is water-cooled and a high pressure water-seal is provided between casing and packing to prevent acid from contacting the packing. A small direct connected pump is used for this purpose. The pump is also equipped with ball bearings. The power required for the pump, if a heat exchanger is used, is 2¼ hp. per ton of pulp.

The strainer is made in sections which follow the contour of the brick lining on the inside of the digester. Each section is suspended in brackets bolted to the digester shell, with provision for expansion and contraction of the strainer sections. The strainer is connected to the digester nozzle by means of a slip joint pipe connection.

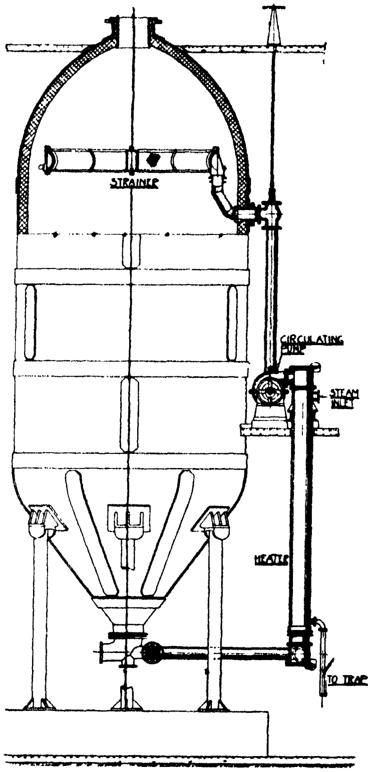


Fig. 49.—
Diagram of sulphite digester showing indirect heating and forced circulation.

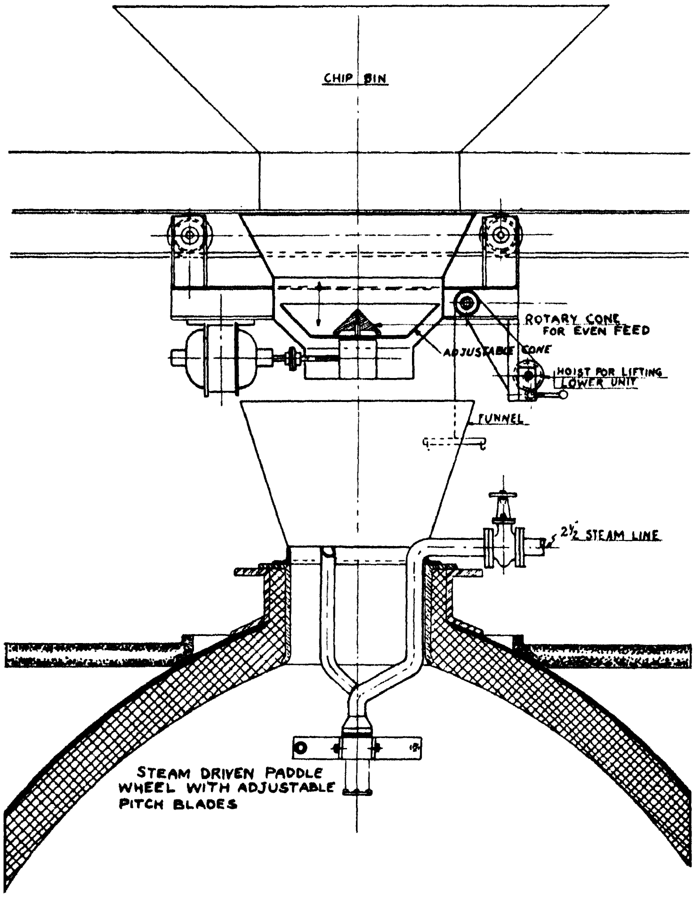
Courtesy:
Fibre Making Processes, Inc., Chicago, Ill.

The chip distributor consists of two units: the lower with paddles, shaft, bearing and support, and the upper unit with motor speed reducer permanently mounted in the hopper inside the trolley frame. On one side of the trolley there is a hoist for lowering and raising the distributor unit. The two units are quickly disconnected by means of a coupling. The motor is located in the center of the hopper, providing a simple, compact design with ample room for the flow of chips from the chip bins.

The forced circulation system of digestion adapts itself very easily to the use of automatic control. In so doing, the human element is practically eliminated. By using automatic control results can be duplicated from day to day.

With an automatic control arrangement the time temperature cam is cut to a predetermined operating schedule, and the valve in the steam line operates according to this schedule. The pressure controller maintains the desired pressure in the digester throughout the cooking period by relieving according to the cam schedule. These cams are easily cut to suit any desired schedule and changed without difficulty.

This process which has recently come into wide use both with direct cooking and with modifications of the Morterud indirect cooking process employs a spherical acid-storage tank, called an accumulator, which is insulated to retain the heat and is acid resistant and capable of standing the pressure involved.



Courtesy: Fibre Making Processes, Inc., Chicago, Ill.

FIG. 50.—Diagram showing chip charging device with which digester shown in Fig. 49 is equipped.

The Chemipulp System.

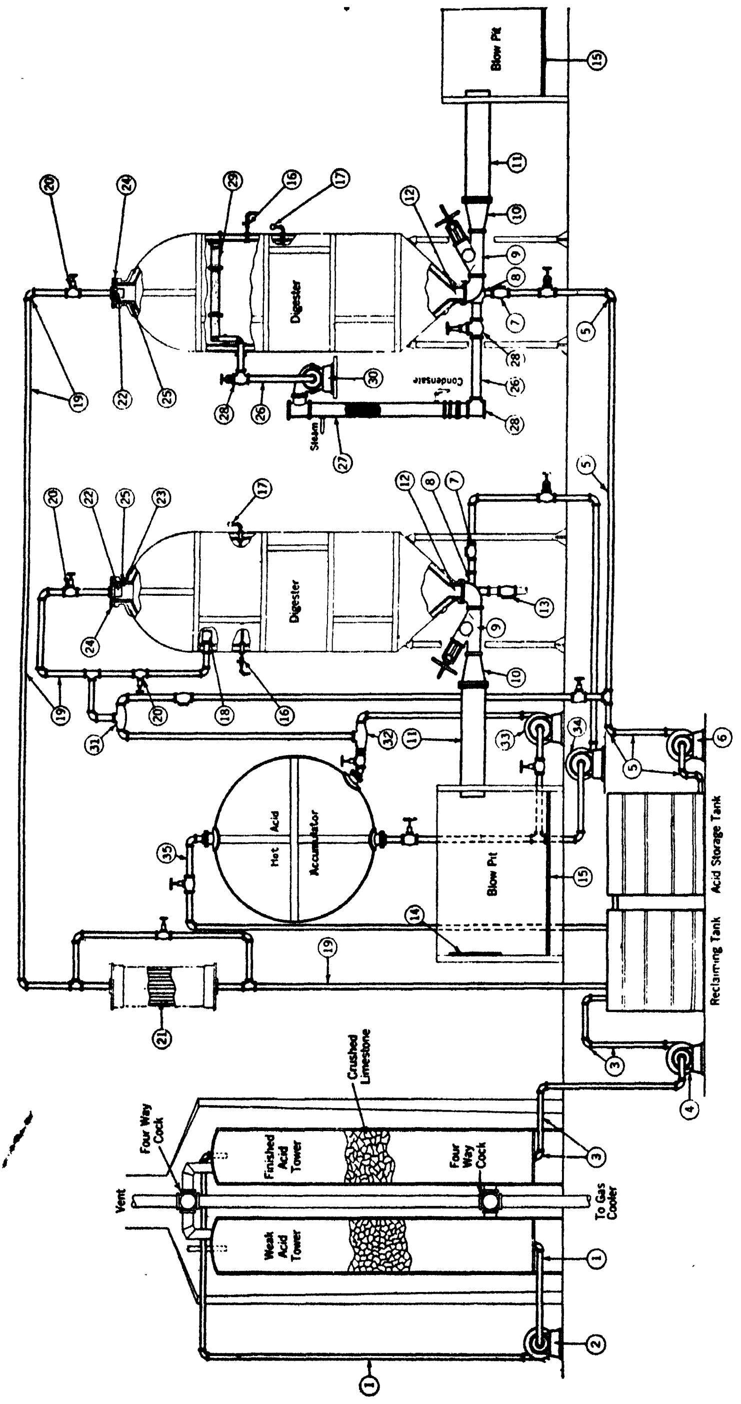
The Chemipulp recovery process which is in use in a large number of representative modern sulphite plants is typical of the research and development that has been devoted to this subject of recent years. This system differs from the ordinary relief system in the following respect: the installation of acid-storage accumulators capable of withstanding heat, pressure, and the corrosive effects of cooking acid. The method of accumulator construction is therefore similar to that employed for digester service; in fact, digesters that might otherwise be idle may be so employed, although spherical accumulators provided with standard digester linings find favor where spare digester capacity is insufficient to release digesters for this service. Digesters and accumulators are provided with gauge glasses, to make operating control of liquor levels possible. Accumulator capacity required is from a minimum of one and one-third charges of acid to a maximum of three charges.

The relief system is modified by providing high-pressure and low-pressure relief lines from the digesters, the high-pressure line having sufficient capacity to deliver both top and side relief to the accumulator system, and the low-pressure line connecting with the distributors in the absorption tanks. A vent line, having a vent to the atmosphere, is also provided to relieve air from the digester during filling period.

An eductor and a cold-acid pump of sufficient head to produce 75 lb. pressure at the eductor, which is located in the high-pressure relief line between the last digester and the accumulator must be provided. This pump supplies cold acid continuously to the eductor jet, and may also provide a recirculation of cold acid through the low-pressure line back to the acid tank. Some installations, considered less efficient, do not use the eductor, in which case, the cold-acid pump delivers to the accumulator.

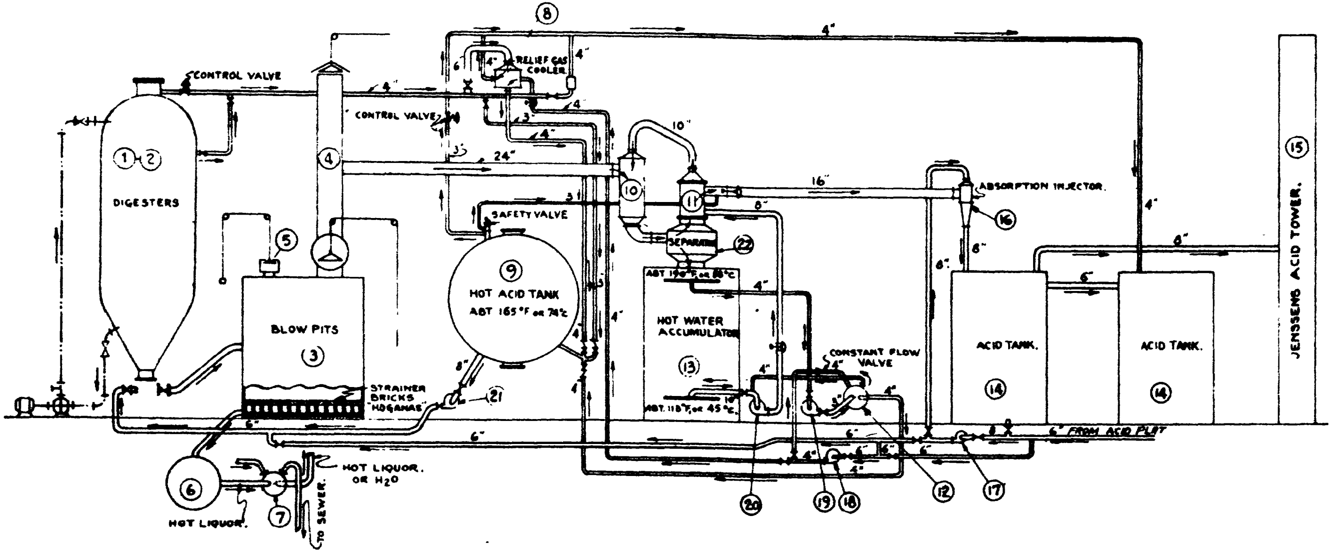
A vent connection must be provided at the accumulator head with pressure-control valve relieving the accumulator to storage tanks; also a pump (130-ft. head, 1000 to 1500 gal. per min.) to deliver hot acid from the accumulator to the digesters. The cooling systems for relief gas and liquor are dispensed with.

The operating procedure is somewhat as follows: When a digester is ready for filling, the accumulator is full of acid, heated and strengthened by the relief from previous cooks. The digester is filled with chips, and, with the top cover bolted on, acid from the accumulator is pumped into the digester, while the displaced air is vented to the room. The vent is closed when gas shows, and the relief is continued through the vent line to absorption tanks or towers. In some earlier installations, this relief is taken through the low-pressure line to the tanks; in others, it is blown to the atmosphere. When the digester is full, the vents are closed, and the pumping is continued to develop a hydraulic pressure of 40 to 45 lb. in the digester, whereupon the top and side relief valves are opened; thus hot acid from the accumulator, carrying with it inert gases entrained in the chips, and water displaced from them, is circulated by means of the pump through the digester and back to the accumulator. This recirculation has the effect of reconditioning the acid in the digester during the penetration period, bringing out more uniform conditions of chip moisture and acid concentration, and equalizing the temperature throughout the chip mass before actual cooking. This recirculation requires from fifteen



Courtesy: Chemipulp Process, Inc., Watertown, N. Y.

FIG. 51.—Typical Chemipulp system as installed in connection with two sulphite digesters.



Courtesy: Paper Mill Equipment Ltd., Montreal, Canada

FIG. 52.—Flowsheet for "Rosenblad-Tomlinson-Hellstrom" patented heat and SO_2 recovery system for sulphite mills.

minutes to two hours, depending on local mill conditions; and when completed, as indicated by equal temperatures at the top and bottom of the digester, the relief valves are closed, and, after the pump is shut down, the digester is ready for cooking.

Provided uniform conditions are promoted during the penetration period, the digester charge can be rapidly brought up to the desired cooking temperatures and pressures. Relief from the head and side is taken through the high-pressure line to the accumulator; but when, toward the end of the cook, the pressure in this line is too high to permit free relief from the digester, the low-pressure line is used to conduct relief to the absorption tank, where it is cooled by a recirculation of cold acid.

When an eductor is used, the cold-acid pump runs continuously, mixing hot relief in the eductor with cold acid before it enters the accumulator. The function of the eductor is to serve as a mixer to increase absorption, and to reduce the back pressure on the relief line. In the earlier installations, where no eductor was provided, the cold-acid pump delivers direct to the accumulator, usually in batches, after each digester filling.

Rotary Digesters.

Rotary digesters have been used for sulphite pulp especially for the Mitscherlich process and are still extensively used in Europe. They have the disadvantages of having to be used in small units for reasons of construction, constant trouble with repairs to drives and steam connections and numerous other minor disadvantages. They secure uniform temperature and provide mechanical disintegration of the pulp, save fuel and use less liquor, and consequently can be used successfully in countries where operations are carried on on a smaller scale and where labor and construction and repair charges are lower.

Blow Pit.

When the cook is finished the stock is blown from the digester through the blow pipe into the blow pit. The blow pit is a vertical tank of wooden or concrete construction of sufficient capacity to hold somewhat more than two blows, i.e., twice the capacity of the digester. It is strongly reinforced with iron hoops, if of wood, and has a target placed on the side opposite the blow pipe. This is to protect the tank from the violent pounding of the stock as it is blown from the digester under pressure. The target is usually of cast iron, about 1 inch in thickness, and is fastened to the tank with heavy bronze bolts. The blow pit has a chimney-like opening at the top containing baffles to prevent any stock being forced out. This is called a vomit pipe.

The bottom of the blow pit is equipped with a false or second bottom. This second bottom is usually of 3-inch matched plank and is set approximately one foot above the actual tank bottom and is provided with holes approximately 1½ inches center to center. These holes are usually ⅛-inch diameter at the top and flare to ½-inch diameter at the bottom.

Sometimes this false bottom is made of perforated vitrified brick tile set on planks provided with large holes and held in position by wooden fillers wedged between the tiles. Sheets of perforated alloy steel are also now in use.

The purpose of the false bottom is to permit of washing the stock after it has been blown into the pit. The pit is filled with fresh or white water to a height of two or three feet on the stock. Fresh water is preferable because white water always contains some acid and it is necessary to wash all acid out of the stock if paper that will not deteriorate rapidly after being made is to be achieved. This water filters down through the stock and passes through the perforated bottom, carrying much of the acid with it, to the sewer or a save-all. This operation is repeated until the stock is washed free from all acid. In some modern mills rotating washing drums are used for this purpose.

The blow pit is fitted with a lead pipe connection at a point just above the drainer or false bottom. This is usually 8 inches in diameter and leads to the pump used to pump the stock from the pit to the intermediate stock chest. This pump is usually a centrifugal stock pump A pump running at approximately 1,000 r.p.m. will deliver the stock against a head of 40 feet with a power consumption of about 25 hp.

The stock as it is left in the blow pit after washing is of a consistency of about 12 to 15 per cent air dry, and in order to get it out it is necessary to use fresh or white water to thin it down. This is done by cutting it with a high pressure hose line. This operation is called hosing or sluicing, and the usual method is to cut the stock nearest to the suction line of the pump and then to cut and hose towards that point. The hose is usually a standard 2½-inch fire hose and should have approximately 35 or 40 pounds nozzle pressure to obtain good results.

Digester Hang-Ups.

The term *"hang-up"* means part of a charge of chips left in the digester in the form of pulp after blowing. This explanation is superfluous to experienced sulphite men, but beginners will welcome some hints on the subject.

The *causes* are: too rapid steaming, thus boring a hole through the mass of chips; too wet chips which, being too heavy, will not circulate; inadequate supply of acid; withdrawing too much liquor by side-relief prior to the blow; too high pressure at the time of the blow, which tends to blow a hole through the mass of pulp, leaving the remainder adhering to the cone and walls.

The *remedies* are: careful, closely watched steaming; the use of properly seasoned wood; use of a liquid level gauge to enable acid volume to be held at the proper level; more skilful use of top and side relief. Opening the steam valve will often "shake up" the digester. In stubborn cases the pulp must be washed out of the digester with water, or else the digester re-blown by adding water enough to cover the pulp, bringing up the pressure, and then blowing as usual. Pulp left in a digester in the form of a hang-up *must* be removed before proceeding to recharge the digester.

Intermediate Tanks.

The object of the intermediate tank is to supply a storage between the blow pit and the screens. This tank should be of approximately 2 or 3 tons capacity, air dry stock, and should be equipped with an agitator. Such tanks make sure of the stock being of a much more uniform consistency than if it were pumped direct from the blow pit to the screens. The power required to drive the agitator is about 8 hp. in a tank 15 feet in diameter.

In making fine writing papers from sulphite frequently a number of intermediate tanks are used in which the stock is washed systematically, first with white water and finally with pure soft water. Such tanks are usually tile lined and equipped with corrosion resistant agitators and fittings.

7. The Acid Plant

The function of the acid plant is to manufacture the solution used to digest the chips in the digesters.

Numerous forms of equipment for manufacturing this solution have been devised, a great deal of ingenuity having been devoted to this end since the early days of the sulphite process.

It is not our intention to devote space here to an account of the many various systems that have been tried. We will, however, explain the general principles of acid making and the forms of equipment in general use in America at the present time.

Chemistry of the Process.

Sulphur, when burned, unites with the oxygen of the air to form sulphur dioxide, SO_2, a gas which dissolves readily in water. There is always a tendency for this sulphur dioxide to take up more oxygen, becoming oxidized to sulphuric acid. In fact, this is the way in which commercial sulphuric acid is manufactured. In burning sulphur for the manufacture of sulphite pulp every precaution is taken to prevent the formation of sulphuric acid.

Sulphur dioxide in the presence of water and bases, such as lime or magnesia, forms solutions of lime or magnesia bisulphite. If more sulphur dioxide is added than the base will hold in combination, it goes into solution in the liquid, the amount depending on the temperature and pressure. The diagrams in Figs. 53 and 54 show the solubility of sulphur dioxide in water at various temperatures and pressures.

The liquid, generally called "acid," which is used in the sulphite digesters consists of lime and magnesia bisulphites in solution together with free sulphur dioxide in solution. The acid may also contain some sulphate and some monosulphite, but if the operation is properly conducted the amounts of these compounds will be negligible. Their presence is very undesirable.

This acid is distinctly corrosive and has to be handled in equipment constructed of materials selected to resist its corrosive action. All pipes, connections, valves, pumps, etc., with which it comes in contact must be of bronze, hard lead, stainless steel or some other acid resisting material.

Raw Materials.

Sulphur: Sulphur is one of the chemical elements, being denoted in chemical symbolism by the letter S. Most American sulphur comes from Louisiana and Texas, where it is obtained in a high degree of purity from deep borings out of which it is expelled by superheated water, after which it is allowed to solidify in bins. It is a hard yellow solid which is crushed

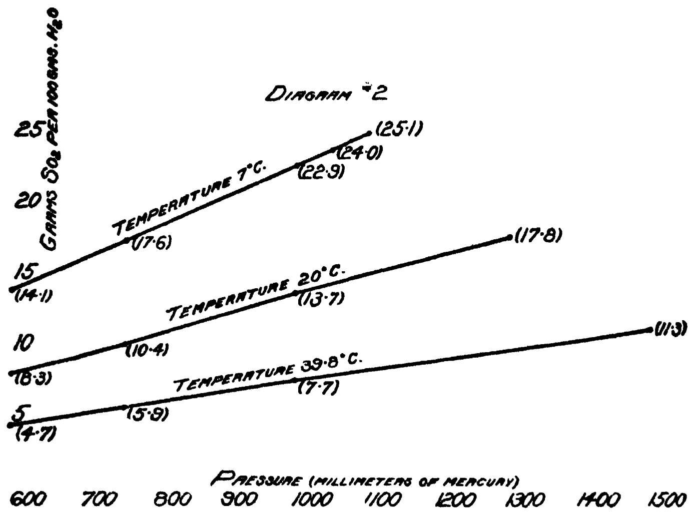


FIG. 53.—Solubility of SO_2 in water at constant temperatures and varying pressures.

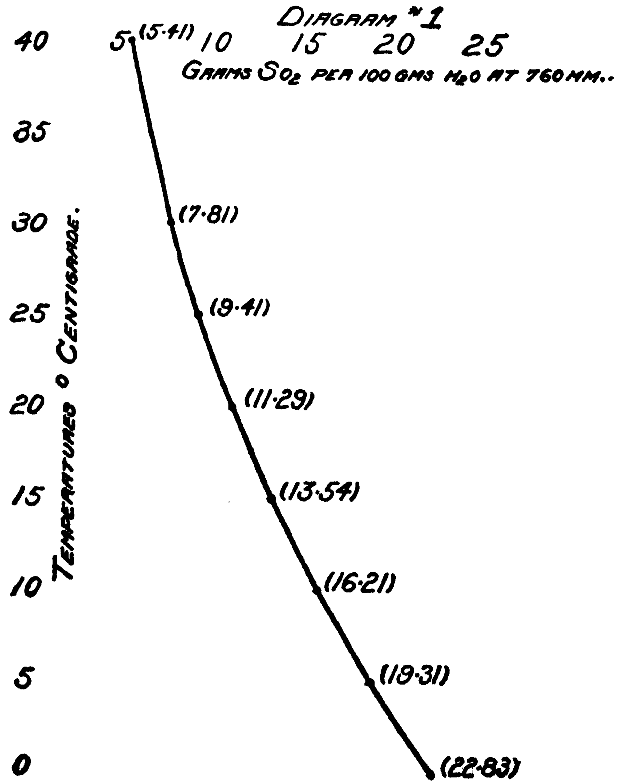


FIG. 54.—Solubility of SO_2 in water at different temperatures.

and pulverized to various degrees of fineness according to the use to which it is to be put.

Sulphur should be stored at the mill in bins, which may be of wood, concrete or metal. A number of bins of moderate capacity is preferable to one huge bin because it is easier to inventory the sulphur periodically and also the fire risk is less. The bins frequently have bands painted on them indicating various tonnages of sulphur so that it can readily be ascertained how much sulphur is on hand at any time. It is important that the sulphur storage should be ample, and as this material does not deteriorate with keeping; a liberal supply should be maintained at all times. The sulphur is weighed as it is received at the mill and again when supplied to the burners. In this way an accurate check is kept on the sulphur consumption. Periodical analyses of the sulphur should be made by the laboratory, to determine the percentage of ash in the sulphur for the guidance of the acid and digester departments.

Limestone: The supply of limestone is usually obtained from the nearest location to the mill where it can be economically quarried. Dolomite, or limestone with a high magnesia content, was formerly preferred by mills making strong sulphite such as that used for bag and wrapping papers, writing and book papers, etc. However, nowadays satisfactory pulp of this class is being made with acid from limestone analyzing 97 per cent lime and no magnesia present at all. Newsprint mills, the product of which does not require strength, and which is usually produced by a short cook with weak acid, prefer limestone as low as possible in magnesia. For reasons to be explained later the use of dolomite has become undesirable with the substitution of towers for milk-of-lime systems.

SUITABLE LIMESTONE FOR ACID MAKING

	(1)	(2)	(3)
Loss on Ignition	43.63		
Iron and Alumina	0.74	0.60	0.95
Calcium Oxide	54.10	58.60	56.00
Magnesium Oxide	0.82	1.30	37.90
Silica	0.59	0.68	0.70

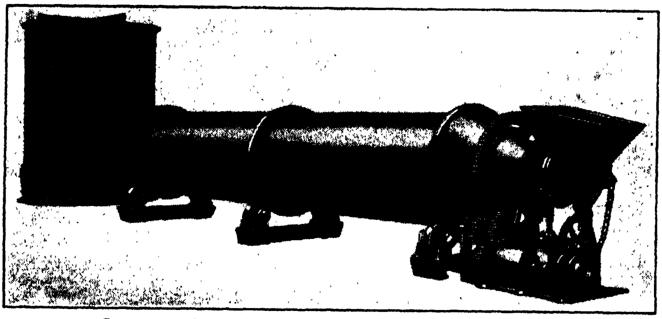
(1) Spanish River, Ont., Canada; (2) Millinocket, Maine; (3) Ohio dolomite.

SUITABLE LIME FOR MILK-OF-LIME SYSTEMS

	Massachusetts	Ohio	New Brunswick
	Per cent		
Calcium oxide, CaO	56.02	58.61	55.96
Magnesium oxide, MgO	40.10	40.25	37.98
Alumina and ferric oxide, Al_2O_3 and Fe_2O_3	0.57	0.12	1.23
Sulphur trioxide, SO_3	0.11	0.15	0.16
Insoluble in HCl, sand, etc.	0.94	0.07	1.51
Silica soluble in acid, SiO_2	0.47	0.15	1.81
Loss on ignition, H_2O, CO_2, etc.	1.43	0.51	1.00
	99.64	99.86	99.65

Sulphur Burners.

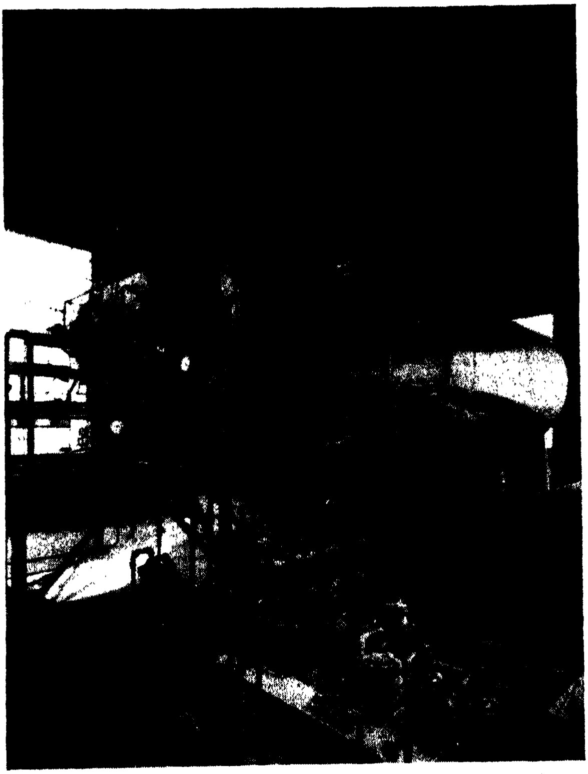
Several different types of sulphur burner are in use. The oldest type, the flat burner, is almost obsolete, nevertheless I will describe it as old installations are still in use in many old mills. These are essentially cast iron retorts, the body consisting of a single casting. The cross section is semicircular or "D" shaped. They are usually about 8 feet long and 2 feet wide on the outside and the maximum height on the inside is about 18 inches. These burners are set in banks in a brick setting. The doors are ranged in a horizontal row at a convenient height from the floor so that the sulphur can be charged into them with shovels. When once ignited, the sulphur maintains combustion if an adequate supply of air is admitted to the burner. This air supply is regulated by dampers in the doors and the regulation must be attended to by a careful and experienced man, because if too much air is admitted there is a tendency to form sulphuric acid which forms sulphates in the sulphite acid which are insoluble and cause trouble in the digester and in the washing of the pulp. Moreover, if too much air is admitted, this excess air dilutes the gas produced in the burners and cuts down the efficiency of the tower system. On the other hand, an insufficient supply of air results in incomplete combustion of the sulphur and this causes sublimation or deposit of unburned sulphur throughout the system, which is troublesome and cuts down the efficiency. The sulphur dioxide leaves the furnace through the pipe which is either bolted to the back of the furnace or else to the top of the arch near the back end.



Courtesy: Glens Falls Machine Works, Inc., Glens Falls, N. Y.

Fig. 55.—Rotary type of sulphur burner.

Owing to the violent changes in temperature inseparable from the operation of sulphur burners of the flat type, there is a notable amount of expansion and contraction in the burner itself. Unless some provision is made to take care of this expansion and contraction, the whole system of pipes leading from the burner will be badly distorted. One device that can be introduced to lessen this evil is to place the burner not directly upon the brick setting but upon rollers which will permit of a certain amount of motion as the burner expands and contracts. Another precaution is to have the flanged joint between the burner proper and the pipe through which the gas escapes more or less flexible. This can easily be done by not having this flange bolted. In this way the two surfaces can slide on each other with some degree of freedom. Of course the two surfaces will have to be practically air-tight as otherwise there would be considerable leakage or infiltration of air.

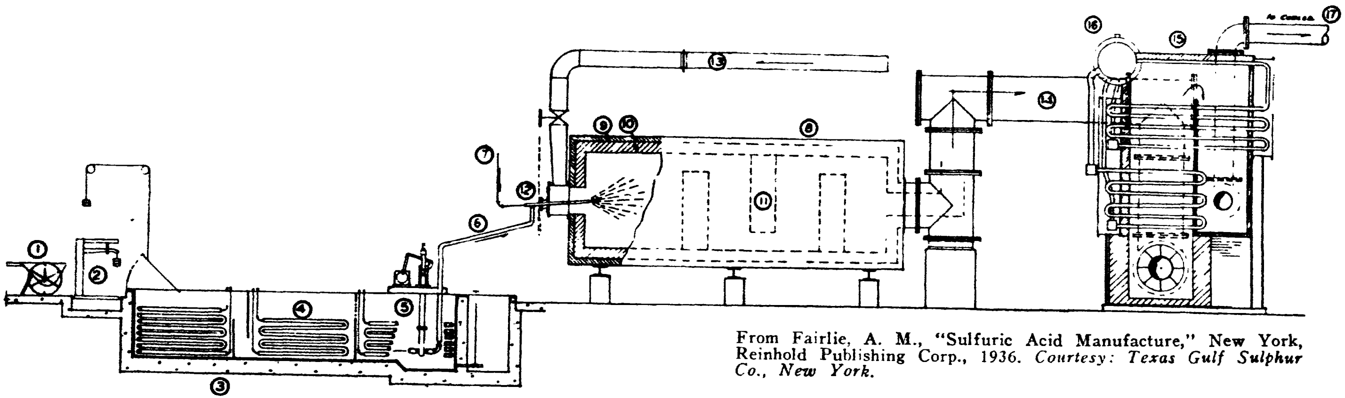


Courtesy: Chemical Construction Corp., New York

FIG. 56.—"Chemico" spray-type sulphur burner installed in sulphite mill on Pacific Coast.

Rotary sulphur burner: This efficient type of sulphur burner was originally developed by Tromblee and Paull. It consists of a cast iron or welded steel cylinder. Fitted to each end of this cylinder is a steel cone. The rear cone connects with a pipe line leading to a steel box lined with fire brick, called the combustion chamber, in which the sulphur gases are mixed with air, and any vaporized unburned sulphur is consumed before the gases go to the cooler. The front cone is fitted with a damper.

In the older forms of this burner powdered sulphur was fed to the burner by a worm from a small bin placed directly above the front cone. In the newer installations the sulphur is melted in a tank equipped with



From Fairlie, A. M., "Sulfuric Acid Manufacture," New York, Reinhold Publishing Corp., 1936. *Courtesy: Texas Gulf Sulphur Co., New York.*

Fig. 57.—Sulphur melting, pumping, spraying and burning equipment of Texas Gulf Sulphur Co.

1. Sulphur buggy.
2. Sulphur scale.
3. Sulphur melting pit.
4. Melting coils.
5. Sulphur pump.
6. Steam-jacketed sulphur pipe.
7. Compressed air pipe.
8. Sulphur burner.
9. Insulating brick.
10. Refractory brick.
11. Baffles.
12. Sulphur spray nozzle.
13. Air intake.
14. Hot-gas flue.
15. Heat-exchanger and boiler.
16. Steam connection.
17. Cooled-gas flue.

steam coils, from which the liquid sulphur is fed to the burner. This tank can be placed over the combustion chamber, thus economizing heat and decreasing steam consumption.

These rotary burners range in size from 8 ft. long and 2 ft. diameter to 15 ft. long and 4 ft. diameter. Two of the latter size will efficiently serve a 100-ton sulphite mill.

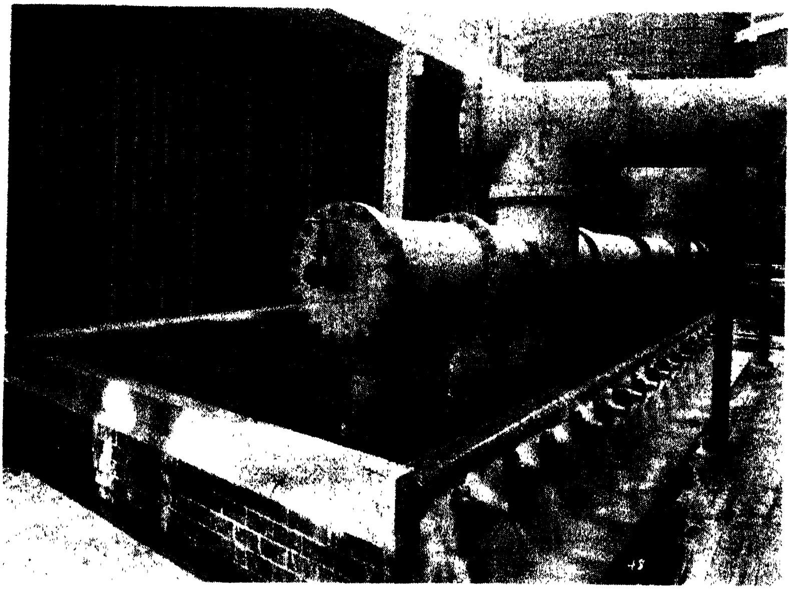
Vesuvius type sulphur burner: This burner consists of a cylindrical steel shell lined with fire brick containing a number of shallow trays. These trays are so arranged that the molten sulphur will drip down from each tray to the one below, burning as it drips. The sulphur is placed in a melting pot at the top of the burner. This melting pot has a needle-point valve in the bottom. A fire is lighted in the top tray and as soon as the sulphur begins to melt the needle-point valve is opened and the sulphur drops down on to the first tray beginning to burn. The heat soon melts all the sulphur in the pot and gradually the valve is opened wider and wider and the burning molten sulphur drips down from tray to tray until it enters the bottom chamber where the ashes and impurities collect. Each of the chambers is provided with a door fitted with a damper for the admission of air. From the burner the gases pass to a combustion chamber wherein the sulphur fumes undergo a final combustion. One of the advantages of this type of burner is that it does not require any power to operate. Moreover, no hand firing is required. All ashes or impurities called "slag" are automatically carried to the bottom of the apparatus where they can easily be removed.

Coolers.

From the combustion chamber the sulphur gas is led to the coolers. It is necessary to cool the gas to about 25° C. before entering the towers. If the air supply has not been carefully regulated sulphuric acid will be formed in the coolers. The volume of air required to burn one pound of sulphur to 15 per cent SO_2 gas is 78 pounds or 9 cubic feet. The burner should be so regulated that about 15 per cent SO_2 gas is formed in the burners. The combustion chamber should be as large as possible and should contain baffles to collect the dust and sublimed sulphur.

If the above precautions have been observed and the gas is properly made it will be cooled in the coolers without any considerable contamination with sulphuric acid and will also be free from sublimed sulphur.

There are numerous types of coolers in use. One type consists of a system of lead pipes flanged to lead headers. The gas enters at one end of the header and passes through the pipes and out through the header at the other end. This whole system of pipes is contained in a vat or pond and the water supply is arranged so that the water enters at the end opposite to the gas entrance. In some cases the system of pipes is only partially immersed in water and is showered with water from sprays. This is much better practice than merely depending on the water in the tank to cool the pipes. On account of poor circulation the water nearest to the pipes will become heated and remain so and the maximum cooling effect will not be obtained, whereas with the spray system fresh water is constantly dripping over the pipes and is also being cooled by evaporation owing to the finely divided water being constantly brought in contact with the air. A very efficient form of cooler is the Sandberg cooler furnished with the Jenssen acid system. This cooler consists of a header and a series of lead pipes placed in a concrete tank filled with water. The gas enters the header and passes through the pipes which stand horizontally and are connected at the top by U bends. Water is sprayed into the top of the cooler and flows down the pipes and out through the concrete tank into the sewer or is



Courtesy: G. D. Jenssen Co., New York and "Pacific Pulp and Paper Industry," Seattle, Wash.

FIG. 58.—Lead gas coolers installed in Jenssen acid system at Florida mill.

otherwise utilized. If the lead pipes are kept in a good state of repair, this water will be perfectly pure and can be used for washing purposes or as boiler feed water, thus utilizing the heat given up by the sulphur gas. This type of cooler is not only very efficient but is easily cleaned as the top of the cooler is readily accessible and the U bends can be taken off and the entire system of tubes cleaned whenever necessary.

The cooler should be as near the combustion chamber as possible so that the cooling of the gas will be rapid. Slow cooling tends to produce sulphuric acid. This is on account of the fact that the best temperature for the formation of sulphuric acid is from 200° C. to 900° C., and on this account the gas should be produced at as high a temperature as possible in the sulphur burner, and then cooled as rapidly as possible in the coolers, so that there is never at any time any considerable volume of gas within the range of temperature favorable to the production of sulphuric acid.

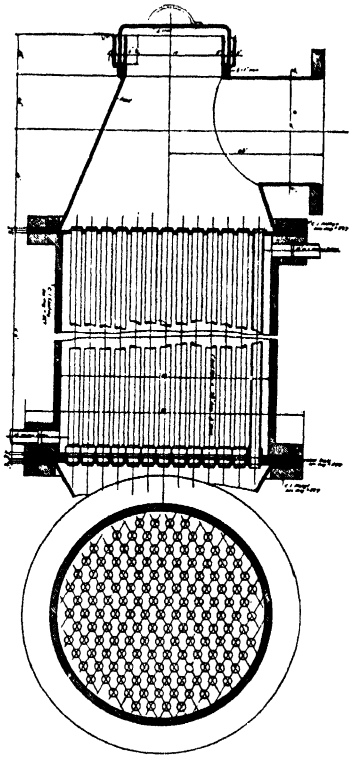


FIG. 59.—
Diagram showing the construction of Sandberg cooler.

Courtesy:
G. D. Jenssen Co., New York

Absorption Equipment.

There are two chief classes of equipment in which the sulphur dioxide gas is brought into contact with the lime and thus converted into acid for use in the digester.

One form of equipment is generally known as the milk-of-lime system. In this system the gas is brought into contact with water containing the lime in suspension. The second and more modern system of acid making is known as the tower system. In this system the gas is brought into contact with limestone, not lime, in the presence of water.

In the milk-of-lime systems the gas first dissolves in the water and the solution immediately reacts with the lime to form monosulphite which is quite insoluble and separates from the solution. The formation of monosulphite goes on in the tank until all of the lime is precipitated in this form. As the addition of gas continues, the monosulphite gradually takes up more sulphur dioxide gas forming bisulphite which, unlike the monosulphite, is readily soluble in water. Unfortunately sulphur dioxide gas in solution tends to form sulphuric acid and in practice there is always formed, together with the bisulphite, more or less sulphate which is insoluble and remains in the acid as a white precipitate, commonly called "gypsum." This precipitate gives a great deal of trouble in the acid and in the digesters. Although it is generally regarded as insoluble, it is not absolutely so and a sufficient amount of it dissolved in the acid afterwards separates out in the digester, where it frequently plugs up in the bottom connections of the digester causing trouble when the digester is to be blown. The removal of this gypsum is a matter of great difficulty, as when it is allowed to accumulate it has to be chipped out with a hammer and chisel. This is troublesome and expensive and involves shutting down the digester, and also is hard on the lining. Sometimes the gypsum will close up the outlet from the digester to such an extent as to make it very slow and difficult to blow out the stock. From the above considerations it will be realized that every precaution should be taken to prevent the formation of sulphate or gypsum in the acid. This can only be guarded against by accurate chemical control of the acid plant and by constant watchfulness on the part of the entire operating force. The cause of sulphate or gypsum in the acid may, as can be seen from the above considerations, lie with the operation of the sulphur burners or the coolers or the milk-of-lime or tower system. If difficulty is found in keeping the acid free from sulphate all of the above possible causes should be carefully investigated.

Milk-of-Lime Systems.

The best known milk-of-lime systems are the Stebbins, Barker, and Burgess systems.

Stebbins System: This is a three-tank system, the tanks being placed one upon the other. The system can be intermittent or continuous but the continuous systems are preferable. The gas is drawn through the system by a vacuum pump which exhausts the excess gas from the highest of the three tanks.

In the continuous Stebbins system, milk-of-lime is supplied to the top tank and flows through the two lower tanks. The gas enters the lowest tank, passes through the solution, is piped from this tank to the bottom of the second tank, through which it then bubbles in the same manner, and finally through the upper tank. The milk-of-lime is prepared by agitating the lime with hot water in an iron tank provided with an agitator. This tank discharges into a large wooden tank also provided with an agitator in which the milk-of-lime is diluted with fresh water to a density of 1° Baumé. From this tank it is passed through a filter into a storage tank where it is held until required for the absorbing system. Provision is made for drawing samples from the lowest tank. The Stebbins system is passing out of use on account of the invention of more efficient equipment.

Barker System: This system is the most generally used of the various tank systems. It is a four-tank system, the four tanks being placed one above the other. The milk-of-lime is pumped into the top tank and overflows in succession into the second, third and fourth tanks. From the bottom of the fourth tank it is pumped to the top of a recovery system to be described later.

The gas enters the bottom of the lowest tank, passes through the solution into the bottom of the second tank and in the same manner into the third and fourth tanks. Just as in the Stebbins system, the gas is drawn through the system by means of a vacuum pump connected to the pipe by which the excess gas is removed from the highest tank.

In the Barker system the tanks are placed one directly above the other in a tower. In actual practice four tanks are not used, but one tall tank divided into four compartments by means of partitions. The recovery or reclaiming system used with the Barker milk-of-lime system is practically the same as that used with tower installations to be described later.

The advantages of the Barker system over other milk-of-lime systems are compactness, lessened expense for repairs and greater ease of cleaning. It is also easier to operate the Barker system in a continuous manner than other milk-of-lime systems. However, while probably the best of the milk-of-lime systems, this system exhibits many disadvantages when compared with tower systems. These disadvantages will be more readily understood after the tower system has been discussed. They are more usual in Europe than in America.

Beveridge[1] says that the finished milk-of-lime has a specific gravity of 1.0075 and contains 6.31 grams per liter of CaO and 4.19 grams per liter of MgO corresponding to 91 lb. lime per 1,000 gal. acid.

Burgess System: In this system the gas is admitted through hollow agitator arms which are rotated in the tanks. In other respects it is almost exactly like the Barker system.

Tower Systems.

The earliest forms of acid making equipment were tower systems, the towers consisting usually of high wooden columns of circular cross section. The towers were filled with lumps of limestone or dolomite, the latter mineral being a limestone which contains a high percentage of magnesia. The gas from the sulphur burner entered the bottom of the tower and rose in an irregular manner, its passage upwards being intercepted and broken by the limestone. Water was sprayed into the top of the tower in such a manner that it would flow down through the tower, covering all the pieces of limestone with a film of water as it flowed.

The engineering difficulties connected with the construction and maintenance of towers were so numerous and so formidable that the earlier types of towers, such as those designed by Mitscherlich, Ritter and Kellner, etc., were largely abandoned in America in favor of the milk-of-lime systems previously described.

However, with improved facilities for constructing towers, the system has come back into favor to such an extent that it has largely supplanted milk-of-lime systems in the majority of sulphite mills. The most efficient tower system is the Jenssen, the towers of which are constructed of reinforced concrete, lined with acid resisting tile. They are slightly con-

[1] Beveridge: Papermakers' Pocket Book, p. 99.

ical in form in order to prevent packing of the limestone. Single towers have been largely superseded by two, three and four tower systems. The two tower system is most usual. The three tower system is exactly the same as the one to be described here except that one tower is always idle in reserve for cleaning and filling. In the four tower system one tower is always idle and of the other three two are used as strong towers, the other one being a weak tower. The writer discerns little advantage in three or

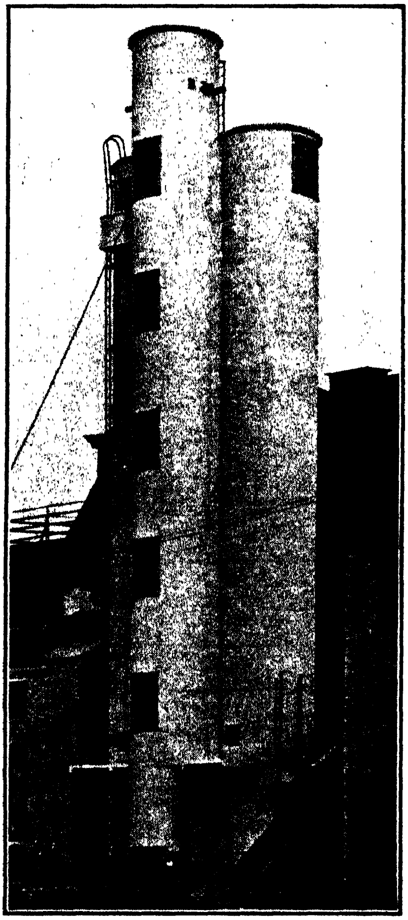


FIG. 60.—
A recent installation of Jenssen towers.

Courtesy:
G. D. Jenssen Co., New York

four tower systems to warrant the increased first cost. Some mills desiring very strong acid (high free SO_2) at all times, have introduced special pressure absorbers made of acid-resisting material (brick or stoneware or lead-lined steel) ahead of the usual towers. Some mills also refrigerate the tower acid to enable them to maintain a higher free SO_2. Such expedients are unusual, however.

The following is a description (for which we are indebted to the G. D.

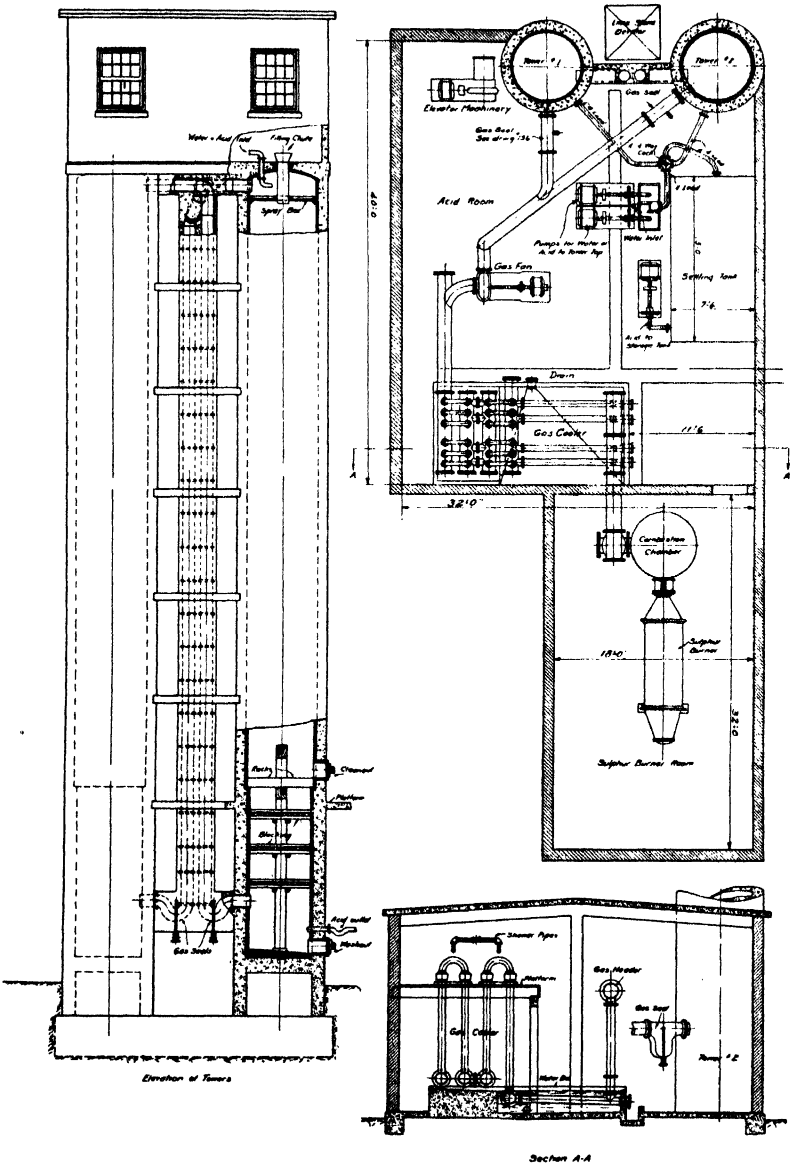


FIG. 61.—Diagram showing construction and operation of Jenssen tower system.

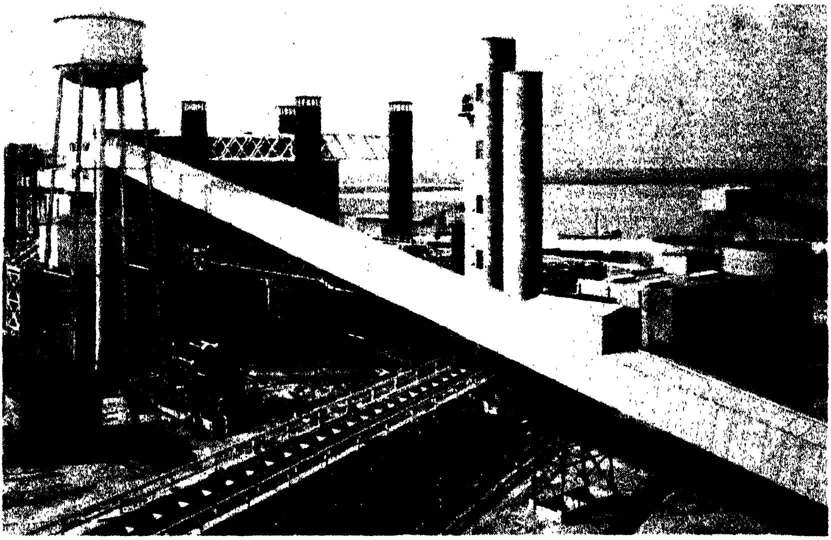
Jenssen Co.) of a typical two tower installation. A lead covered steel fan, directly connected to a variable speed motor so as to allow the capacity of the plant to be carried at any desired point, blows the sulphite gas through the concrete towers which work in series. After the gases have passed through the first tower, they enter the second tower at the bottom through a tile pipe. The unabsorbed gases (carbonic acid, nitrogen, oxygen) pass out into the air through a pipe on top of a second tower. The feed water is distributed from the top of the second tower in which it forms a very weak acid, which is pumped into the first tower where the finished acid is made. The grates on which the limestone rests are elevated from 17 to 20 feet above the gas inlets and the space between the gas inlet and these grates is filled with a wooden checker work fixture. The reason for this arrangement is to allow the acid to be saturated with free SO_2 before the gas strikes the limestone. Careful experiment has shown that from 17 to 20 feet of wooden checker work is sufficient to bring the acid to the point of saturation. Raising the grate still higher would not influence the content of free SO_2 to any extent. By arranging the towers in this way, it has been possible to produce with 15 to 16 per cent gas and a water temperature of 5° C. a tower acid containing 4.5 per cent total SO_2, 3.1 to 3.2 per cent free SO_2 and such an acid in connection with a proper reclaiming system and proper operation of the digester relief, brings the percentage of total SO_2 in the cooking acid up to 7 per cent or higher.

When the towers have been in operation two or three days they are reversed, the second tower being used as the first and vice versa. This allows the first tower to be charged with limestone as the cover on top can be removed after creating a slight vacuum with a steam jet, the gas in this way being prevented from entering the charging room. The high efficiency of this system is demonstrated by the fact that over 90 per cent of the gas is absorbed in the first tower, the towers being operated under forced draft and with a large volume of water. For this reason it has been found that cleaning the limestone grates is a thing of the past. The system can be shut down on Sunday morning and started up on Monday without any cleaning whatever. With this system the regulation is very simple, there being only one water valve to attend to, and the system is frequently run from ten to twelve hours without changing the water valve.

The flexibility of the system is as great as any milk-of-lime system. If a higher content of combined SO_2 is desired in the acid this can be done in two ways, either by heating the feed water so as to accelerate the chemical actions in the towers or by recirculating some of the acid from the first tower back to the top of this tower again which will raise the lime content to any desired point.

The above arrangement of the towers is used where a straight calcium limestone not exceeding 8 to 10 per cent magnesium carbonate is at hand. Where a limestone or dolomite containing as high as 40 to 45 per cent magnesium carbonate is to be used, tower construction has to be changed. It is well known that calcium carbonate is easier to dissolve than magnesium carbonate, and due to this lack of uniformity in the solution of magnesium and calcium carbonate, the latter is first attacked by the gases with the result that the surface of the stone crumbles and a sludge is formed. In order to dissolve this sludge the grates, when a limestone high in magnesia is being used, should be elevated 40 feet above the gas inlets and four towers should be used in order to obtain sufficient capacity to cover the slower absorption ability of the high magnesia stone.

Until recently, it has been the opinion of many that acid high in magnesia was to be preferred. The explanation of this has been that magnesium bisulphite is decomposed easier by steam in cooking than calcium bisulphite and that the sulphates of magnesia are soluble whereas the sulphates of calcium are insoluble. Possibly these facts had a bearing on the quality of pulp produced in former days when sulphite mills used acid low in free SO_2 and high in lime. Today, however, with excellent means of reclaiming the digester gases and obtaining cooking acid containing from 5 to 7 per cent total SO_2, the preference for magnesia over calcium has, in the writer's opinion, absolutely disappeared. Mills which have changed from milk-of-lime to straight calcium limestone have confirmed the above experience.



Courtesy: G. D. Jenssen Co., New York and "Pacific Pulp and Paper Industry," Seattle, Wash.

FIG. 62.—Jenssen acid towers at Florida mill showing limestone conveyor in left foreground; also chip conveyor crossing picture diagonally from lower right to upper left.

One of the advantages of the tower system is lower sulphur consumption. The tower system is very flexible compared with the milk-of-lime system. The output or the composition of the acid can be changed easily by any one of a number of means such as changing the volume of water admitted to the towers, altering the temperature of the water, increasing or decreasing the speed of the fan or vacuum pump, etc. The upkeep of the tower systems is much more economical than that of milk-of-lime systems. In the milk-of-lime systems sulphate or gypsum forms quickly and plugs the holes in the bottom of the tanks, the connecting pipes, etc. Acid of much higher strength can be made in the towers than is possible with the best milk-of-lime systems. Moreover, the cost of lime is high compared with that of limestone. Furthermore, limestone is not subject to deterioration while lime slacks, especially in the summer time, and requires special storage facilities. Also, whereas the limestone is constant in chemical composition, the lime is constantly changing and it is impossible to estimate the quantity of lime to use in a milk-of-lime system without making new calculations on the basis of frequent and careful chemical analysis of raw materials.

Efficiency of Tower Systems.

The tower system offers the great advantages of economy in power and materials, ability to adjust itself quickly and easily to changes in manufacturing conditions and reliability in operation.

It is stated by Henry F. Obermanns [1] that in changing from a three tank milk-of-lime system (five of which systems were required for a 100-ton mill) to a tower system the following advantages were derived: "Each tank system had its own vacuum pump requiring about 35 hp. or a total of 175 hp. for vacuum pumps alone. To this is to be added another 150 hp. for agitators for the various tanks. On the other hand, the entire power necessary for the operation of the tower system amounts to about 50 to 60 hp. for the operation of the fan and water pumps. This means a saving of from $10,000 to $12,000 per annum. With the old system operating continuously sulphur consumption ran about 15 per cent on basis of bleached pulp, or about 300 pounds of sulphur per ton. With the towers the consumption is from 11¾ per cent to 12 per cent. Further saving is in the substitution of limestone for burnt lime. Wear and tear is very small as compared with constant repairs and replacements with the old system. In labor there is no particular saving, as no men could be eliminated with the introduction of the towers, but the acid-maker was left with no manual labor to perform, thus being free to devote all his time to proper supervision."

Proper Strength of Acid.

Very divergent views are held as to the proper strength of acid and the proper proportions of free and combined. It used to be thought that acid should have a high combined. A usual analysis in the old days was 4.00 per cent total, 2.75 per cent free and 1.25 combined. In such an acid only 70 per cent of the total is free. Modern acid makers like to have anywhere from 78 to 88 per cent of the total acid in free form.

The writer, after lengthy experimentation, has come to use an acid, with wet wood and a cook of ten to ten and a half hours duration, analyzing 4.65 per cent total, 3.50 free and 1.15 combined; for dry wood, total 4.39 per cent, free 3.25 and combined 1.10 to 1.15. By wet wood we mean wood containing approximately from 40 per cent to 50 per cent moisture and by dry wood we mean wood containing 27 per cent to 35 per cent moisture. The above strengths are the strengths of the cooking acid. The strength of the raw acid is about 3.60 per cent total, 2.18 per cent combined and 1.42 per

[1] Technical Association Papers, 1918, p. 28.

cent free in the case of the wet wood; and 3.86 per cent total, 2.37 per cent free and 1.49 per cent combined in the case of the dry. This acid is made at about 4.5° Be. the strength being brought up to the total mentioned with reclaimed acid. For cooking bleached stock stronger acid with a combined of 0.9 to 1.1 per cent and a free of 4.5 to 5.0 per cent giving a total of about 6 per cent is preferable. The above figures are for unbleached stock and are all based on the use of ¾-inch chips which run from 55 to 60 per cent within this specified length and it is also assumed that dry steam is supplied, generated at 150 pounds boiler pressure and with a pressure of from 60 to 68 pounds of dry steam on the digesters.

However, the above just applies to certain grades of sulphite requiring definite strength and quality. The writer would not hesitate to use stronger or weaker acid were the conditions different. Newsprint can be made with weaker acid, particularly if the wood is dry. R. E. Cooper states [1] that an acid (raw) analyzing total 3.50 to 4.00 per cent, free 2.40 per cent and combined 1.30 to 1.60 per cent is satisfactory for newsprint. This acid when strengthened with reclaimed acid analyzes from 5 to 6 per cent total, 4 to 5 per cent free and about 1 per cent combined. Robt. B. Wolf [2] states that one summer the acid in the plant he was operating dropped from 6 per cent to 4.25 per cent and the decrease in the strength of the pulp was so noticeable as to cause several of the mill's customers to inquire as to the cause. When a refrigerating plant was installed and the acid went up to over 5.5 per cent the strength test of the paper immediately increased from 65 to 85. Mr. Wolf explains these results on the grounds of the higher maximum temperature and increased cooking time needed with the weaker acid. He states, moreover, that the consumption of wood per ton of sulphite was markedly affected. With the strong acid it took 1.65 cords of wood to make a ton of bleached sulphite, whereas with the weaker acid it took 2 cords.

The combined should be kept above 1 per cent if possible, certainly above 0.9 per cent. A lower combined will mean using much more bleach in making bleached sulphite and also the pulp will be of poorer quality. It has been stated by Prof. McKee that letting the combined drop to below 0.8 per cent will double, or even treble, the bleach consumption, Dr. Bjarne Johnsen recommends from 0.9 to 1.1 per cent combined.

Strong acid means a higher sulphur consumption. Modern reclaiming systems make possible the maintenance of acid strengths that would have been out of the question before such systems were used, but with the best reclaiming systems there is a direct relation between the sulphur consumption and the strength of the acid. For one thing, it is not always possible to relieve all of the gas to the reclaiming system before blowing. In one mill the conditions are such that the digesters have to be blown very light to keep the temperature down. This involves blowing at a time when the acid tests 1.6 per cent free, which means blowing sulphur into the air at the rate of about 150 pounds per ton of pulp. Systems for reclaiming

[1] Guide to Sulphite Pulp Manufacture. Paper, Inc., New York, 1918, p. 26.
[2] Technical Association Papers, 1918, p. 62.

the fumes from the blow pits have been devised to take care of just such cases as this.

Theoretically 190 pounds of sulphur should be required to make 1 ton of spruce sulphite pulp. Most American mills use much more, some as much as 300 pounds. E. R. Barker states that certain Scandinavian mills make good pulp using less than 190 pounds.

Superheated Steam.

Some pulp makers favor the use of superheated steam in the digesters. It is certain that its use facilitates the maintenance of the strength of the acid, but on the other hand there are numerous disadvantages. Further comments on this subject will be found in the chapter on the power plant.

Reclaiming Systems.

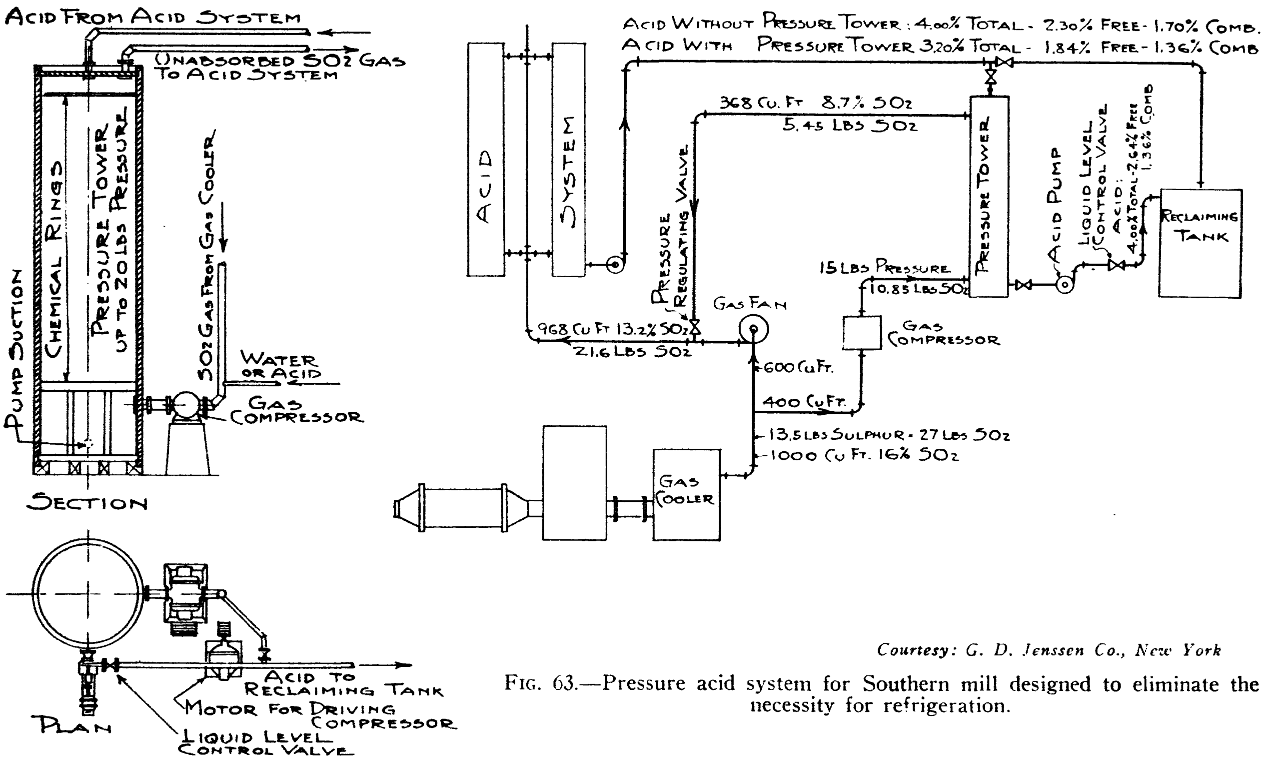
Recovery towers are the chief feature of the reclaiming system. These are usually of concrete and may be filled with wooden checker work or with logs or with chemical stoneware rings. Dilute acid from the tower system is pumped into the top of the reclaiming tower and flows down it, meeting and absorbing the gas from the relief lines of the digesters. The liquid never absorbs all the gas and the unabsorbed gas fills the space in the tower above the liquid. This makes a pressure of gas on the liquid which enables it to hold more gas in solution than if air were present above the surface of the liquid, which is an advantage.

The reclaiming of the relieved liquor is very simple, as it is simply run to tanks, from which it is mixed with the raw acid.

The gas, however, has to be cooled before going to the reclaiming towers. The coolers are similar to those used for the cooling of the gas from the burners. The effect of temperature on the strength of the acid is very marked. Reference to the diagrams in Figs. 53 and 54 (p. 150) show how rapidly the solubility of sulphur gas in water decreases as the temperature rises. Whereas at 0° C. 1 volume of water will dissolve approximately 80 volumes of sulphur gas, at 40° C. it will only dissolve about 19 volumes. Consequently cold water should be used in the towers, the reclaiming system should be kept cold and all pipe lines containing raw or cooking acid should be laid out with this in view. In some mills refrigerating systems have had to be installed to keep up the strength of the free acid in summer.

Pressure and Vacuum.

The milk-of-lime systems were worked under vacuum. That is, the gas was drawn through the system, not forced through it. One milk-of-lime system was introduced operating under pressure (that of Francke) but it had other drawbacks that prevented its wide application. Theoretically the tower systems are pressure systems, but the pressure is so low that it has no effect one way or the other on the strength of the acid. With milk-of-lime systems, however, pressure is much preferable to vacuum as it will



Courtesy: G. D. Jenssen Co., New York

FIG. 63.—Pressure acid system for Southern mill designed to eliminate the necessity for refrigeration.

permit of an acid much higher in free SO_2. Pressure systems are more used in Europe than in America.

Acid Storage Tanks.

An adequate supply of uniform cooking acid must be on hand at all times. For a 100-ton mill at least 4 wood tanks of sound construction and at least 48,000 gal. capacity should be installed. They should be interconnected with lead pipes fitted with lead valves, preferably of the lubricated type. Each tank should have a manhole at the top and a test cock at a convenient position and either a set of gauges or a liquidometer installation so there can be no uncertainty as to the amount and strength of acid on hand. The acid from the tower system should enter the bottom of the storage tank most remote from the one from which acid is drawn for the digester. Concrete tanks lined with tile, and tanks of acid-resisting brick are also being used for this purpose.

Burning Pyrites instead of Sulphur.

Pyrites is sulphide of iron, containing about 54 per cent sulphur and 46 per cent iron, when pure. Commercial pyrites is rarely pure. The mineral pyrite is mixed with other sulphides and with ordinary rock. However, in most parts of the United States and Canada, supplies of pyrites can be obtained yielding from 33 per cent to 48 per cent sulphur.

The possibility of burning pyrites instead of sulphur in pulp mill acid plants is probably chiefly interesting in Canada, since there are no deposits of sulphur in that country and the pulp mills there secure all their sulphur from the deposits of the southern United States. However, as the practice develops it may become very interesting to mills located in those portions of the United States remote from the sources of supply of sulphur and near satisfactory pyrites deposits. Several Scandinavian mills use pyrites with excellent results.

The manufacturers of sulphuric acid have developed the art of burning pyrites to a high degree of efficiency. However, several conditions enter into the burning of this material for pulp mill purposes that are not met with in the sulphuric acid plant. The manufacturer of sulphuric acid is pleased rather than otherwise if some of the sulphur burns to SO_3 in the pyrites furnaces. The pulp manufacturer has to avoid that condition. Temperatures have to be carefully regulated. Some pyrites ores contain a metal known as selenium and the presence of this in even very small proportions is detrimental as it causes the SO_2 to oxidize to SO_3, thus forming sulphates in the digester acid. The presence of copper is also undesirable.

There are a number of pyrites burners on the market, possibly the best known of these being the Herreshoff Furnace and the Wedge Furnace. Both of these are mechanically operated furnaces with circular hearths on which the ore being roasted is stirred with rotating arms. It is not necessary to describe these furnaces here in detail as anyone interested in the possibilities of pyrites in the pulp mill will find detailed information on such equipment in standard text books on metallurgy and the manufacture of sulphuric acid.

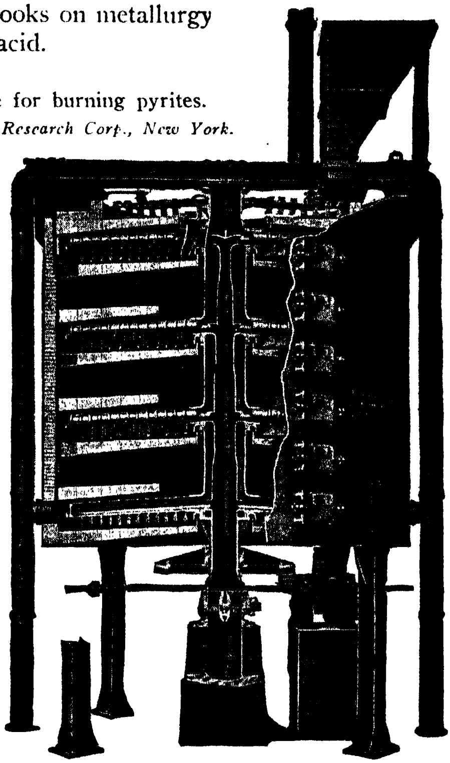
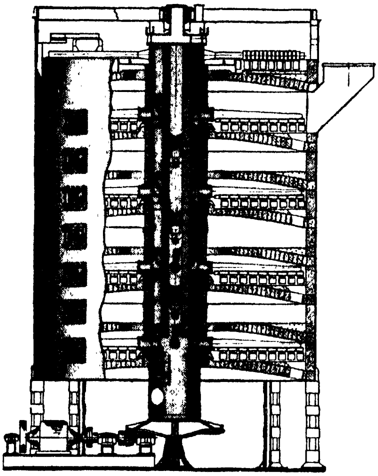


FIG. 64.—Herreshoff furnace for burning pyrites.
Courtesy: Nichols Engr. & Research Corp., New York.



Courtesy: Bethlehem Foundry and Machine Co., Bethlehem, Pa.

FIG. 65.—Wedge furnace for burning pyrites.

Furnaces of the rotary kiln type have also been used, the best known of these being the Jones which has been used in sulphite mills in Canada.

Pyrites burners will not yield as rich a gas as sulphur burners. About the best they will yield is 12 to 16 per cent SO_2. On the other hand, there is less free oxygen in the gas, which is an advantage. A mill contemplating using pyrites should have a large tower capacity, since about 30 per cent more gas will have to be passed through the towers to produce acid of a given strength. Also very cold water for the towers is a requisite. Granted these conditions good pulp can be made using pyrites in the acid plant. It is all a matter of comparative costs. First cost of the equipment is high.

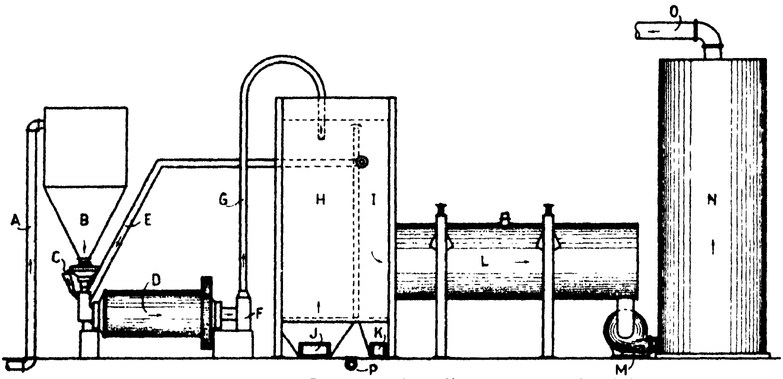
According to Dr. A. W. G. Wilson,[1] of the Canadian Department of Mines, a pyrites burning equipment for a 100-ton sulphite mill would consist of:

Two mechanical roasters, provided with hopper feeds, belt conveyors for charging ore to the hoppers and removing cinders to the cinder bin. Main flue, with dust discharge hoppers. Dust chamber, with dust discharge hoppers. Auxiliary cooler, with dust discharge hoppers. Fan, driven by variable speed motor. Scrubbers, with liquor tank and centrifugal circulating pump, and driving motor.

[1] Paper read before the Technical Section of the Canadian Pulp and Paper Association, Montreal, Jan. 30, 1918. Reprinted in "Paper," Feb. 13, 1918, pp. 102-134.

Assuming three shifts per day, three furnace men and three laborers will be required in constant attendance. In addition the mechanical equipment will require daily inspection by a machinist and occasional repairs and adjustments.

Dr. Wilson makes some careful calculations of the cost of pyrites burning as compared with sulphur and comes to the conclusion that for Canadian 100-ton mills, paying $30 or more per ton for sulphur, that a daily saving of $163 would be possible. This would pay the interest and depreciation on the plant and yield a very satisfactory profit.



Courtesy: Canadian Institute of Mining and Metallurgy

FIG. 66.—Freeman flash roaster and steam boiler.
Plant capacity, 1,500 lbs. pyrite per hour; floor area, 900 sq. ft.; maximum motor load, 25 hp.
From: Fairlie, A. M, "Sulfuric Acid Manufacture," New York, Reinhold Publishing Corp., 1936.

KEY TO DRAWING

A. Pneumatic conveyor.
B. Feed hopper.
C. Disc feed.
D. Air-swept mill and dryer.
E. Hot air pipe.
F. Fan.
G. Fuel pipe.
H. Combustion chamber, primary.
I. Combustion chamber, secondary.
J. Cinder discharge and air port.
K. Dust outlet.
L. Fire-tube boiler, 75 hp.
M. Exhaust fan.
N. Scrubber and cooler.
O. Lead duct to lime tower.
P. Pneumatic conveyor for calcines.

Nichols-Freeman Pyrites Burning System.

This system, developed in Canada, is similar to a pulverized coal installation. Pyrites is ground very fine in a tube mill. Preheated air blows the pyrites powder into a vertical refractory-lined kiln, the entrance being at the top. Air is blown in at the bottom. As the glowing pyrites particles fall they meet this air and combustion is completed. The iron oxide and ash drops to the bottom and is carried away by a conveyor. The hot gases pass through an arrangement of baffles and thence to a waste heat boiler. According to Fairlie [1] this 125 hp. boiler will deliver steam at 160 pounds to the mains of the paper mill—approximately one pound steam per pound of pyrites and enough to cover the operating cost of the installation.

[1] Fairlie, A. M., "Sulphuric Acid Manufacture," p. 117, New York, Reinhold Publishing Corp., 1936.

8. The Alkaline Processes

The two alkaline processes for making chemical pulp—the *soda* process and the *sulphate* or *kraft process* may well be considered together to avoid needless repetition. The recovery of soda from the process liquor, a matter of greatest economic importance in this branch of the industry, is much the same for both processes.

First, however, let us get clearly in mind the differences between the two processes.

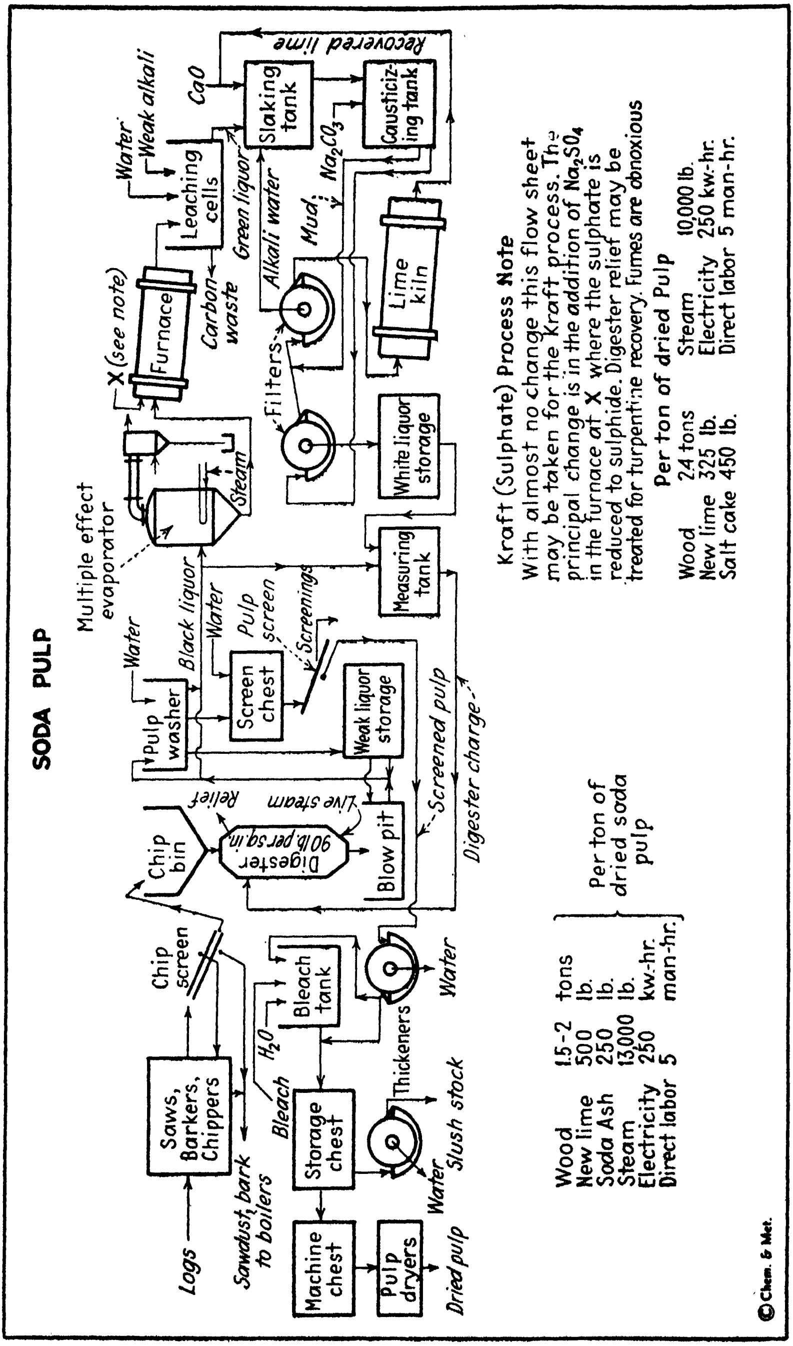
COMPARISON OF THE ALKALINE PROCESSES

Soda Process	*Sulphate or Kraft Process*
1. History: Developed by Watt and Burgess in England 1853-1854. Introduced in America shortly thereafter.	1. History: Developed by Dahl in Danzig 1879 in searching for a cheaper make up chemical for the soda process. Not introduced in America until 1907.
2. Wood Used: Mostly broad leaf woods such as poplar, birch, maple, chestnut, etc.	2. Wood Used: All kinds of wood usable but specifically coniferous wood, as yellow pine, jack pine, tamarack, spruce, hemlock, and fir.
3. Chips: Chip size more critical, $\frac{3}{8}''$ to $\frac{7}{8}''$ length.	3. Chips: Not so particular about chips; can be longer, $\frac{5}{8}''$ to 1″ long.
4. Use of Pulp: Book, magazine, and absorbent papers. Soft short fibered pulp.	4. Use of Pulp: All high test paper and board, bag and wrapping paper. Fibers longer and stronger. "Kraft" meaning strength. Recently progress being made rapidly in production of bleached kraft suitable for news, book papers, etc.
5. Make up chemical, caustic soda or soda ash.	5. Make up chemical, salt cake, Na_2SO_4.

The Soda Process.

The soda process for the manufacture of chemical wood pulp depends on the chemical fact that alkali at high temperatures will dissolve all the other constituents of wood except the cellulose, leaving the latter in a form suitable for paper manufacture.

The soda process is much older than the sulphite process and is, of itself, simpler. However, in order to be carried on at a profit, it is necessary to recover the soda and most of the problems of soda pulp manufacture are connected with the operation of the recovery department.



Courtesy: Chemical and Metallurgical Engineering, New York.

Not only is soda pulp necessary for certain varieties of paper, but the soda process will serve to utilize many kinds of wood that cannot profitably be dealt with by the sulphite process.

Poplar is the principal kind of wood used for soda pulp, but practically all of the broadleaf woods and some spruce, pine, hemlock, etc., are also worked up by this process; also residues from extracting chestnut chips, etc. for tanning extract.

It is not necessary to prepare the wood so carefully for the soda process as for the manufacture of sulphite pulp. The bark is removed, but it is not generally considered necessary to exercise the extreme care to get rid of all the small particles of bark that is usually exercised in making good sulphite. No attempt is made to eliminate knots or decayed wood. The more drastic solvent power of the soda lye readily reduces even knots and bark.

The wood is chipped just as for the sulphite process, except that the chips are usually a little smaller, being from $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in length. The chips are screened in exactly the same manner as for sulphite pulp and are then conveyed to chip bins ready to be placed in the digesters.

In the older soda mills rotary digesters, either horizontal or spherical, similar to those used for boiling rags, were extensively used, heated with steam coils, the steam entering through the trunnions and the coils rotating with the digester. They were of small capacity and the cost of upkeep was high. The digesters were constructed of steel plate without any special lining, as steel plate resists the action of alkali about as well as any metal.

These rotary digesters have largely been replaced by stationary vertical digesters, similar to those used for the sulphite process, but usually somewhat smaller, although some soda pulp mills are now using very large digesters, even larger than the usual sulphite digester. In most cases the direct cook is used in these digesters, live steam being introduced at the base of the digester. However, in a few cases jacketed digesters have been employed.

Trouble has been occasioned by the impossibility of keeping ordinary riveted steel plate digesters tight when filled with soda lye. Although steel plate resists the soda lye very well, leaks develop where the shells are riveted, presumably because of electrolytic action set up between the shell and the rivets, the composition of the two being sufficiently different to cause this effect. With a jacketed digester, if the steam pressure is kept in excess of the pressure within the digester, any leaks will be inwards and comparatively harmless.

Welded digesters are now being used by some of the large manufacturers of soda pulp with conspicuous success. These digesters provide entire freedom from leakage. The size in which such digesters can be furnished is constantly increasing, as the art of welding advances, and some have been made sufficiently large for use in the sulphite process.

Systems for circulating the liquor have been employed a good deal in connection with the soda process. One important mill uses steam injectors for this purpose. The indirect process, whereby the liquor is heated in a separate heater and pumped through the digester has been used for the soda process with considerable success in Europe and is now being introduced in America. This process has the advantage that the liquor is not diluted and consequently the evaporating problem in the recovery plant is simplified. Difficulty has, however, been encountered in discharging the digesters and it is usual to complete the process with live steam.

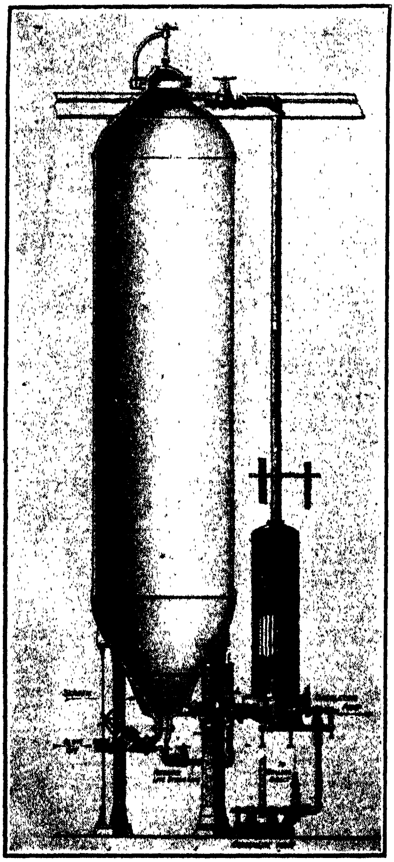
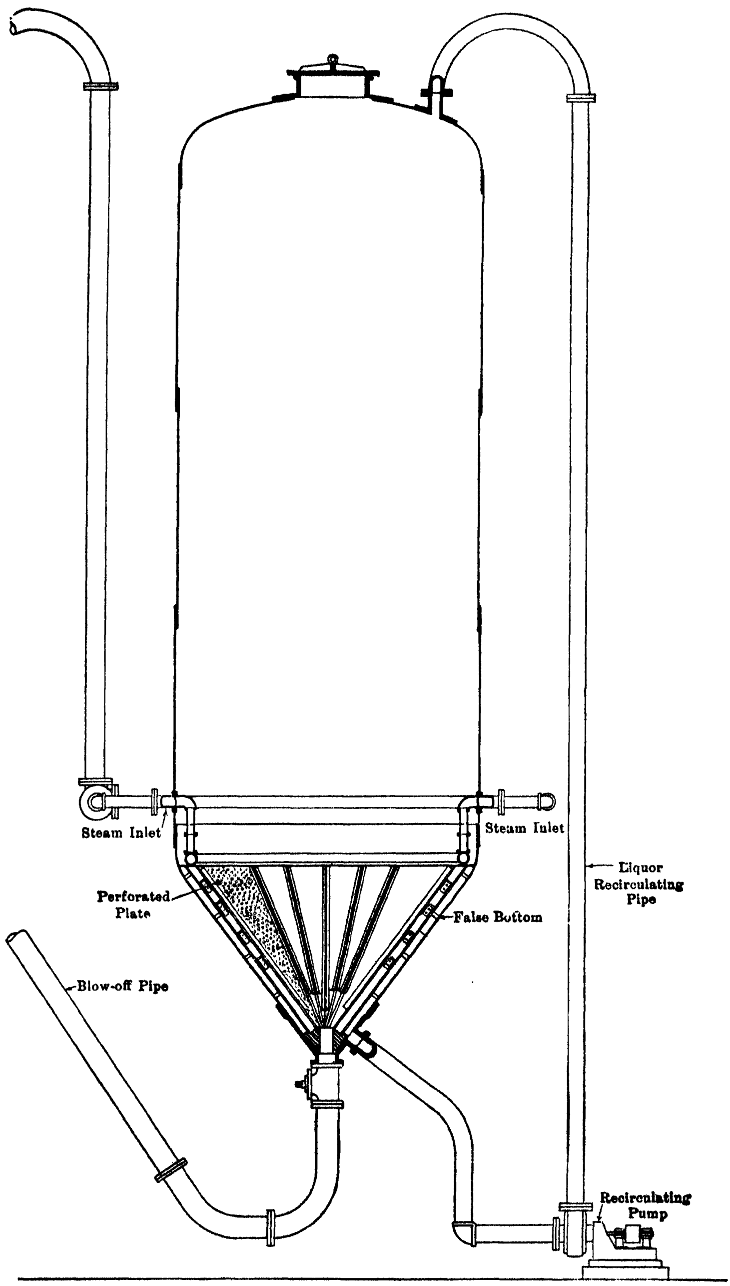


FIG. 67.—Soda or sulphate process digester arranged for indirect cooking.

Courtesy: Fibre Making Processes, Inc., Chicago, Ill.

A digester of the stationary type 7 feet in diameter and 29 feet high holds about 3½ cords of chips and 4,200 gallons of liquor. This would be a small digester. Soda process digesters as large as 19 feet by 65 feet have been used. This liquor is caustic soda solution usually 11.5° to 12° Baumé at 60° F.

When the digester is full the lid is bolted on and the steam admitted. The pressure is brought up to maximum as quickly as possible and maintained until the end of the cook. In this regard this is a much simpler



From: Sutermeister, E., "Chemistry of Pulp and Paper Making," New York, John Wiley & Sons, Inc., 1929.

FIG. 68.—Diagram of vertical soda process digester showing inlets, pump and piping.

process than the sulphite cook. Pressures over 90 pounds used to be unusual and in the older accounts of the process pressures from 60 to 90 pounds are spoken of as good practice, but in the modern soda mill the pressures are much higher, 125 or 130 pounds being quite ordinary, 110 lb. being about the average. About 5000 to 6000 lb. steam will be used per ton pulp.

The length of the cook depends chiefly on the dryness of the wood. The dryer the wood, the more rapidly it absorbs the caustic soda solution. Usually the cook is completed in from 6 to 8 hours. In order to circulate the liquor, the pressure is relieved from time to time. This causes dilution of the liquor from the new steam entering and loss of heat units, and is one of the arguments against the direct cook as compared with the indirect methods where forced circulation is used, because in the soda process there is no reason apart from promoting circulation for relieving the pressure until the cook is completed, i. e., no gas is generated during the process which has to be relieved as is the case in cooking sulphite pulp. The use of rotary digesters also eliminates the need of wasting steam in relieving to promote circulation.

When the cook is completed the valve at the bottom of the digester is opened and the contents blown into a receiving tank. This tank is usually elevated above the wash pans, in which the liquor is eliminated from the pulp, as the digester pressure is sufficient to elevate the pulp to the height of the receiving tank. The steam escapes through a vent at the top of the tank, this vent usually being provided with baffles to prevent any pulp or liquor being blown or splashed out.

The contents of the receiving tank are next run into the first of a series of wash pans, usually four to a digester, which are provided with perforated false bottoms through which the liquor drains from the pulp. Dilute hot liquor from a certain portion of the recovery system is then sprayed on the pulp in the first pan, which it frees from alkali to a certain extent, at the same time becoming fortified itself. Following this operation more and more dilute liquor and finally clean hot water are sprayed on the pulp for long enough to remove the last traces of dissolved intracellular matter and alkali. This water goes to the recovery system also as it drains from the pulp.

The contents of the digester when blown are of quite a different appearance from the contents of a sulphite digester, being dark brown and in some cases black, and having a distinctive empyreumatic odor.

The pulp, when the liquor is washed from it, is of a gray or brown color which it does not lose until it is bleached.

The whole principle of washing the contents of the soda digester is to thoroughly get rid of every last trace of alkali and dissolved intracellular matter without diluting the wash liquors any more than is absolutely necessary, as all these liquors have later to be evaporated to recover the soda. Very small traces of liquor left in the pulp render bleaching very difficult and seriously impair the value of the product. Excessive use of wash water makes recovery too costly. In modern mills continuous rotary vacuum washers are much used and are a great factor in promoting economy.

For these reasons the pulp, at each stage of the washing, is washed with the liquor from the pan just before it in series, and the small amount of fresh water used for the final washing of a lot of pulp passes in succession through the whole series of washing pans or tanks (usually four or five in number) in each succeeding one of which the percentage of black liquor retained by the pulp is greater. At the end of the operation the liquor is used to wash the pulp fresh from the digester, as mentioned above, and as a result of this operation is brought up to a concentration approximating, in properly conducted plants, about 55 per cent of the original strength. The capacity of the wash pans should be sufficient that no liquor will ever have to be drained to waste. Of course, some soda is unavoidably lost, but if less than 95 per cent of the soda goes to the evaporators from the pans there is something wrong in the system.

The completely washed pulp is hosed out of the washing pan in exactly the same manner that sulphite pulp is hosed from a blow pit, which has been described in the chapter on the sulphite process. A pump elevates the stuff to the screens. The remainder of the treatment of soda pulp is very much the same as already described for sulphite pulp. However, diaphragm screens are used almost exclusively for soda pulp. The reader will probably recollect that when discussing the screening of sulphite pulp we described both diaphragm and centrifugal screens and stated that although centrifugal screens were more efficient, where the quality of the paper being produced would tolerate their comparatively incomplete screening action, the manufacture of fine papers required diaphragm screens. Soda pulp is used chiefly for good book and writing papers, hence the use of diaphragm screens in such mills in preference to centrifugal screens.

Recovery Systems.

Early in the development of the soda process it was realized that it would be necessary, in order to make the process attain maximum economy, to recover and re-use the alkali in the waste liquor. This development was urged forward in many localities by litigation with a view to preventing the waste liquors from being run into flowing streams.

To clearly understand the recovery process, the reader should remember of what the "black" liquor is composed. It holds two main ingredients, organic matter in solution and carbonate of soda. Now, when sufficiently concentrated, the organic matter will burn, yielding a considerable amount of heat which can be utilized in the first stages of concentration of the liquor. At the end of the process we will have a mixture of carbonate of soda, unburned carbon and incombustible mineral matter from the wood (ash) and this mixture goes by the name of "black ash."

The specific gravity or density of the liquor at the commencement of the recovery process depends on the strength of the original liquor charged, the moisture in the wood, whether the cook was with direct steam or by

COOKING CONDITIONS EMPLOYED AT SPECIFIC AMERICAN SODA-PULP MILLS[1]

Reference No.	Digester: Kind	Digester: Size	Digester: Wood capacity	Digester: Manner of heating	Quantity of chemicals charged: Actual caustic soda (NaOH)	Quantity of chemicals charged: Total soda expressed as carbonate	Quantity of cooking liquor charged: Per cook	Quantity of cooking liquor charged: Per cord
		Feet	*Cords*			*Lbs. per cord*	*Gallons*	*Gallons*
1	Cylindrical, stationary, vertical	....	3	Live steam or steam jacket.	....	1,000	2,800–3,000	[2] 930–1,000
2	Cylindrical, stationary, vertical	28 by 7	3–3.5	Live steam	720–860 pounds per cord.[2]	1,030–1,300 [2]	3,400–3,500	[2] 975–1,150
3	Cylindrical, stationary, vertical	....	3	{ Steam jacket / Live steam }	....	1,000	2,500	[2] 830
4	Cylindrical, stationary, vertical	49 by 10	15	Live steam	625 pounds per cord	....	13,000	[2] 870
5	Cylindrical, rotary, horizontal	20 by 7	3.5	Live steam	25 per cent = 650 pounds per cord	....	[2] 2,750 3,100	[3] 780–900
6	Cylindrical, stationary, vertical	30 by 8	5.5	....	....	....	....	....
7	Cylindrical, stationary, vertical	40 by 9	....	Live steam	....	....	....	....
8	Cylindrical, stationary, vertical	30 by 8	5.5	Live steam	....	....	....	....
9	Cylindrical, stationary, vertical	42 by 9	12	Live steam	....	....	9,300	[2] 775
10	Cylindrical, stationary, vertical	27 by 7	4	Live steam	....	885	3,600	900
11	Cylindrical, stationary, vertical (welded)	29 by 7	....	Live steam	2,792 pounds per charge [2]		4,200	....
12	Cylindrical, stationary, vertical (welded)	29 by 7	3.5	Live steam	610 pounds per cord	....	2,930	840
13	Cylindrical, stationary, vertical (welded)	30 by 7	4.0	Live steam	650 pounds per cord	....	3,200	800

[1] Each report represents a single mill except as specified for reference No. 11.
[2] Calculated from other data given.
[3] Statement by A. G. Paine, Jr. Conditions employed by mills of the New York and Pennsylvania Co.

Cooking Conditions Employed at Specific American Soda-Pulp Mills—*Continued*

Reference No.	Cooking liquors at start of cook: Density, Baumé	Density, Twaddell	Density, Specific gravity	Concentration of NaOH	Causticity	Cooking pressure per square inch	Durations of cooking: Total	From start till cooking pressure is reached	At cooking pressure	Blowing pressure per square inch
					Per cent	*Pounds*	*Hours*	*Hours*	*Hours*	*Pounds*
1	4–12°	[1] 11–18°	[1] 1.05–1.09	Equivalent of 1 pound soda ash per gallon.	92	110-120	8–12 (8 for poplar)	2–3	5–10	
2	14°	[1] 22°	[2] 1.11	9 per cent [2]	88–92	110	10–12	1.5–1.8	8.2–10.5	
3	10–15°	14.24°	[1] 1.07–1.12	5–10 per cent [1]	....	110-120	9.5–10	1–2	7–5.9	
4	7.5°	[1] 10°	[2] 1.05	Equivalent of 0.96 pound total alkali per gallon.	82	75	5.8	1	4.8	75
5	13–14°	[1] 20–22°	[1] 1.10–1.11	8.5–10 per cent	....	110	7.5	....	....	Not blown
6	14–16°	[1] 22–26°	[1] 1.11–1.13	....	....	100	6–8	....	....	
7	14–16°	[1] 22–26°	[1] 1.11–1.13	....	....	100	6.8	....	....	
8	[1] 11–12°	17–18°	[1] 1.08–1.09	....	....	110	5.5–6	....	....	
9	10.5°	[1] 16°	[1] 1.08	....	....	105	10	....	....	
10	11°	16.4°	1.081	6 per cent Na_2O	....	110	....	....	8	
11	11.5–12°	[1] 18°	[1] 1.09	8 per cent [1]	98	125–130	[3] 6–8	....	....	110
12	12°	18°	1.091	8 per cent	90	110	8	2.5	5.5	75
13	12°	18°	1.091	9 per cent	92–95	110–120	4.5–6	1.5–2	3–4	

[1] Calculated from other data given.
[2] Statement by A. G. Paine, Jr. Conditions employed by mills of the New York and Pennsylvania Co.
[3] Not specifically known whether time is total duration or duration at maximum pressure.

COOKING CONDITIONS EMPLOYED IN THE SODA PROCESS OF WOOD-PULP MANUFACTURE

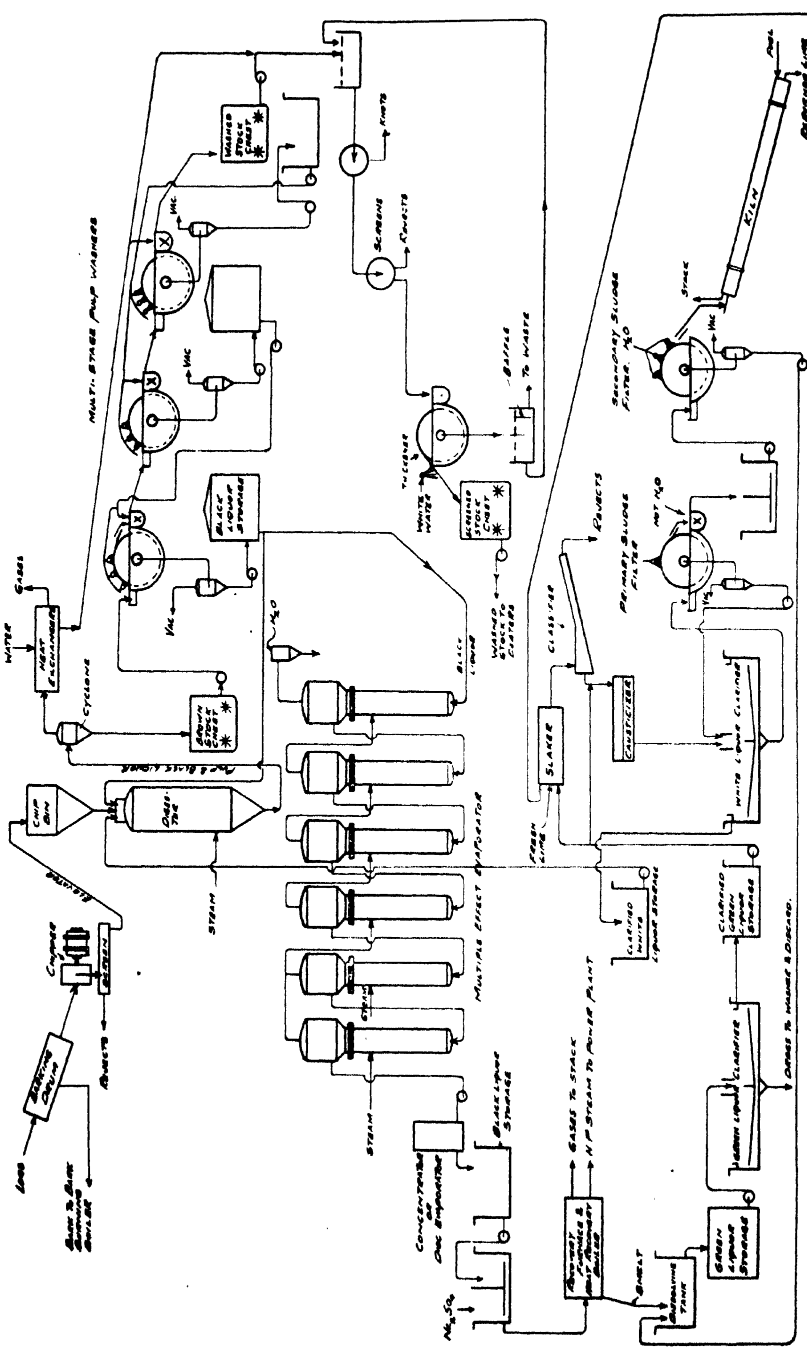
Reference No.	Practice followed	Digester				Quantity of chemicals charged		Quantity of cooking liquor charged	
		Kind	Size	Wood Capacity	Manner of heating	Actual caustic soda (NaOH)	Total soda expressed as carbonate	Per cook	Per cord
			Feet					*Gallons*	*Gallons*
1	Watt and Burgess process								
2	Watt and Burgess process								
3	Sinclair's process	Cylindrical, stationary, vertical.			Direct fire				60 per cwt. dry wood
4	Houghton's process								
5	European practice (1870)					336 lbs. per ton green wood.			
6	American practice (1870)	Cylindrical, stationary, vertical.	16 by 5	1 cord	Direct fire or steam jacket				
7	American practice (1880-1890)	Cylindrical, stationary, vertical.	27 by 7	4.3 cords	Live steam	444 lbs. per cord [1]		3,400	[1] 765
8	American practice (1880-1890)								
9	American practice (1880-1890)	Cylindrical, stationary, vertical.			Jacket, coils, or direct fire.				More than 700
10	American practice (1880-1890)	Rotaries			Live steam				700
11	Modern practice								
12	Modern practice (American)	Cylindrical, stationary, vertical.	27 by 7	4.5 cords	Live steam	450(°) - 920 lbs. per cord.[1]	635(°) to 1,320 lbs. per cord.[1]	4,000-5,000	[1] 900-1,100
13	Modern practice (American)	Cylindrical, stationary, vertical.							
14	Modern practice (Canadian)						800-950 lbs. per cord.		
15	Modern practice					12-20 per cent of weight of wood.			
16									
17									
18									
19	Modern practice	Stationary or revolving.			Live steam	16-20 per cent.			
20	Modern practice (American)				Live steam				
21	Modern practice	Stationary			Live steam				
22	Modern practice (Swedish)			8.5 cu. meters (=300 cu. ft.)[1] of chips		637 kilos (=1,400 lbs.)[1] Na_2O for charge.		6,000 liters (=1,321 galls.)[1]	

[1] Calculated from other data given. [2] Strong solution of caustic soda.
[3] In addition to the total time of cooking Congdon reports: Time required for charging digester, 30-45 minutes; for relieving pressure and blowing, 45-60 minutes; total period for a cook, 11-11½ hours.

COOKING CONDITIONS EMPLOYED IN THE SODA PROCESS OF WOOD-PULP MANUFACTURE—*Continued*

Reference No.	Cooking liquors at start of cook					Cooking pressure per square inch	Cooking temperature	Durations of cooking			Blowing pressure per square inch	Authority
	Density			Concentration of NaOH	Causticity			Total	From start till cooking pressure is reached	At cooking pressure		
	Baumé	Twaddle	Specific gravity									
					Per Cent	*Pounds*	°*F.*	*Hours*	*Hours*	*Hours*	*Pounds*	
1	12°	18°	[1] 1.09	6 per cent [1]	......	60	....	....	....	....	....	Griffin and Little, 1894.
2	(2)	(2)	(2)	....	......	90	....	....	....	10-12	....	Clapperton, 1907.
3	....	....	....	....	......	180-200	....	....	....	0.5 or less	Not blown	Watt, 1907.
4	4°	[1] 6°	[1] 1.03	2 per cent [1](?)	......	180	....	....		....	....	Houghton; Griffin and Little, 1894.
5	....	....	....	....	......	150-180	360-375	....		....	....	Silcox, 1875.
6	12°	[1] 18°	[1] 1.09	7 per cent [1]	......	65 or more	....	6	....	....	65 or more	Hofmann, 1873; Watt, 1907.
7	11°	[1] 16°	[1] 1.08	7 per cent [1]	......	110	....	[3] 9¾-10	2¾-3	7	45	Congdon, 1889; Watt, 1907.
8	8-15° at 60° F.	[1] 12-24°	[3] 1.06-1.12	....								
9	11° for poplar.	[1] 16°	[1] 1.08	....								
	12-14° at 60° F.	[1] 18-22°	[1] 1.09-1.11	6-9 per cent	.....	90-110	....	[4] 8-10	....	....	....	Griffin and Little, 1894.
10	(5)	(5)	(5)									
11	....	....	....	....								
12	10-15° at 60° F.	[1] 14-24°	[1] 1.07-1.12	6-8 per cent	......	90-110	....	....	....	8-10	....	Cross and Bevan, 1900.
				5-10 per cent [1]	92-94	100-120	....	[1] 8½-13	2½-3	6-10	75	International Library of Technology, 1902.
13	(2)	(2)	(2)									
14	....	....	....	....	......	100-110	....	....	(6)	(6)	....	Clapperton, 1907.
				....	......	....	....	....	....	....	....	De Cew, 1907.
15	10-14° ...	15-22°	[1] 1.07-1.11	5-7% Na_2O	......	130-160	360	[4] 6	....	....	....	Stevens, 1908.
16	10° .... / 12°	[1] 14° / [1] 18°	[1] 1.07 / [1] 1.09	....	......	132-147 / 88-118	.....	[4] 6	....	....	....	Schubert; Stevens, 1908.
17	12-14° ...	[1] 18-22°	[1] 1.09-1.11	7-9 per cent [1]	......	73-147	....	[4] 5-6	....	....	....	Ernst Muller; Stevens, 1908.
18	10-14° ...	[1] 15-22°	[1] 1.07-1.11	5-7 per cent [1]	......	73-176	....	[4] 5-6	....	....	....	Klemm; Stevens, 1908.
19	....	....	....	....	......	70-80	....	8-9	....	....	....	Sindall, 1908.
20	....	....	....	....	......	100-130	338-355	....	....	....	....	Beveridge, 1911.
21	13°[1]	20°	[1] 1.10	....	......	100-150	....	....	....	6-8	....	Cross, Bevan, and Sindall, 1911.
22	....	....	....	....	......	125	353	....	....	1-2	....	Hennefeld, Beveridge, 1911.

[4] Not specifically known whether time is total duration or duration at maximum pressure.
[5] Stronger liquors than Ref. No. 9
[6] Less than 10-12 hours.



Courtesy: Swenson Evaporator Co., Harvey, Ill.

FIG. 69.—Flowsheet of a modern kraft pulp mill showing recovery system.

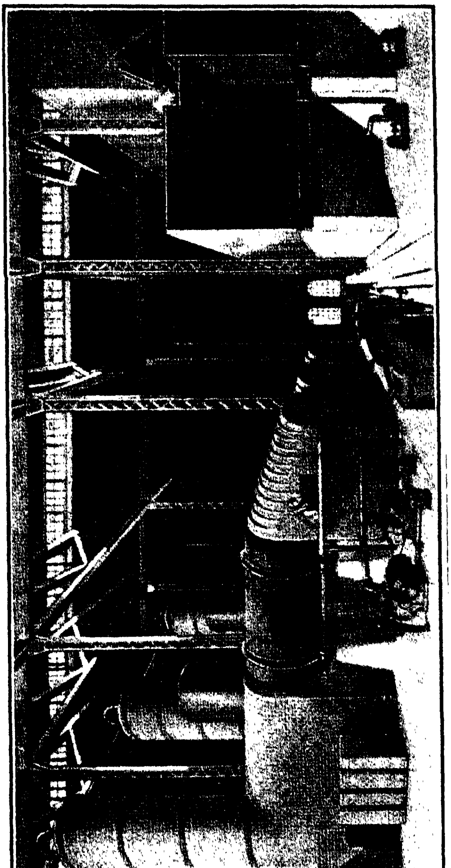


Fig. 70.—Recovery system for soda mill showing rotary furnaces.

the indirect method and the efficiency of the washing system. In one American mill operating the soda process on a large scale the density is 12.75° Baumé at 70° F.

The temperature of the black liquor in the storage tanks after the blow will usually not be less than 160° F. and may be much higher. In modern American mills using indirect cook, or rotary digesters, and charging white liquor of 18°-20° Bé. at 180° F. a concentration of solids in the black liquor as high as 25 per cent may be achieved: even with heating by direct-steam good modern practice would call for at least 15 per cent total solids. Writing in 1894 Griffin and Little spoke of a concentration of 4° Bé. (corresponding to 6 per cent solids) as being usual practice, which gives some idea of the great advance in efficiency of soda recovery in American mills. Expressing the concentration in percentage of total solids is greatly preferable to degrees Bé. as the latter vary greatly with the temperature due to the expansion of the liquid.

The three chief factors governing the concentration of the black liquor are (a) the concentration of the white liquor charged to the digester (b) the amount of water from condensation of cooking steam (c) the water added during the washing operation. It is chiefly in connection with the latter that improvement has been made.

When a new soda mill is started the original soda lye or white liquor is made up by dissolving soda ash in water to test 20° Bé. at 60° F., causticizing this with lime, and adding soda ash (or in the kraft mill salt cake) as the recovery system gets into operation.

The first attempts at recovery utilized open evaporating pans. Such inefficient equipment was soon abandoned in favor of multiple effect evaporation in suitably designed equipment. Today many special recovery systems such as the Tomlinson, Murray-Waern and Wagner are encountered in modern mills: these will be briefly described later.

Multiple Effect Evaporation.

The theory of multiple effect evaporation is a vast and complex subject, but the following brief explanation of the principle may be helfpul. The boiling point of water becoming lower as the pressure is decreased (i. e., the vacuum increased), it is possible to make water evaporate from a solution being concentrated at a lower temperature by decreasing the pressure. When water is boiled at atmospheric pressure it boils at 212° F. and the vapor given off has also this temperature. In addition to the heat units it possesses simply by virtue of being at 212° F., it also possesses a large additional number of heat units that have been put into it in converting liquid water into water vapor, or steam. This heat will again be given up when the steam is condensed. It is called the latent heat of steam. A pound of steam at 212° F. will have about 1146 units of heat, of which about 964 will be in the form of latent heat.

Now, a multiple effect evaporator is really a series of boilers, so arranged that the steam from the first boiler, or "effect," will be carried over and used as the heating agent in the next effect. The second effect is able to boil at a lower temperature than the first owing to the maintenance of a partial vacuum. The steam from the second effect goes to a third, which operates at a still greater vacuum and thus to a fourth, and perhaps even fifth and sixth effects. Four effects is a usual number in practice. Finally the steam from the last effect goes to a condenser.

Equipment utilizing this principle has been designed with such engineering skill as to make almost perfect utilization of the heat supplied to the machine. The first multiple effect evaporators used in the paper industry were of the well-known Yaryan type, and although these evaporators have largely been replaced in recent years by equipment of improved design (such as the Scott, Swenson, Zaremba and Buffalo evaporators), there are still a good many of them in use and a description will not be out of place.

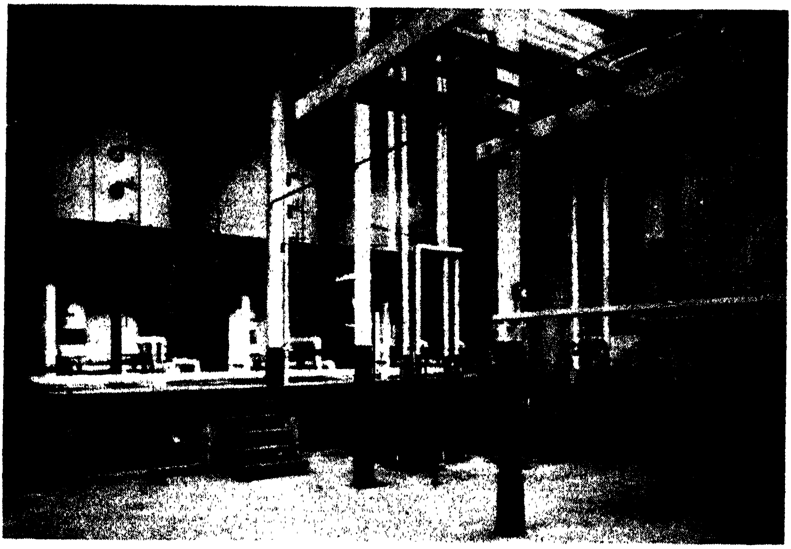


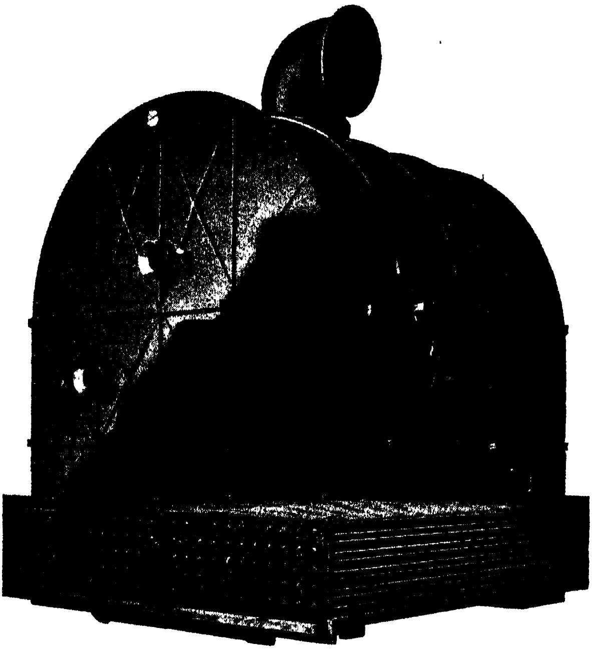
FIG. 71.—Multiple-effect evaporators in recovery department of soda pulp mill.

Yaryan Evaporator.

Each effect of this evaporator is like a boiler with a number of horizontal pipes arranged in coils parallel to the shell. A supply pipe feeds the liquor into a header at the back of the machine from which the coils lead. The steam is admitted into the shell surrounding the coils. At the front of the machine the coils end in a header which serves as a separator, separating the vapor from liquor and foam, and in which a partial vacuum is maintained. The difference between the pressure at which the liquor is supplied and the partial vacuum in the front of the machine keeps the liquor constantly moving forward, forming a film on the surface of the tubes, and in this way a new surface of liquid is constantly exposed to the action of the steam. The liquor from the separator of the first effect is pumped into the second effect and the vapor from the first effect is supplied to the shell of the second effect to give up its heat, and the operation is repeated for as many effects as there may be. The liquor is usually concentrated from its original density to from 32° Be. to 40° Be. at 60° F. Of course, the concentration could be carried much higher in modern evaporators, but this is not done because of the difficulty of pumping such very thick liquors. Moreover, the further evaporation of such liquors is not necessary as from 37° Be. to 40° Be. has been found a good strength for burning.

Multiple Effect Evaporators.

No attempt will be made to describe in detail the various types of modern multiple effect evaporators, as to do this in any adequate manner would be quite beyond the scope of this book, and the subject is well covered in treatises on chemical engineering, and in the catalogs of the leading evaporator manufacturers.

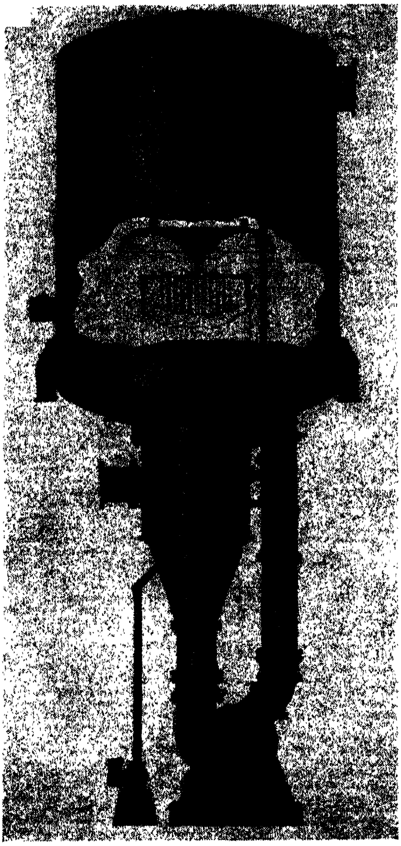


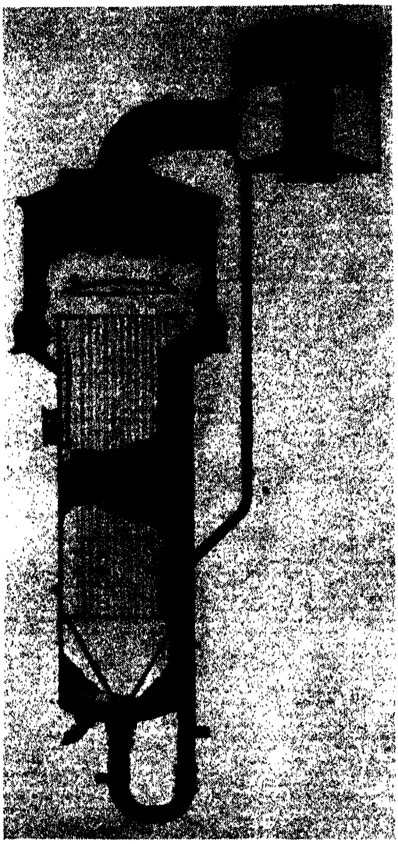
Courtesy: Swenson Evaporator Co., Harvey, Ill.

FIG. 72.—Typical horizontal tube evaporator.

This is a rectangular evaporator with horizontal tubes located near the bottom of each effect. It is made up in sections of heavy cast iron plates with machined and drilled faces and flanges. The assembled castings are bolted together with a suitable packing material—usually sheet asbestos—making a vacuum tight joint. There is a steam chest at each end cast as an integral part of the vertical tube sheet. Each tube passes through both tube sheets and is packed by special packing plates and rubber gaskets, thus insuring vacuum tightness and resistance to high temperature.

Horizontal tube evaporators were the most usual type in American mills until very recently. They were troublesome because of the fouling of the tubes and the tendency to foam, which was accentuated as the kraft





Courtesy: Swenson Evaporator Co., Harvey, Ill.

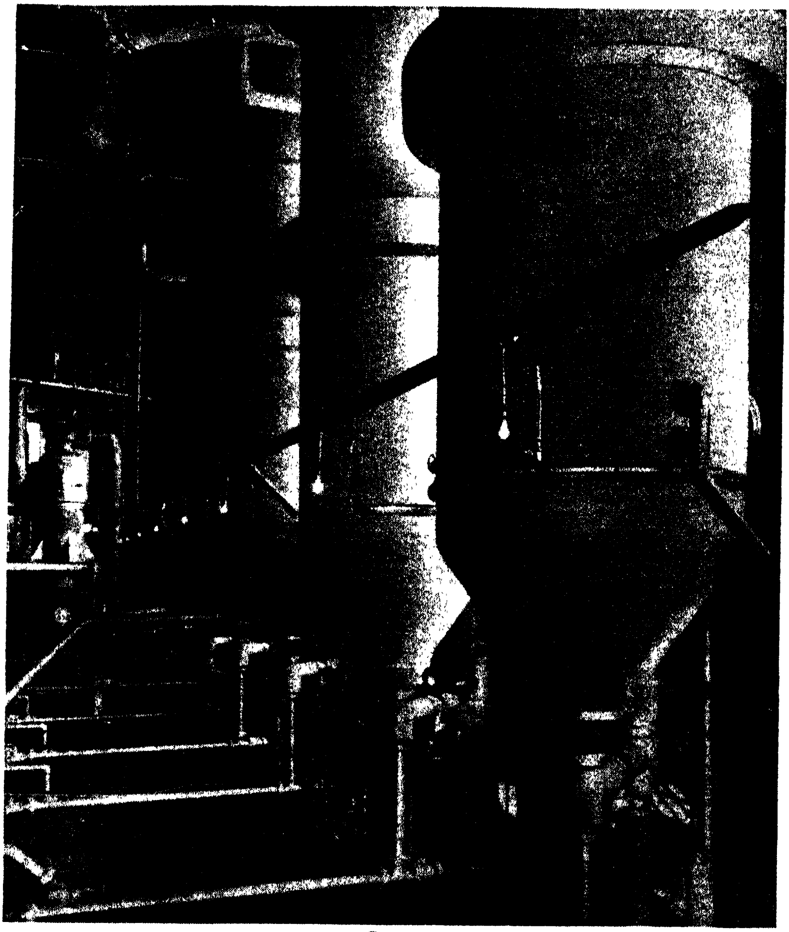
FIG. 73a.—
Forced circulation evaporator.

FIG. 73b.—
Long tube vertical film type evaporator.

process became more general. Vertical tube evaporators of various makes were introduced, the so-called "basket-type" illustrated being the most usual. More recently, forced circulation evaporators have been introduced in which the liquor is continuously circulated by a pump or other mechanical means. Such equipment is notably efficient, but the first cost is high as it is usually built of stainless steel.

Disc Evaporators.

Usually only part of the water is driven off in multiple effects, the remainder being removed with disc evaporators. One of the best known disc evaporators for use in the evaporation of waste liquor is the Carlson and Waern evaporator. This machine employs the principle of exposing a thin film of liquid to direct heat over a large area. This is accomplished by rotating a wheel, or series of wheels, made up of thin steel plates, so that



Courtesy: Swenson Evaporator Co., Harvey, Ill.

FIG. 74.—Multi-body quintuple effect long tube vertical evaporator for kraft mill black liquor, the largest of its kind in the world.

the plates are alternately dipped in the liquid and then exposed to the hot gases which pass through the evaporator in such a manner that they come in contact with the exposed surfaces of all the plates or discs. The effective surface on an 8-ft. diameter evaporator with 32 discs is about 1600 sq. ft., assuming about 16 per cent of the surface to be at all times submerged. The moisture is absorbed from the film of liquid and passes in the form of vapor to a stack, or to a reclaiming apparatus, as the case may be. While these evaporators are frequently used alone, they can be used most efficiently to follow a preliminary evaporation in some form of multiple effect evaporator. In the sulphate process they are usually used alone as the liquors are usually not so dilute as in the soda process owing to the greater use of indirect cooking in sulphate mills. These evaporators have the advantage that they will handle thick, gummy liquors that would clog tube evaporators.

Courtesy: Swenson Evaporator Co., Harvey, Ill.

FIG. 75.—Discharge end of slaker in re-causticizing system of modern kraft mill.

Rotary Furnaces.

The liquor from the evaporators is sufficiently concentrated that it will support its own combustion when introduced into the rotary furnace. A storage tank heated with a steam coil should be placed in the system between the evaporators and the rotary furnace, and a by-pass should be installed so the liquor can go direct from the evaporators to the rotary when circumstances permit. In this way the maximum amount of heat can be conserved. These furnaces consist of two parts, the rotating part and the stationary part. The stationary part is a fire-box, constructed either of steel-plate lined with fire-brick, or of fire-brick held in place by iron bands. It is fitted with a grate for burning coal or wood, or with equipment for burning gas or oil. It opens into the rotating part of the furnace. The rotating part is a cylindrical steel-plate shell, lined with fire-brick. It is usually from 8 to 10 feet in diameter, unlined, and from 14 to 30 feet long. The lining is about 12 in. thick at the discharge end of the furnace and from 20 in. to 24 in. at the feed end, making the interior conical so that the hot thick liquid naturally flows to the discharge end. According to Spence[1] it requires about 1 lb. of coal burned in the fire-box to produce 6 lbs. of ash in a 14-foot rotary, while 1 lb. of coal will produce 12 lbs. of ash in a 30-foot rotary. When burning liquor from cooking of hard-wood, 70 lbs. of ash per sq. ft. of burning surface per 24 hrs. is considered good and this is increased about 10 per cent for more resinous woods such as spruce, pine, poplar, etc. However, the larger rotaries cause more loss of soda up the stack owing to the increased draft required. The furnace is caused to rotate slowly. This is usually accomplished by iron rings which rest on flanged wheels, the axles of these wheels resting in journals supported by masonry. The rotation of about 1 r.p.m. is accomplished with a worm drive and a gear and pinion. The liquor is run into the end of the rotating cylinder farthest from the fire-box and gradually runs forward, burning as it moves, and the black ash falls out of the cylinder through an opening located just back of the fire-box. The heat produced in this furnace is generally utilized, either in the disc evaporators or for operating

Courtesy: Swenson Evaporator Co., Harvey, Ill.

FIG. 76.—Part of recovery system in sulphate mill showing disc evaporator and waste heat boiler.

a waste-heat boiler which supplies steam to the multiple effect evaporators, or for a preheater for the liquor going to the evaporators. The black ash used to be conveyed, either by trucks or by a conveyor, to the leaching and causticizing department, but is now more usually discharged into a tank situated in a pit under the discharge of the rotary.

In the sulphate process rotary to be referred to later, the effluent is in

[1] Report of the Committee on Soda Pulp, T. A. P. P. I., 1919. "Paper," Feb. 12, 1919, pg. 619.

the form of a liquid called "smelt" and flows into a dissolving tank to form "green liquor" which is later causticized to form "white liquor" which is re-charged to the system, as previously explained.

Causticizing.

The black ash is leached in a system of leaching tanks so as to effectually wash out all the soda, leaving only black, finely divided carbon, which is a by-product. Some modern soda mills work this up into a salable substance used for filtering and decolorizing purposes. Sufficient new carbonate of soda is added at this stage to bring the liquor up to the required strength. As a rule from 10 to 30 per cent of the soda used is lost at every operation and this soda has to be replaced at this stage in the process. The soda has to be causticized before it is added to the liquor. The chemistry of the causticizing operation consists in converting carbonate of soda into caustic soda, or sodium hydroxide. This is done with freshly burned lime. Equipment for causticizing has been developed to a high degree of efficiency by chemical engineers because this operation is important in other industries as well as in paper making. It is a necessary part of the manufacture of soap, the refining of oils and of many other lines of manufacture.

The standard system of causticizing is to add the lime to the solution of soda ash in a tank fitted with a powerful blade or propeller agitator and a perforated false bottom. Freshly burned lime is added to the liquor in the proportion of about 60 pounds of lime for every 100 pounds of carbonate of soda (soda ash) in the liquor. The lime mud produced is thoroughly washed to remove all traces of caustic soda. This is done by repeating the process of washing, settling and decantation until the sludge is as free from alkali as circumstances will permit.

Variations of the causticizing tank have been devised. In some forms there is a suspended basket for the lime. The causticizing tank is provided with steam connections for heating the contents.

In some mills the lime mud is recovered by burning in a rotary furnace to form lime again. This requires a huge furnace, expert attention and a lot of fuel, and has not generally been considered practical, at least where good lime can be obtained at a reasonable price.

The labor cost of the causticizing process is high and it requires a lot of floor space, tanks, piping, steam connections, etc.

Causticizing Processes Employing Filtration: Owing to the length of time required for ordinary settling and decantation, filter presses have been introduced in some causticizing plants. The ordinary plate and frame filter press is too well known to require detailed description here. It has the drawbacks of small capacity and requiring a great deal of labor.

Improved forms of filter press, such as the Kelly press and the Sweetland press have endeavored to overcome these defects by giving an increased capacity for the space occupied and the time required in the operation.

When filter processes are used for causticizing in soda mills the sludge-containing liquor from the causticizer should be sent to a settling tank, from which one decantation of the strong liquor is made. The sludge from this tank is sent direct to the filter presses and the filtrate from the presses is mixed with the decanted liquor. The filter press cake is then washed and the wash water united with the strong liquor to whatever extent may be advisable.

Rotary continuous filters are much more efficient than filter presses for this sort of operation. These consist of a tank in which is suspended a revolving drum, the surface of which is composed of a number of compartments, covered with a Monel-metal wire cloth or other filtering medium. Each compartment is connected to a trunnion fitted with an automatic device so suction or pressure can be applied to each compartment at the particular stage in the operation where it is required. When the drum is immersed in the tank, that portion is supplied with suction and the sludge is drawn against the filtering surface. When that portion comes out of the bath of liquor in the tank, pressure is applied and the film of sludge is forced off, this action frequently being assisted by a doctor blade. These machines are not unlike pulp thickeners or wet machines used in the pulp industry, in their general principle. They deliver a lime cake containing less than 1 per cent soda.

The Dorr Continuous Recausticizing System.

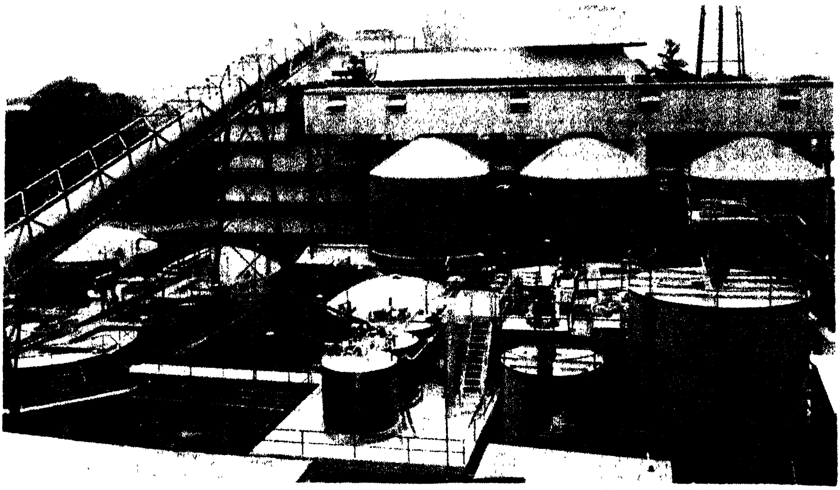
The Dorr continuous recausticizing system is a successful system for avoiding the evils of the former types of causticizing plants, where agitation and the successive washings and decantations were conducted on a batch basis. The principles embodied in the system have long been recognized as sound, in the handling and washing of precipitates in the chemical and metallurgical fields. It makes the whole process of recausticizing continuous from start to finish and has effected marked savings in labor, power and materials. It has also been instrumental in eliminating to a great degree, the personal elements in recausticizing practice.

The use of this system has become practically standard practice in the active southeastern kraft fields. In this area alone, there are today 23 Dorr continuous recausticizing systems, with an aggregate rated capacity equivalent to at least 7000 tons of kraft pulp per day. Elsewhere in America, and in foreign countries more than 40 Dorr systems are in use.

It is likewise used extensively in the soda pulp field, which field however, has been relatively inactive for the last ten years, compared with the sulphate field.

The Dorr continuous recausticizing system is substantially the same for both sulphate and soda mills, from the lime slaking step on through lime reburning. The only difference existing between the systems at the two types of plants is that in the case of a sulphate mill, it is necessary to make provision for green liquor clarification and dregs washing prior to lime slaking; whereas this step obviously is not required at a soda mill. For this reason and also because recent activity is centered in the sulphate rather than the soda fields, this description of the Dorr system relates to its use at sulphate mills as shown in Fig. 77.

Batch vs. continuous processing: The continuous recausticizing plants of today differ from those installed a decade ago just as the modern automobile differs from its predecessor of 1930. Possibly only those directly concerned appreciate this development, because externally the plants may look very much like those of earlier vintage.



Courtesy: Dorr Co., Inc., New York

FIG. 77.—Dorr continuous recausticizing system showing agitators in center, flanked on either side by tray thickeners, for handling green liquor and for decantation of white liquor.

The reaction Na_2CO_3 plus $Ca(OH)_2$ plus $2NaOH$ is a simple one, well understood by the chemist for generations, but speaking from the viewpoint of the chemical engineer, causticizing plants will doubtless undergo much improvement in the future. To complicate the situation, the manufacturer of kraft pulp interjects the presence of sodium sulfide and sodium sulfate and neither the chemist nor the chemical engineer has yet thoroughly understood the effect of these additions on the causticizing reactions.

Batch causticizing plants are virtually a thing of the past due to inherent advantages of continuous operations in all fields, which advantages in causticizing include uniformity of particle size. Under controlled conditions it is easy in a continuous plant to produce uniform lime mud because new lime is always added to a partially reacted slurry, while in batch operation the reaction starts with an excess of soda and ends with an excess of lime. It is hardly possible to produce calcium carbonate of uniform particle size when conditions of precipitation vary so widely throughout each batch.

Continuous settling makes possible withdrawing settled solids at final density under all conditions, irrespective of the degree of clarification at various depths in the thickener or compartment.

Efficiencies obtained: Considering the soda recovery system or chemical end of a pulp mill as a whole, these recausticizing plants have a remarkable record as to chemical recovery. Modern pulp mills use from 200 to 300 pounds of salt cake make-up per ton of pulp, but the caustic plant loses but 5 to 15 pounds of this soda. Lime requirements per ton of kraft pulp vary from 400 to 550 pounds. Today, well operated recausticizing units lose but 25 pounds and these small soda and lime losses are almost entirely in the kiln or lime reburning unit, not usually considered a part of the recausticizing plant itself.

As to efficiency of conversion, a modern continuous unit can consistently give approximately 99 per cent of the theoretical causticity at any given strength and sulfidity.

Before discussing causticizing in detail, let us review the soda circuit in a kraft mill. White or cooking liquor is high in caustic soda and sodium sulfide and low in sodium carbonate and sodium sulfate. In the digester a considerable portion of the active soda is converted to sodium salts of organic compounds and these organic bodies are later burned in the recovery furnace to Na_2O or Na_2CO_3. Salt cake is added to the recovery furnace to make up losses in the sodium sulfate-sodium sulfide circuit but the sodium carbonate-caustic soda circuit must get its make-up soda from destruction of these organic sodium compounds. When the furnace smelt is dissolved the sulfide content of the liquor is correct and it is this green liquor (dissolved smelt) which must be recausticized to convert as much as possible of the sodium carbonate present to caustic soda. This then is the feed to our causticizing plant.

Factors governing design: No adequate plant can be designed today without knowing (1) the location, (2) the size, (3) the type of pulp, sulfidity required, etc., and (4) whether or not the pulp is to be bleached.

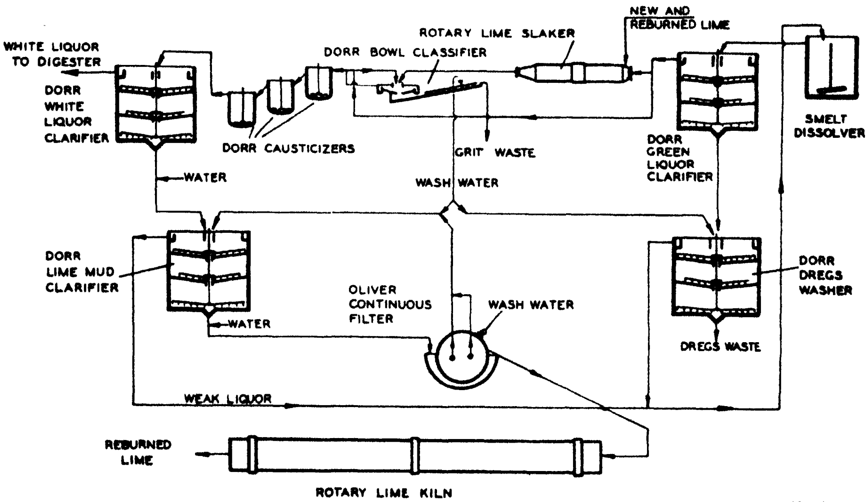
The location may determine how much equipment must be housed, whether combination or unit type settlers will be more economical and, for instance, if foundations must be piled, smaller diameters should be chosen, thus indicating multi-compartment settling units.

The size often determines whether or not lime will be reburned, whether multi-stage decantations or two decantations and filtration will be preferable and whether pumping or gravity flows will prove more economical. Very large kraft mills are reburning lime mud for less than \$2 per ton CaO, while in smaller mills the cost approaches \$5. Apparently any mill of 100 tons pulp production daily, should recover lime from the calcium carbonate sludge by reburning.

The type of pulp or type of wood used often governs the quantity of cooking liquor required, its Na_2O content and the sulfidity. Northern woods normally require higher sulfidities and very generally more chemical digestion and less mechanical treatment. More chemicals or less sulfidity mean more caustic plant, larger agitators, more calcium carbonate produced and accordingly larger thickeners. High sulfidity liquors are much more corrosive to iron and steel and fast moving parts must be made of alloy steel, 18-8 or similar materials. For most southern mills, iron and steel generally make for the most economical layout.

If pulp is to be fully bleached, usually little or no black liquor is returned to the digesters, and more and weaker white liquor is required. Usually this means more causticizing equipment, although there seems to be some difference of opinion among pulp manufacturers as to this point.

The function of any recausticizing plant is then to take the recovery furnace smelt dissolved in weak liquor and convert its soda ash content to caustic soda. No change in the sulfide content of the liquors results, this having been taken care of in the recovery furnace itself. Calcium carbonate is precipitated and must be removed from the cooking liquor and this precipitate must be reburned so that its lime value may be reused. Omitting such accessories as elevators, feeders, conveyors and pumps, the causticizing plant comprises a slaker, a causticizing station and the equipment for separating the caustic liquor from the insoluble sludge.



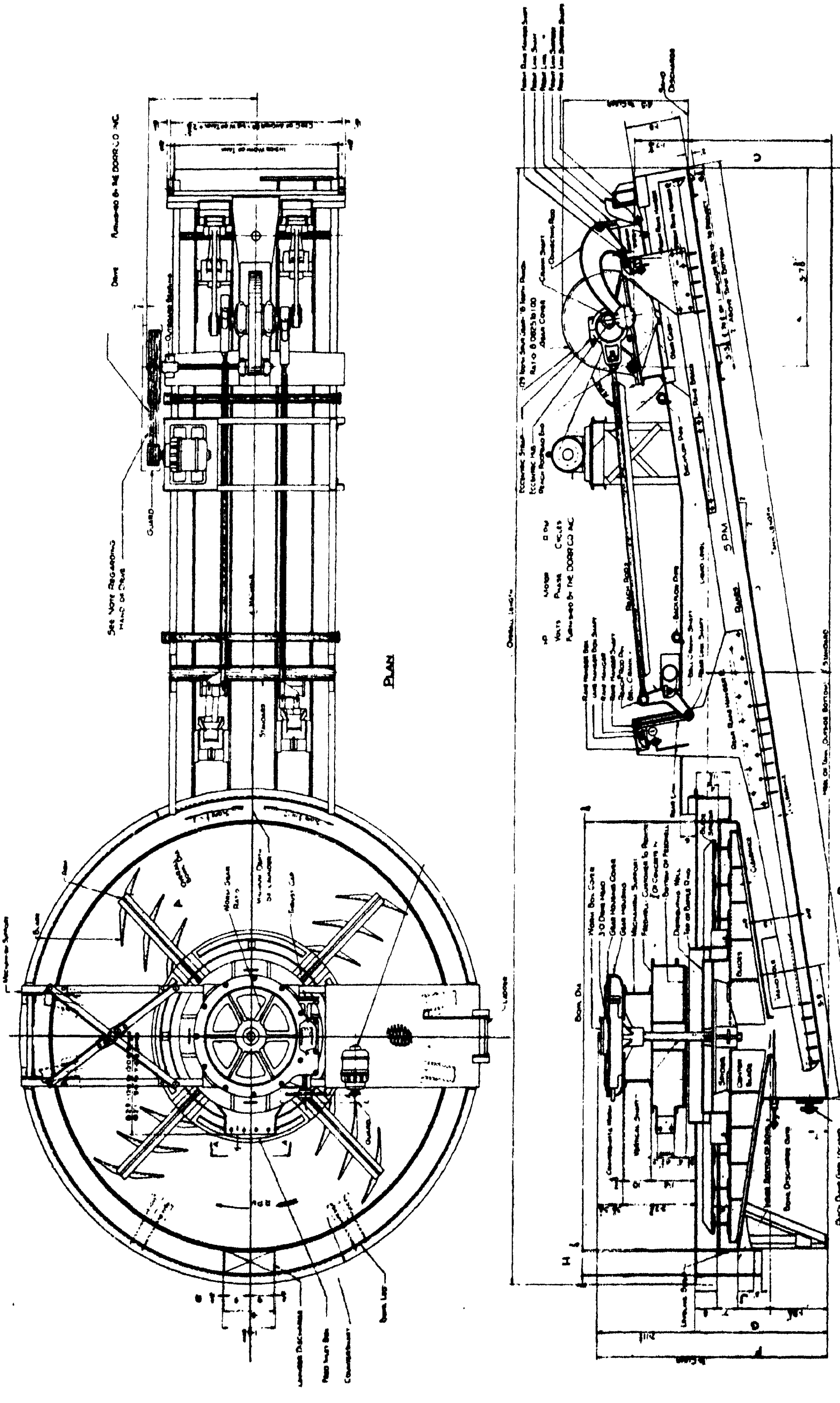
Courtesy: Dorr Co., Inc., New York

FIG. 78.—Flowsheet of Dorr continuous recausticizing system.

Description of the Dorr System.

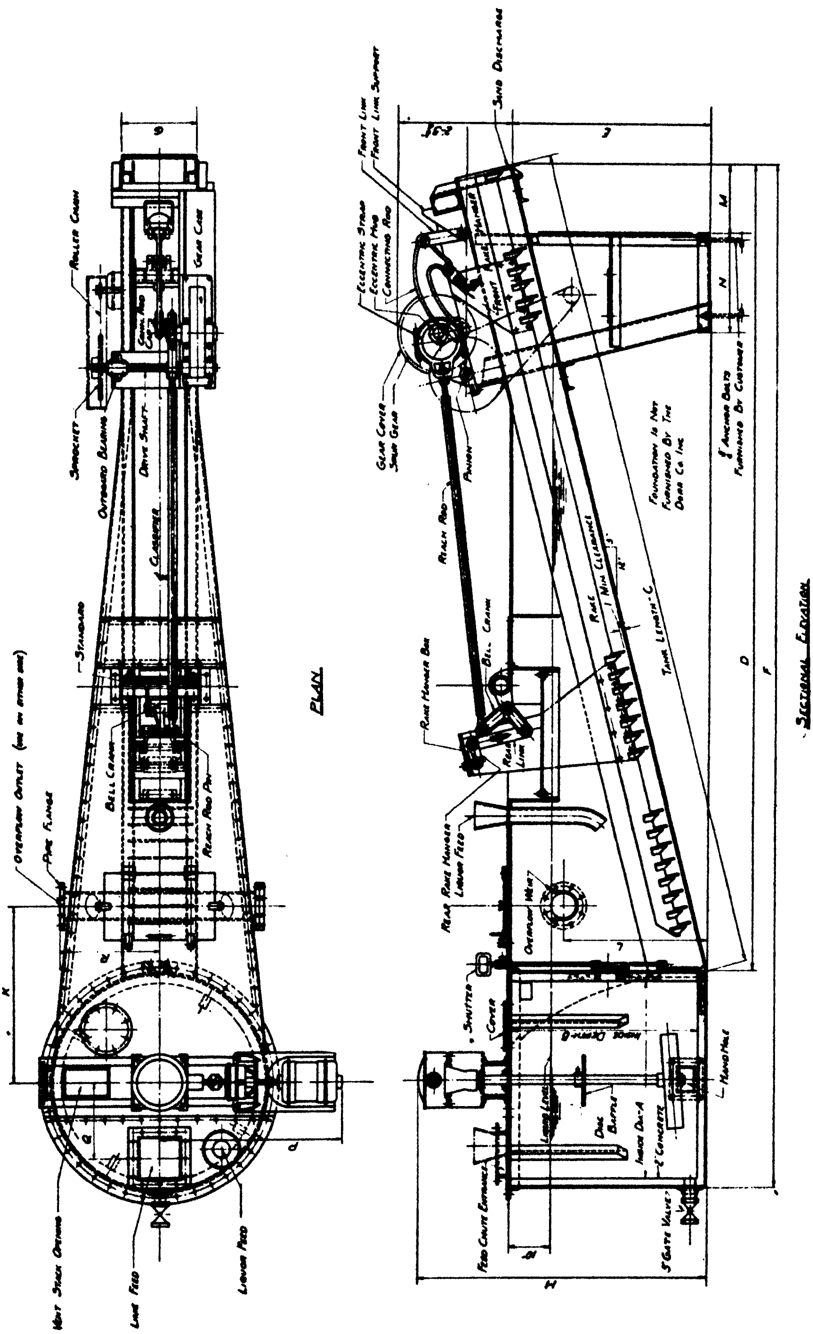
Figure 78 is a flowsheet of a Dorr continuous recausticizing system at a typical sulfate pulp mill and shows all of the equipment used and its interconnection for the various processing steps. A description follows:

Green Liquor Handling: Raw green liquor from the smelt dissolver in the upper right hand corner of the flowsheet flows first to a multi-compartment Door tray thickener, which overflows to slaking and causticizing a clear, green liquor and discharges to the subsequent washing step the green



Courtesy: Dorr Co., Inc., New York

FIG. 79.—Diagram of Dorr classifier.



Courtesy: Dorr Co., Inc., New York

Fig. 80.—Diagram of Dorr slaker.

liquor dregs. These dregs then pass to a multi-compartment Dorr thickener of the washing type, wherein the individual tray compartments are arranged in series for washing purposes. The dregs are discharged to waste with a minimum content of soda and the resulting weak wash water joins other weak liquors and is utilized for the dissolving of new smelt.

Lime Slaking and Degritting: The clarified green liquor is split into two portions, one of which is used for slaking new and reburned lime in a rotary lime slaker, and the other for diluting purposes in the subsequent Dorr classifier, Fig. 79, and Dorr recausticizing agitators. The milk-of-lime suspension, discharged from the rotary slaker, is degritted in the Dorr classifier which follows; the grit-free milk of lime plus soda solution being overflowed to the recausticizing step; and the mineral impurities, containing grit, sand and unburned core, are rejected by the classifier to waste.

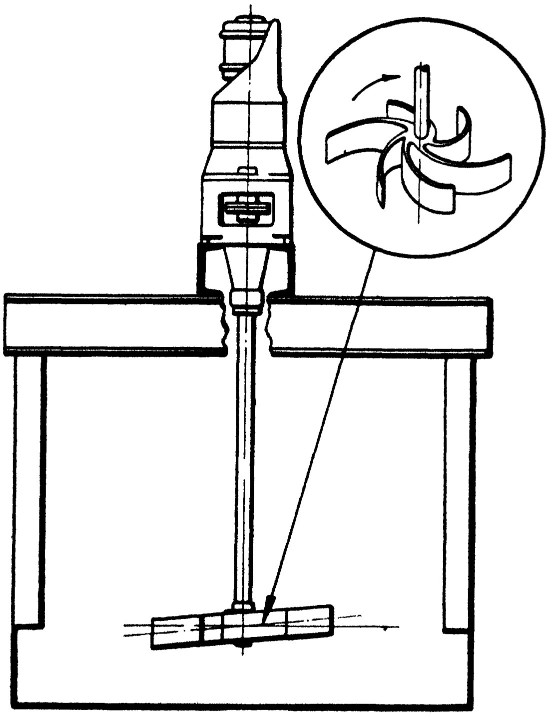


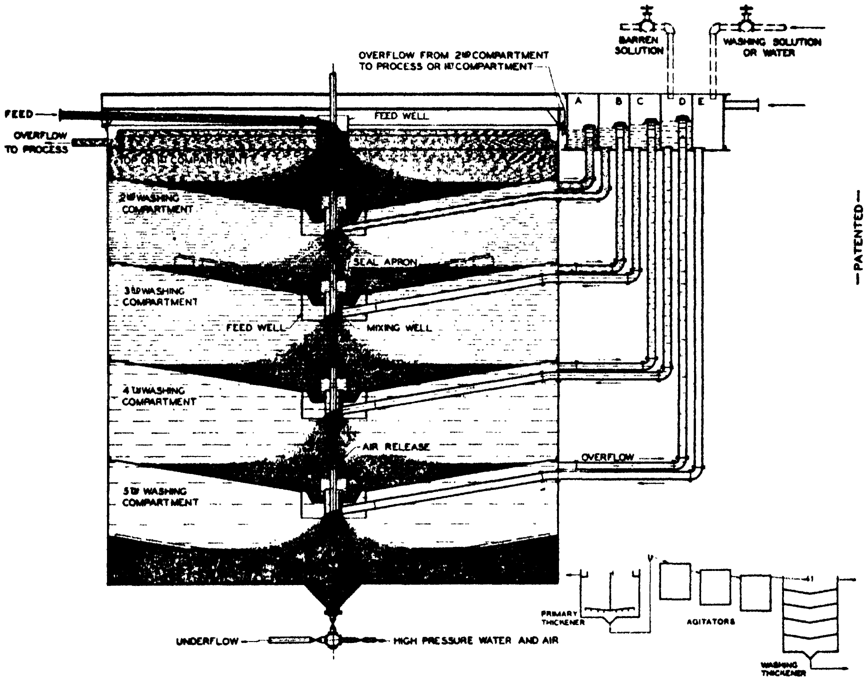
FIG. 81.—
Diagram of Dorr recausticizing agitator.

Courtesy:
Dorr Co., Inc.,
New York

It should be noted here that although not shown on this flowsheet, present practice calls for carrying out both the lime slaking and degritting operations in a new Dorr unit known as the Dorrco slaker, Fig. 80, rather than in two individual units as indicated.

Recausticizing: The grit-free calcium hydrate suspended in clarified green liquor which overflows the Dorr bowl classifier, is pumped to the first of three continuous Dorr recausticizing agitators, arranged in series at slightly different elevations. Each agitator, Fig. 81, is equipped with a Turbo type agitator that gives mixing in two planes. The volume provided in three agitators gives one hour's contact during the recausticizing, which has been found sufficient to give causticities of 99 per cent of the theoretical.

White Liquor Decantation: The discharge from the last of the three Dorr recausticizing agitators flows by gravity into the feed box of the Dorr white liquor clarifier, which is a multi-compartment Dorr tray thickener. The tank is divided into several super-imposed settling compartments operating in parallel, and is insulated against temperature drops.



Courtesy: Dorr Co., Inc., New York

Fig. 82.—Diagram of Dorr multi-compartment tray thickener used as a lime mud washer.

The overflows from the various compartments are combined and constitute clear, white liquor which is sent to the digesters. The underflow discharge is a heavy, calcium carbonate mud, which must then be washed free from entrained soda solution.

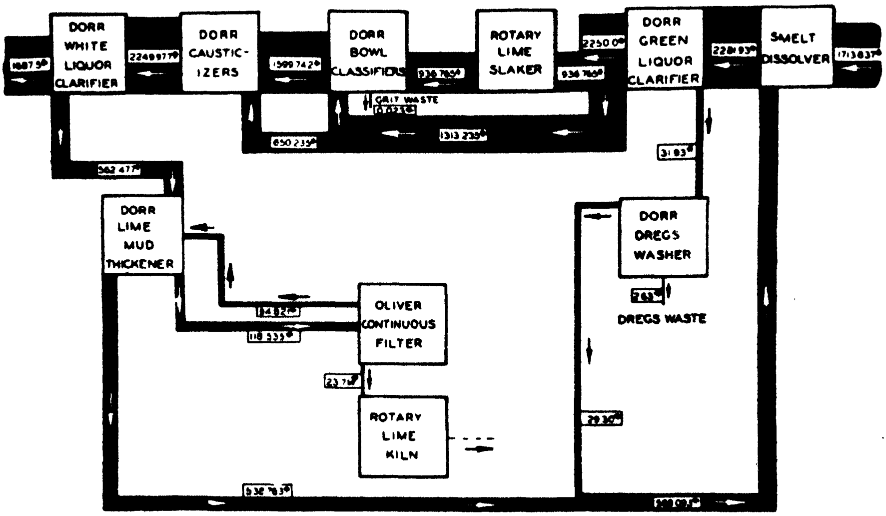
Lime Mud Washing: The lime mud from the foregoing Dorr white liquor clarifier next enters the Dorr lime mud washer, Fig. 82, which again is a multi-compartment tray thickener. Here it is diluted and washed with weak wash water and discharged, low in soda content, to a final dewatering step on rotary vacuum filters. The weak liquor resulting from the washing operation is utilized for dissolving new smelt, just as was the wash water originating in the dregs washing step.

Lime Mud Reburning: The lime mud is dewatered and given a light wash on a rotary vacuum filter, before discharging into the rotary lime kiln. Such wash water as is used on the vacuum filter joins the wash water circuit and is utilized as indicated on the flow-sheet.

The rotary kilns may be fired with power, coal, oil or natural gas. The reburned lime issuing from the discharge end is stored in a bin adjoining the bin containing new lime and eventually re-enters the system via the rotary lime slaker.

A Typical Chemical Balance.

The actual chemical workings of a typical Dorr recausticizing system are well illustrated in Figure 83, which shows diagrammatically a soda balance at a recent installation. The reader should note that it is laid out very much like the equipment layout in Figure 78 and shows by broad lines and figures, the chemical conditions existing at each of the steps in the flowsheet.



Courtesy: Dorr Co., Inc., New York

FIG. 83.—Diagram showing soda balance at a typical Dorr recausticizing installation.

This soda balance was made in the No. 2 Dorr recausticizing system at the Union Bag & Paper Corp.'s sulfate pulp mill at Savannah, Ga., in 1937, which has a capacity equivalent to 750 tons of kraft pulp per 24 hours. The study on which this balance was made represents a three weeks' period of continuous sampling and indicates a total soda loss of 26.36 lbs. of Na_2SO_4 per ton of pulp, corresponding to an overall soda recovery of 98.84 per cent. In this connection it should be borne in mind that in the manufacture of sulfate pulp from 250 to 300 pounds of salt cake must be added to the liquor system for each ton of pulp produced.

CHEMICAL BALANCE IN A DORR RECAUSTICIZING SYSTEM IN TERMS OF SODIUM SULFATE PER TON OF PULP

(a) Soda Entering as Sodium Sulfate	
Raw green liquor	2281.93 lb.
(b) Soda Recovered as Sodium Sulfate	
As strong white liquor	1687.5 lb.
As weak green liquor	29.30 lb.
As weak white liquor (and this includes soda from filtrate)	538.789 lb.
(c) Soda Lost as Sodium Sulfate	
In classifier grits	0.023 lb.
In green dregs to sewer	2.63 lb.
In filter cake to kiln	23.71 lb.
Summary	
(1) Total soda entering	2281 93 lb.
(2) Total soda recovered	2255.566 lb.
(3) Total soda lost	26.364 lb.
(a) Overall soda recovery in green liquor system	99.88%
(b) Overall soda recovery in white liquor system	98.95%
(c) Overall soda recovery in Dorr System	98.84%

Typical Operating Results.

The table below gives typical operating results at a 300 ton a day kraft board mill in the South. This is not the same mill as covered in the preceding table.

OPERATING RESULTS

General Overall Plant Results (6 Weeks' Daily Average)	
Daily production kraft pulp, tons per 24 hr.	310.8
Green liquor production, cu. ft. per ton pulp	87.2
Availability of reburned lime, per cent	79.9
Total lime required, lb. per ton pulp	474.3
Loss of salt cake in system, lb. per ton pulp	0.676
Green Liquor Handling	
Density of clarified green liquor, deg. Bé.	20
Temperature of clarified green liquor, deg. F.	180
Equivalent salt cake in washed dregs to sewer, lb. per ton pulp	0.676
Lime Slaking	
Lime Slaked, lb. per ton pulp	474.3
Washed grit rejected, lb. per day	1,580.0
Dilution (liquid to solid) slaker discharge, ratio	3.63/1
Dilution (liquid to solid) classifier overflow, ratio	6.35/1
Recausticizing	
Detention period during causticizing, hours	1.74
Temperature during causticizing, deg. F.	200–210
Causticity or conversion after causticizing, per cent	84.0
White Liquor Production	
Temperature of clarified white liquor, deg. F.	185
Causticity of clarified white liquor, per cent	85.2
Density of clarified white liquor, deg. Bé.	20–22
Dilution (liquid to solid) thickened lime mud, ratio	1.5/1
Lime Mud, Washing and Filtration	
Moisture content filter cake, per cent	51.5
Equivalent sodium sulphate content washed cake, per cent	1.37
Mud washing efficiency secured, per cent	99.3

The table below lists the connected horsepowers of all motors, which may be compared with an average power load for a full 24-hour period of between 67 and 75 hp.

CONNECTED HORSEPOWER OF MOTORS

Drag conveyor, unloading new lime	5
Rotary lime crusher	10
Bucket elevator, crushed lime to bin	3
Bucket elevator, reburned lime to bin	5
Lime feeders and screw conveyor	5
Rotary lime slaker	10
Bowl classifier	5
Thickener, green liquor clarification	2
Diaphragm sludge pump for above	1½
Thickener, dregs washing	2
Diaphragm sludge pump for above	1½
Causticizers (3)	10
Thickener, white-liquor clarification	2
Diaphragm sludge pump for above	3
Thickener, lime mud washing	2
Diaphragm sludge pump for above	3
Diaphragm sludge pump, spare	3
Repulping agitator, filter feed	1
Continuous vacuum filters (4)	12
Vacuum pumps (2)	30
Filtrate pumps (2)	6
Centrifugal pump, filter overflow recirculation	3
Miscellaneous centrifugal pumps, liquor circulation (4)	30
Total	155

This Dorr system, which is quite typical of recent southern installations has demonstrated its ability to produce easily the quantity of digestion liquor required to produce 310 tons of kraft board per day, with a soda loss corresponding to only 0.67 pound of sodium sulphate per ton of pulp. The clear digestion, or white liquor, has a temperature of 185° F., a strength of 20-23° Bé., and a causticity of 85.2 per cent and contains, on the average, 175 grams per liter total alkali, consisting of 115.2 grams per liter NaOH, 31.8 grams per liter Na_2CO_3 and 28.1 grams per liter Na_2S. A small quantity of soda, equivalent only to 1.37 per cent Na_2SO_4, is contained in the filtered lime mud, but all of this is returned to the system, since the lime cake is reburned in a rotary kiln and subsequently reused.

Control by Sampling.

Control of a continuous recausticizing system should not be done on a hit or miss basis. This means that the sampling procedure and analytical apparatus should be simple, so that it can be followed accurately at a bench in the recausticizing room by operators who have only the faintest conceptions of the relation of chemistry to the physical and mechanical workings of the plant.

Some suggestions in these respects follow, and a more extensive paper on this same subject, containing charts, graphs and detailed analytical methods, will be found in "How to Control the Continuous Recausticizing System," presented at TAPPI Convention, New York, Feb. 21-24, 1938, appearing in "Paper Trade Journal," March 3, 1938.

Lime.

New—Sample each carload between elevator and the storage bin. Analyze for CaO, in the plant laboratory.
Reburned—Take a pint sample every hour and analyze the composited sample for CaO each shift, in the plant laboratory.
Combined Limes—Take a sample hourly from the feed to the slaker and analyze the composited sample for CaO each shift, in the plant laboratory.

Classifier Grits.

Take one sample each shift and test in the plant laboratory for Na_2O and CaO.

White Liquor.

Take hourly samples to be tested by the operator in the plant for activity.
Send hourly composited samples to the main laboratory each shift for complete chemical analysis—activity, causticity, sulfidity, and total soda.

Thickener Underflows.

Weigh timed samples hourly for operator to use in calculating dilution.

Filter Cake.

Take hourly samples to be composited each shift and analyze in the plant laboratory for Na_2O and CaO and moisture.

Green Liquor.

Take hourly samples to be composited and sent each shift to the main laboratory to be tested for total soda and per cent insoluble solids.

Green Liquor Clarifier Underflow.

Weigh timed samples hourly for operator to use to calculate dilution.

Green Liquor Dregs.

Same procedure as above.
Hourly samples composited by shifts and sent to laboratory for Na_2O analysis.

In addition to these tests and samples, if the system is to be in balance always, the operator must (1) note the quantity of white liquor produced, (2) read the meter for fresh water to the green liquor and white liquor systems, (3) watch the weak liquor feed volume as well as the volume of the green liquor consumed, and check the weight of lime entering the system.

Efficiency of Causticizing Processes.

In discussing the relative merits of the different causticizing processes used in soda pulp mills and their efficiency as regards steam consumption and alkali accounted for, it is necessary to form some basis of efficiency. In the older decantation process, in most general use, time and capacity are the principal efficiency factors.

An alkali room (causticizing room) having ten pans (each of such capacity that when charged with liquor, causticized, properly settled, drawn off and mixed with a properly settled first wash, there will be enough liquor for two digesters) is capable of furnishing liquor enough for twenty digesters in 24 hours. In other words, each pan should be allowed 24 hours for one complete cycle in order to obtain good economical results. This will allow the strong and first wash each 4½ hours and each of the other three washes 3 hours to settle before syphoning off the clear liquor. When handled in this way, the lime sludge discharged will contain about 85 per cent weak liquor and 15 per cent solids by volume, or 68 per cent weak liquor and 32 per cent solids by weight. The loss of soda in this sludge discharge will be from one-half to three-quarter per cent of the total soda used.

Thorough agitation is also a necessary factor in causticizing soda efficiently. If the agitator shaft is provided with one set of wings near the bottom, it should make at least 30 r. p. m.; but provided with three sets of wings at three different heights, the speed of the shaft can be cut to 16 to 18 r. p. m. and give equally good results. Of two mills using the same size alkali pans, the same quality of lime, and all other conditions the same, excepting the speed of the agitator shaft, the shaft in one mill made 20 r. p. m. and in the other 30 r. p. m., with the result that the former was obliged to use about 8 per cent more lime than the latter; and, on account of using extra lime to get the same causticity, 6 per cent less liquor was syphoned from the strong pan in the former mill, after allowing the pans to settle the same length of time.

When using a lime containing 94 per cent active calcium oxide, it is customary to use from 550 to 600 pounds of lime for each 1,000 pounds of sodium carbonate causticized, in order to get a strong liquor having 92 per cent of the total soda causticized. This strong liquor when mixed with a first wash of 97 per cent causticity, will furnish liquor of about 94.5 per cent causticity for the digesters. The lime when slacking in the pan of liquor heats it and will furnish about 480 B. t. u. per lb. or 268,800 B. t. u. for every 1,000 pounds of sodium carbonate causticized. This will raise the temperature of the liquor about 30° F. If the liquor from the leachers tests 160° F., the lime added will raise the temperature to 190° F. so that it is only necessary to add enough steam to raise the temperature 27° higher to reach boiling point. It is only necessary to boil the pan of liquor about 15 minutes, when the agitation is good, but agitation should be continued from 20 to 30 minutes longer.

The influence of quality of lime on time necessary to boil the liquor is important. The calcium oxide content of a lime, as found by analysis, very often comes far from representing the active content of the lime. Samples of lime with a total calcium oxide content of 85 per cent have shown an active content as low as 72 per cent. The principal cause for the difference between the actual and active calcium aside from that present as carbonate, is the presence of an excessive amount of silica and alumina in the form of silicates, which has been fused by overburning in the kiln, and encloses some of the active lime, making it difficult for the slacking water to reach it. Lumps of this lime will stand in hot water as long as 25 minutes without breaking down, while a lump of good slacking lime will break down completely in about one minute. It will be found advantageous to make a rough slacking test in the alkali room, when a car of lime appears refractory; and if it requires much time for the lumps to break down better results can be obtained by boiling the pans of liquor an additional half hour. By the old process, allowing 24 hours for one complete cycle, eight pounds of soda ash can be causticized per cubic foot of pan capacity in 24 hours. Many soda pulp mills have increased their production to such an extent that the alkali room is worked far beyond its capacity; and the result is inefficient operation in this department. The original ten pans are trying to do the work of fifteen, which results in cutting the cycle of time 16 hours in place of 24, and causing a loss of from 3 per cent to 4 per cent of the total soda causticized.

The newer processes cannot be considered substitutes for the causticizing process, as the first step in the operation is the same in every case. The soda ash must first be causticized by boiling with lime. It is from this point on that improvements have come to the assistance of the soda pulp manufacturer. By a small addition to his alkali room he is able to secure, with the same number of pans, an increase in capacity of 100 per cent to 150 per cent. The improvements consist in new methods of separating the liquor from the sludge after the causticizing process is finished, effecting a saving of time and space, and cutting down the loss of soda in the sludge discharges.

Percentage of Recovery.

Throughout the recovery plant in a soda mill everything must be reduced to standard methods and accurate records must be kept, otherwise there is sure to be a steady loss in soda which cannot be explained by any one factor. Such a loss is usually the sum total of a great many things that are not being done as they should be. When the standard amounts of liquor or water to be used for washing, the standard time for washing, etc., have been worked out on the basis of tests made by the laboratory, strict adherence to these standards should be insisted on and a system of records devised to show how well the system is working out. Just as in the sulphite process, accurate records should be kept of each digester cook. Then the time consumed in washing each charge in the washing pans should be recorded. The records of the evaporator department should show the concentration of the liquor from the washing pans, the density and temperature of the concentrated liquor produced (these measurements should be made hourly) and the pressure maintained on each effect of the evaporator. The concentration and temperature of the evaporated liquor should not vary perceptibly from hour to hour. If they do, a thorough investigation should be made of the working of the evaporator system. The liquor going to the rotary furnaces should be tested several times each day and the total amount of this liquor should be known. A careful record should be kept of the amount of fresh soda added.

In making up the liquor for use in the digesters a hydrometer should be used to determine whether the liquor is up to standard or not, and the degree of causticity should be determined by the laboratory. The help in the alkali room can easily be trained to make the causticity tests which can be checked from time to time by the chemist. Needless to say, the digester liquor must be absolutely uniform. If abnormal amounts of soda have to be added to bring the liquor up to strength it is evidence that some detail of the recovery system is not in proper working order. Although the operation of this department should be checked by chemical tests in the laboratory from time to time, the actual work is done by men who must be instructed simply in terms of so many pounds of lime and soda and so many inches of liquor.

To calculate the percentage of recovery in the mill it is only necessary to know the number of pounds of soda in the liquor charged to each digester, and the weight of new soda used each day. The new soda added is deducted from the total soda and in this way the percentage of recovery worked out.

There is no reason why, with efficient equipment and intelligent, careful supervision, the percentage of recovery should not be in the neighborhood of 95 per cent. This, however, is unusual and the writer knows of two mills, which are usually considered very good soda mills, where the management is satisfied if the percentage of recovery exceeds 85 per cent although it frequently is as high as 90. Probably the average throughout the country would be much lower than this, in all likelihood not higher than 75 or 80 per cent. The chief factors which make the actual percentage recovery lower than the theoretical are: (1) the pulp is not washed long enough or carefully enough in the wash pans; (2) the draft in the rotary furnace carries away some soda mechanically (modern mills are installing devices to recover this soda); (3) some soda is left in the lime sludge after causticizing; (4) some soda is retained by the carbon of the black ash through incomplete washing; (5) poor or improperly operated evaporators will allow some of the soda liquor to escape with the condensate; (6) leaks, spilling, inaccurate weighing and general carelessness. It is usual to charge all losses not otherwise explained to losses "up the stack." The following remarks are from a paper on this subject by George K. Spence.[1]

One of the biggest problems confronting the soda pulp mill superin-

[1] Report of the Committee on Soda Pulp, T. A. P. P. I., 1919. "Paper," Feb. 12, 1919, pg. 619.

tendent today is that of recovering the black ash passing out of the rotary stack.

Some have tried to do so in a wet way by spraying the stack with weak liquor or water, but so many products of combustion and destructive distillation are reclaimed with the ash, that it forms a dirty conglomerate mass, difficult to handle. It is too dirty to send to the leachers, not strong enough to burn without evaporation, and contains too much suspended solid matter to send to the evaporators. The washing has been accomplished very efficiently; but, as stated above, it has been a very difficult matter to prepare the resultant liquor for use.

Attempts have been made to separate the solids from the liquor by passing it through a plate and frame filter press; but this process is very slow and unprofitable. We give below a partial analysis of solids removed by the press and the liquor from solids.

Solids

Water	= 54.65%		
Organic Matter	= 19.22%		
Mineral Solids	= 26.13%	Insoluble	= 1.00%
		Sodium Carbonate	= 23.94%
		Sodium Chloride..	= .688%
		Sodium Sulphate..	= .49%

Liquor

Water	= 72.23%		
Organic Matter	= 9 64%		
Mineral Solids		Insoluble	= .02%
		Sodium Carbonate	= 12.41%
		Sodium Chloride..	= 1.90%
		Sodium Sulphate..	= 2.51%

A centrifugal apparatus has been used, and the resultant solids and liquors showed about the same analysis as the foregoing; but the results of the experiment were not very satisfactory. It does not seem possible to reclaim the rotary stack losses satisfactorily in a wet way.

There have been several methods suggested for collecting this dust in a dry way, the most feasible of which appears to be the Cottrell electrical precipitation process. By this method the dry dust is collected, while the moisture and gases pass out, owing to the high temperature in the stack.

This is an expensive installation as the units are small, requiring 360 collecting electrode pipes 15 feet long and 8 inches in diameter to handle 50,000 cubic feet of gas per minute. Moreover special generating, transforming and controlling equipment is required. The operating expenses, including interest, depreciation, royalty, power, labor, etc., would be about $20,000 a year on such an installation. If by draught control it is impossible to keep the stack losses below 7,000 lbs. of soda a day in a rotary department sending 50,000 cubic feet of gas per minute up the stack, it is advisable to use this or some other dry dust saving system. The Cottrell electrical precipitation system has been installed in the rotary department of quite a few alkaline pulp mills.

While it may not always seem advisable to install an expensive system to reclaim this ash, this important point in the recovery department should not be overlooked. It should be under efficient contiol at all times, and the speed of the flow of gas so regulated as to produce the best burning results, with the smallest possible loss of soda.

In order to determine the loss of black ash from any one or from all rotaries, it is necessary to pass a measured volume of gas through a filtering medium, enclosed in a sampling tube, after which the volume of the gas is reduced to dry gas at standard conditions (32° F. and 29.92 inches of mercury) by means of the following formula:

$$V = V' X \frac{459 + 32}{459 + T} \times \frac{B-S-P}{29.92}$$

V = volume of dry gas at standard conditions.
V' = volume of gas as registered on meter.
T = temperature of water in meter in degrees Fahr.
B = barometric pressure at point where sample is taken.
S = suction in inches of mercury as read from meter gauge.
P = aqueous tension at meter temperature (taken from psychometric tables).

From this corrected volume and weight of dust caught in the filter, the amount of dust per cubic foot of dry standard gas can be calculated. By means of the wet and dry bulb readings in the flue a correction is made for the aqueous vapor pressure in order to bring results to flue conditions. The amount of soda in the dust is determined, which multiplied by the volume of gas passing through the flue, will give the amount of soda lost during any specified time.

It is first necessary to take a Pitot tube traverse of the flue in order to determine the average velocity of the gas throughout the cross-section of same.

A convenient station can be then selected at which to take Pitot tube readings, while samples are being taken, and use a correction factor for the average velocity. For example, if the average velocity is 21 feet per second, and the station selected showed 21.6 feet per second when the traverse was taken the correction factor for this station is $\frac{21}{21.6} = .972$, which should be used to multiply all succeeding Pitot tube readings by in order to obtain the average velocity through the flue.

The velocity of the gas is determined by means of the following formula: $V = 2.9 \sqrt{T.H.}$

V = velocity of the gas in feet per second.
T = absolute temperature in degrees Fahr.
H = velocity head in inches of water.

The volume of gas passing through the flue is determined by multiplying the velocity in feet per minute by the cross-sectional area of the flue in square feet, giving the result in cubic feet of gas per minute.

The velocity of the gas entering the nozzle of the dust collector should be the same as that in the flue. In order to measure the gas at the proper velocity it is pulled through a water filled gas meter by means of a steam or an air syphon. The dust can be caught in paper thimbles when the temperature is under 450° F. If the temperature exceeds this, Alundum thimbles should be used.

1.—Meter reading in cubic feet.

2.—Temperature of water in meter in degrees F.

3.—Suction (negative pressure) on meter in inches of mercury as shown on gauge.

4.—Temperature of gas in the flue in degrees F. (with pyrometer).

5.—Velocity of the gas in the flue in feet per second.

6.—Static pressure in the flue in inches of mercury.

7.—Wet bulb reading in the flue in degrees F.

8.—Dry bulb reading in the flue in degrees F.

It is also necessary to know the barometric pressure at the point where the sample is taken.

By tests made in the above manner it has been found that 14-foot rotaries lose from 450 to 1,000 lbs., 16-foot rotaries from 650 to 1,300 lbs., and 30-foot rotaries from 2,500 to 4,000 lbs. of soda up the stack in twenty-four hours.

Many varieties of dust collecting chambers have been constructed between the rotary and the stack, some of which are fairly efficient; but, as a general rule, the ash collected represents only a small percentage of the amount of ash passing up the stack.

The Sulphate Process.

The sulphate process is a modification of the soda process in which sulphate of soda is used to replace soda ash. This process was invented by Dahl in Europe about 40 years ago. The Scandinavian pulp makers were finding it hard to sell their soda pulp in competition with the then recently introduced sulphite pulp and welcomed the sulphate process for which they obtained sodium sulphate cheap from England, where it was a by-product of the chemical factories. The first introduction of the sulphate process in America was at the plant of the Brompton Pulp & Paper Co. in Canada in 1907, since which time the industry has developed rapidly. It was originally used for making a pulp which was subsequently bleached yielding a very fine grade of stock from which excellent soft pliable papers suitable for book and other purposes could be made. A considerable amount of sulphate pulp is still prepared which is subsequently bleached, especially in Europe, but the greatest application of the sulphate process today is in making what are known as kraft papers. Kraft paper is an exceedingly strong, tough paper, ideally suited for wrappings and bags. It is not bleached, having a natural brown color which is characteristic of this variety of paper. As there is a great demand for this product and as a number of woods can be reduced to pulp by this process much more economically than by any other, manufacture of kraft paper by the sulphate process has assumed very large proportions in the paper industry.

Originally kraft paper was made by only partially digesting the pulp and subsequently completing the process by mechanical means such as grinding in a kollergang or edge-runner. This procedure required a great deal of power and also gave a very limited output as the capacity of the kollergang was comparatively small. In the modern production of kraft pulp, the cooking is more thorough, and the subsequent disintegration of the pulp is accomplished in the beaters and Jordans and in some modern plants in Jordans alone.

The sulphate process costs more to operate than the soda process, especially as concerns the recovery system.

The Cooking Liquor.

Although the process is known as the *sulphate* process because sodium sulphate is used in making up the liquor, a number of other compounds of soda are present in the liquor as used. The liquor as actually used contains in solution:

Sodium Hydroxide	($NaOH$)
Sodium Sulphide	(Na_2S)
Sodium Carbonate	(Na_2CO_3)
Sodium Sulphate	(Na_2SO_4)

The actual digestion of the pulp is mainly effected by the sodium sulphide in the liquor and it has been suggested that *"sulphide process"* would be a more correct name than *"sulphate process"* for this method of making pulp. A high percentage of sulphate or carbonate in the cooking liquor is undesirable.

Equipment.

The digesters used for the sulphate process are of the same general types as those previously described in connection with the soda process. They must be well insulated to avoid heat losses and excessive condensation. Just as in the soda process no special lining is required, such as is used in the sulphite process, because the cooking liquor does not attack the metal of the digester. Direct cooking such as is used in the sulphite process is extensively employed. However, recently various systems of indirect cooking, the digesters being equipped with a system of forced circulation, have been successfully applied. It is claimed by the proprietors of one such system that it will reduce the cooking time to one-third of that required by the direct cook, that it will save chemicals, and that it will render the evaporation problem in the recovery of the liquor much simpler, owing to the fact that in the indirect cooking process the liquor is not diluted by steam. It is stated that the actual saving for a three-ton digester based on six cooks daily will amount to 1,500 tons annually. The objection to the indirect process in the past has been based on the difficulty of keeping the equipment in good order. Today metallurgical progress has largely disposed of this objection. Great attention has also been paid to the details of the design of the heaters and pumps in these systems and they are in successful operation in many sulphate mills today.

Vertical Rotary Digester.

Horizontal rotary digesters are little used because of difficulty in charging. Spherical rotary digesters are in use in a few mills only. The usual type of rotary digester is the vertical, revolving around trunnions, which must rest in strong bearings on a strong foundation as they support the huge vessel. The height of the digester is about three times its diameter and both ends are conical, at an angle of 45 degrees from the vertical. At the top is a cast-steel neck fitted with a cover for charging. This is about 20 in. diameter. At the bottom is an outlet about 8 in. diameter for dis-

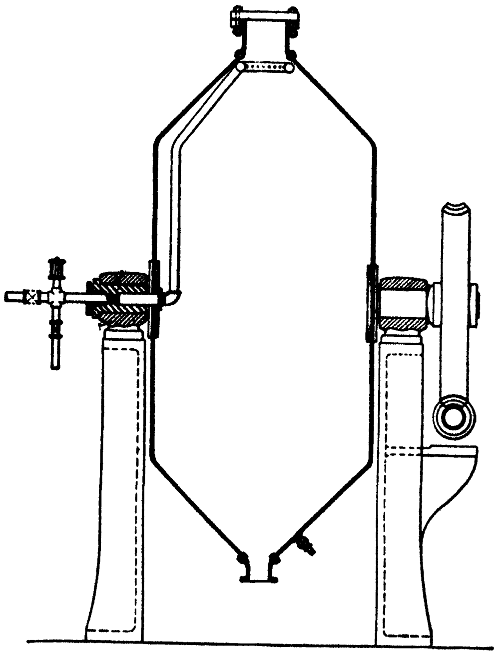


FIG. 84.—Diagram of typical vertical rotary digester.

From "The Manufacture of Pulp and Paper," Vol. 3, 3rd ed., 1937, by courtesy of the McGraw-Hill Book Co., Inc., New York.

charging. The steam pipe enters through the trunnion and continues up the wall of the vessel to near the top where it terminates in a perforated ring through which the steam is admitted to the pulp. Near the outlet is a sampling cock which is also used for relieving air and turpentine vapor in the early stages of the cook. For this purpose a hose is attached and the digester rotated so that the cock is at the top, to prevent any liquid being passed out. The rotating mechanism is a worm-gear driven by an individual motor with powerful starting torque.

Such digesters have usually a capacity of about 3 tons air-dry kraft pulp. Some have been built for as much as 5 tons, but the mechanical difficulties increase with the size. They are usually rotated about once every 10 minutes. The condition of the bearings and the steam joints in the trunnions must be given constant attention.

Vertical Stationary Digesters.

Compared with a sulfite digester these are tall and narrow. They are unlined. Some modern kraft digesters are very large, for instance 60 ft. high and 16 ft. wide.

The bottom is cone-shaped at an angle of somewhat less than 90 degrees. The top is dished. Steam is supplied through a perforated coil in the bottom of the vessel. Frequently this coil is fabricated into a self-supporting nest or basket. The steam pipe and coil must be of ample capacity to permit rapid steaming. The relief valve is on or near the neck to prevent any possible loss of alkali in relieving. In other respects the digester is much like a sulfite digester except that the contents are usually blown through a diagonal pipe into a "cyclone" located above the washing tanks instead of into a blow pit. If the pressure is lost before all the pulp is blown up, live steam has to be used to complete the operation. The chip bins, located high over the digester charging floor, must be of ample capacity—for a 100 ton mill at least 300 tons of chip capacity, which calls for a very staunchly and durably constructed digester house.

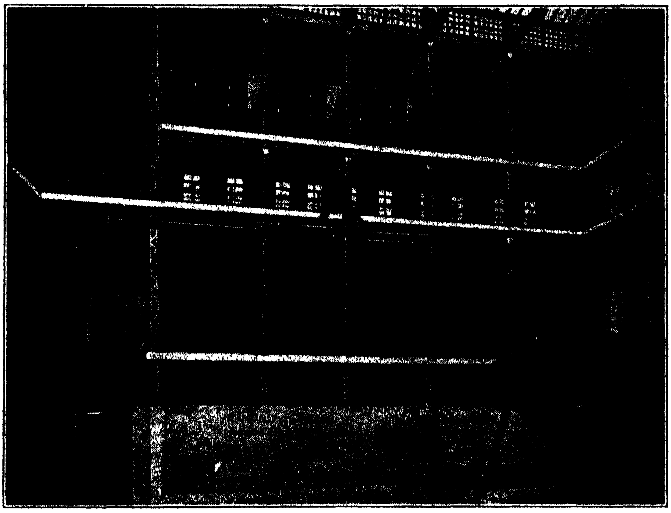
Details of the Process.

The wood is prepared for the sulphate process exactly as for the sulphite process, the chips being from $\frac{5}{8}$ in. to 1 in. long, excepting that it is frequently not considered necessary to exercise such extreme care to eliminate all bark and unsound wood as in the case of the sulphite process. This is because the cooking liquor used in the sulphate process will dissolve any particles of bark or unsound wood and they will not be found in the finished pulp.

The above remarks should not be interpreted as meaning that unbarked and dirty wood can be used in the sulphate process to produce the best quality of pulp. The wood is barked for use in the sulphate process just as in the sulphite, but the extreme care which the best manufacturers of sulphite pulp use to prevent particles of bark ever getting into the digesters is not necessary in the sulphate process. For instance, if a block happened to have a few shreds of bark adhering to it after leaving the barking drum, it would hardly be necessary to remove this bark by hand as should be done in making sulphite pulp.

The wood is chipped just as for the sulphite process and the chips stored in bins from which they are run into the digesters. The procedure for charging in the sulphate process is somewhat different from in sulphite. Liquor is first admitted to the digester, running for about one minute. Then liquor and chips are fed together until the required amount of chips is charged. Often a little steam is admitted as soon as the coil at the bottom of the digester is submerged. This helps distribute, soften and pack the chips. Paddles and mechanical chip packers are also sometimes employed. Finally the digester is gasketed and closed just as in the sulphite process. The pressure is brought up to 20 or 25 pounds at which point the cold air present in the charge is relieved. Immediately thereafter, the pressure is brought up to maximum which is usually about 100 pounds and no relieving is necessary from that point on as, unlike the sulphite cook, no gas is formed during the cooking. There is no top pressure and the temperature and pressure will correspond right up to the end of the cook.

The duration of the cook depends on the quality of pulp to be produced and also on the percentage of moisture present in the wood, and other factors. From 2½ to 6 hours, depending on conditions, is usual; and short cooks, say 3½ hours, predominate. When the cook is completed, the pulp is blown into closed diffusers instead of the open blow pits usual in the sulphite process. These are pressure vessels and retain the steam and other vapors. In making the sulphate pulp it is customary to blow the digesters at a somewhat lower pressure than is usually the case with sulphite digesters. This is done by relieving the pressure just preliminary to the blow. It is claimed that blowing at low pressure will yield a better quality



Courtesy: Swenson Evaporator Co., Harvey, Ill.

Fig. 85.—The interior of sulphate mill showing digester, diffusing tanks and evaporators from which the liquor is pumped direct to the rotary furnaces.

of pulp in addition to making the washing of the pulp an easier matter. The steam blown off is passed through a separator which eliminates turpentine which is always formed in connection with this process. The steam is used to heat some of the water used in washing the pulp.

A very thorough washing is necessary for this class of pulp not only to give a pure stock, but also to recover the highest possible percentage of chemicals used in the process. As a general rule the pulp is washed in a series of diffusing tanks. The diffusing tanks are closed as the vapors given off in the sulphate process are malodorous and noxious. In the first of these tanks it is washed with waste liquor and in each of the succeeding ones with more and more dilute liquor until it is finally washed with pure water. By this process, the percentage of soda in the liquor is systematically concentrated.

The waste liquors all go to a recovery system and the efficient operation of this recovery system is the most important detail in connection with a successful operation of a sulphate mill.

The recovery system consists of evaporators and rotary furnaces quite similar to those already described in connection with the soda process. Where the indirect cook or rotary digesters are used multiple effect evaporators are sometimes dispensed with, the liquor being sufficiently concentrated to go direct to the disc evaporators.

Courtesy: Swenson Evaporator Co., Harvey, Ill.

FIG. 86.—Recovery equipment being installed in large sulphate mill. The vertical structures in the background are waste heat boilers.

However, the later stages of the recovery are somewhat different owing to sulphate of soda being substituted for soda ash in this process. The black ash from the rotary furnace is mixed with sulphate of soda and sawdust and conducted into a smelting furnace lined with soapstone (Alberene stone), or refractory brick. Air is forced into the furnace and the black ash is burned, during which operation part of the sulphate of soda is reduced to sulphide of soda. Some carbonate of soda is also produced and some of the sulphate of soda passed through this process unaltered. The hot gases from this furnace are used to heat the rotary furnace in which the final concentration of the waste liquor has previously taken place. The fused alkali from the smelting furnace runs into a dissolving tank set in a concrete pit and filled with an agitator where it is dissolved with the proper quantity of water or weak liquor from the washing of the lime mud in the causticizing department. It is then pumped to the causticizing system. The causticizing system and the general arrangements for preparing the liquor for charging the digester are not materially different from those used for the soda process.

The fresh liquor from the causticizing department, usually known as "white liquor," is generally made stronger than is intended to be used in the digesters, and is subsequently diluted with black liquor, thus making up the volume and concentration required for the digester. This is generally done with tanks provided with floats. The tanks have previously been calibrated, i. e., the operator knows how many gallons are represented by an inch of height on the tank.

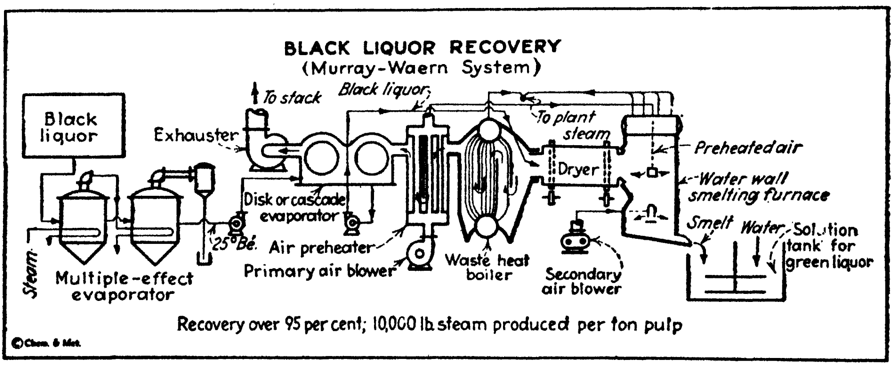
The composition of the cooking liquor depends on many factors such as the nature of the wood, the duration of the cook, etc., but in general it should analyze about 40 to 65 grams per liter of caustic soda and about 15 to 40 grams per liter of sodium sulphide. The total amount of mixed caustic soda and sodium sulphide will be about 16 to 23 pounds per 100 pounds of wood to be pulped, on a bone-dry basis. The sulphate and the carbonate should be kept low in the cooking liquor, as neither of these chemicals has any active part in the pulping process. The sulphate will be high if the reduction in the smelting furnace is not properly conducted. Incomplete causticization is the chief cause of an excess of carbonate. Even if the reduction should be complete in the smelting furnace, there will be some sulphate in the liquor as sodium sulphide will always gradually oxidize to sulphate in solution. In actual practice the liquor contains small amounts of many other compounds of sulphur and soda.

The success or failure of a sulphate mill depends largely on the efficiency with which the recovery system is operated and very accurate chemical control is necessary if the best results are to be obtained in this department. Much that has been written on this subject relates to European conditions which are not identical with those in America and much money has been wasted in attempting to import Scandinavian sulphate practice bodily to this continent. New and improved methods of recovery are constantly being devised by American chemical engineers and evaporator builders which are based on actual knowledge of American conditions. We can only comment on a few of these developments which have been previously referred to in this chapter.

The Wagner Recovery Furnace.

This embodies an attempt to greatly increase the efficiency of heat utilization in the recovery furnace over what is possible with the traditional rotary furnace combined with some form of waste-heat boiler. In the Wagner system there is a single large vertical furnace in which the entire recovery process is consummated. The furnace is circular in cross-section, but the top-half is larger than the bottom. It is about 20 ft. high, 12 ft. diameter at bottom and 14 ft. at top. The liquor is sprayed into the top. Air is injected at the bottom by a positive-pressure blower. The roof of the furnace is lined with boiler tubes, covered with fire-brick, that connect with a three-drum steam boiler at the rear. The gases from the furnace pass through the boiler, a dust trap and finally a scrubber where they are thoroughly cooled and washed before going to the stack. There is an induced-draft variable speed fan between the boiler and the scrubber. This is driven by a variable speed motor, and by it the operation of the whole unit may be controlled. In some installations a Cottrell precipitator is added to the scrubber. The furnace is lined with soapstone (Alberene) or chrome-brick and discharges the hot liquid smelt into a dissolving tank. A recent modification called the Ross-Wagner Furnace has a larger furnace, being 30 ft. high, 12 ft. diameter at the bottom, and the top 14 ft. square, this part of the furnace being water-cooled and filled with vertical tubes ending in headers above the top of the furnace. These headers connect directly with the drums of the boiler, the furnace thus being an integral part of the boiler. Soot blowers keep the tubes clean. The boiler can be adapted for any working pressure desired. Salt cake for make-up is injected directly into the furnace.

Usually this is done by an automatic feeder, but in some installations the salt cake is dissolved in the black liquor fed to the furnace. The black liquor is fed to the furnace at a concentration of from 60 to 70 per cent solids, being brought to that density by means of multiple-effect evaporators.



From: "Chemical and Metallurgical Engineering," New York

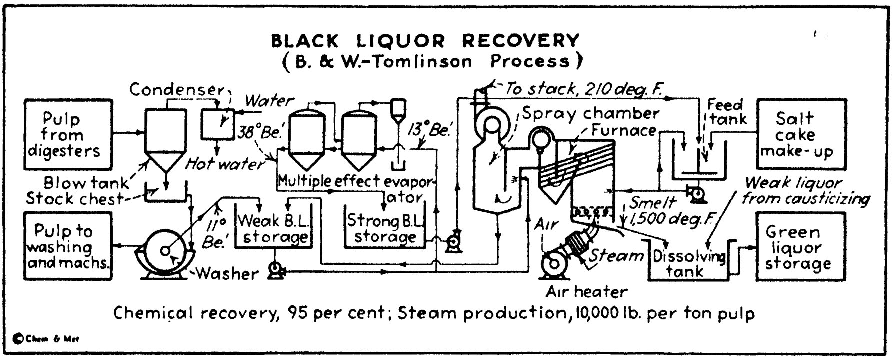
FIG. 87.—Flowsheet of Murray-Waern system of black liquor recovery.

The Murray-Waern Process.

This process for recovering chemicals from black liquors in sulphate pulping process for paper pulp was developed and first installed at plant of Champion Fiber Co., Canton, N. C., by Adolph Waern; improved by

D. J. Murray Mfg. Co., and combined with improved waste-heat recovery by Combustion Engineering Co., present sales agents. Installed in several mills, operating on both northern and southern woods, it is recovering over 95 per cent of chemicals and producing about 10,000 lb. steam per ton pulp.

Black liquor is evaporated to 25° Bé. in multiple effect evaporators, then at 180° F. passes to cascade or disk evaporator, heated by hot waste gases. Gases from latter evaporator pass to fan and stack at less than 250°F., liquor to rotary dryer. Dehydrated, charred liquor from dryer discharges into smelter where sodium sulphate is reduced at high temperature to sodium sulphide by organic content in combustion. Smelt flows to dissolving tank, hot combustion gases through dryer, waste heat boiler and air preheater to evaporator and stack. Air preheater supplies air for smelter, or air may be preheated in jacket around smelter. In first case, smelter has water walls for cooling and steam production.



From: "Chemical and Metallurgical Engineering," New York

FIG. 88.—Flowsheet of Tomlinson process of black liquor recovery.

Tomlinson Process.

This process recovers chemicals and heat from black liquor; it was developed by George H. Tomlinson, of Howard Smith Paper Mills, Ltd., Montreal; first installed at Windsor Mills, Quebec, plant of Canada Paper Co. It makes substantial savings in cost of pulp produced by the sulphate process. A Tomlinson recovery unit consists of a completely water-cooled furnace, over which is set a standard Babcock and Wilcox cross-drum boiler; behind which is located a spray tower. The unit may also be equipped with a superheater, an economizer, and an air heater for increased production of steam. The results include improved recovery of chemicals and maximum heat recovery, with minimum labor, maintenance and space. Average chemical reduction is 90 to 95 per cent and recovery of chemicals, 95. The unit delivers 10,000 lb. steam from and at 212° F. per ton pulp. It can be operated by one full-time and one part-time man. The maintenance cost is negligible, probably five cents per ton.

Operation is as follows: weak liquor from washers, at about 15 per cent solids concentration, is circulated through spray tower, in contact with hot gases from boiler, becoming slightly concentrated. It then flows through multiple-effect evaporators where solid concentration is increased to 55 per cent. Salt cake is added and mixed with black liquor; the mix is sprayed into the furnace under pressure through a nozzle located in the uptake wall.

Courtesy: Jeffrey Mfg. Co., Columbus, Ohio

FIG. 89.—Rotary kiln for calcining lime sludge at large kraft mill in South.

A horizontal spray of coarse particles impinges on the side and rear walls of the furnace. The particles are dehydrated, accumulating as porous char to a thickness of 12 in. The char breaks off and falls onto the hearth in lumps, building up to the level of the primary air ports. The secondary air is admitted above the char. The smelt melts and flows to the dissolving tank.

9. The Groundwood Mill

Groundwood pulp constitutes the lowest class of pulp because of the inferior strength, length and stiffness of its fiber. As a result of these characteristics it is almost impossible to obtain a sufficiently strong sheet on the machine by the use of groundwood pulp alone, but it has, when mixed with a certain percentage of chemical pulp, a wide application in the manufacture of certain grades of paper such as newsprint which are only called on to give service for a short time and then are destroyed.

Most United States and Canadian groundwood is made of spruce: balsam ranks far below in amount ground, and hemlock, pine, poplar and birch follow in the order named.

Making groundwood, as the term implies, is purely a mechanical process—the essential feaure of the process being the placing of a log under pressure against the surface of a revolving stone. There are, however, some slight modifications of this process, the products of which are called semi-chemical pulps, wherein wood before being ground is submitted to a steam treatment.

Very great improvements have been made in the production of groundwood of recent years: artificial stones much more uniform and durable than the natural ones; automatic temperature control systems for all types of grinders; improved grinders of both the pocket and magazine type and improved testing methods all have contributed.

There are many items to be considered in the manufacture of groundwood the most important of which are: (1) Power; (2) Quality of wood; (3) Preparation and handling of wood; (4) Burring of the stones; (5) Temperature and pressure; (6) Speed of stone; (7) Organization; (8) Good mechanical equipment.

Freeness.

As the terms *"free stock"* and *"slow stock"* will be in constant use in this chapter and will be frequently met with elsewhere in this book their exact meaning should be explained. *"Free"* stock is that which consists of coarse fibers. It drains quickly. It will not felt readily when squeezed together. "Slow" stock consists of fine fibers, with frayed ends, from which a dense mat is formed from which water drains slowly. The degree of *"freeness"* of the stock is determined by the rate of drainage of water from it, other factors being equal, such as the nature of the fibers and the temperature.

Power.

Groundwood mills are ordinarily located where there is plenty of available water power; otherwise steam or electric power is used. Up to within a few years ago practically all pulp grinders and other motive power for running screens and presses, etc., was supplied by water turbines, but today the synchronous motor driven groundwood mill is most usual. In this branch of the industry the total horsepower used has grown from 10,000 to something around 70,000 and this figure is steadily increasing as manufacturers are beginning to realize the efficiency of motor driven grinders. If sufficient water power were available the year round there would be no necessity for motor driven grinders, but it is due to the fact that uniform water power is not always available that the water wheel is being replaced by the motor. When water is low a certain number of grinders or of pockets are withdrawn to lessen the load. Some mills find it necessary to make all of their groundwood pulp during that period of the year when water power is uniformily available, but this handicaps other operations at such times when the groundwood mill is not in operation; for during these times the paper mill constantly calls for a variation of free and slow stock which cannot be supplied by the groundwood mill as a result of insufficient water power. With electric equipment production can be maintained with purchased power if necessary.

In grinding wood for newsprint about 60 hp. per ton in 24 hours is required with efficient modern grinders. In old mills the power consumed will often run as high as 80 hp. For groundwood suitable for wrappings or tissues the power consumption will be nearer 100 hp. even in the best mills. Even at best the process of grinding wood is mechanically very inefficient indeed, the friction wasting over 90 per cent of the power in the form of heat. Probably nothing contributes so much to conservation of power as the proper dressing of the pulpstones. The author will dwell further on this point later in the chapter.

Quality of Wood.

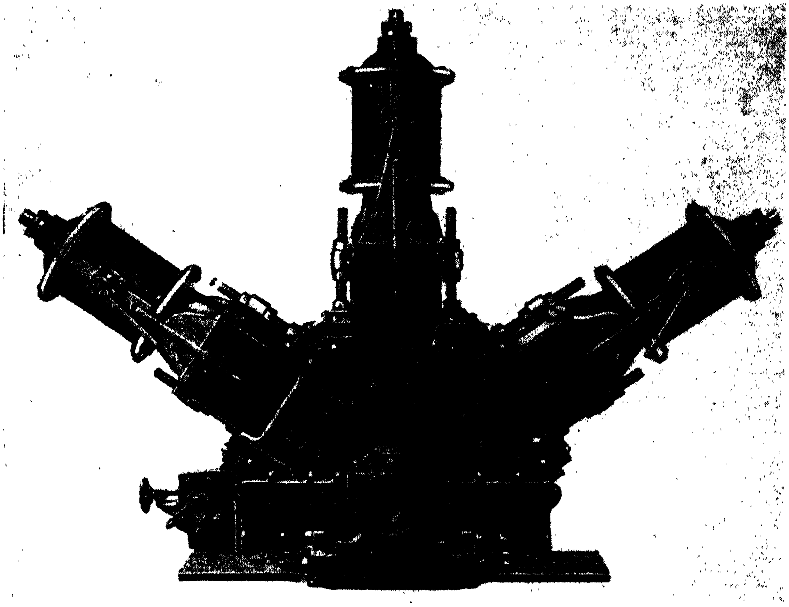
The quality of mechanical pulp is determined to a large extent by the texture of the wood, the age and the seasoning. Wood for grinding must be sound, that is to say, the interior must not be reddened by disease, neither blue nor black owing to the felled trees being left too long exposed to the damp air. The moisture in the air permits slow decomposition of the ligneous fibers, attracts insects, and develops mold.

The best wood is that which, after the trees have been felled, has been preserved on a dry and very airy spot, stacked consecutively so as to allow active circulation of air, and which is used within six to twelve months after cutting. The fresher and greener the wood the more easily will it grind, the yield will be higher and less power will be consumed. It is more difficult to secure a long, free stock from wood that is dried and has been seasoned than from good fresh material. Pitchy wood should not be used for making groundwood pulp unless previously treated by steam.

According to U. S. Forest Service 100 cu. ft. solid barked white spruce will yield 2,400 lb. groundwood; hemlock 2,030 lb.; balsam 1,910 lb.; jack pine 2,150 lb.; aspen 2,200 lb. and birch 2,950 lb.

Equipment.

The equipment of the groundwood mill includes grinders of various types, all of which are efficient under proper management, grind stones with proper burring facilities, sliver screens, stock and pressure pumps, pulp screens, flow boxes, wet machines, stock tanks and hydraulic presses. We must also include generators whether they are run by water, steam or electricity. With the above equipment and with intelligent supervision groundwood pulp can be economically and efficiently made.

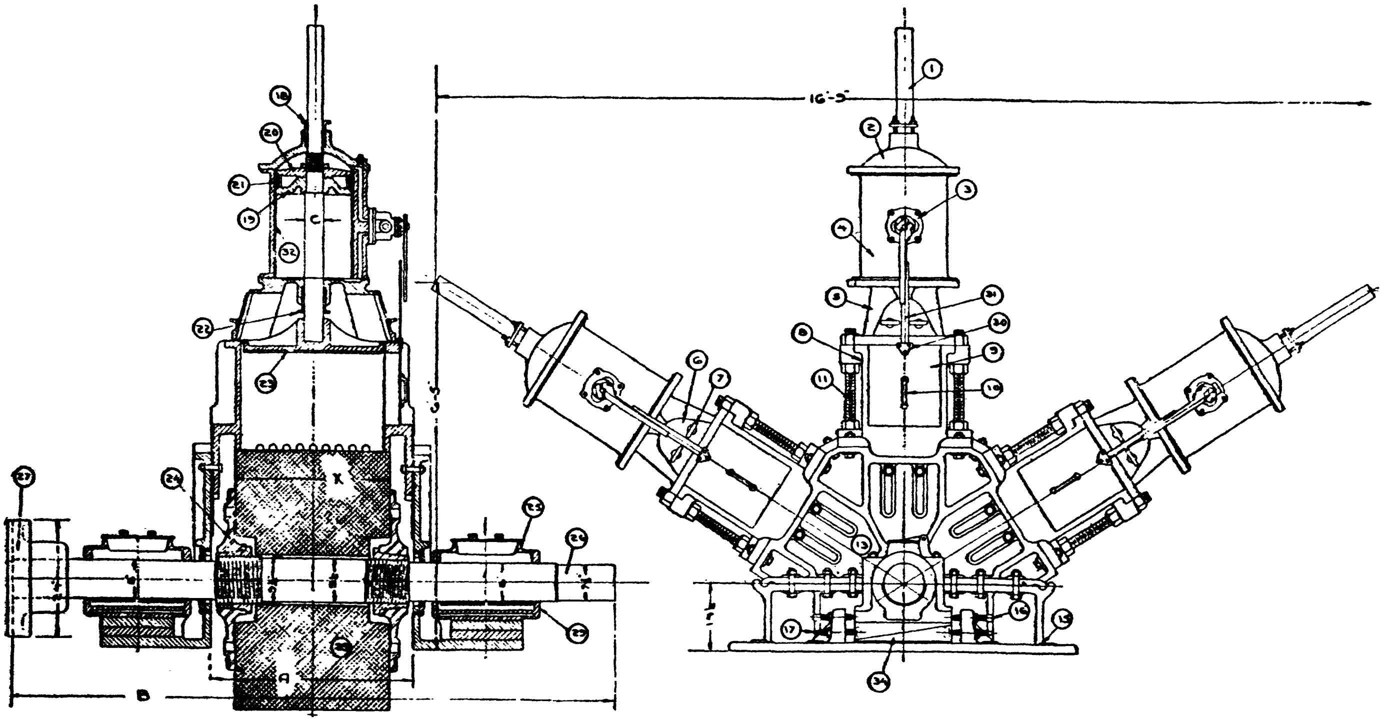


Courtesy: Carthage Machine Co., Carthage, N. Y.

FIG. 90.—Typical three-pocket wood pulp grinder.

Grinders.

The type of grinder most generally used consists of a large grindstone usually from 54 inches to 62 inches in diameter and wide enough to accommodate 16-inch or 24-inch blocks. There are some grindstones in operation 54 inches wide which accommodate 4-foot wood. Both natural grindstones quarried in Ohio, Canada or England, and artificial stones made from silicon carbide, crystolon and similar abrasives are in use. The artificial stones give greater uniformity. The grindstone is mounted on a shaft and revolves inside an iron casing which usually has three compartments. Some four pocket grinders are built but with these usually only three pockets are in use at a time. At the upper extremity of each of these compartments are hydraulic cylinders fitted with piston heads and as the wood is fed into the compartment the head forces the wood against the

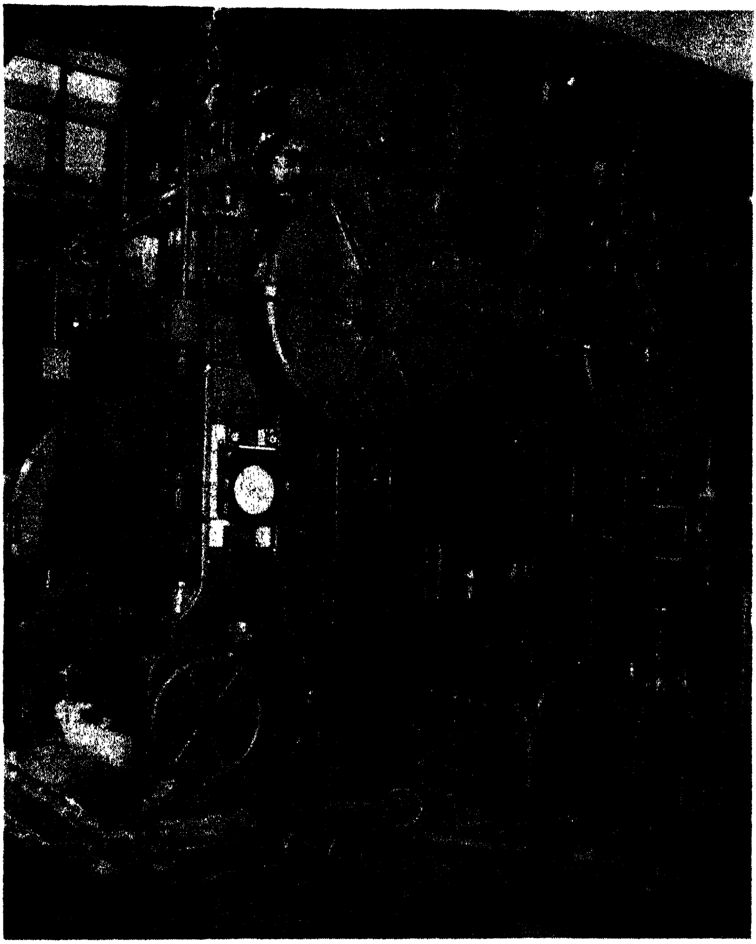


Courtesy: Carthage Machine Co., Carthage, N. Y.

1. Piston. 2. Cylinder Top. 3. Valve. 4. Cylinder. 5. Saddle. 6. Saddle Door. 7. Saddle Door Handle. 8. Pocket. 9. Pocket Door. 10. Pocket Door Handle. 11. Pocket Adjusting Screw. 12. Bridge-tree. 13. Side. 14. Save-all. 15. Base. 16. Box Adjusting Screw. 17. Wedge Adjusting Screw. 18. Top Piston Gland. 19. Piston Head. 20. Piston Cover. 21. Piston Ring. 22. Bottom Piston Gland. 23. Pocket Follower. 24. Flange. 25. Box Cap. 26. Shaft. 27. Coupling. 28. Key Plate. 29. Box. 30. Door Guide. 31. Door Guide Rod. 32. Cylinder Lining. 33. Stone. 34. Wedges.

FIG. 91.—Diagram of typical three-pocket grinder.

revolving stone. The pressure is furnished by either a close fitted centrifugal pump or a duplex or triplex plunger pump. The pump is usually driven from the grinder spindle. The friction between the stone and the wood causes an intense heat which necessitates the use of a large stream of water the object of which is to clear the stone and also reduce the tempera-



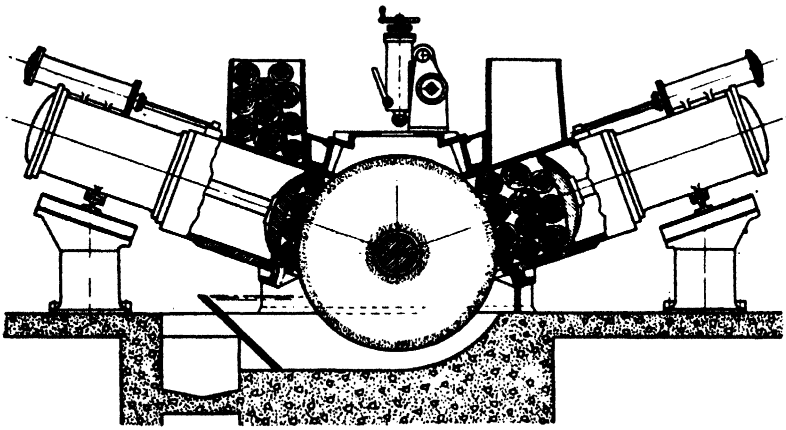
Courtesy: Taylor Instrument Companies, Rochester, N. Y.

FIG. 92.—Modern continuous magazine type grinder.

ture of the operation. Failure to keep the temperature sufficiently low causes the stone to become glazed and the stock is burned lifeless and short. The capacity of the grinder depends on the nature of the wood and the power available, but it usually runs from two tons to seven tons per 24 hours and requires approximately 200 to 600 hp per grinder.

Magazine Grinders.

These grinders have been developed to reduce labor cost and increase production. The first cost is high but the saving in operation is also impressive. Magazine grinders use 48-inch wood. They use very large stones, usually 62 inches in diameter. Much more of the surface of the stone is usefully employed. A modern magazine grinder will make up to 25 tons air-dry spruce newsprint pulp per 24 hours which is about 50 per cent better than the best results with hand-fed three pocket grinders. The labor cost is reduced more than 50 per cent. Also magazine grinders are driven at a constant speed by synchronous motors (usually one motor drives two grinders) which permits a higher average speed and cuts down power losses and also at times contributes to power factor correction. Usually 2400 hp motors are employed running at about 225 r.p.m.



Courtesy: Montague Machine Co., Turners Falls, Mass.

FIG. 93.—Diagram showing operation of Great Northern semi-magazine type grinder.

The Great Northern Grinder.[1]

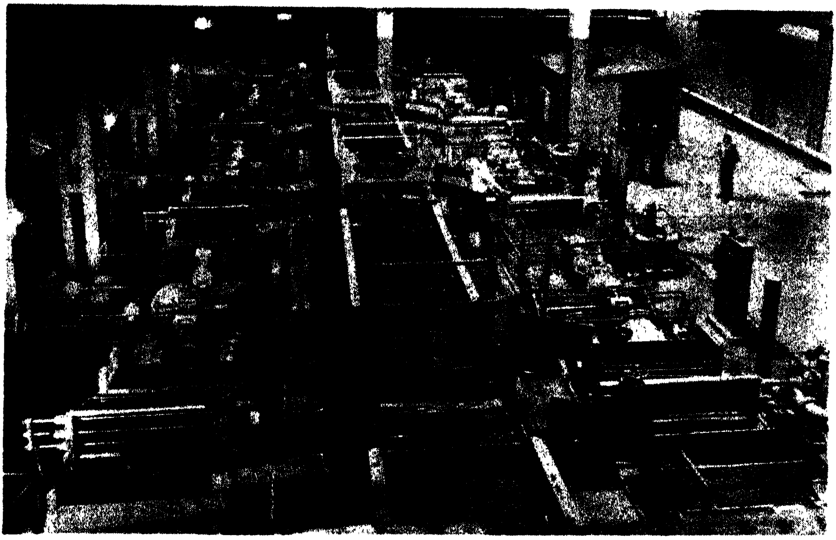
This design of grinder is a natural outgrowth of the conventional 3-pocket design, which had made such a large contribution to the manufacture of mechanical pulp.

The two pockets are inclined at an angle of 20 degrees from the horizontal. Each magazine contains a single charge of wood. The bottom of the magazine in the form of a sliding steel plate also forms the top of the pocket. When this plate is withdrawn, by means of an auxiliary hydraulic cylinder provided for the purpose, the charge falls into the pocket. While the charge is being ground, there is ample time to refill the pocket. The operator is able to observe and make sure that the wood lies properly in a pocket before the sliding door is closed, which reduces binding to a minimum.

[1] U. S. Patents 1,164,074 and 1,757,031.

Ordinarily two grinders in a line are driven by a synchronous motor, hydraulic turbine or a combination of the two. The feeding conveyor is located between the two grinders with walkways at the sides. Where specific gravity of the wood permits, a water conveyor is used and one man feeds four grinders without undue exertion. Working conditions are pleasant also because the design lends itself to ventilation and the grinding room can be kept free from vapors.

A hydraulic truing lathe is mounted on top, which adds greatly to the convenience of stone dressing.



Courtesy: Finch Pruyn & Co., Glens Falls, N. Y.

FIG. 93a.—Typical installation of Great Northern grinders.

Hydraulic operation is performed from the walkways. The pockets are adjustable as the stone wears down. Side frames are designed with a removable section for convenience when changing a stone. When these sections and the hydraulic lathe have been removed, the shaft assembly and stone can be hoisted clear vertically.

The Great Northern grinder is built for a stone size of 62″ diameter by 54″ face for 4 ft. wood and it is built also for 30″ wood or 24″ wood. For 4 ft. wood the shaft runs in anti-friction bearings and for the shorter lengths either anti-friction or plain bearings may be used. In the design for 4 ft. wood the pockets are 31″ wide and for 30″ or 24″ wood they are correspondingly narrower.

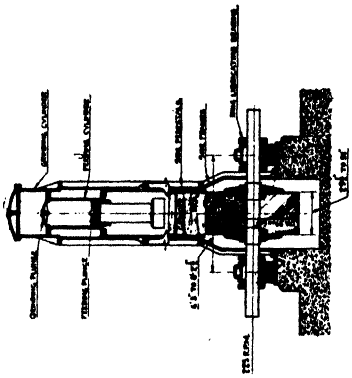
The Kamyr Grinder.

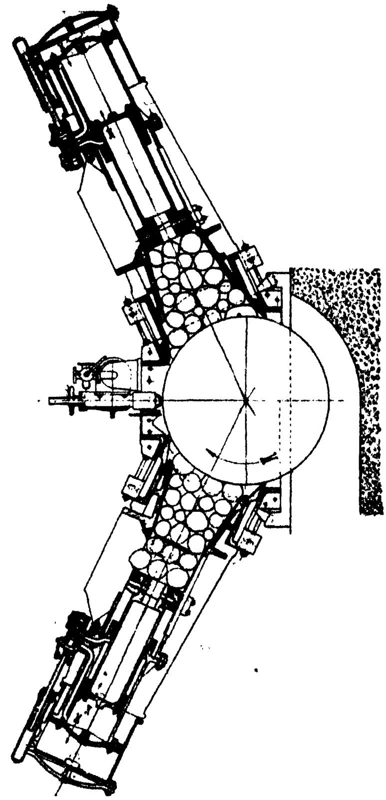
The Kamyr grinder is equipped with two pockets of double plunger system. The stone, having a diameter of 1,500 mm (60″), is fastened to the shaft by means of screwed-on centers of cast steel. The shaft, running

FIG. 94.—Kamyr semi-magazine type grinder.

Below. Diagram showing operation of Kamyr grinder.

Courtesy: Paper Machinery Ltd., Montreal, Canada.



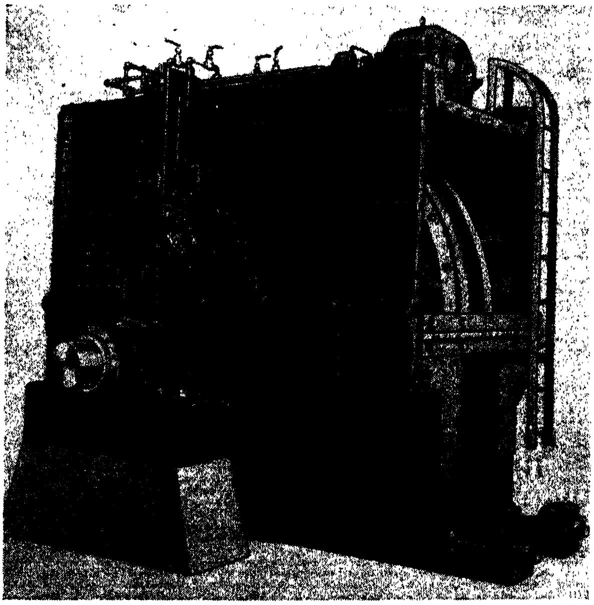


in two specially designed roller bearings, is made of forged steel of a special grade and provided with right- and left-hand threads for fastening to the stone. The bearings and the side frames are mounted on common bed-plates of cast iron. The side frames are provided with rounded bosses fitting into the corresponding holes in the base. When changing stones the grinder is swung up, the bosses acting as a hinge. There is ample space between the side frames and the stone, and there is no fear of pulp or wooden parts sticking there. Before each pocket there is a spray pipe with cleaning arrangement in order to keep the grinding face of the stone clean, *i.e.*, free from pulp. The two grinder pockets which are screwed on to the side frames have frames of steel which carry the pressure cylinders as well as the automatic valve device. The side frames are made into guides for the grinder pockets.

The pressure cylinders have an inside diameter of 700 mm. ($27\frac{1}{2}''$) and are provided with inlets for water as well as necessary safety valves. The feed cylinder is placed in the pressure cylinder, which is attached to the side frames. The cover of the feed cylinder, which is attached to the charging pocket, also works as grinder pressure piston. The packing between the piston and the cylinder is of a special kind. The cast-iron feed cylinder has a diameter of 400-450 mm. ($15\frac{3}{4}''$-$17\frac{3}{4}''$) with inlet for necessary pressure water. The pressure cylinder as well as the feed cylinder has metal linings.

The press plate is fastened to the lower end of the feed piston and is guided on its lower side by the grinder pocket. The press plate also has a dead-steel which passes clear of a knife fixed on the charging box. During the return stroke of the feed piston, the logs are held in position by means of automatically acting triggers placed on the charging box, which is made in two parts, both of steel. The lower part which is conical serves as a magazine for the wood which is pressed like a solid mass continuously against the stone. On the upper side of the charging box there is a cradle on which a sufficiently large number of logs may be piled up to be loaded into the charging pockets in question. This cradle can be turned and emptied with a single manipulation when the charging pockets are ready for a new supply of logs. The hydraulic valve arrangement works entirely automatically and the design of the valve system is such that wear of the parts is practically nil. A mixture of filtered water (or condensate) and a special lubricating emulsion, dissoluble in water, is used as pressure liquor. This fluid circulates in the whole pressure system by means of the pumps and is at the same time a reliable lubricant for the cylinder packings and the whole valve system.

The logs in the conical part of the charging box are pressed against the stone by the box and the pressure piston. At the same time a new supply of logs is put into the upper part of the box. When the logs in the charging pocket are ground down to such an extent that the magazine approaches its lowest position in relation to the stone the feed piston starts to work automatically and presses a new charge into the conical part of the magazine. At the same time the magazine withdraws from the stone and returns to its uppermost position in relation to the stone. The new charge of logs being pressed in, the feed piston retires automatically to its original position where it remains until the magazine again approaches the stone and a new supply of logs has to be brought forward. During this return period the logs are kept in position by automatically acting cast-steel triggers provided with springs of steel. Throughout this operation a continuous pressure is maintained between the logs and the stone, and the grinding goes on incessantly. The magazine widens somewhat towards the stone and the logs are pressed into the magazine with a higher pressure than that of the grinding, thus preventing the logs from getting jammed or building bridges.



Courtesy: Appleton Machine Co., Appleton, Wis.

FIG. 95.—The Roberts Grinder.

For the operation of the grinder two pumps are necessary: one high-pressure centrifugal pump for the feed-pressure and one low-pressure centrifugal pump for the grinder pressure, also one hydraulic electrical grinder regulator. In the pressure line from the pump there is an air vessel for which a small compressor delivers the required pressure. For checking the pressure there is a recording pressure gauge and for checking the temperature of the pulp during the grinding a recording thermometer is arranged. The sharpening apparatus is designed for hydraulic or mechanic guiding and made in such a way that the sharpening of the stone can be done exactly according to the desired quality of pulp. The sharpening apparatus is placed under one of the charging pockets at the lower end of the grinder stone.

The Roberts Grinder.

This grinder differs radically in principle and construction from any other type of grinder that has been used in the production of groundwood pulp. It eliminates hydraulic pressure operated pockets and is designed for continuous grinding of wood. It is rectangular in appearance, with heavy cast iron walls. In this box-like chamber a massive ring slowly revolves in a non-concentric circle around a standard pulp stone. The stone surface and the ring surface thus form a wedge shaped pocket having a circular top and bottom. The pulpwood in this chamber is constantly drawn into the wedge and forced against the stone face at a predetermined pressure. The grinder is built to handle wood in four foot lengths and to accommodate a stone 54 in. diameter by 54 in. face. At 240 r. p. m. this grinder produces about 25 tons of pulp in 24 hours. At higher speeds, such as 350 r. p. m., from 45 to 50 tons of pulp are delivered in 24 hours. From 1500 to 2500 hp. motors are used to drive the unit at above mentioned capacities.

As the groundwood pulp reaches the grinder pit, it falls to the sliver screens, a series of iron plates perforated with $\frac{3}{8}$-inch or $\frac{1}{2}$-inch holes that remove the larger bull slivers, knots, etc., which are carried off from the surface of the screens by a drag conveyor, dumping the bull slivers in a receptacle at the top of its course. The screen and conveyor are constantly showered with water to wash off any fibers adhering to the large slivers. These bull chips are in turn sent to a sliver grinder or else burned as fuel in the boiler house. Either flat or rotary screens can be efficiently used for the removal of these large bull slivers.

The stock freed from these large slivers is pumped to a centrifugal or diaphragm pulp screen, which removes the last traces of slivers and coarse stock. This stock pump is either a slow speed fan pump or a plunger type pump. It is very good practice to design the pipe suction from sliver screen to suction of pump of ample size to handle stock without unnecessary friction. An 8-inch open impeller centrifugal pump will handle the stock from four 3-pocket grinders under ordinary conditions and will pump the stock to the screens with approximately 20 hp. This figure is for a stock line of 8 inches diameter and approximately 150 feet in length. Through these screens only the finest fibers are permitted to pass, the rejected coarser particles being passed through a Jordan or some other machine for reducing and refining them, after which they are again passed over the screens. The construction and operation of these screens is described in detail elsewhere.

At this point in the process the consistency of the stock is about one-half to one per cent, as a large amount of water is required for disintegrating and washing and screening—approximately 150,000 gallons of water per ton of air dry product.

The removal of a certain percentage of water from this very dilute mixture is ordinarily performed by means of a decker or pulp thickener which is a cylinder revolving in a vat of stock, the cylinder being fitted with a wire netting of about six meshes to the inch, which supports a finer wire cloth. The top of the cylinder is above the contents of the vat and as it revolves the water passes through to the inside and leaves a thin layer of pulp on the outside. At this point the machine resolves itself into either one of two types depending on whether deckered stock or pressed stock is to be made. If stock is to be used in the mill direct, it can be scraped off from the top of the cylinder with a doctor and then pumped to the beater as required. For this purpose, either an open impeller double suction centrifugal pump or a triplex ball valve pump is suitable. This operation is that of deckering while the machine consisting of vat, revolving cylinder and doctor for removing the stock is termed a decker. The other type is that of the wet machine or press. This will be described in the chapter on the screening and refining of pulp. Where the paper mill is isolated from the pulp mill the stock is prepared in this lap form.

Under ordinary conditions where stock is to be shipped to a short distance the ordinary wet press previously described gives a lap of stock sufficiently dry for transportation. From an economical standpoint where stock must be shipped a long distance it is advisable to submit the laps from the regular wet press to the action of a hydraulic press which leaves only 40 per cent of water in the stock. There are theories to the effect that pulp containing 70 per cent moisture will not decay as rapidly as the hydraulically pressed pulp. In the case of a low test pulp when a certain amount is piled, the weight exerted presses the air out and results in the canning of the pulp, leaving a wet mass which preserves the groundwood just as wood which has been sunk in a river is preserved.

Water Supply.

The water supply for the grinder showers and slush pipes for the groundwood mill is usually furnished by a centrifugal double suction closed impeller pump. The fresh water is taken from a water screen of revolving cylinder type, the size commonly used being 42 inches diameter by 84 inches long, the capacity of this size being 750,000 gallons for 24 hours. This size will supply a 4-grinder mill of approximately 8 ton capacity and will require 12 hp to drive both water screen and pump, provided the pump is not pumping against a head greater than 50 feet, and through a discharge pipe of 8 inches diameter, with 10 inches suction on the pump. The water is constantly re-used in the form of "white water" which contains nearly 20 per cent of the fiber content, and is collected in a white water tank. To this supply fresh water is admitted when needed for make-up. The white water passes through a save-all prior to discharge to recover the valuable fiber.

Operation of the Groundwood Mill.

In the manufacture of groundwood pulp one of the most essential factors, so far as cost is concerned, is that of handling the raw material. All modern plants have studied this question and have arranged their plants so that waste of material and unnecessary handling of material shall be reduced to a minimum, since the raw material itself is the most expensive item.

The wood in its course from the wood yard through the mill up to the grinders should not be touched by hand but should be conveyed by a system of conveyors that will eliminate costly hand manipulation.

The question of barking and cutting and preparing the wood has already been taken up in the chapters on the sawmill and the wood room and therefore call for no further discussion.

Burring: Closely allied in importance to the choice of raw materials is the question of the burring of the stones as the surface of the pulp stones has an extremely important effect upon both the quality and the quantity of pulp that the grinder will produce. Stones suitable for grinding pulp for wall board and various bag papers would not be suitable for making a light weight Manila sheet containing from 40 to 60 per cent of ground-

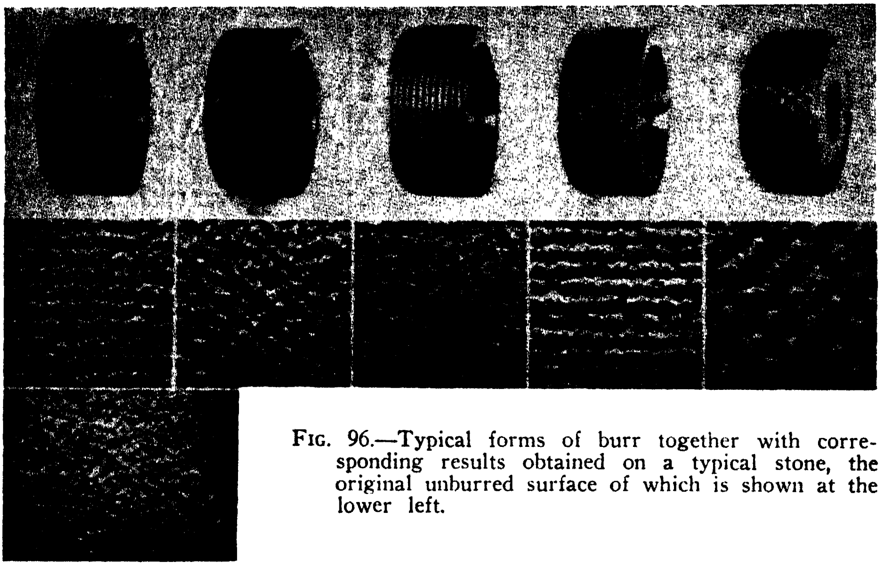


FIG. 96.—Typical forms of burr together with corresponding results obtained on a typical stone, the original unburred surface of which is shown at the lower left.

wood. This necessitates, consequently, the selecting of grindstones properly surfaced for the particular grade of pulp desired. A coarse stone should be used for coarse pulp while a stone with a finer grit should be used for fine pulp. Since stones vary in texture to a large extent, these natural variations must be regulated by proper burring of their surface so that this irregularity will not show up in the finished pulp.

The object of burring is to expose new sharp particles of grit and at the same time provide depressions in the stone. The operation is performed by means of a burr held against the revolving stone by a hand-operated stick or a mechanical or hydraulic dressing attachment. There are many different types of burrs on the market all of which differ slightly in pattern on the outside circular circumference. It is the author's belief that, if two types of burr are taken and the stones ground to the same depth in each case, the resulting products will be similar indicating that if the stone is properly dressed the product will be good, regardless of the type of burr. However, there are some types of burr whereby it is easier to maintain a desired surface and which eliminate a large amount of the personal element in so far as dressing is concerned.

When the grinder pressure and speed are held constant the effect of sharpening the pulp stone is to increase the production and produce a pulp of a coarser quality.

Influence of Temperature: Temperature conditions greatly influence the quality of the final product. The pulp of most value to the papermaker is that which has the best felting properties. To obtain this, the pulp should not be ground too cold, for under these conditions the stones are kept clear of pulp and have a much greater cutting action, resulting in pulp that consists of small bundles of fibers instead of single fibers. This causes it to have no felting properties. On the other hand, grinding pulp too hot results in the so-called worthless flour pulp, which is of no value to the papermaker as the fibers are practically dead and inert. Too hot grinding also causes an excessive wear on the surface of the stone.

It used to be thought that a temperature of 140° F. was a good average temperature at which to obtain a mechanical wood pulp approaching as nearly as possible the quality of a chemical wood pulp. In the past 10 years grinding temperatures have been steadily increased and in the best mills today 155° F. to 170° F. is quite usual and as high as 190° F. sometimes allowed.

Automatic Temperature Control: A sensitive thermometer bulb installed close to the stone, just above the stock level in the pit records the actual *grinding temperature.* The bulb should be of such a form, and so located as to give the temperature clear across the stones. This bulb actuates a sensitive automatic valve on the line supplying the grinder showers, increasing the supply of water when the stone tends to run too hot and decreasing it as the stone cools down. Regardless of the type of grinder, automatic temperature regulation gives increased production, decreased power consumption, more uniform "freeness" of the pulp and longer service from the stones, with less burring.

Pressure: Other variables remaining constant, the production varies directly with the cylinder pressure. The quality of the pulp is determined by the unit pressure with which the wood is forced against the surface of the stone. In grinding a round stick ten inches in diameter, the pressure on the stone will be one-tenth as great when the greatest diameter is reached as when the stick presented a width of one inch near the beginning of the operation, with the ultimate result that the product contains a mixture of fibers produced under a continuous change of unit pressure.

The speed of the pulp stone has a greater influence on production than upon the actual quality of the stock itself, in that the production increases directly with the peripheral speed. But in electrically driven installations the fluctuation is very slight. This variation in speed applies more to water driven units.

The Human Element In Grinding Wood.

In the production of mechanical pulp the human element is an important factor. As a result of the slight readjustment of pressure, temperature, speed and burring the slightest change of workmanship from man to man will have its effect not only on quality but on production. Within certain limits this factor can be controlled by careful supervision, by periodical checks on the mill's operations. It is a well established fact that production will be lowered during night shifts which is easily accounted for. The decrease is caused by the manner in which the pulp wood is fed into the cells of the grinder. This can be so arranged that a block can be wedged between two others, producing a resultant of pressure on the perpendicular sides of the pocket instead of transmitting the pressure to the stone. The stick does not grind away so fast and the operator gets a chance to take a rest. Such factors cause many times decreased production as a result of inefficient workmanship and lack of supervision.

Between the power from the motors or waterwheels, condition of stone surface, cylinder pressure, speed of stone and the human factor there is a very intimate relation. None can be altered without having an effect upon the others.

In groundwood mills operated by water power, when the speed of the stones rises too high production suffers. Some of the most frequent causes for a rise in speed are (1) binding of the wood on the sides of the wood compartments, (2) withdrawal of pressure from one or more grinder cylinders, (3) not replenishing a pocket immediately after it has become empty of wood, (4) drop in pressure in the pump line, and (5) freshly sharpened stones. It will be observed that many of these causes can be traced directly to the operator.

The quality can be controlled within certain limits for different degrees of sharpness of stone by manipulating the cylinder pressure and using lower pressures on a sharp stone and higher ones on a dull stone. Lowering the cylinder pressure for sharp stones causes the speed to rise and if the gate opening is decreased production suffers excessively. Increasing the pressure with a view to increase production requires an increase in power delivered to the pulp stone in which case all of the installation may not be operated.

Grinders have been developed with specially adapted pockets to eliminate the binding which is one of the causes of rise in speed and loss in production, but apparently did not meet with any marked success. Centrifugal pumps have been belted to grinder shafts in order to increase the cylinder pressure with rise in speed of the stone and in this manner restore the speed to normal. Their action is rather sluggish, beside producing large variations in pressure which decreases the uniformity of the pulp. Governors attached to the grinder shaft control the speed successfully but do not permit the water wheels to operate at maximum capacity, since the cause of the decreased load is not removed, and the grinderman can not readily notice faulty performance. Relief valves at the pressure line at each grinder permit adjustments of cylinder pressure to keep the turbines properly loaded but require considerable attention.

As a means of controlling the speed between fairly narrow limits the method of using fewer than the total number of pockets on any line of grinders should give good results. By this method the surplus pockets are kept filled with wood to which the pressure is applied when the load is withdrawn from other pockets for purposes of replenishing or rearranging the wood. The period of increased speed ordinarily accompanying these latter operations is eliminated, and at all times a maximum load may be maintained upon the turbines.

The control over speed should be primarily to maintain production, while quality is probably best controlled by the condition of the surface of the pulp stone. It has been pointed out that the dressing or burring of the pulp stone involves to a very great extent the human factor, and does not permit an exact duplication of treatment.

Each superintendent or manager has his own theories about the method of grinding, and as a result, scarcely any two mills operate under the same conditions, even when grinding the same species and turning out similar products.

For example, one mill producing newspaper has 135 hp applied to each grinder; the pressure computed to the basis of a 14-inch cylinder is 17.5 lbs. per square inch, and the peripheral speed of the stone is 2,660 feet a minute. In another mill, with the same size installation and making the same class of paper, each grinder has 625 hp. applied to it, uses a pressure of 72 lbs. on a 14-inch cylinder, and a peripheral speed of 3,540 feet a minute. A variation of from 135 hp. to 625 hp. to the grinders is seen in the example cited.

Reports of power consumption per ton of pulp in twenty-four hours show a range of from 65 to 100 hp. In view of the extreme variation in the conditions of manufacturing mechanical pulp, it is no doubt true that some mills are operating under conditions of very low efficiency. From experiments it has been determined that the utilization of a considerable amount of power is necessary to obtain a strong paper. It has been noted, however, that paper increases in strength with the power consumption only up to a certain value; above this value the strength will decrease. Maximum efficiency in the production of a mixed groundwood and sulphite paper of a given strength requires the proper adjustment of both the power consumption of the grinder and the percentage of sulphite in the mixture. For instance, it might be desirable to use a small amount of power per ton of pulp and a relatively high proportion of sulphite, rather than a higher power consumption and lower proportion of sulphite. The proper adjustment would depend, of course, on the relative value of groundwood produced by high and lower power, and sulphite fiber.

In electrically driven mills many attempts have been made to control the pressure in the cylinders of the grinders so that nearly constant full load would be carried by the motor. This is desirable, of course, from an electrical standpoint, because by holding constant full load on an electric motor, advantage is taken of its highest operating efficiency. Furthermore, it will be readily appreciated that by maintaining conditions at their full load value, the output of groundwood will be very much increased over a condition where the load falls below normal.

The earliest form of regulation, consisting of belting the pressure pump to the shaft of the grinder, so that when the grinder increased its speed the pump would do likewise and deliver a greater pressure on the cylinder, thereby reducing the speed of the revolving grindstone, is useless on an electrically driven grinder, since the motor speed is practically constant.

A form of regulation better adapted to electrical installations consisted of a throttle operated by the grinder man, who, between his duties of filling the pockets with wood, was supposed to watch an indicating meter and adjust the pressure according to the load as shown by the meter. This method, however, had its shortcomings, for a heavy load would always seem to appear when the grinder man was otherwise occupied.

Electrical Pressure Regulators.

Other systems of regulation have been tried, among which is a solenoid connected to the throttle valve so fluctuations of load on the motor would actuate the solenoid and raise or lower the valve stem. It was found that regulation was not very close and fluctuations in the water system would occur with such rapidity as to cause a pumping action and inability to control the load with any degree of reliability or accuracy. This would cause excessive peaks and high power cost, particularly where power is purchased from a power company.

An electrical automatic pressure regulator has recently been invented and is now in successful use in a number of mills for which the following advantages are claimed:

1. Prevents peak load charges.
2. Prevents overload on motors.
3. Eliminates underloads so motors may operate at practically 100 per cent load factor.
4. Increases the production of groundwood.
5. Improves the quality and uniformity of the pulp.
6. Reduces the amount of splinters or shives.
7. Reduces the amount of short fiber which is carried away in the white water.
8. Reduces the maximum demand horse power where power is purchased and allows, when desirable, all motors to be operated at the exact value of the generator capacity where a mill has its own power plant.
9. Improves the service rendered by the power company by maintaining constant load and better power factor and voltage regulation.
10. In installations involving several grinders, the number of grinder operators can be reduced, as supervision over the load taken by the grinders is not required.
11. Increases materially the electrical performance of the motors and transformers by maintaining them at their full load efficiency.

12. Prevents shutdowns on account of overloads and consequent loss of production.

13. Is absolutely "fool proof" and cannot be interfered with by the grinder operators.

14. The regulator can be adjusted to control the grinder load only or the entire mill load.

15. Small amount of power required to operate the regulator—less than 1-6 hp.

16. Although the grinder operators have to handle considerably more wood, due to the increased production, yet the elimination of responsibility for peak loads and the relaxation from constant attention usually required has been welcomed by the men in charge of grinders.

17. The regulator allows the power station to figure on the exact maximum demand of a paper mill, and where several mills are on one line, the sum of the individual maximum demands will be the exact capacity necessary to be furnished, no extra allowance being necessary to take care of the overloads.

18. The regulator is easily adjustable for load setting in case the demands of the power station or mill vary.

The installation of such a regulator does not involve changes in the system of piping, and pumps used in mills can be used without any extensive alterations, a positive pressure or centrifugal type of pump acting equally well.

Regulation is obtained by automatically varying the water pressure in the cylinders of the grinders so as to obtain constant load upon the motor driving them. Variations in load take place when the pressure is taken from a cylinder preparatory to charging a pocket and again when the pressure is reapplied; also during grinding, since less power is required when the circumference of a log is in contact with the stone than when a greater area of contact is presented when a log is partly ground away.

All the above variations produce a fluctuating load and resultant loss in production, as is obvious by an inspection of the curves taken from a graphic meter chart.

It is seen that without the regulator, as the area of wood in contact with the stone varies, the power taken by the motor varies, since constant pressure is usually maintained in the cylinders of the grinder. In other words, there is constant pressure in the cylinders, but not constant unit pressure on the wood, since its area is varying continually. In order, therefore, to obtain constant pressure per square inch of wood, it is necessary to vary the cylinder pressure a few pounds from normal to secure this, and also to maintain constant load on the motor.

Since pressure per square inch and power variations can be kept constant by controlling and varying the normal water pressure by a few pounds, it has also been desirable to provide means whereby the slight pressure changes are brought about gradually so as to prevent the formation of splinters and shives, as now occurs when the wood is brought in contact with the stone after pressure is applied to a pocket. As a result of this and the constant unit pressure, not only an increased production is secured, but a more uniform grade of pulp is obtained.

The system of regulation most suitable for a particular application is determined largely by the operating conditions which obtain and the class of product manufactured. In two mills having all conditions the same, that which would be suitable for one would be wholly inadequate for another. The proper installation to be made in a given case, however, can readily be determined by a casual inspection.

In carrying out the installation of the regulator, a series or current transformer of suitable ratio is placed in circuit with the motor driving the grinders and connected so that fluctuations of load will cause the moving element of the primary regulating relay to respond therewith. This moving element operates either up or down, depending upon whether the load is above or below the predetermined value, said value being obtained by balancing the movable arm equally between the contacts by a screw adjustment when the indicating meter registers the desired load. As the primary regulating relay element moves upward or downward beyond a certain adjustable distance, a set of contacts is closed, causing the secondary relay or magnet switch to operate, thereby energizing one of the solenoids of an hydraulic regulator valve. Instantly, the core of the solenoid is raised to its extreme position, opening both ports, which were previously closed, thereby admitting hydraulic pressure to the upper end of the cylinder through the other pilot valve port; the piston in the cylinder is thereby forced downward, opening to a larger extent the balanced regulating valve. This permits an increase in pressure in the grinder cylinders, thus increasing the load on the motor driving the grinders.

As soon as the electric load has reached the point for which the primary relay is set, the primary circuit will be broken, causing the secondary relay to break the secondary circuit, and the core of the solenoid immediately drops, forcing the pilot valve pistons to the lower position, which closes both ports, thereby preventing the admission or escape of water from the hydraulic cylinder, and consequently locking the piston of the hydraulic cylinder in the exact position which it occupied between one valve closed. This is usually in some mid position between one end or the other of the cylinder. The piston in the balanced regulating valve controlling the admission of water to the grinder cylinders will, of course, occupy a corresponding position to that of the piston in the hydraulic cylinder, which would be partly open.

Now, as long as the load remains constant, a state of equilibrium will exist in the system; but if the load should increase above the point for which the primary regulating relay is set, contact would be made in that direction, causing the other switch of the secondary relay to close its secondary circuit, energizing the other solenoid, and opening the other pilot valve. The opening of this pilot valve opens both of its ports, admitting hydraulic pressure to the lower end of the hydraulic cylinder through one of its ports and exhausting water from the upper end of the cylinder through its other port.

The piston in the cylinder will then be forced upward and the balanced regulating valve piston correspondingly raised, thereby shutting off some of the pressure applied to the grinder pockets and reducing the load on the grinder motor. As in the first instance, when the load reaches the value for which the primary regulating relay is set, the circuits will be opened, the pilot valve returned to its normal position at the lower end of its stroke, closing both ports and locking the piston hydraulically in some mid position of its stroke at whatever point it happens to be when the correct load value is reached.

The primary regulating relay can be adjusted for any degree of load by simply raising or lowering a screw, so that in localities where the power company changes the available demand from day to day, it will be found very easy to make the desired adjustment and so prevent the occurrence of peak loads.

In order that there may be stability in the operation of this regulator, as in the operation of any governor, there must be a certain limit between the contacts of the primary regulating relay, where the regulating valve will be inactive. One of the most vital points to be met with in the successful operation of the regulator is the length of the time between the change of the load on the grinder motor and the change of water pressure in the cylinder of the grinder. Between these limits, a number of operations are performed, and in accomplishing the proper results, we have given considerable attention to the most efficient speed of operation of the regulator; that is, the ratio between the speed travel of the solenoids and the distance of travel of the valve piston controlling the admission water to the grinder cylinders. This time ratio is adjustable from .2 second and up, so that an exact point for an installation can be set.

There are several limiting points from a practical standpoint that must be considered, among which is an unnecessary operation of the regulator, preventing close regulation, because the time element of the sequence of operations taking place when the pressure is to be regulated has a direct effect upon the hydraulic equilibrium of the system. This condition should not produce hydraulic oscillations or severe shunting will result, causing surges and inability to regulate with any degree of accuracy.

In order to dampen any irregularities in the hydraulic system, use is made of a surge tank of suitable capacity and connected with a by-pass check valve between the main regulating valve and the grinders. This surge tank acts in somewhat similar capacity to a surge tank in a penstock line of power plant.

When the balanced regulating valve controlling the entrance of water to the grinder cylinders is suddenly opened a certain amount of increasing pressure on the side toward the grinders is dissipated into the surge tank, cushioning the effect and preventing an abrupt seizure of the wood upon the grinding stone, thereby reducing the formation of splinters and shives. When the balanced regulating valve is suddenly closed, to a certain extent reducing the pressure at the grinders, a certain amount of pressure is admitted from the surge tank, thereby eliminating any tendency for the regulator to shunt when the by-pass check valve is properly adjusted.

The object of the by-pass check valve is to prevent a large and rapid delivery of pressure from the surge tank to the grinders, but yet be able to absorb considerable excess pressure when the balanced regulating valve is suddenly opened. To secure positive operation, compressed air is maintained in the top portion of the surge tank.

As a further refinement, the gate or piston of the balanced regulating valve is so designed that in opening it the area of port opening increases as the square of the degree of raising of the piston from its seat. By this means a heavy inrush of water is prevented when the valve is first opened, but an increasing amount is allowed as the opening increases. When the valve closes, the amount of water is reduced speedily at first, but tapers off to a minimum as the piston approaches its seat. This gradual change of water will not be slow enough, however, to allow a drop in load on the motor, but by this characteristic, abrupt changes in pressure are prevented and smoother operation secured.

In addition to a regulator for motor operated grinders, there is also a regulator for waterwheel-driven grinders. The apparatus comprising this type is similar to the regulator for motors, except that a centrifugal governor belted to the grinder shaft is substituted for the actuating solenoid of the primary regulating relay. This arrangement maintains constant speed and constant load, so that the gate opening of the waterwheel may be fixed at the best position to permit the most efficient operating speed of the wheel.

On account of the class of labor usually employed, the apparatus has been made as near "fool proof" as possible, so that the operation of the regulator cannot be interfered with by the grinder men.

How to Tell Good Groundwood.

A man accustomed to the manufacturing of groundwood can usually very closely determine the quality of the pulp by observing a few simple rules. The flow of the pulp over the grinder dams, the speed of grinders, pressure gauge, the heat of the pulp (judging from steam arising from casing of grinders caused by friction), the size of cylinders, color of pulp, the sound of the grinders, the amount of slivers running into the sliver screen, etc. All these points can be observed in passing through the grinder room without a close inspection of the pulp. A skillful groundwood pulp maker can casually walk through a grinder room and tell very closely the condition without closely inspecting the pulp or asking questions.

First—The pulp should be a rich creamy color; this indicates that the grinders are not allowed to run too hot, so that the pulp is not burned.

Second—The flow of the pulp over the grinder dams should reveal to the experienced eye the texture of the pulp. Coarse pulp will fill up to the top of the dam and break over it in chunks instead of flowing over smoothly.

Another useful device is the use of a long, sharp-pointed stick for detecting the presence of holes and uneven spots on the surface of the stone. If such a stick is held against the surface of the stone as it revolves, being gradually moved across the surface, any irregularities in surface will reveal themselves by making the stick vibrate. The sense of touch will soon learn to detect even very slight defects in the surface of the stone. This device obviates the necessity of shutting down the grinders to find out if the stones need burring, etc.

Practical Details of Groundwood Manufacture.

Groundwood constitutes the lowest class of pulp because of the inferior strength, length and stiffness of its fiber. With these characteristics it is impossible to obtain strong paper by the use of groundwood alone. Satisfactory newsprint is however made from groundwood alone, and groundwood is a valuable adjunct to other forms of pulp.

Good sound spruce makes the best groundwood, and almost all groundwood made in United States and Canada is from spruce, with small amounts of balsam, hemlock and other woods. Power, quality of wood, preparation and handling of wood, quality of grindstones, intelligent sharpening of stones, temperature and pressure, speed of stones and good mechanical equipment are the chief essentials. The making of good groundwood must be conducted by practical men, experienced in the art, who are familiar with its uses in all the various grades of paper in which it is used, for instance, groundwood is responsible for the quality of newsprint paper, since at least from 75 to 80 per cent of it is used in newsprint. It will be seen that the successful operation of a paper machine running on newsprint at a speed of say 1000 feet per minute is very largely dependent on the skill of the groundwood maker. Consider the difference in the quality and texture of groundwood used in making catalogue paper that must have a fine printing surface and must be opaque so that prints and cuts will not show through the paper. Go to the opposite extreme and consider the quality of groundwood used in making wallpaper and still coarser paper. Obviously the groundwood maker must be a specialist and not a novice.

If a newsprint sheet becomes too free on the Fourdrinier wire so that it will not close up properly, the remedy is in changing the quality of the too free groundwood as a result of permitting the surface of the grindstones to become too coarse, carrying too much pressure, running the stones too hot, etc. The stones may be conditioned to make the pulp less free by dulling the surface or better still by the use of burrs better suited to the grade of pulp required. The effect of carrying too much pressure against the wood makes the pulp coarse and free. If the stones are allowed to get too hot this also renders the pulp coarse and free. The control of the heat of the stones may best be accomplished by the use of an automatic temperature control.

Slow groundwood is produced by the use of fine-cut burrs, running the stones not too hot, and using less pressure against the wood. In the case of burrs used for dressing the surface of pulpstones there is no one common burr that applies to all grades of groundwood. Burrs are made in chisel points, straight cut, spirals, etc., depending on the quality of pulp required.

Groundwood may be inspected while grinding by observing the steam rising from the stone, the rate of production, the feeling of the pulp and by testing a small sample of the pulp on a blue glass. Pulp is tested with a blue glass, a pane of thin blue glass about 6″ x 6″ square set in a frame; a small sample, say two teaspoonsful of the pulp is placed on the glass and mixed with water until it is thin enough to separate the fibers. Hold the glass level and over a light. By looking down through the pulp and glass, the fibers and coarse material can be seen. If the sample contains too much fluff, too many shives and coarse material, condition the grinding surface of the stone accordingly. A laboratory test may be made with special equipment.

This is the object for keeping the cutting surface of the pulpstone well washed with a spray of clean water from a shower pipe to prevent the cutting surface of the stone from filling, as a file will do if it is not kept clean. Moreover, a stone will get hot if it is not kept cool with a spray of water, causing damage and perhaps spoiling the stone. The surface of a stone will chip if it gets too hot and sometimes burst. 140° F. is a good average temperature.

Pulpstones: The usual size of a pulpstone is 54″ in diameter and 27″ thick for grinding 24″ wood. The quality of a stone selected depends on the quality of groundwood desired. The quality of the pulpstone varies. There are fine, coarse and medium grits, some soft and some hard. Pulpstones must be cared for in storage. They must *not* be stored out of doors, exposed to heat and cold, snow and rain. The freezing of a pulpstone ruins it. Pulpstones should be well seasoned before put in use. Green pulpstones direct from the quarries are full of quarry sap and should be seasoned for a year in a dry warm place before using. The producing life of a good pulpstone varies from six to eighteen months, depending on its hardness, the method and frequency of sharpening and operation.

The quality of groundwood pulp may be standardized. All the elements in the process of grinding, screening, pressure, speed of stone, temperatures and rate of production must synchronize one with the other.

The usual speed of a 54″ pulpstone is about 240 r.p.m. The peripheral speed of 240 r.p.m. on a 54″ pulpstone is about 3393 feet per minute. These speeds vary under changed conditions, such as wearing down the stone to 40 inches in diameter. The speed limit of a pulpstone—mechanical factors such as the mechanical strength of the stone, the method of clamping the stone on the shaft, etc., fix its speed limit. The general practice for safe operation is to keep the peripheral speed of the stone below 3500 feet per minute. There are several types of automatic speed controls for pulpstones. If the stones are driven by water wheels, the water wheel gates must be governed by a throttling device, which will open or close the gates gradually or in direct proportion to the increase or decrease of the stone speed. Slamming the gates shut or open causes a violent water hammer which is liable to rupture the wheel casings or penstocks. The speed of electrically-driven pulpstones is easily governed.

Groundwood Screens: Groundwood pulp screens differ from those used for screening kraft or soda pulp; finer cut screen plates should be used but in all other respects they are essentially the same.

Pulp Grinding: The beginning of the use of groundwood in paper is within the memory of men who have spent a lifetime in the manufacturing of paper. Fifty or sixty years ago there was very little groundwood used in making paper. Its use was considered as a dangerous experiment and an adulteration, even if it were used in homeopathic doses. Papermakers in those days would as soon add 5 per cent or 10 per cent groundwood to their food, because there was an abundant supply of raw material such as rags of all qualities and kinds, jute, hemp, etc.

Since that time the use and demand for good quality groundwood has increased to such voluminous proportions that it has become a headliner. The urge for more and better pulp produced at the lowest possible cost has been a great incentive to improve along these lines. The great improvement in the reduction of manufacturing cost of groundwood must be credited to the development of the magazine pulp grinders.

In the present year it would be difficult to find many paper mills that are not using groundwood pulp to some extent. The development of groundwood pulp to the present high standard of quality and quantity has taken many years which is not unlike the development of other industries.

The manufacturing of groundwood pulp has been greatly improved within the past few years both as to quality and tonnage. The advent of the magazine grinder has been responsible for the increased tonnage per unit and much improved quality. Semi-magazine grinders are now making from 17 to 20 tons per stone in 24 hours, while in most cases the 3 pocket grinders make about 7 tons per stone in 24 hours.

The difference between these two systems is the greatly increased size of the stones and the continuous pressure of the wood against the stone which produces a more evenly ground pulp of better quality and a greatly increased tonnage per unit. Temperature control, the crowning accomplishment and a much needed finishing touch to quality, quantity and dependable every day supply of good groundwood has been supplied by the Taylor Instrument Cos. in an automatic temperature controlling instrument for regulating the heat produced by friction of wood against grindstones, as used in the making of groundwood pulp. A variation in heat means a variation in quality of product and affects the quality of paper correspondingly. Wood ground too hot produces coarse fibers and free quick draining stock. Wood ground too cold produces the opposite, fine, slow draining stock. Without the automatic temperature control the product contains both of these extremes and every other quality in between. Every grinding unit in the mill produces a different quality of pulp, if the heat is not controlled automatically.

The importance of a groundwood stock uniform in the characteristics best suited to the product made in each plant has been responsible for a steady improvement in the design of wood pulp grinders, types of stones, size and speed of driving unit, pocket pressures, compensating pressure governors, and grinding temperatures, until today the groundwood process is standardized to an extent that would have seemed difficult twenty years ago. One of the greatest changes in the shortest period of time has been in the temperature at which groundwood pulp is produced. Up to and until about nine years ago, grinding temperatures very seldom exceeded 145 degrees F., and in many plants was from 15 to 30 degrees below that point. During the past nine years grinding temperatures have been steadily increased until now 155 to 170 degrees are quite standard, and in many plants temperatures of 190 degrees or more are maintained.

Sudden fluctuations in grinding temperatures are a serious strain on grinder stones, both natural and composition types, and cause practically all of the spalling, cracking, and even more serious accidents by stone explosions.

With automatic temperature control maintained within 2 to 4 degrees of any definite predetermined point there is a material increase in production; also, a definite decrease in power consumption per ton of stock produced and a more uniform freeness in the stock. Also, there are indications of a lower stone cost due to a longer period between burring operations and the elimination of damage to stones caused by wide fluctuations in temperature under hand control.

The application of temperature control is important in the operation of all types and sizes—the smaller pocket type as an aid to the increase in production necessary to justify their operation in competition with more modern equipment, and the larger capacity as an aid to the high efficiency necessary to justify the large investment involved. The degree of value depends entirely on the operating standards and practice in each plant.

TYPICAL SPECIFICATIONS FOR GRINDER

To be latest design and finish, having............... pockets and taking a stone 54" in diameter, 27" face for 25" wood.

Base Plates: The Base Plates are of cast iron 6' long, in the form of an angle plate, the vertical part forming part of the grinder side up to the shaft center. Top of upright is planed to receive the sides. At each end of the base plate will be a socket suitable for the boss on the side frames, the two together forming the hinge of the side frames, when they are lifted. The base plate is 2¼" thick on the horizontal part and 1¼" thick on the upright and is heavily ribbed to insure rigidity.

A pad is cast on the base together with lugs. The pad is machined to receive main journals and lugs are fitted for the adjusting screws.

Four 1¼" holes are bored in the plates for the anchor bolts.

Sides: The Grinder sides to be made of cast iron, heavy in design with strengthening ribs under each pocket and to be machine finished where all connections are made. These frames to be made of our latest pattern which is thoroughly well suited to its duty. The sides of each frame will be slotted for the adjusting bolts which secure the pockets in position; the slots to be reinforced with strengthening ribs. On the inside of the grinder case there are to be three 2" ribs for each pocket; the center ribs to be planed to extend ¼" higher than the ribs on either side of same. On the end of each pocket there is to be a groove planed to correspond with the extended ribs in these grinder sides. The bottom of the flange of the grinder side where it connects with the base plate is machine finished and to have slotted holes for the six through bolts, 1" diameter. To the grinder sides, around the shaft is fitted a case to be packed with rubber packing to prevent the stock running out. These sides when placed in position stand 37" apart.

Pockets: The Pockets are 1½" thick, made of cast iron and each in one casting. Length of pocket inside 25½". The pocket doors will take wood 14" in diameter.

Three strips are cast on both sides of inside of pockets to assist in the alignment of the piston rod, and reduce friction of the wood. The ribs extend from top to bottom. The working side of the pocket at the bottom, which extends across the face of the stone, is fingered, also the ends. The pocket can be so adjusted that this face will just clear the stone, largely preventing slivers. The opposite side of the pocket is cut out at the bottom, to give ample room for possible slivers. Provision is made to prevent accumulation of slivers between pockets. The ears on each side for supporting the pocket in the proper position are 3¼" deep, through which the adjusting bolts pass. A strong ribbed foot extends at each end of the pocket for connecting same to the sides. Can adjust the pockets from the 54" diameter stone to 58" diameter stone. The top and ends are machine finished. The tops of pockets are completely covered by the bottom head of the hydraulic cylinders, preventing any pulp flying out. The pockets at each end or side where they come against the frame are machined, provided with a groove in which the raised rib on frame of grinders forms a guide, which is machine finished to size 2" wide ¼" thick, so that whether the pockets are up to a 54" stone, or down to a 38" stone, the pockets always maintain the same position in these guides and cannot move out by the center line of machine in either direction. The adjustment is given to the pockets by two large bolts, 2" diameter with double jam nuts on each side of pocket wings. To further insure the pockets from shifting their position and partly to relieve the adjusting screws of the tension imposed on them, bolts passing through the side frame and sides of pockets are provided. The position of the pockets on the grinders are at such an angle that the pulp after being ground will not hang up in the pockets. On the bottom of three sides of the pockets are 2" fingers for discharge of the pulp, which will prevent larger slivers from working out.

Pocket Doors: The Pocket Doors are made of soft steel ⅛" thick. Size of door 14 x 14½". These doors slide in a groove and are held in position by a guide which is connected to the pocket. Fittings for guide pieces are brass. The handles for doors are cast iron.

Pillow Blocks: The Pillow Blocks or main bearing are to be heavy cast iron boxes having a bearing for the shaft, 18¼" long. The boxes are to be {babbitted / wood lined}

Our babbitted box is of a water-cooled oil ring type, so designed that a water-circulation is kept up in each box thus keeping it cool. Our best copper hardened babbitt is to be used, the box then bored and fitted to the shaft.

Our wood lined boxes are lined with blocks of maple after being boiled in tallow. The box is then bored out to fit shaft.

These boxes are adjusted by means of the two wedges on which they rest. The wedges in turn are adjusted by two screws with lock nuts fitted to the two lugs on the base plate.

These wedges are planed on the face thereby rendering adjustment easy.

Yokes or Bridgetrees: The Yokes are of cast iron 44" long, 5" wide, one on each side of the pocket. They are heavy and heavy ribbed from the ends to the center. A pocket is bored in each to receive the adjusting screw nut. The top is flanged to receive the two adjusting screws which support the grinder pockets. The yokes are machine finished where they connect to the grinder sides.

Bottom Cylinder Heads of Saddles: The Bottom Cylinder Heads are accurately fitted to cylinder and cover the entire pocket. Bored for brass gland and piston rod. A brass ring is fitted in each head under packing gland. This brass ring will take all the wear of the piston rod. It can be removed and a new one put in its place, thereby saving the lower cylinder head. The brass gland is split and made heavy and deep, insuring a good packing. The head has a door, front and back, which can be quickly removed when gland requires readjusting or repacking. This head is heavily ribbed; is machine finished where it connects to top of grinder pocket, and is held in position by eight stud-bolts, hex nuts. The brass gland is held in position by three ¾" brass stud-bolts and hex brass nuts.

Hydraulic Cylinders: The Hydraulic Cylinders are 22" long, ⅝" thick with flanges on each end ¾" thick. The face of flanges are machine finished; also outside diameter of lower flange, which is made to enter lower cylinder head, insuring perfect alignment. The cylinder is bored to receive a hard-drawn seamless brass tubing............. inches inside diameter, ⅛" thick. This tubing is forced into place under pressure and rolled. The side of the cylinder shell is fitted to receive the hydraulic valve. There is no piping between valve and cylinder. Cylinder and valves are all tested before leaving the factory.

Top Cylinder Head: The Top Cylinder Head is nicely fitted to the cylinder, and made to enter inside diameter of cylinder, making perfect alignment. Fitted with heavy brass gland using ½" square packing. This gland is also made deep, insuring ample packing for the work. The glands are held in position by three ¾" brass stud-bolts with hex brass nuts. All cylinder heads connect to cylinder with seven ⅞" bolts with hex nuts.

Hydraulic Piston Rods: The Hydraulic Piston Rods are made of soft steel 5′ 8″ long, 2 15/16″ diameter at the lower end, and 2⅝″ at the upper end, which passes through the top cylinder head. The Piston Head and follower are held in position on the piston rod by two brass hex nuts, one being a jam nut.

Piston Head and Follower: The Piston Head and Follower are 1/16″ less in diameter than the bore of the cylinders. The heads slip against a shoulder bearing on piston rod. The follower is ¾″ thick and 1¾″ thick through the hub and held against the packing and head by two brass nuts on the piston rod. These heads are packed with six rings of flax packing ½″ square. The piston is fitted with a cast iron spring ring, 2¾″ wide.

Pocket Follower: The Pocket Follower is made of a good strong gray iron from a straight pattern and having the ribbed surface where it comes in contact with the wood. It is 24″ long, in width just clearing the sides of the pocket. Diameter of the hub 5½″. Heavy ribs extend from the hub to corners. This follower is pressed and bolted on piston rod.

Shafts: The Shafts are made from steel forgings............inches in diameter in the bearings and............inches in the stone. Threads for flanges are cut so both flanges slip off same end of the shaft. Two half "V" threads to the inch to receive the flanges, cut right and left hand. End of shaft fitted to large wrench for removing stone.

Grinder Flanges: The Grinder Flanges are made from steel castings 38″ diameter, 6½″ through hub. Machine finished where face of flanges come in contact with stone. Four 1⅞″ holes through flanges in which are fitted two steel pins for removing flanges from shaft. Threads are cut right and left hand to fit grinder shaft.

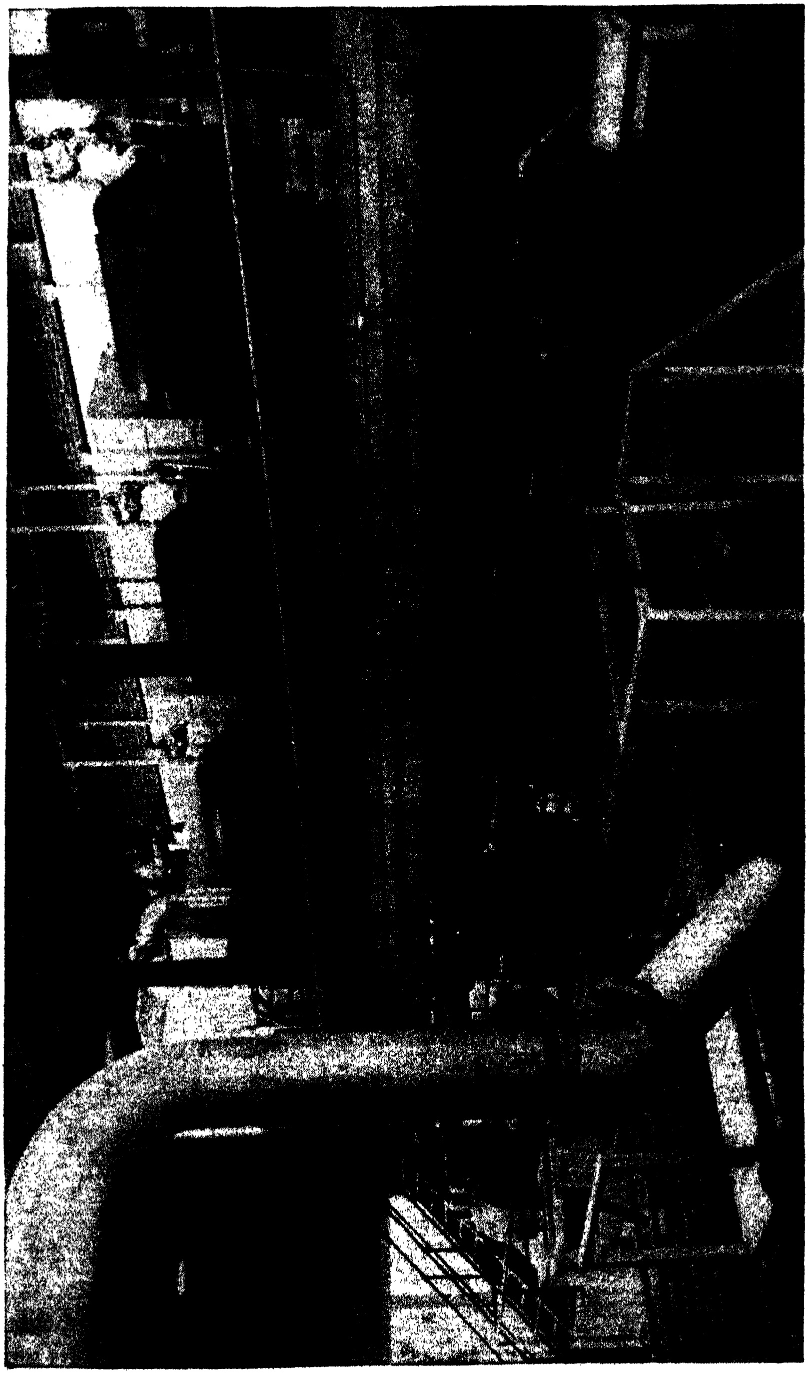
Couplings: (Flange) Couplings made of good strong gray iron.
(Compression) Outside diameter..........hub diameter............
length of coupling. Couplings lock on face.

Tools: One large wrench for removing flanges from shaft, also set of steel wrenches for nut on the grinders. One stone truing tool with disc holder and six discs; one burr holder and six cast-iron burrs.

Fittings and Piping: Each grinder fitted with three improved 4-way valves.

Packing: All cylinder heads are put on with sheet packing 1/16″ thick.

Painting: All grinders to be painted with good durable paint.



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

Typical screen department in important kraft mill in Arkansas showing knotters on upper level, rotary screens below and thickeners in foreground.

10. Screening and Refining of Pulp

Whether pulp comes from the mechanical process, or from one of the chemical processes it must be very thoroughly screened and refined before it is ready either for pressing into laps for shipment and storage or for immediate delivery to the paper mill in the form of deckered stock.

Screening.

The purpose of screening is to remove the small percentage of coarse and irregular fibers from the good stock, and also to eliminate foreign substances such as shives, knots, burnt or undercooked chips, brick-dust and dirt. (A "shive" is a small bundle of unseparated fibers.) In the mechanical pulp mill the pulp moves steadily to the sliver screens from the grinder pit as described in Chap. 9. In the sulphite process the product of two or more cooks is held in intermediate tanks at a consistency of about 2.5 per cent air-dry ready for delivery to the screens. In the alkaline process the pulp from the diffusers is held in a horizontal stock chest at a consistency of about 5 per cent air-dry, if a ball valve stuff pump is employed, or not more than 2.5 per cent if using a centrifugal pump.

Development of Screening in the Paper Industry.[1]

The background of history may help to give a better perspective on the present. A hundred years ago there were no screens. An effort was made to keep the paper free from the mechanical impurities we now call dirt by careful preparation of the rags from which all paper was made. The lumps and knots were removed from the paper, not before, but after it was made. The sheets were gone over by hand and the knots removed by picking them out with a penknife. The first screen of which I find any record is one invented by Richard Ibotson of England about 1830. This was a screen in which the box containing the plates was vibrated. It was the forerunner of the knocker type of flat screen, which was almost exclusively used in this country up to about 1890 to 1895. The diaphragm screen soon followed, but it was not perfected and had no great sale while the knocker screen flourished. When it did find itself and get under way, it quickly replaced the knocker screen. For one thing, it was very much cheaper, both to manufacture and to use; for another thing, it was about that time that wood pulp came into widespread use and the conditions of screening were easier. With all its noise and expense, the knocker screen had a

[1] For these observations on the development of screening, as well as for much information elsewhere in this book, I am indebted to Mr. Phillips Dennett of the Bird Machine Co., East Walpole, Mass. I also wish to acknowledge my special indebtedness to Mr. E. J. Trimbey of Trimbey Machine Works, Glens Falls, N. Y., for information regarding their latest developments in screening equipment, and last, but not least, to the Improved Paper Machinery Co., Nashua, N. H., for constant cooperation of great value.

highly developed ability for putting long rag stock through fine cut plates, and many a superintendent whose paper-money memory is long enough has now and then a wish that he had his Gould screen back.

Rotary screens date back to about 1860, when Christian Wandel, a German, invented the original Wandel screen, an outward flow type. About the same time there were invented inward flow rotary screens, of which George Bertram, of Edinburgh, brought out one of the earliest, if not the first. The important thing about this is not accuracy concerning the date or the original inventor, but the fact that rotary screens of both types have been known so long and yet until so recently left undeveloped. They did

Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 97.—Typical installation of flat screens in operation viewed from above.

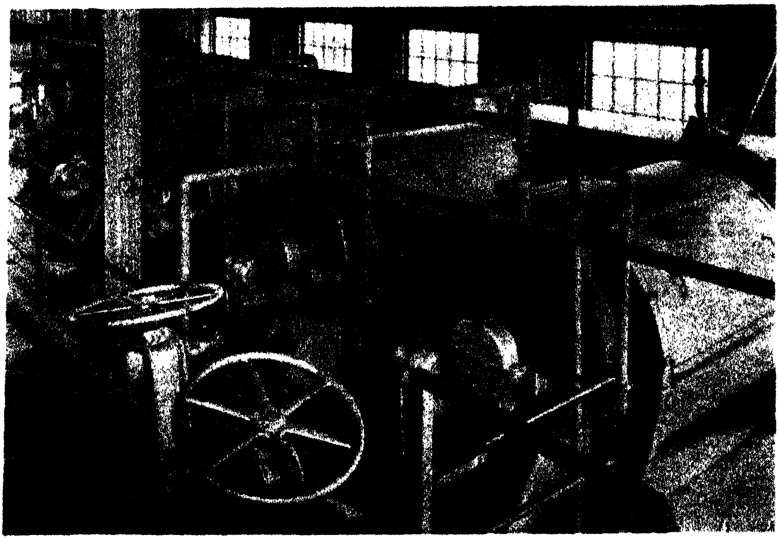
soon become the screen commonly used in European countries, but they were never used in the United States until well into the present century. One or two of the German or British screens had been imported before that time, but these were not successful, mostly because the European design was unsuitable for the much harder mechanical conditions imposed by American mills. The same reason held back for a long time the development of rotary screens, after they were first manufactured in this country. The mistake was made of depending too much on the success of the various screens in the mills abroad, and the error persisted for years before it became apparent that in order to utilize the full value of the rotary principle, it would be necessary to devise a form of construction suitable to the particular demands of American mills. It is only in the last ten years that great progress has been made.

Following the development of wood fiber and the establishment of pulp mills as the chief source of supply for paper making fibers, wholly new demands were made on screening apparatus. This does not seem to have been quickly realized, and for what seems like a long time the pulp mills used exactly the same kind of screens as were used in paper mills, first knocker screens and later flat diaphragm screens. It was really the beginning of the present century before screens were developed for the particular needs encountered in the screening of pulp.

In discussing screens it is convenient to classify them into two broad groups—pulp screens and paper screens. In some cases the same screens may be used for both kinds of work, but this is not general, nor productive of the best results. Purely as a mechanical matter, screening pulp is very different from screening stuff for a paper machine. To begin with, the physical characteristics of the fiber in the pulp mill are in most cases different from the fibers found in paper mills, with one large exception—newsprint mills, where the stock is handled continuously in slush form. Without exception, there is another great difference—the amount of tailings which have to be removed. The stock which is delivered to the screens in the pulp mill carries from 6 to 10 per cent of tailings, while in the case of paper machine stuff the amount of material to be rejected is a small fraction of one per cent. This is an extremely hard condition which the pulp screen has to meet. On the other hand, the pulp screen has an advantage in this respect, that the stock can be diluted to any consistency desired. The paper screen is often handicapped by lack of water, the limit of dilution being that which can be taken care of on the paper machine. The screen is thus governed by the paper machine and cannot be handled as might be best if it were working independently, as the pulp screen does.

The primary function of the paper screen is quite different from the removal of a large quantity of tailings, as in the case of the pulp screen. Early paper screens were called "pulp dressers," "knot catchers," or "knotters." Their object was to supply the paper machine with fibers well separated from each other as well as from the knots or bundles of fibers that were not reduced in the beating process or had gathered themselves together while on their way to the paper machine. A paper screen is a comb, as well as a knot catcher. It is also true that the paper screen should remove mechanical impurities of one kind or another, generally called dirt, which have in some way got into the stock, but this is almost incidental. The major duty of the paper screen is to put onto the paper machine wire a supply of stock which will be a homogeneous mixture of water and thoroughly separated fibers free from knots or slugs or slime.

Considering pulp screens, there are two types chiefly used, centrifugal screens and inclined diaphragm screens. A third type, the inward flow rotary screen, has been used to some extent, mostly in Europe, but it has not gained any large success. It will be considered later as a paper screen, where it is today the outstanding type. By far the largest tonnage of pulp made is screened through centrifugal screens. This includes newsprint sulphite, other relatively low-grade sulphites, sulphate and soda pulp, mostly the pulps which are made to be used by an adjoining paper mill, and not to be sold. It is compact, of great capacity, and very well perfected, from the mechanical viewpoint. The chief disadvantages are inability to screen pulp clean enough for exacting requirements, and heavy power consumption. The other largely used type of pulp screen is the inclined diaphragm screen, which I think holds its place largely because of one very valuable feature—its ability to produce pulp of the cleanest kind. It is used



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 98.—Installation of five "Impco" knotters, individually driven by motor reduction units, at a Pacific Coast mill.

by most mills making high-grade pulp or almost any kind of pulp for sale in the market. Most of the foreign pulp which is imported for our paper mills is made through this type of screen. The diaphragm screen as made today is vastly improved over similar screens of a few years ago. The power requirements are about the same; the cost of operation, including attendance and repairs, is very much higher. In the words of one very capable critic, the diaphragm screen compares unfavorably with other types because it involves a large amount of moving parts per ton of product screened, and consequently a high cost of repairs.

Slab Screens.

These consist of a grating of iron bars set at an angle of about 30° from the horizontal in a riffle about 18 inches deep through which the pulp runs, the bars being parallel with the sides of the riffle. A series of scraper drags hung on chains scrapes off any large slivers, knots, etc., deposited on the bars. These slab screens are mainly used in the initial screening of groundwood pulp.

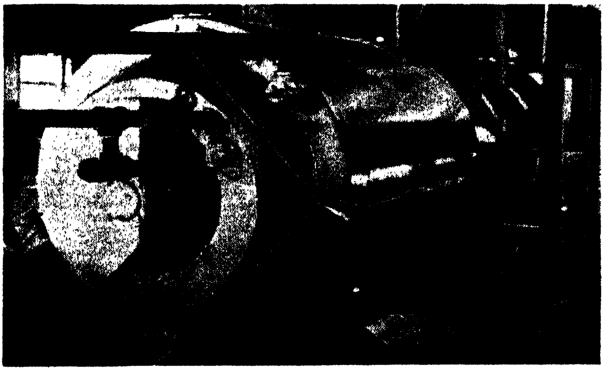
Sliver Screens.

These are of two types: *flat* and *rotary*. The flat sliver screens are exactly the same in construction and operation as the slab screens described above except that they have plates of perforated metal, usually with ⅜-inch perforations, instead of steel bars.

Rotary sliver screens consist of a semicircular trough containing a set of wooden arms attached to a rotating iron spider. The bottom of the trough is made of perforated metal. The scrapers eject the slivers and knots into a sluice whence they are either washed to waste or returned to the grinders. The good stock passes through the perforations. In some cases the flat screens are made to vibrate and in some cases the shells of the rotary screens revolve. The object of all these devices is to free large volumes of stock from a small but troublesome percentage of waste material quickly and perfectly.

Knotter Screens.

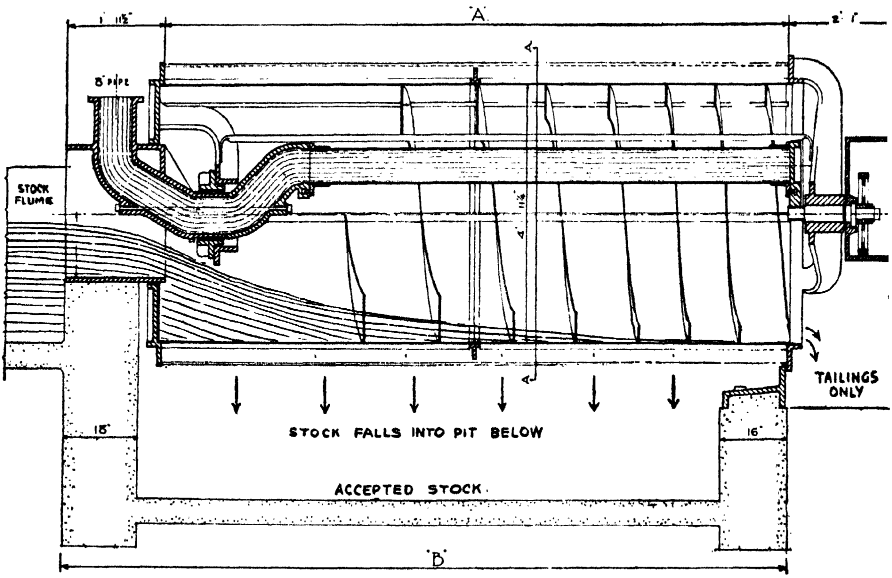
The stock from the intermediate tank gravitates (or is pumped if it is not possible to arrange the equipment so it can gravitate) to the knotter screens. The flow of stock is regulated by a gate valve. If there is more than one knotter screen there is a header and the stock is distributed to each knotter screen.

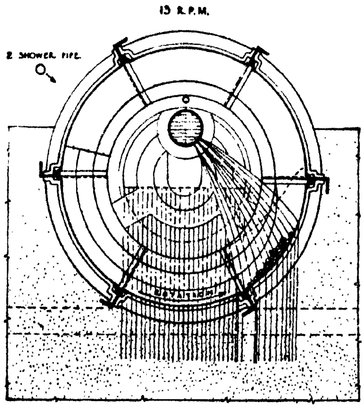


Courtesy: Trimbey Machine Works, Glens Falls, N. Y.

FIG. 99.—Trimbey rotary knotter.

The oldest and simplest type of knotter screen is the rotary type which is fitted with screen plates that allow the good stock to pass through but reject the large knots or lumps of uncooked fiber. These are much like the rotary sliver screens described above except that the perforations are much finer and shower pipes are usually provided. These knots and uncooked lumps run out of the end of the screen, impelled by a worm device, and are converted to a screenings grinder which makes them into pulp suitable for lower grades of paper, such as mill wrappers. While going through the knotters the pulp is showered with water to wash off any fibers that might adhere to the knots or large uncooked lumps. The amount of water (which may be either pure water or white water) dilutes the stock to approximately 1 per cent air dry.





SECTION A.A.

FIG. 100.—Diagram showing operation of typical rotary coarse screen.

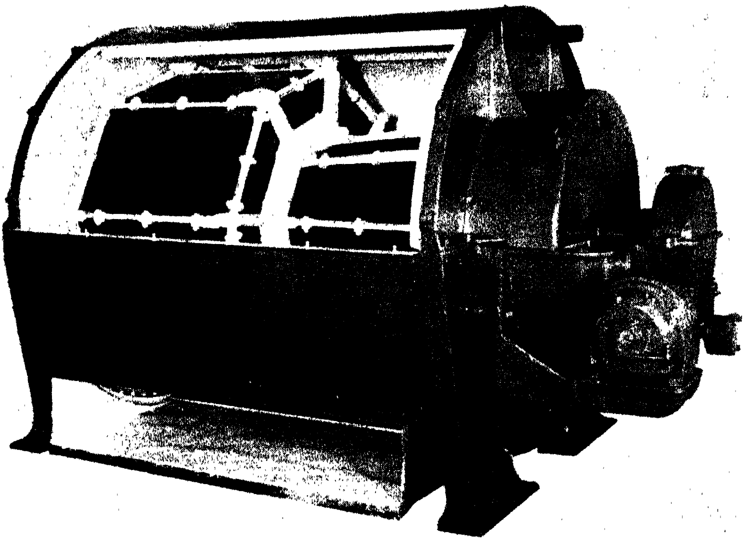
Courtesy:
Fibre Making Processes, Inc., Chicago, Ill.

The capacity of a standard knotter screen of this type is approximately 100 tons per 24 hours at a speed of 22 r.p.m. and with a power consumption of approximately 2.5 hp. The pressure on the shower pipe of the knotter screen should be from 15 to 20 pounds, preferably the latter.

Centrifugal Knotters.

This type of knotter screen has but one moving part, the rotor, consisting of a large diameter octagonal drum with smaller secondary octagonal drum supported on a central shaft which is carried in bearings. The drive is an integral reduction unit with 2 hp motor.

The stock enters through a stationary central chamber and is delivered to the plates over a horizontal lip of the inlet casting, which gives even distribution into each succeeding compartment of the rotation drum.



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 101.—Centrifugal knotter showing rotating octagonal drums.

Accepted stock readily passes through the plates, the rejections are retained by radial plates and elevated during the succeeding half-revolution of the drum and delivered into an inclined chamber filled with water. From this chamber, they flow into the second compartment of the drum, where additional washing by light showers takes place. Any remaining fiber removed in the second compartment is accepted. The capacity of this screen is 125 tons per 24 hours at about 25 r.p.m.

Riffler.

The stock in passing from the knotter screen to the next set of screens (which are either centrifugal or diaphragm screens) passes through what is called a riffler. This is a shallow wooden sluice about 6 or 8 feet wide, equipped with a set of baffles all along the bottom. The riffler is on a level, without any incline, so that the current is leisurely, being produced by the pump that draws the stock from the riffler. In this device the various heavy impurities that may be in the stock, such as brick dust from the digesters, sink to the bottom and are held by the baffles. The riffler should be about 18 inches deep and the baffles about 8 inches high and 8 or 9 inches from each other. The capacity of the riffler should be sufficient to take care of the output of the digesters and the length is governed chiefly by the amount of space able to be devoted to it, the longer the better.

The stock from the riffler is either pumped or gravitates to the screens. If it is pumped a centrifugal pump with wide impellers specially designed for handling stock is generally used. For a 100-ton mill a 12-inch slow speed pump of the above kind will serve very well and will lift the stock from 40 to 50 feet, which is generally sufficient.

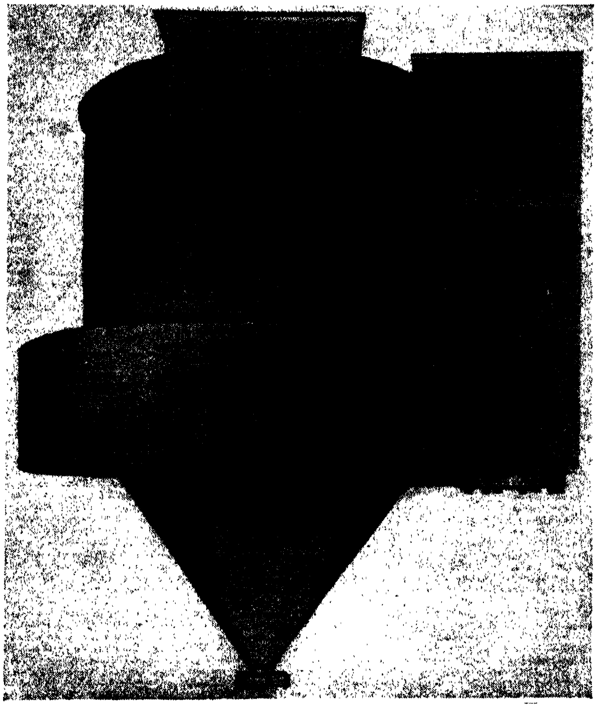
FIG. 102.—Discharge end of riffler showing pump.

Screens.

The screens may be either centrifugal screens or diaphragm screens. For fine papers, such as book and writing, the writer is still of the opinion that diaphragm screens are preferable. For papers such as wrappings, bag papers, newsprint, etc., centrifugal screens are quite satisfactory and their upkeep is much less troublesome and expensive. The centrifugal screens may be either horizontal or vertical, the former being much more usual in modern plants.

The diaphragm screen is the same type of screen as is described in connection with the Fourdrinier machine in Chapter 13.

The centrifugal screen consists of a runner or impeller surrounded by a cylindrical screen plate, this in turn being surrounded by a steel plate shell. The stock is urged against the screen plate through ports by the centrifugal force of the runner and the good stock passes through. The rejected stock passes out the base of the screen and goes to a secondary screen which is of the same construction, only coarser. The good stock from the secondary screen is usually put back through the system and goes again through the primary screen. The rejected stock from the secondary screen goes to the screenings chest. Another type of screen operates on the same principle but is of a horizontal design.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 103.—Walker whirlpool riffler.

It is a well-known principle that dirt will settle within the center of a whirlpool and, by using a cone, it can center the dirt settling out and falling down the cone, which has a feed of clear, cold water to keep any fibers from settling. The dirt removal is accomplished efficiently with practically no loss in fiber, as the cold water is drawn off at the bottom of the cone.

The entire battery of screens is supplied by a canal-like head box, with gates opposite each screen intake so that the flow to the screens can be regulated and any particular screen can be cut out at any time. In order to have the stock supply to the screens at a constant head there is an overflow from the head of the canal-like head box controlled by an adjustable dam. The overflow leads back to the riffler pump by a return pipe. The stock in the screen head box is diluted with pure water to a consistency of about .5 per cent air dry.

The usual type of centrifugal screen runs at about 400 r.p.m. and has a power consumption of approximately 35 hp.

Centrifugal screens are kept clean by means of a specially designed portable shower on the end of a hose which can be inserted between the screen plates and the outer shell. The pressure on this shower should be not less than 30 pounds, as keeping the screen plates clean is a very important factor in operating centrifugal screens. The size of the screen plate openings may vary from 55/1000 to 100/1000 inch, depending on the grade of stock being screened.

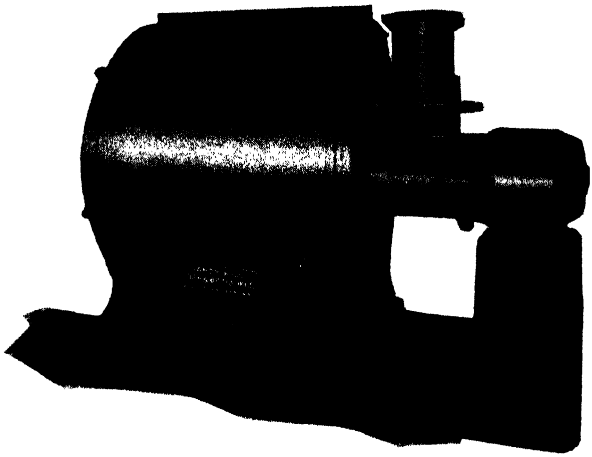


FIG. 104.—Sandy Hill centrifugal screen showing modern completely enclosed drive and streamlined design.

Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

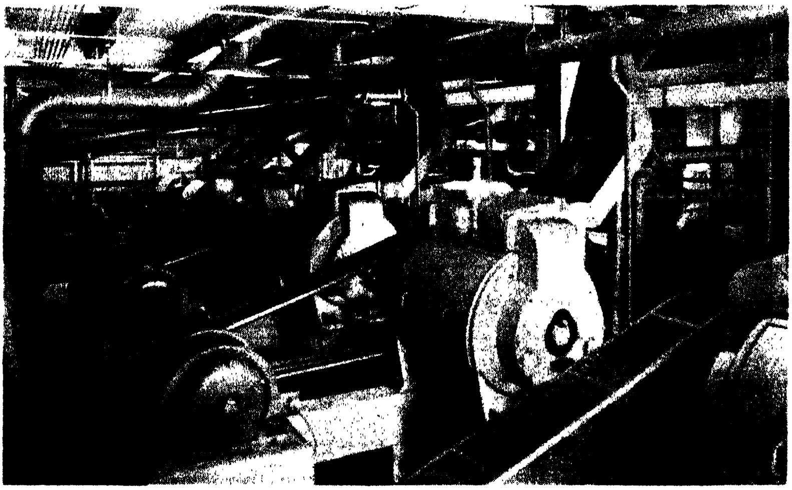
The rejected stock from the knotter screens gravitates, if possible, to a screenings or tailings chest from which it is pumped with a 6-inch fan pump to the screenings grinder. The power required to pump the screenings from a battery of screens in a 100-ton mill making sulphite, with a good arrangement of pumps and grinders, would be approximately 15 hp.

The screenings grinder used is very often an old Jordan, although a number of special screenings grinders are on the market. However, the Jordan is generally satisfactory, especially when the stock is delivered to it with the pump pressure as in the layout described. The action of the acid in the stock on the Jordan knives wears them away very fast and care should be taken to keep them in good shape.

From the screenings Jordan the stock is pumped with a fan pump to a screenings chest, into which the rejected stock from the stock screens is also run. From this chest the screenings presses, which are simply wet machines devoted to this particular duty, form the stock into laps.

Centrifugal pulp screens with round hole perforations have been used for screening groundwood for many years. More recently they have been used for screening sulphite; and now many of the best grades of soda pulp are being screened in them. There is yet, however, a feeling that centrifugals will not deliver a satisfactory quality for the better grades of sulphite. For that reason installations combining flat and centrifugal screens are the usual thing.

Among the newer applications for centrifugal screens is their use in board mills. For such an application the screens must be designed with generous clearances between plates and moving parts. Screens of such design can be used advantageously on old paper stock, in conjunction with continuous beaters and rifflers, for removing and defibering paper flakes with a minimum of damage to fiber lengths.



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 105.—Battery of "Impco" centrifugal screens in kraft mill in the South.

Under test, these screens have shown a production of 140 tons each with .140-inch perforations at a hp. consumption of under .35 hp. per ton. With .100-inch perforations, three screens can handle continuously the 210 tons required for one paper machine; actual peak capacity is more nearly 100 tons each.

Another field in which screens of this kind can be economically used is for pre-screening ahead of flat screens, either with or without the addition of knotters.

With increased emphasis on quality, sulphite mills, which formerly used 0.008 in. or 0.007 in. slots, are going to finer cuts. This procedure naturally reduces the capacity of existing equipment and requires more screens. Frequently, the added room required for the additional screens is not available without expensive alterations or additions.

As an alternative, knotters can be used for screening out the coarser material. These machines take up relatively a small amount of space and require only a small amount of power.

All but a very small percentage of the shives in the knotter stock can be removed by passing it through centrifugal screens with moderately small sized round holes. Then, this pre-screened stock can be handled by flat screens with finer cut plates, fewer screens being required and with a marked improvement in quality of screened stock.

Some mills screen their pulp both before and after bleaching. Other mills may consider such practice desirable but do not have necessary space available for a double installation of flat screens. They also might consider the cost of an equipment installation of this kind prohibitive.

Centrifugal screens with round hole perforations, due to their high tonnage per unit, would require comparatively little floor space. Their first cost is relatively small. Therefore, it is suggested that they can be used for the entire screening operation before bleaching and that the former flat screen equipment equipped with finer cut plates could be used for the screening of the stock after bleaching.

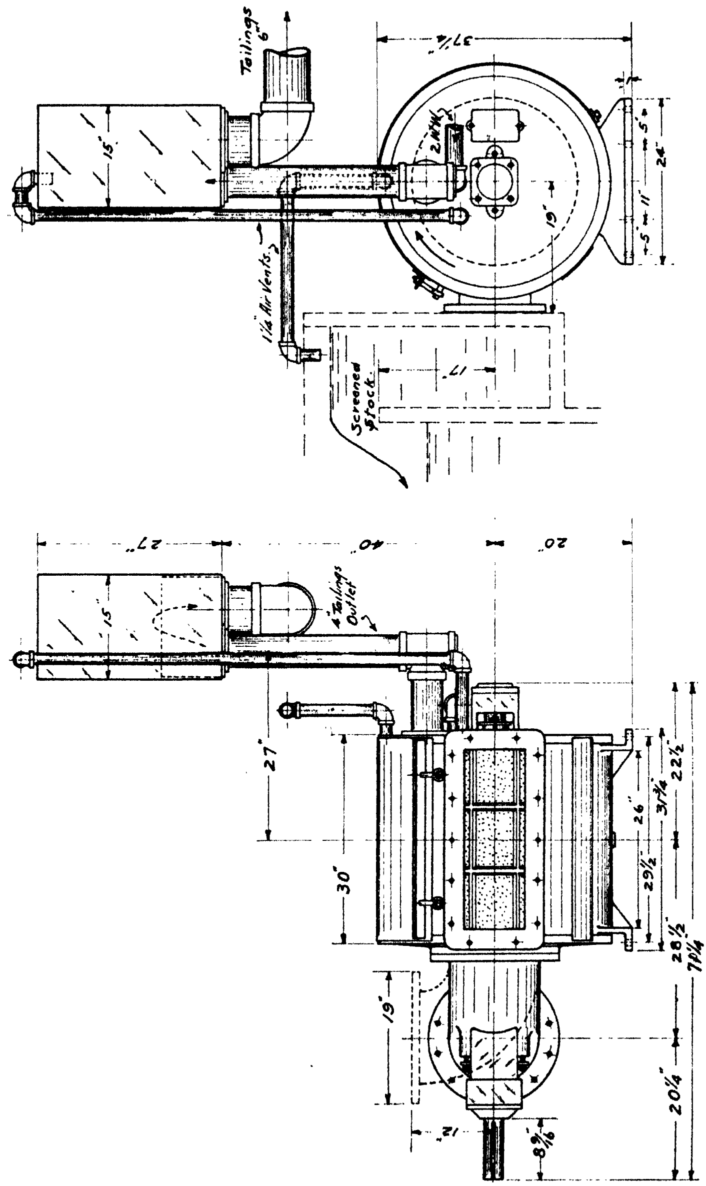
The power requirement of the earlier designs of centrifugal screens was greater than that of flat screens. Greater efficiency in this respect, however, is obtained with more recent designs. Sulphite, for example, can be screened through 0.050 in. diameter round hole perforations in one of these newer designs, a design which combines both centrifugal and diaphragm action in one unit, for considerably less than one horsepower per ton; and soda pulp with similar equipment can be screened for less than 0.4 horsepower per ton.

The Trimbey Centrifugal Pulp Screen.

Supply should come from an open spout or box with the level three to four feet above center of screen. The rotor accelerates the velocity and delivers it into the body of the screen as a rapidly revolving hollow shell of liquid. This rotation is maintained by the two broad blades of the distributor which have a slight "warp" to advance the rejects across the face of the plate to the tailings end where they are "scooped out" by the inclined cast lip at the tailings outlet and are elevated into the tailings box from which they can flow by gravity to the tailings screens located on the same level as the first screens. The accepted stock is also elevated two feet above the center line of the screen and goes to the thickeners without pumping.

Plates are frequently used having two or more sizes of perforation in the same screen. As the dirt and refuse become more concentrated approaching the tailings outlet smaller perforations are used. This increases the cleanliness of the stock without materially reducing the capacity.

Consider the rotating mass inside the screen as made up of concentric rings of liquid held in contact with the plate by centrifugal force and with a compressible air core at their center. The liquid one inch from the plate and into which the blades of the distributor project will be moving at the same velocity as these blades; the liquid adjacent the plate will be travelling much slower. If a sliver moves toward the plate end-on its advancing end penetrates into areas moving at slower velocities and it takes a position parallel to the screen plate. Approaching the plate in this position those fibers which are materially longer than the diameter of the holes are swept on and pass out as tailings. They are neither drawn

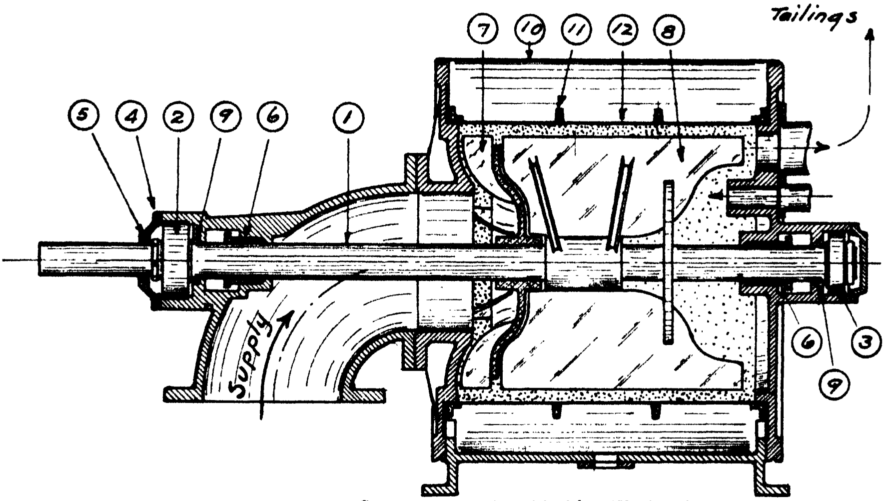


Courtesy: Trimbey Machine Works, Glens Falls, N. Y.

FIG. 106.—Diagram of Trimbey centrifugal pulp screen showing connections.

through the plate end-on nor wedged into the holes. That this is a fact and not mere theory is proven when after weeks of service, even as groundwood tailings screens, scarcely a sliver will be found in the holes.

The plate is self-cleaning without showers. Due to the slight drop in pressure in the wake of the rapidly revolving distributor blades, combined with the back pressure on the outside of the plates set up by the head on the screened stock and the compressible nature of the inner air core, there is just sufficient back-flow established to lift or to float off the accumulated layers of fibers which would otherwise cover and clog the perforations.



Courtesy: Trimbey Machine Works, Glens Falls, N. Y.

FIG. 107.—Diagram of Trimbey centrifugal pulp screen showing details of construction.

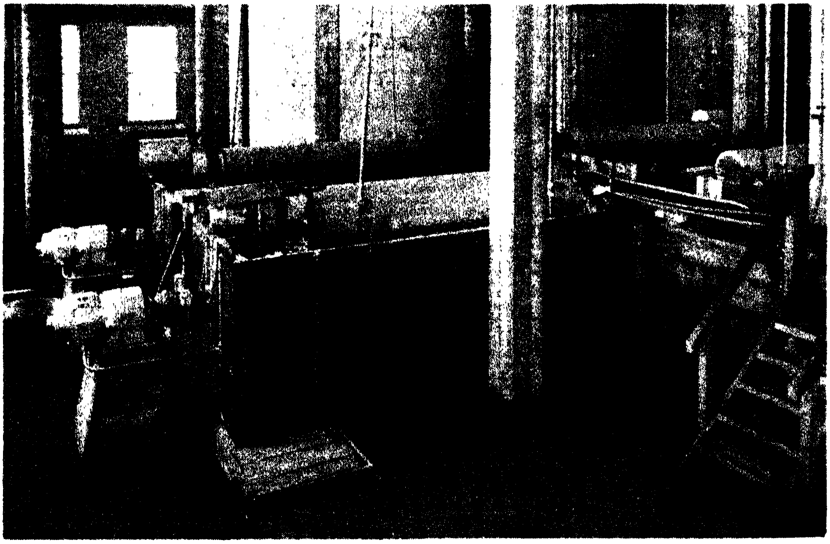
1. Shaft.
2. S K F bearing.
3. S K F bearing.
4. Elbow cap.
5. Oil seal.
6. Packing gland.
7. Rotor.
8. Distributor.
9. Oil seal.
10. Outer cover.
11. Screen plate frame.
12. Screen plate.

In large mills the number of tailings screens required may be reduced and screening conditions generally improved by passing the rejects from the first screens through an intermediate screen with coarser perforations. This at once clears away from the system the greater part of the refuse material which the knotters have not previously removed. The accepted stock from these intermediate screens then becomes the supply to the tailings screens which can be fitted with finer plates. The capacity of the tailings screens will be greatly increased, closer screening will be secured, and the accepted stock from these screens can then join that from the first screens and go to the thickeners. Since the identical construction is used for first screens, intermediate screens and tailings screens, and in each case both the screened stock and the rejects are elevated sufficiently to feed the succeeding screens by gravity, no pumping of rejections or accepted stock is required and all screens can be placed at the same level and adjacent to each other.

The rejects from all first screens feed from their tailings boxes into a common open header which serves as the supply spout for the tailings screens. Those screens which may be used for either first screens or tailings screens have a double tailings box, one outlet from which feeds into the supply header for the tailings screens and the other goes either to the sewer or to a refiner.

Deckers and Pulp Thickeners.

The good stock from the screens gravitates either into the vats of the wet machines, which form it into laps, or to the decker which thickens it enough that it can be used directly in the beaters.



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

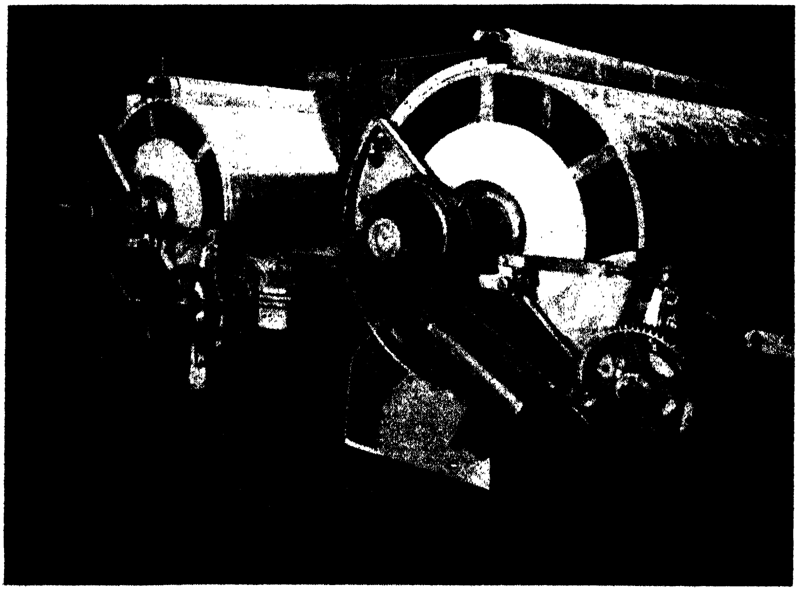
FIG. 108.—Open cylinder deckers in operation at Pacific Coast mill.

The bearings are anti-friction and are carried on a very rigid pedestal outside of the vat, therefore removing any chance of misalignment due to warping of the wood.

The reader may wonder why the stock is formed into laps at all when these laps have later to be broken up and mixed with water in the beater. In other words, it may seem strange that all the stock is not simply run through deckers and then to the beaters. This latter plan is not practicable because frequently the sulphite mill is making much more pulp than can at that time be used in the paper mill. Every mill must carry a storage and laps are the most convenient form in which to store pulp. Moreover, many mills sell pulp as such to other paper manufacturers and laps are the form in which pulp is shipped.

Courtesy: Oliver United Filters, Inc., New York.

Fig. 109.—Modern continuous automatic rotary vacuum type of decker.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

Fig. 109a.—Kamyr pressure thickener and washer used as a decker in bleached sulphite pulp plant.

However, it is good practice to run as much stock as possible from the screens to the deckers, in this way eliminating the power required for pressing this portion of the stock, as well as the labor and upkeep on the presses that would be needed to handle it.

Various forms of pulp thickeners are used, of which the decker is the most usual. The object of all these machines is to reduce the water in the stock to a certain predetermined percentage.

The decker consists of a cylinder revolving in a vat of stock. The cylinder is first covered with a foundation wire (usually 14 wires to the inch) over which the finer outside wire is stretched. This outside wire is from 50 to 60 mesh and against it the pulp is drawn by the suction. Wire as coarse as 40-mesh can be used if the save-all equipment is sufficient to catch all the fiber let through by this coarser wire. On top of the cylinder is a couch roll covered with felt jacketing or soft rubber. Against this couch roll a doctor blade presses at such an angle that the pulp slides off it continuously and down into the stock chest at which stage it is referred to as deckered stock.

Another form of pulp thickener consists of a wire-covered drum against which the stock is drawn by vacuum. A mechanical arrangement shuts off the vacuum and applies pressure as the drum emerges from the vat of stock in which it rotates. In this manner the pulp is blown off the drum instead of being scraped off by a doctor. It is claimed for these machines that they give a greatly increased production together with a higher efficiency of water extraction, which is no doubt true, but the first cost is greater and the power required also greater on account of the vacuum pump required.

The deckered stock chest should be equipped with an agitator running at a speed of approximately 8 r.p.m. in order to prevent settling and keep the stock of constant consistency until delivered to the beaters.

The pipe line from the deckered stock chest to the beaters should form a loop, *i. e.*, the pump should be running and pumping stock all the time, returning the stock not used in the beaters back to the deckered stock chest. This eliminates the possibility of the stock draining and plugging up the system. A 6-inch fan pump with a 12-inch suction running at approximately 800 r.p.m. will furnish deckered stock for 6 beaters at a power consumption of approximately 15 hp.

Wet Machines, or Presses.

The wet machine is used for that portion of the stock produced by the sulphite mill which cannot be deckered and used as deckered stock. It is practically a decker with a felt and press rolls added. The felt goes round the couch roll so that it comes in direct contact with the film of pulp that is picked up by the cylinder. This film is carried forward on the felt between the press rolls and allowed to wind around the top press roll. When it becomes thick enough it is cut off with a wooden pin. The size of the sheet thus made is governed by the circumference and width of the top press roll. This sheet is deposited on a folding table in front of the

Courtesy: International Nickel Co., Inc., New York.

FIG. 110.—Vacuum washer and thickener showing Monel metal wire cloth and binding wire on the drum.

press roll and folded lengthwise twice and crosswise three times, making a sheet of pulp about 18 inches by 24 inches. These are called laps.

The machine is driven through the bottom press roll, the felt acting as a belt, driving the cylinder and the carrying rolls.

Pressure is applied to the top press roll by means of a system of compound levers with weights, or by springs, or occasionally by hydraulic pressure. Hydraulic pressure is used chiefly by mills which are preparing

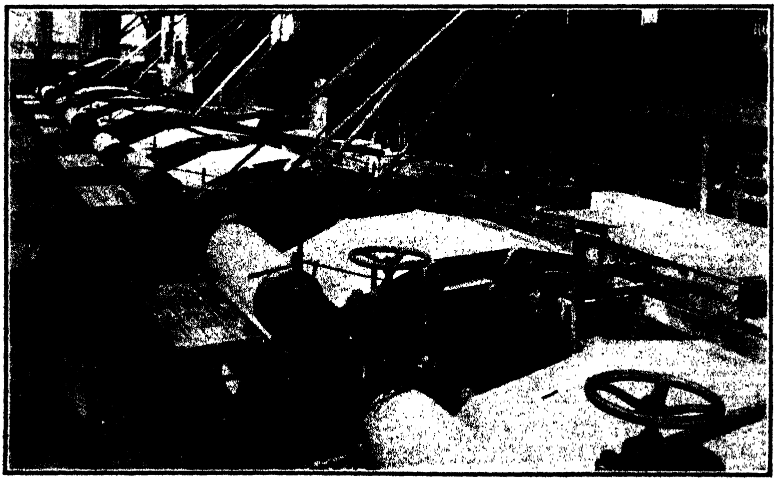


FIG. 111.—View in sulphite mill showing installation of wet machines.

pulp for shipment to a distance, in which case it is desired to eliminate all possible water. In such cases the pressing on the wet machine is frequently followed by further pressing in a specially designed hydraulic press.

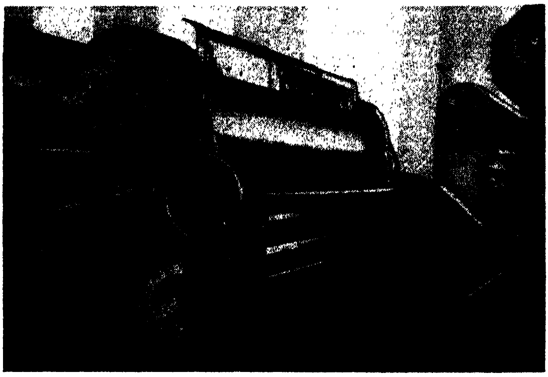


FIG. 112.—Kamyr feltless wet press for dewatering pulp and preparing it in lap form, showing nickel cast iron rolls.

Courtesy: International Nickel Co., Inc., New York.

Comparing levers with springs, the writer favors levers, because it is possible to note readily just how much pressure is being applied and because it is a check on the wet machine tender with reference to the moisture test of the pulp. The levers and weights are also a more yielding system and less likely to destroy a felt in case the layer of pulp becomes excessively thick or some foreign substance gets carried between the press rolls. The levers are more quickly disengaged and can be more accurately reset exactly at the pressure previously exerted.

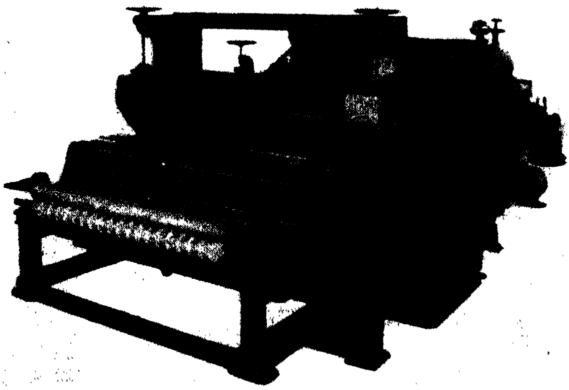


FIG. 113.—"Impco" hydraulic wet machine equipped with Monel winding wire and face covers on cylinder mold.

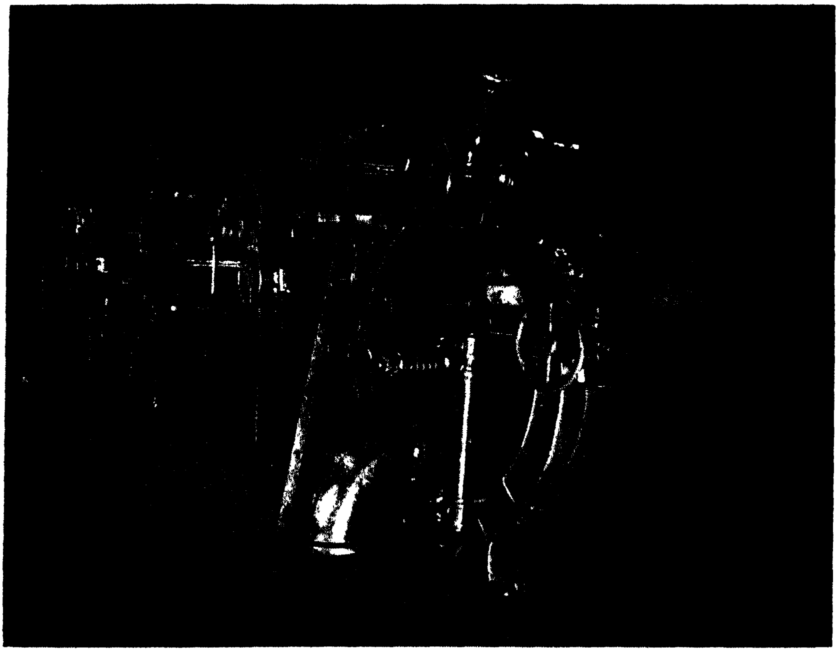
Courtesy: International Nickel Co., Inc., New York.

The ordinary wet machine, equipped with levers or springs, can produce a pulp approximately 40 per cent dry.

If the mill is equipped with efficient save-alls, so that it is certain that all valuable fiber is caught in the white water, wire as coarse as 40-mesh can be used, allowing much more rapid production on the wet machine.

The help in charge of the wet machine should be made to keep the packings on the ends of the cylinders perfectly tight so that the stock does not leak through and go into the white water.

Should the pulp suddenly become full of shives and dirt the trouble can usually be traced back to the screen plates of the centrifugal screens and it will be found, very likely, that a piece has broken right out of one of these, or that they have cracked. Another cause of dirty pulp suddenly appearing is a dirty vat. Pulp frequently shows dirt from this cause when a wet machine is started after having been shut down.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 113a.—Kamyr feltless wet machine for producing pulp 56%-58% air dry for long distance shipping.

Refining.

In general refining alludes to any process applied to imperfect pulp or screenings, or other rejects to perfect a satisfactory product. It is a relative term. Stock that is highly refined from one point of view may yet require a lot of work done on it for other purposes. Refining is by no means confined to salvaging screenings as some writers seem to think: it is applicable to all grades of stock, even for the finest writings and book paper.

There are many types of refining equipment. Coarse slivers are often returned to the grinders in mechanical pulp mills. Jordan engines, much used as refiners or "screenings Jordans," are described in Chap. 12. Kollergangs or "runner mills" are not much used in America, due to high power consumption and labor cost and restricted output, but are highly favored in Europe: the first kraft pulp was refined in kollergangs. To the author's knowledge, no American mills are using them today. Stone roll beaters are another application of the same principle.

Ball mills and rod mills adapted from the ore concentrating field are widely used in the West and in Canada. The rod mill is very efficient, and has a "beater-like" action on the stock, which is fed through the trunnion at one end and discharged at the other. Rubber-lined rod mills present interesting possibilities: at least one such installation is in use.

Claflin engines, described in Chap. 12, are very good for refining. There are many other special machines of which the Bauer refiner is possibly the most generally known.

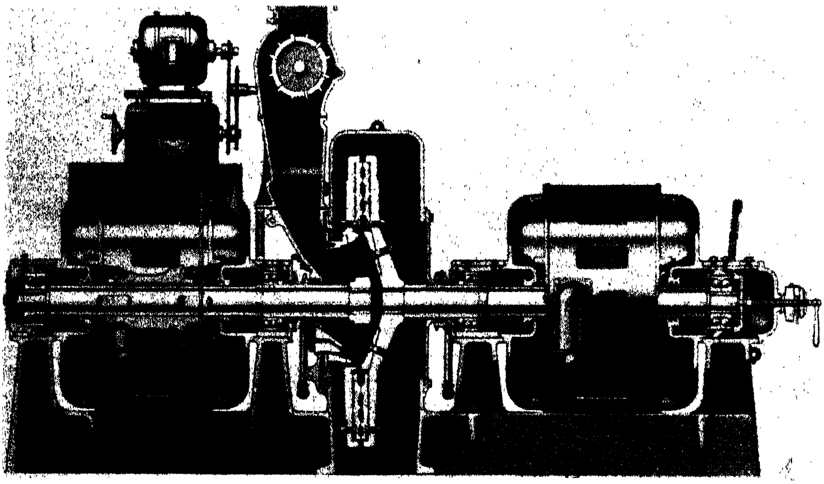
The Bauer Refiner.

There are two general types of Bauer machines: one employs a single revolving disc with a stationary disc of the same general type against which the revolving disc acts; the other is a machine with two revolving discs acting against each other. Means are provided for adjusting the position of the discs with great accuracy. The working faces of the discs are made either of iron with a small proportion of chromium and nickel, or of various alloys including stainless steel.

These disc machines have a wide range of application, from the making of mechanical pulp from chipped wood to the refining of chemical pulp for the paper machine. These different effects are obtained by varying the essentials of the machine. For instance: speeds can be varied from 300 r.p.m. single disc to 1800 r.p.m. double disc. The 1800 r.p.m. double disc has therefore 12 times as high relative speed between the two co-acting discs as the 300 r.p.m. single rotating disc. Type of plates can be varied. There are some 17 different types of pulp plates used on this machine; the clearance between the plates can be varied; the pressures holding the discs in position can be varied; also the quantity of water in the mixture passing between the discs; temperature of the pulp mass between the discs, etc.

Mechanical pulp suitable for wallboard, boxboard, chip board, and various other types of board can be made from wood and vegetable fibers. The properties demanded in the finished fiber determine whether the wood or other vegetable matter shall be simply chipped and fibrated without further treatment or whether it shall be soaked—cold or hot—or whether it shall be steamed under pressure, or given a slight chemical cook or a full chemical cook. The Bauer pulpers are used on and make pulp from products treated in all these ways. For instance, one application where they are making wallboard, they use about 30 hp. days—*i. e.*, 720 hp. hours—per ton of wallboard mass. In another mill making 9 point stock for corrugating from waste chestnut wood chips which have been semi-chemically cooked, they use about 12 hp. days per ton—*i. e.*, 288 hp. hours—to make a pulp that goes directly to their machine Jordan.

The Bauer Refiners can refine all rejects in a groundwood mill so they can go in No. 1 groundwood pulp for news. To refine groundwood screenings they require 25 hp. (600 hp. hours) or less per ton, making the capacity approximately 12 to 15 tons per unit per day. On groundwood knotter screen rejects the capacity would be approximately 8 to 10 tons for the same unit with a power requirement of approximately 30 hp. days or 360 hp. hours per ton. Even the bull screen rejects such as slats and stick ends, which come through between the pockets and the stone, can be refined in the Bauer if they are chipped to a form that can be fed. These require around 35 hp. days (840 hp. hours) per ton to refine them to stock that can be used in news sheet.



Courtesy: Bauer Bros. Co., Springfield, Ohio.

FIG. 114.—Sectional view of motor driven Bauer double-disc refiner.

In the kraft mill screenings and kraft knotter rejects can be refined so that they can go into No. 1 board stock or if they are screened in circuit with the Bauer, they can be refined so that they can be used in No. 1 kraft paper stock. The power requirements here are anywhere from 18 hp days (216 hp. hours) for kraft screenings up to 30 hp. days per ton from kraft knotter rejects to be used in paper.

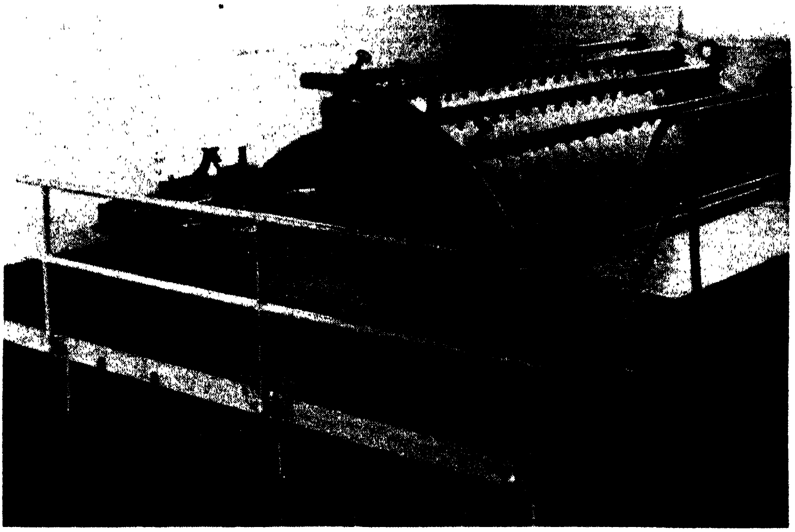
Sulphite pulp rejects—both screenings and knotter rejects—can be run at very large tonnage capacity. Sulphite knotter rejects alone can be run at around 10 hp. days or 240 hp. hours per ton. This will reduce them fine enough to be used directly in machine wrapper or any other product for which they are suitable.

11. Bleaching

Wood pulp, regardless of the process by which it is made, must be bleached if it is to be used in any of the finer varieties of light colored paper.

Rag pulp, straw pulp and pulp made from esparto, jute, and most of the other miscellaneous materials from which paper of any kind is made, require bleaching in order to enhance the value of the product.

The bleaching of rag stock is a comparatively simple matter owing to the relative freedom of such stock from colored impurities which have to be eliminated by the bleaching agent. It should be borne in mind that most rag stock of the better grade is made from material which has already been submitted to bleaching in the processes of textile manufacturing, and any coloring matter which may be present is in the form of dyes added by the textile manufacturer or finisher, which are relatively easy to remove when compared with the coloring materials embodied in wood pulp which are an integral part of the fiber itself.



Courtesy: Oliver United Filters, Inc., New York.

FIG. 115.—Continuous rotary washer in bleaching department of Canadian mill.

Wood pulp, no matter how carefully made, and whether produced by the sulphite or the alkaline processes, always has associated with the cellulose a portion of the lignin or incrusting matter ordinarily present in the raw fiber and this lignin carries with it certain colored bodies of highly complex chemical composition. These colored impurities cannot be removed by any amount of washing or mechanical treatment. They are united in a chemical manner with the fiber or cellulose and a chemical process is necessary for their removal.

In addition to the colored materials that are ordinarily present in the fiber, other dark colored substances are produced during the process of digesting the pulp, by the chemical action of the acid or alkaline liquids on the various complex substances contained in natural wood.

Soda pulp should be very thoroughly washed before bleaching or there will be great waste of chlorine due to the avidity of any residual black liquor for chlorine. Thoroughly cooked and washed soda pulp is best bleached at about 12 per cent consistency at a temperature of about 90°F.

Wood pulps and pulps made from esparto, straw, jute, etc., require, as pointed out above, a much more drastic bleaching than rag pulp, resulting in a much larger consumption of the chemical used for bleaching purposes and a much greater proportional loss in weight through the bleaching process.

The object of all successful bleaching practice in the paper industry is to thoroughly bleach the pulp so as to turn out a product of maximum whiteness and purity, which will remain white indefinitely, and, at the same time, not to impair the strength and natural properties of the fiber, not to cause too much shrinkage in weight and volume, and not to have an excessive consumption of the bleaching agent.

Naturally, as in any other process, it is also desirable to reduce the labor employed in the process to a minimum and consequently, whereas bleaching was formerly carried out in simple tanks provided with more or less crude agitators, at the present time numerous highly efficient special forms of bleaching equipment are on the market, all of which are designed with the idea of making the process as largely automatic as possible.

Rag pulp is frequently bleached in a Hollander or washer in which the boiled rags are given the preliminary treatment which converts the stock into what is known as "half-stuff." As a rule, in bleaching this kind of stock, no special bleaching equipment is provided, the bleaching agent being added to the Hollander towards the final stages of the operation and washing being continued sufficiently long after the bleaching effect has been accomplished to wash out the impurities and the surplus bleach.

Bleaching Agents.

Bleaching is essentially an oxidizing reaction. This is shown by the fact that many materials will become bleached when simply left exposed to the wind and weather. All of the various chemicals used for bleaching purposes are used with the idea of oxidizing the colored materials and, of all these bleaching agents, the commonest are certain of the compounds of chlorine. Chlorine, when brought in contact with water, releases the oxygen of the water and it is this freshly released oxygen that exerts the decolorizing action on the fiber.

The commonest bleaching agent, until about 1920, was bleaching powder, a white substance having a distinct odor of chlorine. Today it has been almost entirely replaced by liquid chlorine except in a few mills doing bleaching at irregular intervals. It readily absorbs moisture from the air and for this reason must be kept in covered drums or other vessels which will exclude air. The chemical composition of bleaching powder is not very definite, but the formula $CaOCl_2$ is generally accepted. The material is bought and sold on the basis of the amount of "available chlorine" present in the bleaching powder. Good commercial bleaching powder or chloride of lime, as it is frequently called, should contain from 35 to 37 per cent available chlorine.

Bleaching powder is usually shipped in steel drums or wooden barrels. The steel drums weigh from 100 to 800 pounds including the weight of the drum, and the wooden barrels usually weigh from 350 to 415 pounds including the weight of the barrels. An 800-pound steel drum such as is ordinarily used for the shipment of bleaching powder measures 30x39½ inches. Where it is necessary to use this material in small quantities it is usually purchased in 5- or 10-pound cans and this is frequently a convenient way of buying and storing the material as the slightly increased cost on account of the containers will be more than offset by the prevention of deterioration in the material.

In Europe bleaching powder is frequently sold on a degree basis, the degrees representing the volume of chlorine which will be liberated from one kilogram of the bleaching powder at standard temperature and pressure. The following is a table of the relation of French degrees to "available chlorine" as given in Griffin and Little.[1]

Relation of French Degrees to Percentage of Available Chlorine

French Degrees	Percentage Available Chlorine	French Degrees	Percentage Available Chlorine
65	20.65	100	31.80
70	22.24	105	33.36
75	23.83	110	34.95
80	25.42	115	36.54
85	27.01	120	38.13
90	28.60	125	39.72
95	30.21	130	41.34

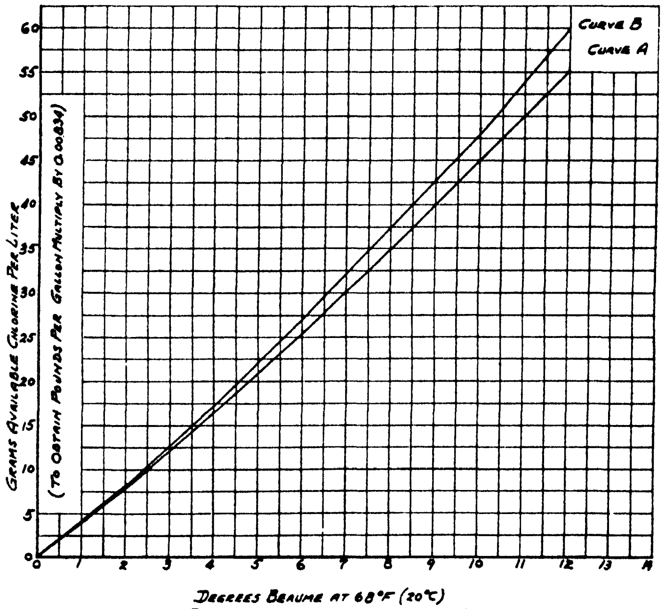
Bleaching powder requires great care in shipment and storage. If the powder is allowed to become wet, or even damp, it will rapidly deteriorate and lose a large percentage of its available chlorine. In case the powder should become actually wet, as might happen in a leaky ship or a bad car exposed to the weather, the decomposition may be so rapid as to cause explosions.

Preparation of the Bleaching Liquor from Bleaching Powder.

The usual method is to place a suitable quantity of bleaching powder in an iron tank provided with an agitator. These tanks are usually painted

[1] The Chemistry of Paper Making.

with red lead ground in oil. The mixture is agitated thoroughly and the agitator then stopped, allowing the mud to settle. The liquid is then drawn into a second settling tank in which the finer sediment settles out. The slime remaining in the agitator is again treated with a fresh quantity of water and the weak solution thus obtained is drawn off into a storage tank from which it is taken for the treatment of a new lot of bleaching powder. In this way the utmost economy in the use of material is obtained. The



Courtesy: Electro Bleaching Gas Co., New York.

FIG. 116.—Degrees Baumé versus grams available chlorine per liter for settled, fresh calcium hypochlorite bleach liquors.

Curve A: Liquor made from good bleaching powder (approximate curve). Curve B: Liquor made from lime and liquid chlorine (accuracy plus or minus one g.p.l.); temperature correction approximately two g.p.l. per 10 deg. C.

slime should be sampled and sent to the laboratory from time to time so as to determine if the washing is being carried out in a sufficiently thorough manner to extract the maximum percentage of available chlorine.

The bleaching liquor should be very thoroughly settled and decanted before being used in the Hollander or special bleaching equipment. Not only is the muddy bleaching liquor less efficient than a pure solution, but it also contains dirt which will cause black specks in the paper.

A hydrometer is usually used for testing the strength of the bleaching liquor. This is a very inaccurate method of testing this liquor because there is not necessarily any definite relation between the density of the solution and the amount of available chlorine present. If the mill has adequate laboratory facilities it would be much better to take samples at regular intervals and have these sent to the laboratory for a determination of the available chlorine present. However, the hydrometer test is better than nothing, and in many mills is the only practical method that can be used. According to Griffin and Little it may be accepted as a rough rule that 1° Bé. on the hydrometer averages about 0.47 per cent available chlorine in the solution.

Chlorine Bleach.

Since 1920 highly purified chlorine gas has become an article of commerce, being sold in liquefied form in steel cylinders and ton containers, considerable work has been done on the bleaching of pulp (and also textiles and other materials) with liquid chlorine instead of bleaching powder.

Very pure liquid chlorine is now on the market at a reasonable price. It is shipped in steel cylinders containing from 100 to 150 pounds in "ton containers" and can also be shipped in tank cars containing 16 or 32 tons. The cylinders measure 53 in. by 8½ to 10½ in.

Standard chlorine containers are made in three designs and five capacities. Cylinders carry 105 pounds and 150 pounds net weight. A container of either of these sizes may be handled by one man and they are shipped in carlots in box cars or in less than carlots. The multi-unit tank car has a special frame with integral cradles into which are bolted fifteen containers each carrying exactly one ton of chlorine. These units are commonly unloaded at the receiving point and stored until needed indoors or outdoors as conditions dictate. Because of their weight (the weight of the container alone is about 1250 pounds), especial equipment must be used for unloading. The car frame is equipped with fixed hand rails which require lifting the containers from the car with a suitable bail or chain clamps and hoist. A crane used for this purpose should have a capacity not less than two tons.

When the multi-unit car is unloaded, the containers are generally stored indoors. In some instances, however, the full containers are stored outdoors in which case the containers and contents quickly reach a temperature approximately that of the atmosphere surrounding them. In cold weather this necessitates moving them indoors where the temperature is not less than 50° F. at least a day before the chlorine they contain will be needed. This permits the containers and contents to warm up sufficiently to build up a vapor pressure that will discharge the liquid contents in a period of 45 minutes to one hour when the container is placed in service.

Although the ton container may be rolled on a smooth floor by one man, the transportation in the plant is greatly facilitated if a proper dolly or lift truck is used.

Stored on skids, the ton containers may be easily handled to and from dollies or lift trucks of corresponding height.

Ton containers are shipped only in carlots attached to the special car frame designed for them. They are never shipped in less than carlot quantities with other freight. The multi-unit car travels as a tank car and pays a freight charge on the net weight of chlorine only.

The single unit car is one carrying 16 tons in the smaller size and 32 tons in the larger size in one forge welded tank built to I.C.C. specifications for Class 105 tank cars. The tank is insulated with 5 inches of cork.

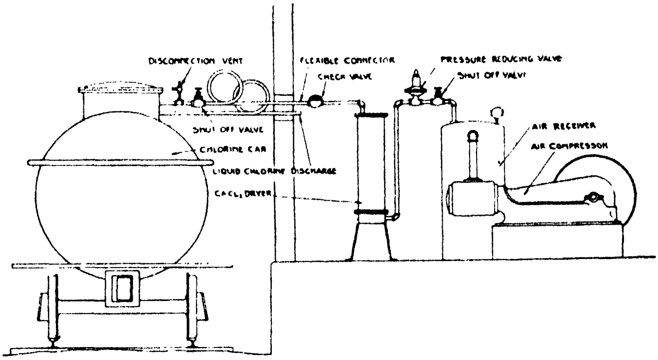
In the dome are four discharge valves. The discharge connections are in duplicate, to permit flexibility in use and to provide alternate equipment for emergency conditions. The two valves in line parallel to the car length are connected to eductor pipes that extend into a shallow well in the center of the tank bottom. Chlorine as liquid is discharged through either of these valves.

Each eductor pipe is equipped with a ball check at the bottom end balanced to act if the flow of liquid from the car exceeds a rate of 5000 pounds of chlorine per hour. This safety feature prevents the car from emptying itself into the air in the event of a broken discharge pipe line or control valve.

The two valves in line across the car connect directly to the inside at the top of the chlorine tank. Only gas may be withdrawn from these valves. They are seldom used for discharging the contents of the car. The reason for this is to be found in the fact that as gas is withdrawn the continued evaporation from the liquid required to provide a continuous supply of gas reduces the temperature of the car contents to a point so low that the vapor pressure is insufficient to maintain a reasonable flow of gas. Since the car is insulated with five inches of cork, there can be no significant replacement of this heat loss through the shell.

In spite of the excellent insulation, low winter temperatures will often reduce the temperature of the liquid and the vapor pressure in the car to a point low enough to reduce the flow of liquid to a marked degree. To avoid interruption of service, or slowing down of bleach making, and other operations requiring chlorine, additional air pressure may be imposed on the surface of the liquid and the flow from the car increased to a satisfactory rate. In some cases this additional air pressure is applied by the manufacturer of the chlorine at the time of loading the car during the cold winter season. In other cases, the user applies air pressure to the liquid through one of the gas valves, in the car dome.

It is essential to provide adequate drying equipment to remove all the moisture from the air used in building up the tank car pressure. Sulphuric acid or fused calcium chloride is generally used as a drying agent. The convenience of calcium chloride makes it preferable for this service. A typical arrangement of compressor dryer and tank car connections is shown in Fig. 117. It is desirable to locate the air dryer close to the compressor and indoors, so as to avoid the possible condensation of moisture from the transported air in sections of the line that are exposed to very low outdoor temperatures. It is also necessary to equip the air line with a pressure reducing valve that will prevent the tank car pressure from rising above 225 pounds per square inch. The safety valve and frangible disc on the tank car are set to release at this pressure. Since it is seldom necessary to have a tank car pressure above 150 pounds per square inch for satisfactory operation, it is advisable to set the air line reducing valve at this figure on the tank car side.



Courtesy: Mathieson Alkali Works, Inc., New York.

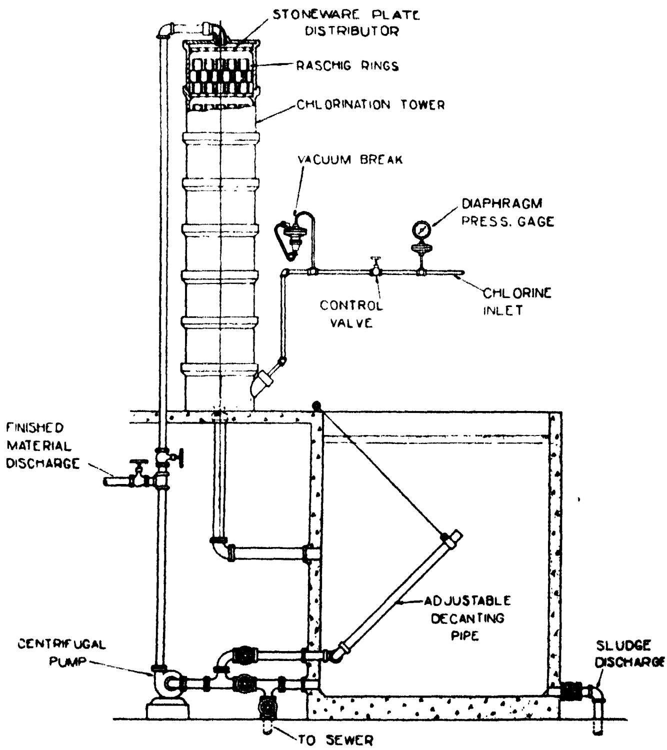
FIG. 117.—Typical arrangement of compressor dryer and tank car connections for unloading chlorine from single unit car.

Valves used for chlorine control on large lines should be of all iron extra heavy construction. Yoke type ammonia valves are suitable for the purpose. Certain special valves are constructed for use with chlorine which have stems, seats, and seat rings of particularly resistant alloys.

Much trouble has been experienced in the past in maintaining chlorine control valves next to the point of chlorination, either in the direct chlorination of pulp or milk-of-lime. As the pipe line extending from these valves usually enters a water suspension of pulp or lime, the solubility of the chlorine in these aqueous liquids will cause them to be drawn back to the control valve when the chlorine flow is stopped, unless the line is vented after being shut off. Hand operated auxiliary vent valves have been used for this purpose, but they leave much to be desired from the chemical as well as human angle. An automatic vacuum break valve has been designed and is now in use in a number of mills, venting the discharge side of the chlorinating line when the rise of liquid in the line threatens to reach the control valve. The control valve is thus protected from extreme corrosion and, naturally, gives longer and better service.

In pulp bleaching operations using chlorination in the first stage, definite quantities of chlorine are measured into known weights of pulp in water suspension. In some plants it is convenient to carry out this chlorination in a Bellmer, Hollander or beater. As such equipment is relatively shallow, it is impossible to use chlorine directly as the depth is not sufficient to permit the gas to dissolve in the pulp suspension before reaching the surface. This is true even where diffusers are used to aid the distribution of the gas from the bottom of the equipment. To cover such conditions, the ejector is used to prepare a water solution of chlorine which is allowed to run into the pulp suspension. The density of the pulp may be that commonly used in such equipment which is seldom lower than 3½ per cent or much higher than 7 per cent. Introduced at a concentration of 1 per cent or more, the chlorine water solution causes some dilution of the stock during the chlorination operation, but the reduction in pulp consistency need not be greater than 4 per cent of the original consistency. Such small reduction is relatively insignificant.

There are now in use three general methods of making calcium hypochlorite solutions for pulp bleaching. This statement does not take into consideration the dissolving of bleaching powder which has become of dis-



Courtesy: Mathieson Alkali Works, Inc., New York.

FIG. 118.—Tower and tank installation for producing calcium hypochlorite for bleach liquor.

tinctly minor importance in pulp bleaching practice. All of the larger mills, and most of the smaller ones, bleaching their own pulp, dissolve chlorine in milk-of-lime by one of the three methods which have become more or less standard for this operation.

Since the materials, general conditions and finished product are the same for each method they cannot properly be called different processes.

Rather, they are variations of the same process; the variations being only in the detail of equipment design and operation.

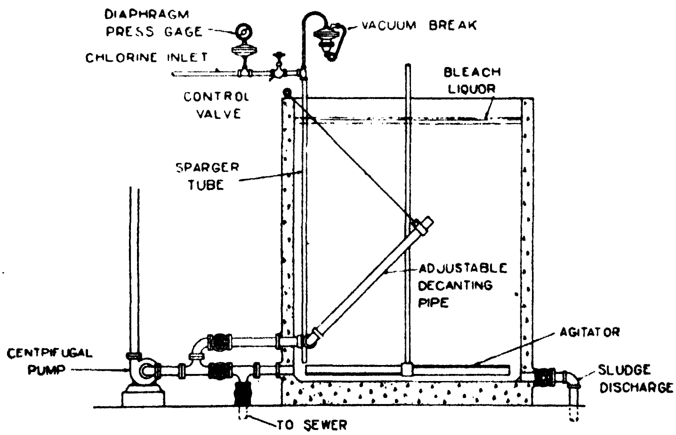
One of the first methods used for producing calcium hypochlorite for bleach liquor was that of the tower and tank arrangement as shown in Fig. 118.

In this equipment the milk-of-lime made up at a concentration of approximately 36 grams per liter is circulated by means of the pump to the top of the tower and in passing down over the packing absorbs chlorine which is admitted at the bottom. The finished solution contains approximately 30 grams available chlorine per liter.

The size of the tank is generally such as to accommodate sufficient milk-of-lime to absorb one ton or more of chlorine. At 30 grams per liter the tank capacity would be 8500 gallons or more.

The tower is of stoneware and is filled with acid resisting packing. The tank is generally of concrete construction. Iron pump, piping and valves are often used although in some instances acid resistant alloys are applied to this service.

The tower and tank system works satisfactorily and produces a good grade of bleach liquor. It is unnecessarily cumbersome since it has been found that the tower is not required for good absorption of chlorine.

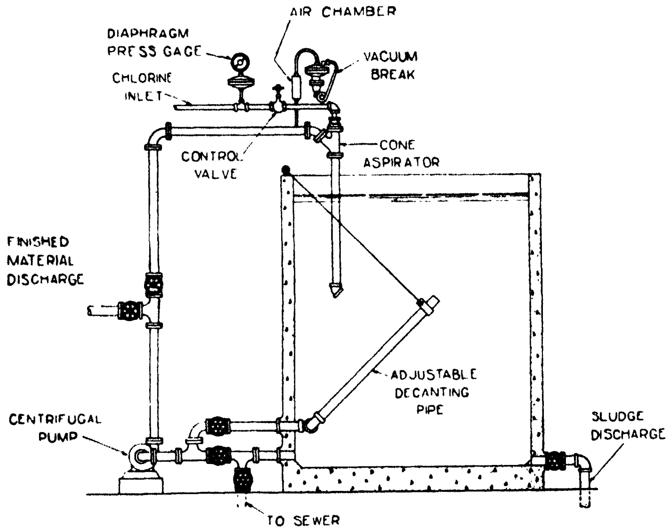


Courtesy: Mathieson Alkali Works, Inc., New York.

FIG. 119.—"Sparger" system for direct absorption of chlorine delivered as liquid to bottom of milk-of-lime tank.

A second system is illustrated in Fig. 119. This represents the direct absorption of chlorine delivered as liquid to the bottom of a tank containing the milk-of-lime. The delivery pipe in the tank is sometimes called the sparger tube. A solution containing 30 grams per liter available chlorine may be prepared in 45 minutes to one hour. In this type of equipment it is necessary to have a tank depth of at least 10 feet to permit complete absorption of the chlorine before the gas bubbles reach the surface.

The third type of bleach make-up equipment is shown in Fig. 120. This consists of the milk-of-lime tank, circulating pump and ejector in the delivery line from the pump. It is not essential to have an agitator in the tank since the pump provides adequate agitation in circulation of the milk-of-lime. The tank may be round, square, or of any other practical shape. It is not limited as to height as the absorption occurs largely in the ejector. If an agitator is not used the floor of the tank is made with a gentle slope to the outlet delivering to the pump. A definite advantage of this design



Courtesy: Mathieson Alkali Works, Inc., New York.

Fig. 120.—Bleach make-up installation consisting of milk-of-lime tank, circulating pump and ejector in delivery line from pump. No agitator is required as pump provides adequate circulation.

rests in the fact that the ejector establishes a negative pressure on the chlorine line and not only aids in the delivery of chlorine from the container but will withdraw the gas to a point where its pressure is less than atmospheric. This naturally means a more efficient and complete emptying of containers.

The following is an analysis of the chlorine sold by one of the leading manufacturers of this product:

Chlorine	99.80 per cent to 99.99 per cent
Carbon Dioxide	0.01 per cent to 0.20 per cent
Air and Oxygen	0.00 per cent to 0.10 per cent

The use of liquid chlorine obviates all the labor, trouble and uncertainty of making up bleaching liquors from bleaching powder and water. Highly efficient special proportioning valves have been devised that will automatically admit enough chlorine to the milk-of-lime to make the solution up to any required percentage of available chlorine. The convenience and simplicity of this method are rapidly becoming more and more appreciated and undoubtedly will be used to an increasing extent in the future.

Special Bleaching Agents.

Chlorine, either in elementary form or in combination as calcium hypochlorite, or as bleaching powder, is by long odds the most important bleaching agent in the paper industry. Probably 95 per cent of bleached pulp today is made with liquid chlorine.

However some attention should be paid to other possibilities. Peroxides are being experimented with and have been successfully used in preparing chemical cellulose. They are expensive but electrolytic peroxide is steadily getting less so. Permanganates have been experimented with for special purposes, and sulphur compounds have been used extensively in bleaching groundwood. Finally there has been some experimentation with electrically generated ozone, but no practical application in the paper industry.

The Bleaching Process.

According to James Beveridge[1] the bleaching properties of a pulp depend upon the process by which it is prepared. As a general rule vegetable fiber when prepared by the sulphite process bleaches more readily than that prepared by the soda or sulphate process. Also sulphite pulp made with an acid high in magnesia usually bleaches more readily than a pulp made with an acid prepared from straight limestone.

The quality of the water used for cleaning the pulp also has an influence on the bleaching process, especially if the water contains lime in any form. In the sulphite process the lime salts precipitate insoluble resin soaps on the surface of the fiber which absorb chlorine in proportion to their presence, and in order to avoid such precipitation the water is sometimes heated to boiling or chemically treated for the removal of lime before it is used. A similar precipitation of lime salts takes place when water containing lime is used for washing soda or sulphate pulp, the lime being precipitated either as carbonate or sulphate by the alkali present. Both of these substances cling to the fiber and carry down with them organic coloring matter which renders the process of bleaching even more difficult and costly than is the case with sulphite pulps.

The loss of weight in bleaching pulp, together with the cost depends on many factors, the most important of which may be enumerated as follows:

1. The raw material from which the pulp is prepared.

2. The process employed for manufacturing the cellulose or fiber, whether this be alkaline or acid, i. e., soda or sulphite process.

3. The purity of the pulp obtained, controlled largely by the conditions under which the fiber is prepared, such as the amount, character and composition of the chemicals used in cooking; the temperature employed; the time given to complete the process; the purity of the water used for washing.

[1] Paper: Oct. 30, 1918.

4. The dilution of the pulp with water, or density of the stock, during the bleaching operation, which insures a more intimate and closer contact of the bleaching agent with the fiber.

5. The temperature at which the bleaching is carried out and the consequent acceleration of the chemical action between the chlorine and the coloring matter.

6. The time allowed for bleaching, controlled by the temperature and density of the stock under treatment.

With regard to these factors, it has been found in manufacturing practice that the greater the yield of fiber from unit weight of raw material, no matter by what process the pulp has been made, the greater is the loss of weight of pulp bleached and the amount of bleaching agent required. It has also been found that the dilution of the fiber with water or density of the stock, and the temperature employed for bleaching, are most important since the first manifestly results in great economy of steam and the second in economy of bleach.

The object of bleaching as applied to paper stock is the production of a better colored fiber for the manufacture of white paper. The agents which may be employed in bleaching are practically all of an oxidizing nature and among them may be mentioned chlorine gas, hypochlorites, hydrogen and sodium peroxides, permanganates, etc. Chlorine gas offers certain advantages, particularly in the removal of shives and metallic particles and in discharging iron mordanted colors from rags, but it is difficult and disagreeable to handle and is very seldom used. The peroxides are not very efficient bleaching agents where wood pulp is concerned and they are too expensive for general use. Permanganates are also too expensive but they differ from hydrochlorites in not attacking the cellulose so strongly and for this reason they have been recommended in certain special cases. Practically, therefore, hypochlorites, and more especially calcium hypochlorite, are the only bleaching agents of any importance in the paper industry and the following remarks apply to these agents only. It is assumed that the preparation and properties of bleaching powder and its solutions are sufficiently well known to need no discussion here and this book is therefore confined to the principles and practices underlying their practical use.

Bleaching is carried out by two different methods; in one a distinct excess of the bleaching agent is used and when the correct color is reached the excess is removed by washing, while in the other the bleach added is only that which will give the desired shade and the operation is concluded when the bleach is practically exhausted. This accounts, to a considerable extent, for the differences of opinion of different experimenters and for the varying results which they obtain, for the method employed has a marked influence upon the results.

According to Sutermeister[1] among the factors influencing bleaching, two of the most important are the concentration of the stock and its temperature. The former is of particular importance when an excess of bleach

[1] Sutermeister, E., "Chemistry of Pulp and Paper Making," New York, John Wiley & Sons, 1929.

is added and the unused part removed at the end of a given time. Under these conditions increasing the concentration increases the rate of bleaching very greatly. Experiments showed that one sample of fiber used up 13 per cent of bleach in about 22 hours when at a concentration of 0.7 per cent, and in 15 hours when the concentration of fiber was raised to 4.35 per cent. Increasing the concentration still higher still further hastens the bleaching action, a sample of similar fiber bleaching in 75 minutes at a concentration of 18 per cent, though the temperature was rather lower than in the previous case. Similar conclusions have been reached by Spence, who found that 10 per cent of bleach was used up in 8¼ hours at a concentration of 3 per cent and in 3½ hours when the concentration was 7½ per cent.

The effect of concentration upon the color produced when a certain amount of bleach is added and allowed to exhaust is not so definitely established. Spence, working on soda poplar fiber found that increasing the concentration gave a slightly whiter fiber, while Sutermeister working on sulphite shows that at densities of 0.7 to 4.35 per cent, the concentration is practically without effect, while raising it to 18 per cent gives a fiber of slightly poorer color. It appears that even very wide changes in concentration cause such small variations in color that they could be corrected by adding or subtracting, at most, 0.5 per cent of bleach on the weight of the fiber.

The temperature factor is one which has a very great influence on the bleaching results. Raising the temperature greatly shortens the time of bleaching. The following table shows the results obtained by Spence on soda poplar using 10 per cent of bleach.

Temperature Degrees F.	Concentration of stock in per cent 5	6	7	7½
	Hours to exhaust bleach			
108-110	7	6¼	5½	5
118-120	5¾	4¾	4	3½
128-130	3¾	3	2½	2¼
143-145	2¼	1	1¾	1½

It appears from this that the effect of a given increase in temperature depends to a certain extent upon the concentration of the stock. Similar tests on sulphite spruce have proved that to exhaust a given amount of bleach at 105° F. requires eight to nine times as long as it does at 150° F.

When it comes to a question of the effect of temperature on the color produced there is again more or less difference of opinion. Cross and Bevan state that esparto bleached at 32° to 39° F. uses only 80 per cent of the bleach necessary at 95° F. to give the same color. Simonsen, working with sulphate pulp found that at 55° F. 7 per cent of bleach was sufficient but that at 95° F. the same color could only be produced with 9 per cent of bleach. Experiments by Sutermeister give indications in the same direction, but the difference in color between samples bleached at 68° and 156° F. was only such as could be corrected by increasing the bleach by about 0.5 per cent, based on the weight of the fiber, or approximately 5 per cent of the bleach necessary for an easy bleaching fiber. Spence's results on soda fiber show that up to about 120° F. increasing the temperature improves the color but beyond this point the color becomes poorer. In his tests the lowering of color between 120° and 145° F. would represent the change produced by about 0.7 per cent of bleach based on the fiber.

There is evidently no hard and fast rule regarding the maximum temperature which may be employed in bleaching, and it is largely a question of personal opinion on the one hand and the type and capacity of the plant on the other. It might very well be possible that under certain conditions it would be better to raise the temperature of bleaching and sacrifice a little bleach and steam rather than go to the expense of increasing the size of the bleaching in order to obtain the increased product. This conclusion is strengthened by the fact that different authorities set the best temperature for bleaching at such widely differing points as 68° and 120° F.

These two factors, together with the amount of bleach added, are the ones upon which the bleach plant superintendent depends for the control of his process. There are however a number of things which greatly affect the bleaching results and to which he should pay considerable attention, especially if he is also in charge of the pulp making processes.

According to Sutermeister[1] in either the acid or the alkaline process the nature of the wood used and the completeness of its cooking greatly affect the results obtained in the bleach plant. If variations occur in the wood, in the strength of the cooking liquor, in the method of cooking, or in the completeness of washing, then irregular results are almost certain to follow in the bleaching plant. This is especially true in the case of the sulphite process and to a less extent in the soda process because the more drastic treatment of the latter tends to take care of wider variations in materials or procedure. If the bleach plant superintendent is not also superintendent of the pulp mill then there should be the closest possible cooperation between the two so that any variations in the cooking process may be known before the stock reaches the bleach plant and causes trouble.

Bleaching Systems.

There are in general two systems of bleaching in vogue today. The older is *Single Stage Bleaching.* This consists of adding the bleach liquor (calcium hypochlorite) to the stock in a suitable vessel; agitating until the reaction has practically reached completion; and finally washing away the soluble waste products from the insoluble bleached pulp.

For chemical reasons too involved to discuss in this book[2] chlorine consumption per ton of pulp is excessive with the single stage process. There are other disadvantages such as deterioration of the fiber. To offset these is the relatively much lower cost of the equipment. Single stage bleaching is probably advisable in mills bleaching less than twenty-five tons

[1] Sutermeister, E., "Chemistry of Pulp and Paper Making," 2nd Ed., New York, John Wiley & Sons, Inc., 1929.

[2] Those interested are referred to: Sutermeister, E., "Chemistry of Pulp and Paper Making," 2nd Ed., New York, John Wiley & Sons, Inc., 1929; Elledge, H. G., "Chlorine for Pulp Bleaching," Paper Industry, Feb. 1936; Coster, N. W., "Bleaching of Western Hemlock Sulphite," Paper Industry, Feb. 1936; Hooker, Jr., A. H., "Theory of Pulp Bleaching," New York, 1937.

pulp per day. Above that figure the waste of chlorine alone should condemn it.

Multi-Stage Bleaching, using two, three or even more stages first treats the pulp with bleach liquor in proportion too small to achieve complete bleaching. Part of the coloring matter is dissolved out. The partly bleached stock is washed and then treated again in a similar manner, and if desired the operation can be repeated three or more times. However, two-stage bleaching is most usual.

In modern plants direct chlorine is frequently used in the first stage and calcium hypochlorite in the second and subsequent stages.

Stock Density.

Until about ten years ago all bleaching of pulp was done at low density, rarely exceeding 6 per cent. Today high density systems, rarely less than 10 per cent, and often as high as 30 per cent are the vogue, saving time, steam and chlorine, but calling for highly efficient agitation. High density bleaching can be applied to either single or multi-stage bleaching. Most modern bleaching systems are high density two-stage or three-stage systems regardless of the design of equipment used.

However some very efficient modern mills are running the first stage with direct chlorine at a consistency of about 3 per cent, cold, in Bellmers and then thickening to about 15 per cent consistency and bleaching hot with calcium hypochlorite in Fletcher bleachers or some similar equipment. In at least one mill this is followed by a final treatment, after thorough washing, with direct chlorine, in a continuous tower at about 3 per cent.

Many of these variations are partially dictated by a desire to utilize tanks and other equipment previously installed.

Bleaching Equipment.

In the older methods of bleaching, the Hollander with a paddle wheel to throw the pulp over the backfall instead of a roll, and sometimes called a "pocher" was used, the fiber being allowed to circulate either cold or hot until the required degree of whiteness was attained. The stock at first was washed in the Hollander after bleaching with drum washers, the washings containing the excess bleach being thrown away. Or, instead of washing, a quantity of antichlor or sodium hyposulphite was added to destroy the excess of hypochlorite present. This was obviously a very wasteful method and a distinct improvement was the introduction of a special draining tank, usually built of concrete and provided with a perforated false bottom of earthenware tiles, into which the pulp was emptied and drained, the liquor being pumped back again to the "pocher" to be mixed with a quantity of fresh unbleached pulp, so as to exhaust any available chlorine it contained. These draining tanks are in use today in many paper mills.

A still further advance was made when a series of open concrete tanks was put down to bleach and store large quantites of pulp, the main principle being to thoroughly mix the bleach liquor and pulp together in a suitable Hollander or "pocher," and after steaming to the required temperature running the whole charge into a tank, there to remain till the fiber came up to the requisite degree of whiteness, a slight excess of bleach liquor being added for this purpose. The liquor was then drained off into a well and from there pumped back to the "pocher" to meet fresh unbleached pulp, thus becoming exhausted of its available chlorine. The density of the stock was in all cases attained with the drum washer.

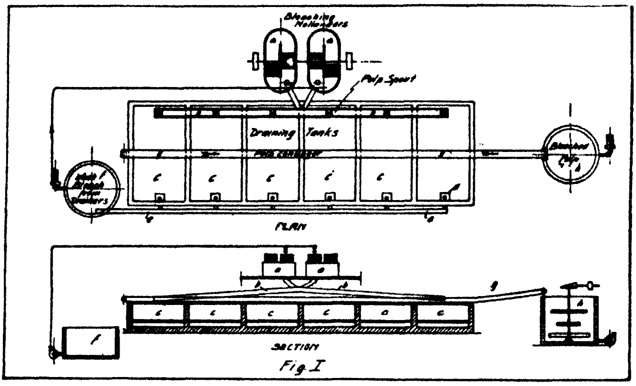
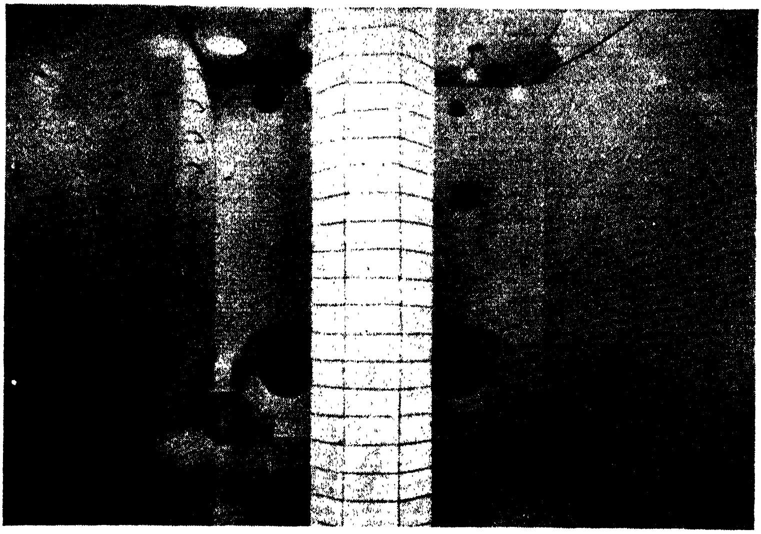


FIG. 121.—Diagram of "pocher" and tank bleaching system.

An arrangement of the kind described above is shown in the illustration. The fiber direct from the screens flows into the "pocher" *a*, and after the desired density has been obtained with the drum washer, the bleach liquor is added and the whole circulated for a couple of hours or so, steam being injected meanwhile till the temperature reaches 100° to 110° to 120° F. The charge is then run off through the chute *b*, into any one of the series of tanks *c*, where it remains at rest for twelve or sixteen hours. By this time the pulp will have reached a good color. The liquor is then drained off through the plug hole *d*, into the pipe *e*, which conveys it to the well *f*, from whence it is pumped back to the "pocher" again. The drained and bleached fiber is afterward conveyed to the beater floor in trucks, or thrown on the traveling belt *g*, and conveyed to the stuff chest *h*, mixed with water and pumped partly to a wet machine on the beater floor, to be made into laps, and partly direct into the beating engines. Such a system manifestly involves much labor, plant and floor space, not to mention a somewhat large expenditure of steam for heating, when hot bleaching is carried on. As a rule not more than 2.5 to 3 per cent density of stock is obtained from the "pocher."

Bleaching apparatus was next designed fulfilling more perfectly the conditions for economy. The vessels or "pochers" were built of tile, or reinforced concrete, and the mixture of pulp, bleach liquor and water kept



Courtesy: Stebbins Engr. & Mfg. Co., Watertown, N. Y.

FIG. 122a.—Interior view of tiled-lined bleaching vat.

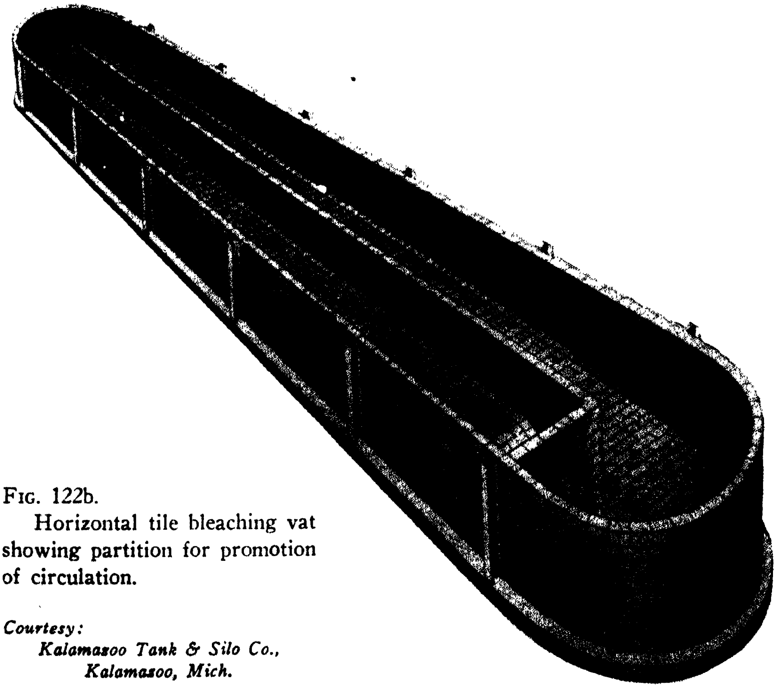


FIG. 122b.
Horizontal tile bleaching vat showing partition for promotion of circulation.

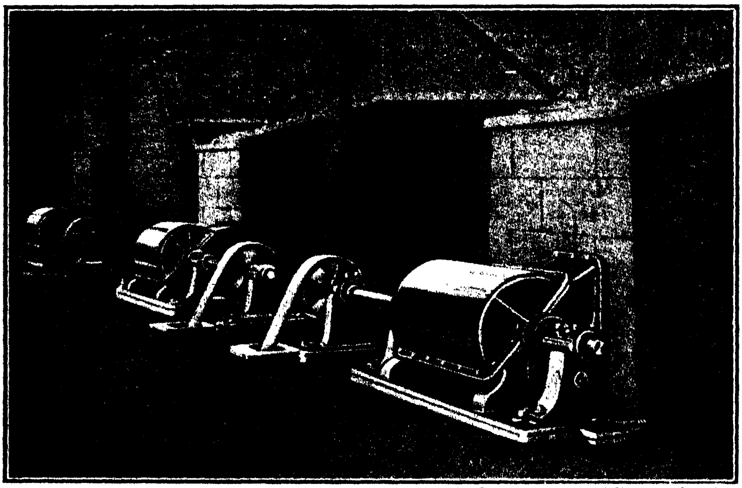
Courtesy:
Kalamazoo Tank & Silo Co., Kalamazoo, Mich.

in continued motion by means of a screw or propeller, until the process of bleaching was practically completed.

The propeller is placed at one end, and in this particular case causes the stock to travel in the direction of the arrows. These bleaching engines are built to hold from one to ten tons of air-dry pulp per charge, and are operated with from four to six per cent stock. Such a degree of concentration insures fair economy in bleach and steam, but they are intermittent in their action, and, in consequence, there is considerable loss of time in filling and emptying. The stock, after it has acquired the right degree of whiteness, is emptied into the chest beneath, from whence it is pumped to the washing and drying machines. The names of Kellner, Partington, Bellmer, Hromadnick, and others are identified with bleaching engines and systems of this kind.

Bellmer Bleaching Process.

Probably the most successful of low density, single stage units is the Bellmer. The propellers are erected outside the bleaching engines on a cast iron foundation plate. They are connected with the engine tub by means of flanges and enclosed funnels projecting in the walls of the tub.



Courtesy: Moore & White Co., Philadelphia, Pa.

FIG. 123.—Bellmer bleach tanks showing propellers.

The propellers are driven by a simple open belt running from above or below the floor. When electric motors are used the propeller axle is direct-connected to the motor. The frame can easily be opened at any time by removing the top, and all parts can be easily removed for cleaning or inspection.

The tub is generally made of concrete or brick and is lined inside with tile, these tiles requiring little cleaning and protecting the inside of the tub from the injurious action of the bleaching fluid. Moreover, the tile lining reduces the friction of the material against the sides and bottom and helps to keep the bleach liquor clean. The tub has no dead points and is designed with enough bottom fall to insure perfect circulation. The dimensions of the tubs can be altered to suit local conditions and they can be installed singly or in batteries. Pipes are provided for the introduction of steam.

Double acting propellers with three running channels are best, but single acting propellers can be installed when desired for installations handling less than 8,000 pounds and are very useful for connecting up with already existing bleaching tubs of the usual form.

The advantages of this system are as follows: The propeller admits the thickest material and will move the contents sufficiently rapidly to be economical. The mixing of the bleaching liquor with the stock is thorough. Formation of scum and knots is avoided. No separate stuff pump is required. Various kinds of stock can be mixed while the bleaching operation is going on.

Continuous Tank Systems.

It has always been the aim of pulp bleachers to invent a continuous system, or one that is nearly so, and quite a number of such have been constructed and operated for many years in Europe and America. Such plants are known in Great Britain as the "tower system" and in America as the "continuous tank system." Neither of these fulfills the most perfect conditions for bleaching, although the tower system is thought to be the better of the two. The towers are usually concrete tanks (preferably tile or rubber lined), with or without conical bottoms, connected together by channels or passages.

A typical system consists of six or more circular concrete tanks 12 feet in diameter by about 20 feet deep, connected together with passages or pipes, at top and bottom alternately. These tanks have flat bottoms and agitators driven by spur gearing at the top, which keeps the pulp in continuous motion. The pipes or passages connecting the tanks at the bottom, are all on the same level, but those for the overflow from 2 to 3, 4 to 5, 6 to 7, and so on through the series, are all on different descending levels, in order to permit the pulp to flow by gravity from the first to the last tank in the series in the direction as shown by the arrows.

Instead of the stock flowing by gravity, it is sometimes pumped from one tower to the next in series. This obviously is forced circulation, and has certain advantages over circulation by gravity, but can scarcely be called a continuous system. It permits of greater concentration of stock, a stronger bleaching fluid in intimate contact with the fiber, and economy of steam for heating when hot bleaching is employed, but under the best conditions, seldom can more than 4 to 4.5 per cent stock be handled, which in the opinion of many is too dilute to yield the most economical results in any continuous system.

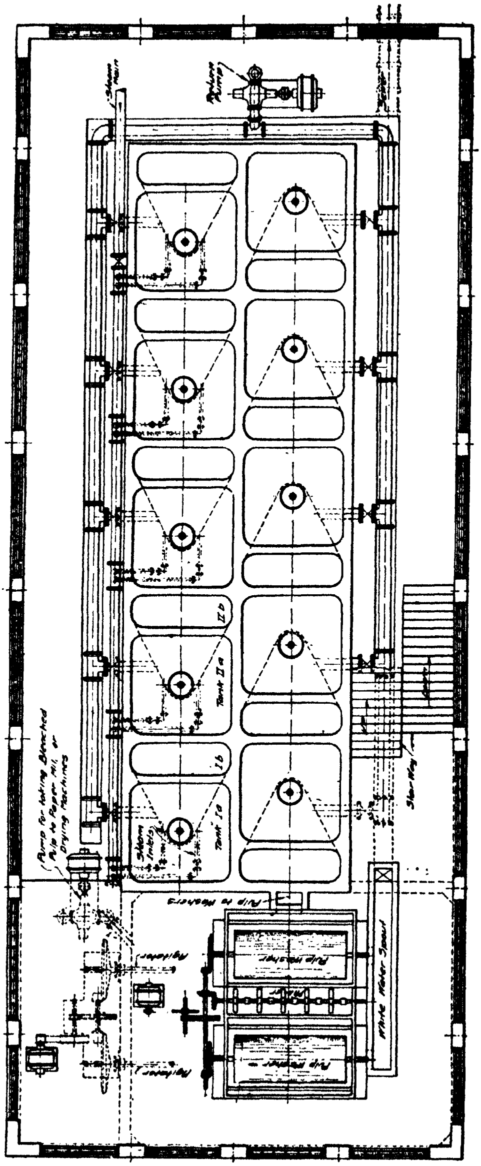


FIG. 124a.—Diagram showing plan of continuous tank system of bleaching.

Skjold[1] describes a method of continuous bleaching in which he employs a series of flat-bottomed upright circular tanks, built of concrete and containing agitators, four or more tanks being employed in the series, connected by an arrangement of pipes, so that the pulp can be pumped from one to the other continuously, or circulated at will from the bottom to the top of each tank; a mixing tank is provided between the wet machine and the first bleaching tank, for mixing the sheet of wet pulp with water of 50° C. (122° F.) and bleaching powder solution of 3.5° Be. The bleached pulp leaving the system is washed on wet machines before it is dried. The tanks in this system are each 4.9 meters in diameter by 8 meters deep, giving a total capacity for the four of about 600 cubic meters, and it is stated, that from forty to forty-five tons of air-dry pulp can be bleached in twenty-four hours, equivalent to nearly 500 cubic feet of tank space a ton a day. This is a large output, which is made possible, perhaps, by the high temperature employed—viz: from 130° to 140° F. The operations of this system are somewhat broken, and Beveridge states that it is doubtful if these conditions as to output could be maintained in constant practice, unless the stock treated were of the easiest bleaching character.

J. E. Heiskanen, in his apparatus (U. S. Pat. 1,277,926), has overcome certain difficulties and has greatly simplified the continuous system. All stock pipes, centrifugal pumps and agitators, are eliminated, the inventor substituting for them propellers for mixing, agitating and circulating the stock through the whole system. These propellers are driven by small motors and as he attains a density of 6 to 8 per cent stock he fulfills the best conditions for economy of bleach liquor and economy of steam for heating. The floor space occupied by the plant is about half of that required for the "continuous tank system" mentioned above.

The unbleached pulp falls from the pulp thickener into the screw conveyor where it is mixed with the necessary quality of bleach liquor and hot water, the mixed stock being conveyed automatically into the first bleaching tank *Ia.* The fiber in this tank is forced upwards by the propeller to the top of *Ib,* where the stream is divided by the regulating gates into two parts, one part giving back into *Ia,* while the other part flows into *IIa.* The proportion going forward into *IIa* varies from one-tenth to one-fifth of the total volume passing the propeller, so that the stock in *Ia* is kept circulating vigorously and is in continual motion. These regulating gates are placed at the top of *Ib, IIb, IIIb,* and so on through the whole series, the flow forward from one tank to another being adjusted by them in accordance with the amount required, and kind of pulp to be bleached. Steam is introduced at the bottom of each tank immediately below the propeller to maintain a uniform temperature throughout the apparatus. After the pulp has progressed through the series of tanks it is discharged into the chest at the end, from whence it flows by gravity, or it is pumped, to washers and finally to the drying machine. The return pump is not essential and is seldom or never used, but is added to enable the operator to pump the stock a number of tanks back, if by accident insufficient bleach liquor has been added.

[1] Svensk Pappers-Tidning, 1905, No. 15, pg. 85.

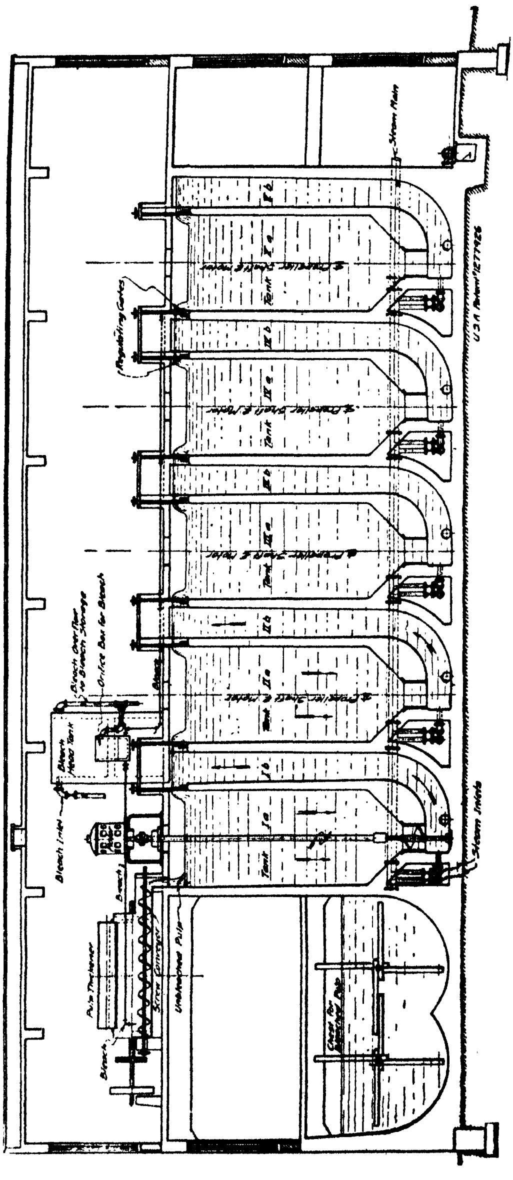


FIG. 124b.—Diagram showing elevation of continuous tank system.

Heiskanen represents that his plant occupies half the floor space of the ordinary "continuous tank system"; that he can attain a density of 7 per cent stock on an average; and that by so doing the consumption of steam and bleach is reduced to a minimum. The consumption of power and labor is extremely low; for in the first case there is very little weight to be moved by the propellers, the columns of stock in *Ia* and *Ib* equalizing themselves, while in the second one man is sufficient to run the tanks from the first tank to the pulp chest. He also allows eight hours or so for bleaching and completes this with a total tank capacity of about 200 cubic feet a ton of pulp a day.

The plant as shown is capable of handling 100 tons of pulp a day, is well designed, and as it is constructed of concrete, lined internally with glazed tiles if so desired, and fitted with bronze working parts in contact with the fiber, the risk of iron spots appearing in the dried pulp is avoided.

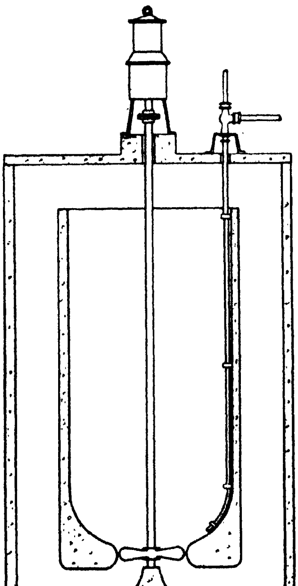
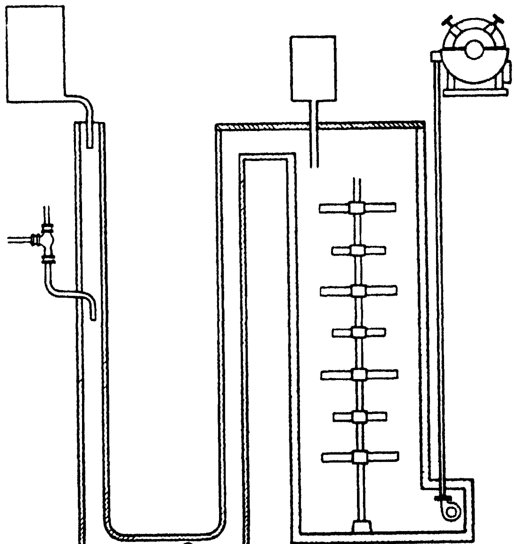


FIG. 125.—Typical chlorination cell adapted for use of Penn Salt dispersion method.

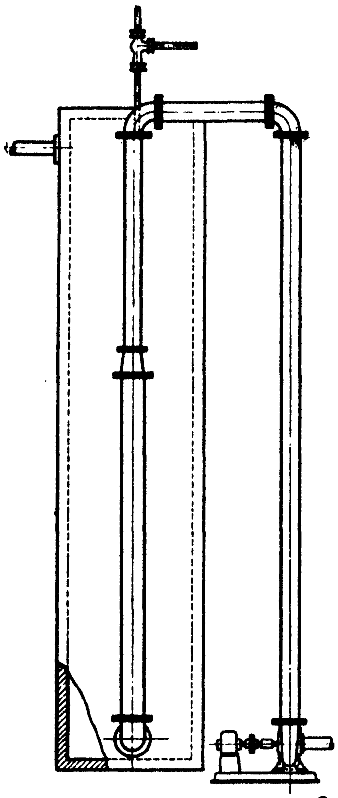


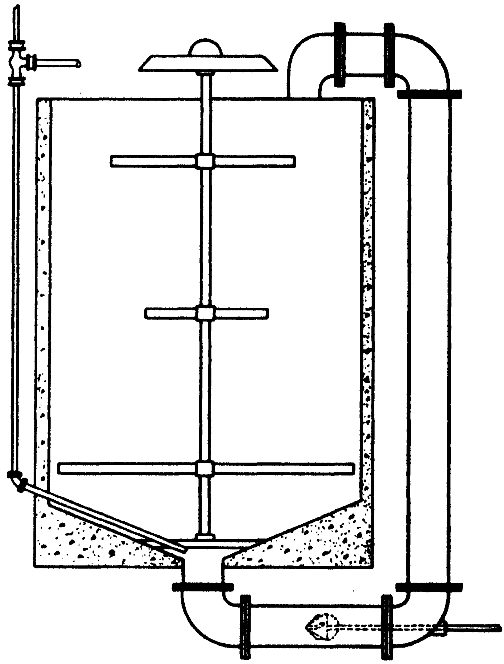
Courtesy: Pennsylvania Salt Mfg. Co., Philadelphia, Pa.

FIG. 126.—Continuous chlorination system fitted with Penn Salt method of dispersion.

High Density Bleaching Equipment.

Fletcher Bleacher and Wolf Bleacher: These very similar machines consist of tall concrete tile-lined chests or tanks, about 30 ft. high, with a centrally located vertical spiral ribbon-type screw conveyor in a draft tube. The pulp is lifted from the bottom at the center and discharged from the top of the draft tube. The calcium hypochlorite reagent is added to the pulp as it comes from the preceding washer or thickener, or else added to the screw conveyor bringing the pulp to the bleacher. The bleacher is not a mixer: it keeps the pulp in suspension while the bleaching reaction is taking place.





Courtesy: Pennsylvania Salt Mfg. Co., Philadelphia, Pa.

FIG. 127.—Continuous chlorination tower.

FIG. 128.—One unit of batch system.

Stebbins Bleacher is very similar to the above except that circulation is aided by a jet of compressed air.

Collins Bleacher is similar but the entire design is broader and not so high. All these bleachers have a kneading action that breaks up shives.

Pennsylvania Salt Manufacturing Co. System.

The Pennsylvania Salt Manufacturing Company's method for the introduction of elemental chlorine into pulp systems is described in U. S. Patent 1,971,241.* In accordance with this invention, an extremely fine dispersion

* Issued to Weitzel, Potts and Underwood August 21, 1934, and assigned to Pennsylvania Salt Mfg. Co., Philadelphia, Pa.

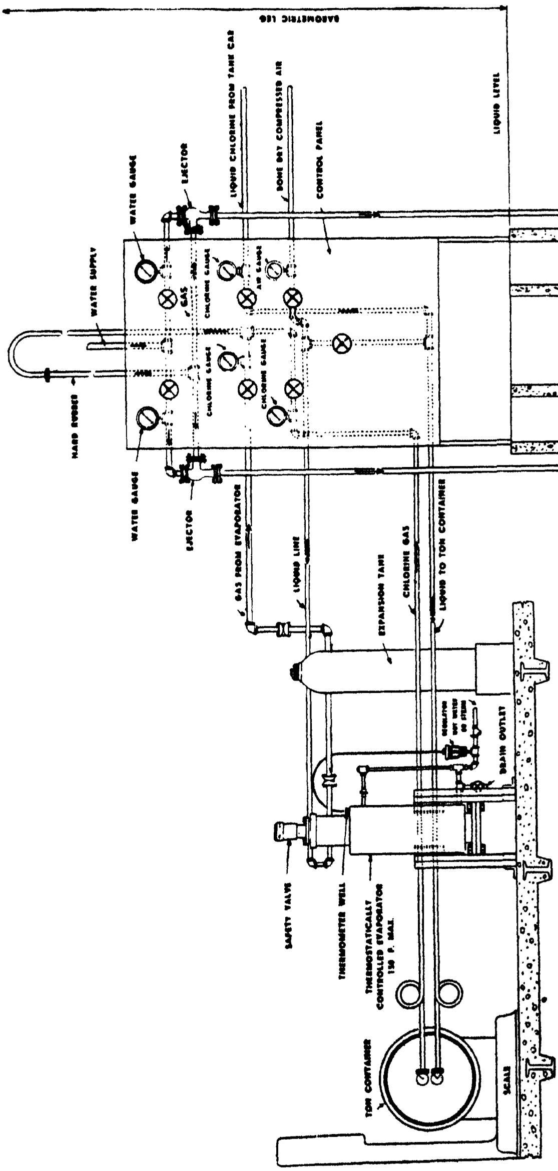


FIG. 129.—Diagram showing arrangement of piping for Penn Salt chlorination process for bleaching pulp.

Courtesy: Pennsylvania Salt Mfg. Co., Philadelphia, Pa.

of chlorine is produced, preferably through the use of a simple ejector. Water is used as a liquid medium and dispersing agent and as the chlorine gas is forced into the ejector under pressure, the amount of the element present greatly exceeds its solubility in the system. The resultant dispersion of extremely small bubbles of chlorine is led directly into the pulp and because of the large surface exposed, an immediate and complete absorption takes place without the necessity of resorting to high speed agitation or gas-tight equipment.

Due to the high concentration of elemental chlorine and the short time for the complete reaction, the small amount of water added does not materially dilute the stock. The process is applicable to both batch and continuous systems and to any step where the introduction of elemental chlorine is desirable.

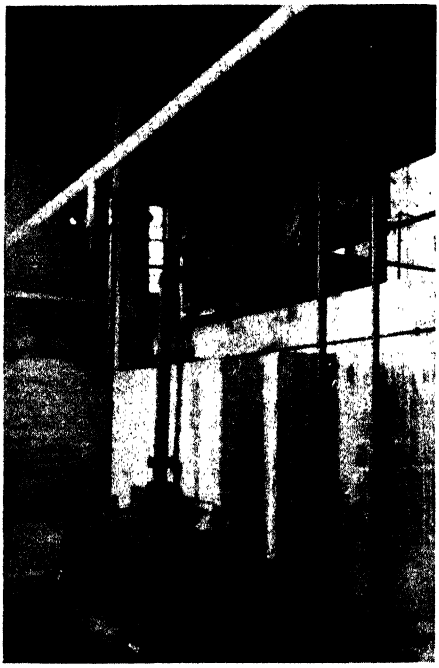


FIG. 130.—
Penn Salt chlorination installation showing arrangement for introducing ejector effluent into Bellmer.

Courtesy:
Pennsylvania Salt Mfg. Co., Philadelphia, Pa.

Some of the indicated advantages and applications of the process are:

1. The apparatus is simple in construction and utilizes standard equipment.
2. A commercial installation can be made at low cost.
3. The system can be incorporated as an integral unit in ordinary plant procedures using existing equipment.
4. The process is easily operated and requires no special technique.

5. It is applicable to the various types of pulp over wide ranges of consistency.
6. It adds chlorine to the pulp as the element and produces direct chlorination reactions.
7. The degree and rate of chlorination can be regulated within any desirable limits without the escape of chlorine gas.

Hooker System.

This system was invented by John D. Rue[1] and assigned to the Hooker Electrochemical Company of Niagara Falls, N. Y., and is distinctive because of the complete absence of moving parts. The equipment is completely constructed of rubber-lined steel. The pumps are also of rubber construction, although certain alloys, such as Hastelloy C, can be used. Chlorine gas is added continuously to stock flowing under pressure at about 3 per cent consistency. Chlorine and stock are promptly mixed by impact against a series of fixed bafflers. After a reaction period of approximately 5 min., alkali is added to the stock still flowing under pressure. Another set of fixed bafflers, similar to those used for the chlorine, mix the stock and alkali.

Characteristic of the process is the addition of chlorine in an amount substantially greater than that which can be consumed within the 5 min. period of acid reaction. On the addition of alkali, the residual available chlorine is converted to hypochlorite, which is allowed to become substantially exhausted in the subsequent period of retention prior to the washing of the pulp. Occasional tests, made on the water suspending the pulp, for the content of the residual available chlorine at the end of the 5 min. reaction period, serve as a guide to the adjustment of the flow of chlorine into the stock.

Electro Bleaching Gas. Co. System.

The stock is chlorinated in batches in the first stage in vertical agitators of wood or tile-lined concrete. There is an inner cylindrical shell, a cone-shaped bottom, and a powerful agitator. The chlorine is introduced at the bottom of the agitator, the amount being determined by weighing. The second stage is carried out in a Fletcher or similar bleacher, calcium hypochlorite being the bleaching agent. In the first stage the temperature is kept below 50° F. and the operation takes about 15 to 30 min. depending on the kind of pulp. Between the two stages the stock is washed on a continuous rotary washer and then thickened before admission to the second stage.

Thorne System.

This system was first introduced in Canada about twelve years ago. It is highly efficient but calls for elaborate equipment which, being mostly of rub-

[1] U. S. Patent 2,001,268, issued to John D. Rue, who assigned it to the Hooker Electrochemical Company.

ber-lined steel construction, is necessarily expensive. In the first stage the unbleached pulp is mixed with a metered amount of chlorine and admitted to a rubber-lined steel chlorination tower, provided with a revolving scraper at the bottom. From this tower the stock goes to a continuous washer and thence to a neutralizing tower identical with the previous chlorinating tower.

Courtesy: Improved Paper Machinery Co., Nashua, N. H.

FIG. 131.—Thorne bleaching installation at Pacific Coast mill showing bottom of rubber-lined steel bleaching tanks. Note the rubber-lined outlet elbows and piping and the four individual agitator drives.

Thence the stock goes over a thickener to a mixer where calcium hypochlorite bleach is added and on to a high-density bleaching tower. From this tower it goes to a continuous washer which delivers it to a low-density gravity bleacher and finally to a storage chest. Chemicals can be added to the mixer, or to the pumps moving the stock from unit to unit. The subsequent towers are provided with rotary scrapers the same as the first. The valves can be arranged for automatic regulation. This system is capable of almost unlimited variation as to density, number of stages or reagents used.

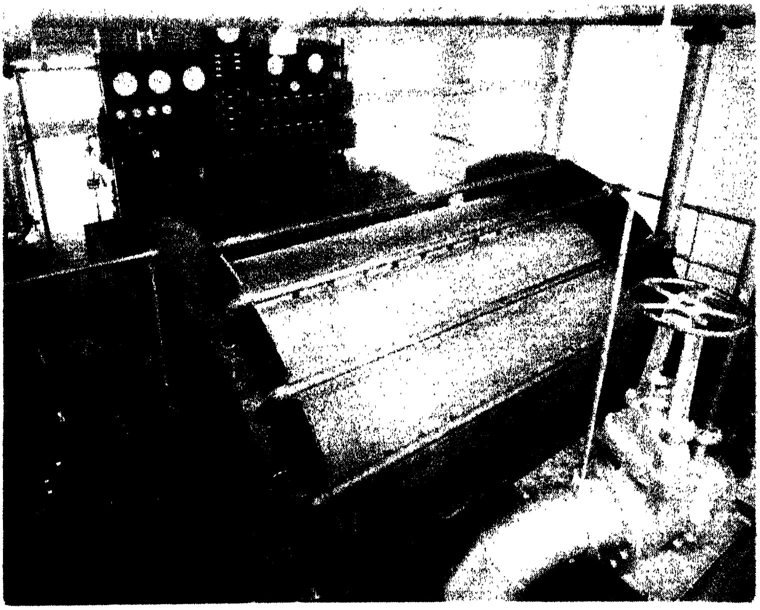
Bleach Consumption.

The amount of bleach required for any particular lot of stock depends, as previously explained, on many factors. We are of the opinion that the majority of mills use more bleach than is necessary. There is a tendency to use bleach liberally, getting rid of any excess of bleach with antichlor. This is wasteful and expensive.

Griffin and Little give the following figures for the amount of bleach required for 100 lbs. of different fibers:

Rags	2 to 5 lbs.
Straw	7 to 10 lbs.
Esparto	10 to 15 lbs.
Soda (poplar)	12 to 15 lbs.
Soda (spruce)	18 to 25 lbs.
Sulphite (poplar)	14 to 20 lbs.
Sulphite (spruce)	15 to 25 lbs.
Jute	10 to 20 lbs.

Of the miscellaneous factors the problem of the completeness of washing of the stock and the nature of the water used merits attention. Considering first the nature of the water itself, apart from any possible contamination



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 132.—Rubber-covered continuous rotary vacuum washer for washing chlorinated pulp after first stage of Thorne chlorination.

This machine is provided with a helical speed reducer and variable speed, direct current motor shown in the foreground for adjusting the washer speed to the required washing rate.

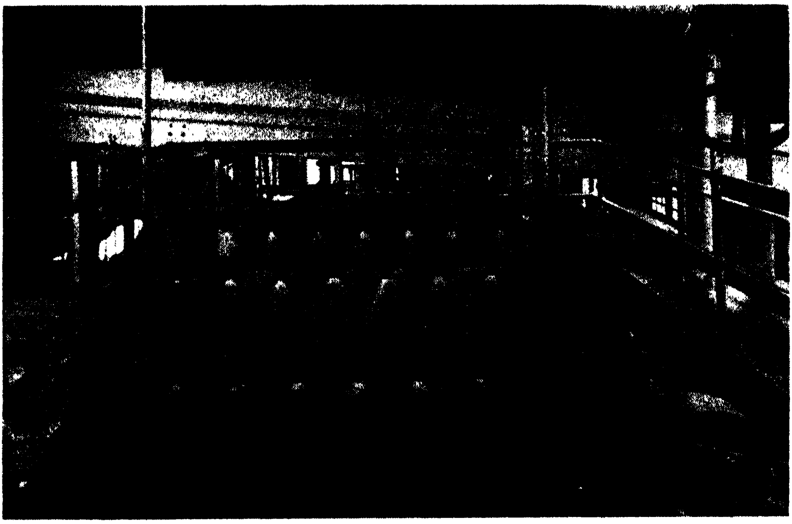
with the waste liquor from the cooking, it is evident that any oxidizable material present will use up more or less bleach. Such materials may be present because of contamination of the source of supply with sewage or wastes from manufacturing plants located further up the stream, or it may be derived from decaying vegetable matter. The amount of such impurities, or their bleach consuming power, can only be found from a careful investigation of each individual case, but Sutermeister cites the results of one such investigation of considerable interest.

The supply in question was obtained from a comparatively short river flowing through very little swampy land and not very heavily contaminated with sewage or manufacturing wastes. Its waters were normally soft and quite low in color. Two tests on this water, taken after it had passed a sand filter, showed that each 1000 lbs. would use up 0.127 lb. of 35 per cent bleach. This appears to be a small item, but if the bleaching is conducted at a concentration of 7 per cent it means 3.4 pounds of bleach per ton of fiber, while if the concentration is only 3 per cent the bleach used by the water amounts to 8.2 pounds per ton. At 2c per pound for bleach this means that it costs from 6.7 to 16.4 cents to bleach the water used with a ton of fiber. For a plant bleaching 100 tons per day for 300 days per year this costs from $2020 to $4920, according to the bleaching system used. While this cost can hardly be avoided, it indicates one advantage of bleaching at high concentration.

In addition to the regular water supply there is the possibility that some waste liquor may find its way into the bleaching system with the fiber. In fact, it is rare that the water entering with the fiber requires as little bleach as the water already described, and in some cases it may require very much larger amounts. Tests extending over six months at one sulphite mill showed that the water entering the bleaching system with the fiber required from 0.215 to 0.805 lb. of 35 per cent bleach with an average of 0.425 lb. for 1000 lbs. of water. Substituting this figure in the former calculation, it is found that if all the water used is of this average quality, in handling 100 tons of fiber there will be expended from $6770 to $14,690 per year for bleaching water. If river water could be completely substituted for this water, an annual saving of $4750 to $9770 would result. Here again this trouble cannot be entirely avoided but close watch should be kept to see that the unbleached fiber is washed as completely as possible. If this is not done very considerable variations may occur in the color of the bleached pulp, for occasionally there is enough waste liquor present in the fiber to use up bleach equivalent to 6 to 8 per cent of the weight of fiber.

Similar tests have been made on the water accompanying soda fiber, and for an average it was found that 1000 lbs. of water used up 0.192 lb. of bleach above the amount required by the filtered river water at the same time. Evidently strict attention is needed in the soda as well as the sulphite process.

While discussing the question of water, mention should be made of the use of "back water" or the water containing small amounts of bleach which has been removed from the bleach fiber. The use of such water in furnishing up the breaking engines is quite common, especially in plants which add more than the necessary amount of bleach and then remove the excess. Tests upon samples of such water have shown that the organic matter present either in solution or suspension continues to use up bleach and thus causes a considerable loss. Sindall and Bacon found that as much as 3.55 lbs. of bleach might be used up by 1000 lbs. of back water while tests by Sutermeister on similar samples showed a bleach consumption of 0.9 lb. to 1.5 lbs. for each 1000 lbs. of water. If it is considered that the consistency of the stock in the breaking engine is 4 per cent and that the water used is all back water, it would mean that a fiber normally bleaching with 10 per cent would require from 12 to 18 per cent because of the quality of the back water. Moreover, the repeated use of such water over and over again would very greatly increase this loss because of the accumulation of organic matter. The practice of using back water is not to be recommended unless it is very strong in bleach and unless the pulp can be thoroughly washed before completing the bleaching; otherwise its use is likely to cost more than it saves.



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 133.—Rubber-covered washer installed in mill making bleached kraft pulp showing action of fresh water showers.

The question of washing the pulp after part of the bleach has been added and used up is one which is worthy of very careful consideration in any plant. Tests on both soda and sulphite pulps have proved that such a treatment effects a decided saving in bleach. If about one-third of the total bleach is added and the stock then washed before adding the other two-thirds, it is found that 9 lbs. of bleach will give fully as good color as 10 lbs. which is added all at once. This saving of 10 per cent of the bleach applies equally well to easy and hard bleaching fibers, but it is obvious that the more bleach the fiber requires the greater will be the saving for a given outlay for equipment and power. A study of these factors should prove whether this modified process would be worth adopting in any given plant.

In any bleaching process agitation is necessary. This serves two purposes—to bring each particle of fiber into equal contact with the bleaching solution and thus promote uniformity, and to bring the bleach solution into contact with air and thus hasten the bleaching action. It has been shown by Taylor that passage of air through bleach solutions liberates hypochlorous acid and chlorine, both of which are more vigorous in their action than hypochlorite. This action is aided by the small amount of carbon dioxide in the air and may be still further hastened by agitating with, or leading into the bleaching equipment, gas comparatively rich in carbon dioxide. If the agitation is conducted in beaters in such a way as to shorten the fibers, as in the case of rag stock, the action is still further hastened by the penetration of the bleach into the canals of the fibers which permits it to act on both sides of the cell wall at once.

Use of Steam in Bleaching.

Raising the temperature hastens the bleaching process, but it considerably increases the consumption of bleach as chlorine is less soluble at the increased temperature and tends to boil out of the solution. Moreover, too high a temperature causes the bleach to attack the cellulose of the fiber itself, giving rise to compounds which cause a yellow color and a lessening of strength in the paper.

Any economical system of bleaching must involve a high density of stock, primarily to economize steam for heating. This is a very important factor. The following is Beveridge's formula for calculating the amount required, which is applicable to every case of hot bleaching:

$$\frac{(WS + W'S' + W''S'' + \ldots\ldots)\ (tf - ti)}{T - tf} = S$$

in which

S = Lb. of steam required.
W = Wt. of air-dry pulp in the charge, in lb.
s = Sp. heat of air-dry pulp (0.65).
w' = Wt. of water associated with the pulp in lb.
s' = Sp. heat of water (1.00).
w'' = Wt. of vessel in which pulp is bleached, in lb.
s'' = Sp. heat of material of which w'' is constructed.
ti = Initial temperature of stock in degrees Fahr.
tf = Final temperature of stock in degrees Fahr.
T = Total B. thermal units in 1 lb. of steam used for heating.

From this formula the following quantities of steam required for different densities of stock bleached at different temperatures have been calculated, taking the initial temperature t, as 60° F., the final temperature tf, as 90, 100, 110 and 120° F., and the total British thermal units in one pound of steam T as 1,190, *i.e.*, steam at 110 lbs. pressure above atmospheric.

Density of stock Pulp	Water	Water associated with 2000 lb. air-dry pulp	Lbs. of steam required to heat the mixture containing 2000 lb. air-dry pulp to 90° F.	100° F.	110° F.	120° F.
3%	97%	64,666 lb.	1881	2421	3053	3699
4%	96%	48,000 lb.	1427	1809	2282	2764
5%	95%	38,000 lb.	1154	1442	1819	2203
6%	94%	31,333 lb.	972	1197	1510	1830
7%	93%	26,571 lb.	842	1023	1290	1562
8%	92%	23,000 lb.	745	892	1125	1269

NOTE.—This table is based on the above formula but the weight of the apparatus w″ has been eliminated. Three per cent should be added to the above quantities of steam in the last four columns to allow for loss of heat by radiation.

Antichlors.

The complete removal of surplus bleach by washing being a very slow operation, many mills used to remove the last traces of bleach with an antichlor. The ordinary antichlor is hyposulphite of soda or sodium thiosulphate (which are just two names for the same chemical). Sodium sulphite, calcium sulphite and sulphite waste liquor have been used also as antichlors. With modern methods of chemical control the use of antichlors has become almost obsolete. It is wasteful, harmful and inexcusable.

Bluing.

A small amount of blue (ultramarine or some other blue) is frequently added to offset any slight yellowness that may be left after bleaching. Sometimes this is done to cover up imperfect bleaching of pulp that is to be offered for sale. The addition of even very little blue soon becomes apparent to the eye of the expert. It can best be detected by rolling a lap of the pulp into a tube and looking into it by a clear north light, or by looking into a folded lap as into the pages of a half open book.

Use of Acid in Bleaching.

Some papermakers add a little sulphuric or other acid in bleaching. This is often alluded to as "souring." The acid is generally added towards the latter stages of the bleach when the stock has almost reached the required degree of whiteness. The action of the acid is that it neutralizes the lime salts and facilitates the liberation of chlorine. Probably the chemist would consider the above explanation inadequate, but the chemistry of this process is really quite complicated. The above is, however, the general effect. Acetic acid is considered less harmful to the stock than mineral acids, and for that reason is favored by some paper makers.

Sutermeister explains that the rate of bleaching is decreased if the alkalinity of the bleach is high and that conversely the addition of acid tends to hasten the process. This is due, as in the case of carbon dioxide, to the setting free of chlorine and hypochlorous acid. The acids which have been proposed for this work are quite numerous, from sulphuric down to acetic acid. Only a small amount is necessary as it is constantly regenerated during the bleaching process, and it should be added in a highly dilute condition in order to prevent local overbleaching and the formation of chlorinated products of a yellow nature. Acid may be used with comparative safety with rag stock and soda fiber since these have already been given an alkaline treatment, and lignin or similar materials which give a yellow color on chlorination are practically eliminated. Besides the advantage of hastening the bleaching action, acid is beneficial in improving the color of the fiber when it is properly used, which, for this purpose, is at the end of the bleaching process when the bleach is nearly exhausted. Under such conditions it gives to the fiber a distinctly better color than could be obtained by the use of the same amount of bleach without acid.

It is usually stated that acid must not be used when bleaching sulphite because of the yellow color produced by chlorination of the impurities accompanying the fiber. This is true if the bleaching is all done in one operation, but Sutermeister contends that if part of the bleach is added with a little acid and the fiber is washed when this is exhausted, it will be found that the addition of a little more bleach will produce a much whiter fiber than if it were bleached with the same amount of bleach added in one lot without acid. This method introduces two modifications from the ordinary process, the use of acid and the intermediate washing and as already explained the latter causes a saving of about 10 per cent of the bleach regularly used. Further tests have shown that sulphite bleached as described with acid gives a whiter fiber than when bleached without acid but with the intermediate washing. The acid, when used in this way, is therefore beneficial though the gain is probably not enough to justify the added expense for acid, for the very complete washing necessary and for the greater deterioration of apparatus due to the acid. The only marked advantage of the method appears to be its rapidity, which is such that three-quarters of the amount of bleach required for an easy bleaching sulphite is used up in an hour when the temperature is 95° F.

Electrolytic Bleach.[1]

Many paper mills have introduced electrolytic plants for the production of their own bleach. It is beyond the scope of this work to explain in detail the construction and operation of such plants, which is really more a matter for chemical and electrical engineers than for papermakers. However, very simple and efficient installations have been designed which, when once installed, can be operated by the usual force of a paper mill without any special skilled attention.

There are a number of cells largely used for this purpose, of which the Allen-Moore,[2] Nelson Gibbs, Vorce, Hooker, Dow and Castner are excellent examples. They all operate by allowing an electric current to pass through a solution of common salt, decomposing it into chlorine and hydrogen. In all but a few very large plants the hydrogen is allowed to go waste.

[1] For details on electrolytic manufacture of chlorine see: Riegel, Industrial Chemistry, Chap. 5: Reinhold, New York, 1937.

[2] See: "Allen-Moore Cell in Pulp and Paper Mill." F. H. Mitchell, Chem. Met. Eng., 21, 370 (1919).

One large paper mill in New England uses the hydrogen to hydrogenate oils and to make hydrochloric acid which they sell. This is an example of what can be done in the way of utilizing by-products. The chlorine is led into vessels where it reacts with milk-of-lime to form 6° Bé. bleach liquor which is used directly in the bleaching process. Caustic soda is also produced as a by-product, and if no use can be found for this in the mill it can be concentrated and sold.

Another type of cell does not separate the products of the electrolytic action and produces sodium hypochlorite liquor, which is used as bleach instead of bleaching powder solution.

Many pulp and paper mills being located where water power is plentiful and, in consequence, electric current comparatively cheap, and being distant from points where chlorine is manufactured, find the manufacture of their own bleach a very profitable proposition.

Bleaching Groundwood.

The bleaching of groundwood is a very difficult matter as this class of pulp contains all the intracellular matter of the original wood. Moreover, there has been little demand for this product in America. In Europe, however, the bleaching of groundwood has developed to quite an extent. The bleaching agent is sodium bisulphite and the operation is carried out on a wet machine, the top press roll of which is equipped with two small felt covered rolls. Above the upper roll is a hard-lead spray pipe. The bleaching solution is sprayed by this pipe evenly on the upper roll, from that it is transferred to the lower of the two small rolls, the intention in this arrangement being to equalize the distribution of the bleach, and from the lower small roll to the sheet of pulp that is winding up on the top press roll. Difficulty has been met with owing to the perforations in the pipe clogging up. A patent distributing box intended to overcome this difficulty has been invented by Schutz (U. S. P. 1,208,670). The sodium bisulphite is used in 2 or 3 per cent solution.

Bleached groundwood is never as bright and white as bleached sulphite. It can always be detected in paper very easily as the bleaching does not prevent the fiber from showing the usual deep red coloration characteristic of groundwood with phloroglucinol.

Bleached groundwood has found its chief application in light weight papers where opacity is desired. It will increase the opacity without decreasing the tensile strength as much as a sufficient quantity of filler to produce the same result would.

For groundwood for bleaching dull stones and high pressure should be used, but this should not be carried so far as to unduly decrease production. In Austria excellent tissue paper is being made from 30 per cent bleached rag, 30 per cent bleached sulphite and 40 per cent bleached groundwood. It has also been used for cheap book and magazine papers.

Relative Efficiency of Different Bleaching Agents.

The question of the relative efficiency of bleach liquors made by dissolving bleaching powder, by absorbing chlorine in milk-of-lime, or by the electrolysis of brine is one which has been productive of much discussion and there are still those who are firmly convinced on both sides. The bulk of the evidence, however, points to the fact that if the comparison is based on the chlorine consumed per unit of bleaching effect a pound of available chlorine will be found to do the same work whether it comes from bleaching powder, from the electrolysis of brine or from calcium hypochlorite prepared by absorbing chlorine in milk of lime. Ahlin states that it is not true that active chlorine produced electrolytically will do more work than an equal quantity from bleaching powder, and this same conclusion is reached by Higgins who finds that a solution made from bleaching powder is just as good as an electrolyzed salt solution. Sutermeister made repeated comparisons of solutions of bleaching powder with those made by absorbing chlorine in milk-of-lime and found no difference in efficiency when the comparison was based on the color produced per unit of available chlorine. It is quite possible that some of the arguments in favor of electrolytic chlorine are based on incorrect comparisons in which the effect of some factor has been overlooked, while it is suspected that others may have been put forth originally by those endeavoring to sell electrolytic equipment.

Another continuous process is based on chlorination in a vertical cylindrical chest similar to the standard draft tube type of chlorinator. A continuous supply of pulp passes to the top of the draft tube. Continuous mixing is maintained and the chest is proportioned so the pulp will be retained for 45 minutes before it overflows to an annular launder attached to the top at the outer edge of the chest. From this point the pulp flows by gravity to a washer on the top floor of the bleach building. As the pulp sheet leaves the washer it is mixed with alkali solution in a puddler and drops into a rectangular chest. As the pulp moves through the chest to the overflow end it is kept in suspension by a traveling propeller type agitator. Retention period in this chest is one hour. At the overflow end the pulp passes to a second washer and another puddler which mixes bleach liquor with the pulp. Through a pipe it drops to another chest similar to the one described and dimensioned for proper retention period.

Another washing follows and in at least one instance a second treatment with calcium hypochlorite is applied and a fourth washing finishes the process.

Only two pumps are used in the entire plant, one to bring the pulp to the chlorinator and one to deliver the finished bleached pulp to the bleached stock chests.

The two bleach plants just described are the representative of complete continuous bleaching system. Certain claims on improved pulp quality are made for the use of continuous chlorination under specified conditions. In this case the advantage is said to result from the possibility of quick application of chlorine and neutralizing after a very short retention period. With a batch process following chlorination any possible economies of continuous operation are lost in adjusting the two stages to each other. Lack of flexibility in the process also militates against convenient treatment of a variety of pulps or various degrees of bleaching often desired on a given pulp. The chlorine consumption is somewhat higher than with the conventional two-stage process and economies of acid washing of the pulp are impossible.

Briefly, then, the continuous bleaching systems will show definite economies in plants bleaching large tonnages of uniform pulp to standard grades. To realize these economies the process must be continuous throughout.

12. The Beater Room

The manufacture of paper, as distinct from the manufacture of pulp, starts in the beater room. In studying the preceding sections, dealing with the various processes for making pulp, it should always have been kept in mind that pulp is not paper—it is merely one of the raw materials of paper, of which there are a number of others of lesser importance, e.g., clay, size, colors, etc. There are many large paper mills which do not manufacture any pulp at all, buying all their raw material from other plants which stop with the manufacture of pulp and do not proceed to make it into paper.

Beaters.[1]

The beaters, or beating engines, are large, oval, tank-like machines usually constructed of 3- or 4-inch cypress or other suitable planks.

Some beaters are constructed of iron, having cast iron or steel plate sides and ends, and a bottom of wood, cast iron or concrete. Concrete beaters are also used. In such cases the customer furnishes the concrete construction and the roll, bearings, bed-plate and various fittings are supplied by a manufacturer.

The dimensions vary according to the requirements. The following is a table of the sizes and dimensions of the beaters made by one prominent American manufacturer of these machines:

APPROXIMATE DIMENSIONS AND CAPACITIES OF BEATERS

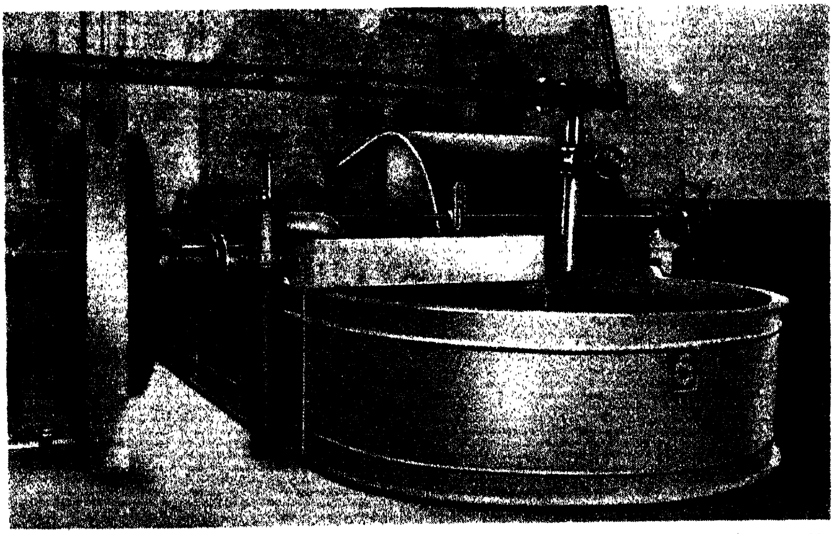
Length	Width of Tank	Size of Roll	Capacity, lbs.	R.P.M.
15′ 6″	6′ 6″	36″ × 34″	300	165
17′ 6″	6′11″	40″ × 36″	500	148
17′ 6″	6′11″	54″ × 36″	500	110
18′ 0″	7′ 8″	40″ × 40″	600	148
17′ 6″	7′ 8″	54″ × 40″	600	110
18′ 0″	8′ 3″	44″ × 44″	800	135
19′ 6″	7′11″	58″ × 42″	800	102
21′ 7″	8′11″	48″ × 48″	1000	124
21′ 7″	8′11″	62″ × 48″	1000	96
21′ 7″	8′11″	54″ × 48″	1200	110
23′ 0″	9′ 7″	65″ × 52″	1200	91
23′ 8″	10′ 5″	58″ × 56″	1500	102
24′ 8″	10′ 9″	67″ × 58″	1500	88
24′ 2″	10′ 5″	62″ × 56″	1600	96
24′ 8″	10′ 9″	72″ × 56″	1600	82
25′ 8″	11′ 2″	60″ × 60″	1800	99
26′ 2″	11′ 2″	72″ × 60″	1800	82
26′ 8″	11′ 6″	62″ × 62″	2000	96
27′ 9″	12′ 2″	72″ × 66″	2000	82

A usual size is about 25 feet long by 11 feet wide. Such a beater will hold about 1500 pounds of completed stock. The usual height of the walls of the beater is about 3½ feet.

[1] These machines were invented in Holland about 1740 and hence are often called Hollanders.

Courtesy: Noble & Wood Machine Co., Hoosick Falls, N. Y.

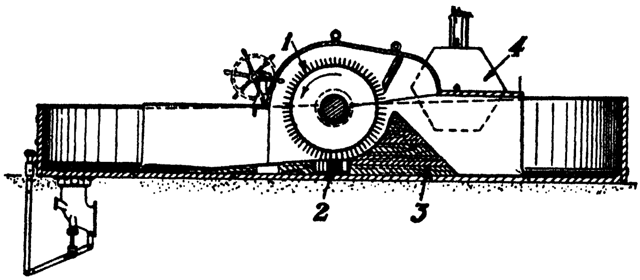
FIG. 134.—Typical beater room in mill making fine writing papers.



Courtesy: Noble & Wood Machine Co., Hoosick Falls, N. Y.

FIG. 135.—Typical standard beater.

Extending through the middle of the tank, parallel with the sides, but stopping short of the ends by about three feet, is a sturdy fence-like partition called the midfeather. The midfeather may be of either wood or iron. On one side of the tank, filling the space between the midfeather and the wall, is a cylindrical beater roll. This roll is so proportioned that its diameter is about equal to its length, the exact dimensions varying with the size of the beater, an idea of this being given by the preceding table. This roll is equipped with a number (usually 78 or 80) of steel bars or knives, each about 8 inches wide and ¼ to ½ inch thick. At the bottom of the tank, directly under this roll is a bed-plate, extending the full width of the roll



Courtesy: Socony-Vacuum Oil Co., Inc., New York.

FIG. 136.—Diagram of beater showing (1) beater roll (2) bed plate (3) backfall (4) washer drum.

and shaped so that its upper surface is parallel with the surface of the roll. The bed-plate is usually about 16 inches wide and 5 inches high and it contains from 32 to 48 knives. These knives are not set exactly parallel with the knives of the roll. They are usually arranged at an angle or in a V-shaped arrangement, as shown in the illustration.

The details of the construction of the roll and bed-plate will be dealt with later in this chapter under the heading "Maintenance of Beater Room Equipment." Such a beater as we have described is frequently spoken of as a Hollander or Holland type beater. Other special types of beater departing widely from the above description, but intended for the same purpose, have been designed. A few of the more important of these will be described later, but the above description covers the usual type of beater in paper mills throughout the world.

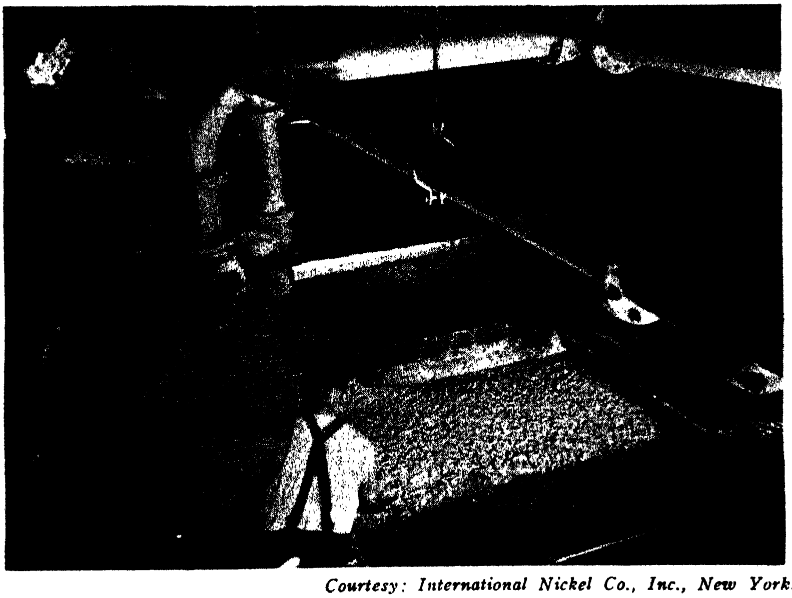
When the beater roll revolves each of its 78 roll bars or knives comes in contact with each of the 42 knives of the bed-plate, so that the roll will give 3276 cuts for each revolution.

With the roll running at a speed of 100 revolutions per minute, it is apparent that there will be delivered 327,600 cuts per minute to any material forced between the roll and the bed-plate.

The beater-roll weighs several tons and may be raised from, or lowered upon, the bed-plate by "Lighter-Bars," which carry the roll in strong journals. Such movement is rendered very accurate by having a hand wheel geared to it in a rather large ratio. Thus the roll may be changed in its relation to the bed-plate a very small fraction of an inch. These fine adjustments are frequently necessary.

The beater help feed into the beater the various ingredients of the paper as determined by the "Formula." When it has been found by experience that a certain percentage of sulphite pulp, a certain percentage of kraft (sulphate) pulp or of groundwood, so much coloring matter, so much "fixing" solution, size, filler, etc., is required to produce a certain definite grade of paper, these percentages are rigidly adhered to every time a run of this paper is made.

Naturally, such measurements and chemical treatment cannot be carried out by guesswork. The percentage of the various ingredients is reduced to terms of weight (the various pulps, sulphite, sulphate and groundwood being fixed on a "5 per cent air-dry" basis) and the "Furnish"—this being the phrase by which the exact formula of a given *grade* of paper is known —is built up accurately on exact scales.



Courtesy: International Nickel Co., Inc., New York.

FIG. 137.—Appearance of stock as it circulates in beater.

When a large mass of pulp is placed in the vat (which is capable of holding 1500 pounds of completed paper-stock) the revolving of the roll will draw the material between itself and the bed-plate and cause a general circulation of the material, around and around the tank, since the mid-feather gives us a perfectly oval path for the "stuff" to travel in.

Sand Trap: A short distance in front of the roll, a small box or trough extending from the side of the beater to the midfeather is set in the floor of the beater. This trough is covered with a screen plate. It is known as a sand-trap and it serves to eliminate small particles of grit and dirt which, on account of their weight, stick to the bottom of the stock as it circulates around the beater. This is used only for fine papers.

Backfall: As the beater-roll turns up the material rather sharply behind it, a cover or decking is necessary at that part, and a little beyond, to hold the mass down to its proper level and prevent its being thrown out of the beater. Immediately behind the beater-roll is a device known as the "Backfall." This is a hump or elevation constructed of wood covered with steel plate, the side of which nearest to the beater-roll conforms in shape to the roll. The pulp is propelled upwards between the beater-roll and the backfall and strikes the cover of the beater which gradually smooths out the flow so that the pulp again becomes level in its travel around the beater before coming under the beater-roll the next time. The tendency to mount up and overflow behind the beater-roll is much more marked in the case of the heavy viscous stocks—such as those containing a high percentage of kraft pulp.

Doctor: Immediately above the backfall and behind the roll is a doctor consisting of a heavy board with a cast iron edge. This doctor is arranged so as to just clear the surface of the roll and prevent any stock being carried around with the roll, deflecting it back over the top of the backfall.

String Catchers: In beating certain classes of stock such as waste paper, jute, etc., strings, rope, wire, etc., are frequently present. The string catcher is a device consisting of a series of bars or fingers secured to a steel shaft which extends over the path of the stock in the beater. The shaft and fingers form a sort of fork or rake which will catch any pieces of string or rope without seriously impeding the flow of the stock. A hand wheel is provided by means of which the device can be raised or lowered, as required. This device not only prevents string and rope from being mixed with the stock but also prevents such material from winding around the beater shaft where it would cause a great deal of trouble.

Emptying and Wash-out Valves: Various arrangements are used for emptying the stock from the beater. One of the commonest is an iron disc resting on a circular seat. In the center is a depression spanned by a cross-bar by means of which the disc is lifted out of its seat, allowing the stock to flow out of the beater. This device has the objection that the opening is relatively small, thus increasing the time necessary to empty the beater. Moreover, if any pressure is created in the stock chest, for instance, when one or more other beaters are being emptied, the disc may be forced up, allowing the contents of the beater to be prematurely dumped. This is guarded against sometimes by a lock type of valve, as illustrated. However, this is no more rapid in operation than the ordinary type and involves fumbling with a locking device at the bottom of a beater full of stock.

Much better are special quick-emptying valves, which are operated by a lever outside the beater. The disc is carried on a riser operated by a series of levers. A spray of water is also provided with this type of valve which assists in the rapid removal of the stock and also keeps the valve seat clean and free.

A still further improvement is a patented stock emptying valve of oblong shape about 6 inches wide located in the bottom of the engine just in front of the roll, extending right across from the midfeather to the side of the beater, its top being flush with the bottom of the inside of the engine. The valve cover lifts up along the side farthest from the roll, and when raised to a vertical position becomes a dam, aiding in forcing the stock out of the beater. It is operated by a shaft extending through the side of the beater and having a lever at its outer end. A shower of water is provided to help the stock out of the beater and to keep the valve seat clean. With an adequate discharge pipe (not less than 18 inches diameter), the stock can be removed from the beater almost instantly without using any rakes and with a minimum of labor. With the ordinary disc valves the use of rakes is generally imperative.

Function of the Beater.

Referring to the roll and bed-plate of the beater as containing "knives" may possibly have caused the reader to think that the main purpose of this machine is to cut the fibers to a given length. While the machine admittedly is used for this purpose, this is not its only function—or its most important one. No less vital than the cutting of the fibers to a certain length is the separating of the *bundles* of fibers (which will exist to a certain extent in even the best grades of sulphite and kraft pulps) and to *brush* or *stroke* the fibers into greater flexibility.

The tiny fibers are *stroked out* by the blunt knives of the beater, in somewhat the same manner that a hairbrush strokes out human hair, and moreover the fibers are caused to *curl at the ends.*

Upon the ability of these fibers to curl and connect with each other, when allowed to "bond" (by removal of the surrounding liquid) depends the strength and toughness of the resulting *paper.* If these fibers are not drawn out to the correct degree, they will not grasp and entwine with each other in the manner which we denote by the term "felting."

It will readily be appreciated that not only must the fibers be "brushed out" and made flexible, but—in order to obtain a sheet which will have strength and thickness—*the fibers must be kept long in the beater.* This applies with particular emphasis to papers of light *basis-of-weight,* of which a great deal is expected—as, for example, fine writings, ledger and bond papers and 28- and 30-pound kraft wrapping and bag papers.

Now, if we are to have a consistent length maintained, it will be seen that (whatever its shape and size) a beating engine must be smoothly constructed so that no stuff can lodge and stay in any part of it, but must circulate uniformly around and around, and beneath the roll again and again. Fillets are provided in the angle between the sides and bottom of the beater so that no stuff can lodge and remain in a position where it does not come under the action of the beater-roll, as might be the case if the sides and bottom of the beater joined at a sharp angle.

Moreover, the roll must be heavy enough to soften thoroughly all pulp and keep it in constant motion. Another great desirability in a beater is to be able to adjust it so minutely as to give us the exact length and quality of fiber we desire—and to maintain the entire output completely uniform.

While we have stated that *long* fibers are vital in certain classes of paper, it is equally important that we must not have them *too long*. Else the paper produced will actually possess less firmness and tensile strength than if the fibers had been a little shorter. This is true because of the paper machine's inability to mesh and quickly drain paper-stuff containing fibers that are beyond a certain length. This point will become clearer after we have discussed the construction and operation of the paper machine.

But, whether the fibers are to be long or short when they reach the paper machine, the basic properties of the paper will depend on the treatment they receive *during the first hour and a half* in the beater. If the roll be put down sharply on the plate at first, the fibers may retain their length, but they will be considerably weakened, and the sheet will have a raw, soft feeling. Such stuff is generally termed "fast" or "free."

In brief, the beater is not an automatic machine. It is an instrument—and one that requires intelligent and experienced control. An inexperienced or careless operator can easily ruin an entire charge of material—especially during the first hour and a half.

The "rawness" alluded to above as caused by putting the roll too sharply down on the plate at first, is often quite noticeable in papers made from kraft pulp. In the *thin* papers of this class, the idea that length of fiber necessarily means *strength* is so often over-stressed that, when the pulp reaches the paper machine, a considerable portion of it refuses to drain properly. The whole matter (as intimated above) lies in the fact that a great part of the worth of the resulting sheet of paper is contingent upon the behavior of the fibers in meshing readily on the paper machine.

Under a microscope, a sheet of thin paper will often exhibit *spaces* between the long fibers, which seem to be filled with a transparent, nonfibrous material. The longer the fibers, the more apparent these spaces will be—and, however minute, their presence must tend to *weaken* the sheet. With fibers just a shade finer, the finest of all will, on the paper machine, tend to settle into these spaces, more closely felting the whole sheet.

So that, while as a general proposition the long fiber does lend the sheet its great strength, it should be borne in mind that this is not the entire value—and that good stock for light, strong papers requires a certain free fiber to be present as well. This will be explained in greater detail when we come to talk of the paper machine, but it is necessary to allude to the fact now in order to illustrate the problems that arise in the proper handling of the equipment of the beater room.

On the other hand, in preparing stuff for *thick* papers, the roll can be put down much sooner after the beater has been furnished. This is so that the stuff may be fine and free, parting with water readily on the paper machine, and giving a close, easily felted sheet. But there is danger here in going to extremes and making the stuff too soft and fine, so that we must not run it too long in the beater.

Blunt plates and rolls are used for stock intended for thin, strong. papers which must be kept in the beater for at least six hours, during which time sharp knives would cut it up altogether too much (making it too free) and preventing it from felting properly on the machine. For preparing such stock the Jordan and other engines, subsequently to be described, are very useful, the stock being beaten a shorter time and finished in the Jordan. In the thick, heavy papers sharper plates and rolls may be used, and the stock is not held nearly so long in the beater. For instance, stock for blottings is frequently only kept in the water an hour and a half.

From the above considerations the reader will be able to understand why the beating time varies over such a wide range in preparing stuff for different grades of paper, ranging all the way from merely mixing the stock and color and then dumping in thirty minutes, to combing out and beating for eight hours or more.

When a large proportion of groundwood is involved (as is the case with some of the cheaper varieties of bag paper, etc.), the beaters must not be heavily loaded (that is, only a comparatively small amount of stuff can be handled in one batch), nor allowed to run very long, since this class of fiber is naturally reduced very quickly, and soon arrives at the state known among papermakers as "slow stuff"—that is, not draining quickly and properly on the paper machine, which is conducive to poor quality and cuts down the productive efficiency of the paper machines seriously.

When excellent folding qualities are especially desired—for instance, in paper to be used for the manufacture of bags—the beating time is protracted, but under these circumstances the roll is lowered only enough to give a *very gentle rub.*

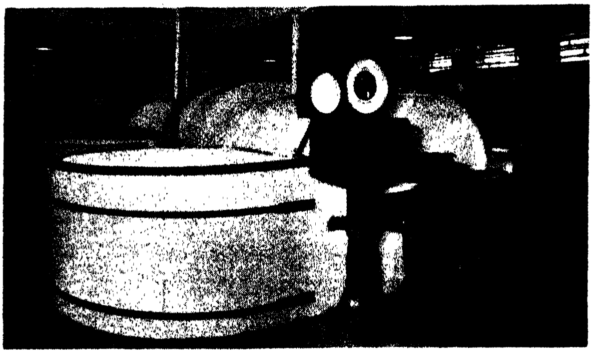
It is always preferable to use separate beating engines for the extremes of adjustment illustrated above. Or, in other words, the beater that is used for greasy slow stuff should not be used for short groundwood fibers. With even the most careful manipulation and adjustment, there is a certain range over which a beating engine operates most efficiently.

Notwithstanding the degree of nicety with which (by means of the hand-wheel geared to the lighter-bars) the roll can be raised or lowered, regulating very minutely the superficial pressure exerted on the ultimate fibers, the stuff produced with sharp bars is inevitably weaker (even if the ultimate fibers be of full length) and it will lack the greasy, well-beaten feel, indispensable in the production of thin, tough papers.

Moreover, long experience has demonstrated that a light beater-roll will draw out fibers much better than a heavy one, even though it takes longer to do it. The crux of the whole matter is the superficial pressure exerted on the fibers by the beater-roll—since, with sharp bars. *the pressure is increased in proportion as the area of the bearing-and-cutting surface is reduced.*

Consequently, it is necessary to determine the type of the beater engine in accordance with the special requirements of the paper it is desired to produce, whether this be writing paper, bag paper, etc.

In the manufacture of some grades of newsprint, with a large percentage of groundwood, a treatment in *agitators* sometimes is substituted for treatment in the beater. These agitators are simply large tanks provided with mechanically driven stirrers to keep the stock in circulation. The pulp is treated with size and alum, and held in the agitator sufficiently long for the size and alum to penetrate the fibers. This is called "soft stock" as opposed to sulphite, which is "medium stock," and kraft would be a good example of "hard stock."



Courtesy: Toledo Scale Co., Toledo, Ohio.

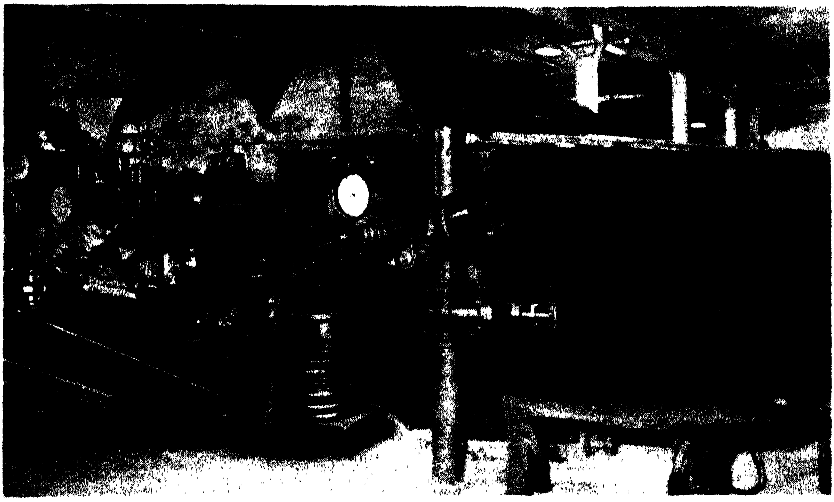
FIG. 138.—Beater equipped with special device for recording beater roll pressure.

Numerous forms of testing instruments have been devised for determining the control of the beater operation, but the human element still governs it to a high degree. The appearance of the stock in the beater and the feel when a handful of it is picked up are the chief points on which the experienced operator relies.

Even the novice, if of an observing nature, will notice that when the stock is first admitted to the beaters, it is cold, bulky and fills the beater to the brim. This appearance will be kept up for some time, the stock breaking at various intervals, just before it passes under the beater roll. As the operation proceeds, however, there is a slight rise in temperature, the stock tends to sink more to the bottom, and at intervals it will *shine* on the surface.

After the stock has been worked in the beater it has a characteristic feeling, quite different from that of unworked stock. The hand will pass through it freely and it will be slippery and "greasy" so that it is practically impossible to retain any large amount in the hand when squeezed. An experienced papermaker, by taking up a handful of stock in a beater, can generally tell how long the stock has been beaten, and how long it will still have to go, from the feeling alone, even if he has no other source of information.

As the treatment the stock requires in the beater depends extensively on how it has been cooked in the digester, it is not possible for the workman in charge of the beater to operate under any fixed rule. Consequently, he must be a man of experience and good judgment. Procedure that may have have produced good stuff from stock resulting from a certain digester cook would have to be altered materially to deal with the next cook produced under slightly different conditions.



Courtesy: Taylor Instrument Companies, Rochester, N. Y.

FIG. 139.—Special type of beater equipped with electric pressure regulator.

Hydration.

In discussing the use of the beater one today constantly encounters the word "hydration." For instance such a paper as "glassine" is beaten so as to have intense hydration of the stock and very slight cutting. In preparing blotting paper, however, there is little hydration. This term hydration alludes to the chemical combination of water with the cellulose of the fiber promoted by the mechanical brushing and rubbing of the beating process. Extreme hydration results in a gelatinous mass quite useless for papermaking. More moderate hydration gives a crisp sheet with a good rattle, but one must always be on guard against such a sheet curling and cockling. Hydration is a most important function of the beater. In fact where mere cutting up of the fiber is called for it can be performed much better in a Jordan or other refiner, as such machines are far more economical of power than the beater. In fact the beater is very wasteful of power, which is one of the reasons so many experiments have been engaged in to perfect new types of beater. When making grades of paper such as "glassine," calling for highly hydrated stock, it is well to arrange ample stock chest capacity, and allow the beaten stock to age 48 hours or more.

Unbeaten stock (half-stuff) will hydrate very little under such circumstances, but beaten stock will hydrate to a marked degree. Old-fashioned practical papermakers were familiar with this phenomenon long before the chemists came along with an explanation for it.

Furnishing Lap Stock to the Beater: The beater should be filled up with water until the roll begins to circulate the water. Assuming that the furnish is to consist of sulphite and groundwood, the sulphite should be furnished first, the laps being carefully opened before being placed in the beater. During the furnishing the roll should be away from the bed-plate sufficiently far to prevent it from jumping as the laps of stock go through. After the sulphite has all been furnished, the groundwood is put in. The roll should be kept up off the bed-plate until the laps are thoroughly disintegrated, then the roll can be lowered to the degree decided on by the beater engineer. Size, color and alum can then be added in the order mentioned. A sufficient interval of time should be allowed to elapse between the furnishing of each of these ingredients so that each will be thoroughly worked up with the pulp before the other is added.

In making paper from kraft and sulphite separate beaters should be used, as if it is attempted to beat them in one and the same engine, the sulphite will be overbeaten long before the kraft is properly worked up. The best way is to use two beaters, one for the sulphite and one for the kraft and to mix the stock in a chest after the beating is completed.

In making a paper 75 per cent sulphite and 25 per cent kraft, for instance, six beaters could be used, five on kraft and one on sulphite. The sulphite can be dumped after half an hour's beating whereas the five beaters working on kraft will be kept running six hours or more.

In making book and writing papers, the beaters must constantly be stirred, special attention being paid to the corners where, in spite of fillets, stock will accumulate.

The treatment the stock receives in the beaters depends to some extent on what is going to happen to it next. The next operation—treatment in the Jordan engine or some other type of refiner—is generally correlated with the treatment in the beater, and the work of preparing the stock for the paper machine divided between them. Before treating of the Jordan engine, however, we will discuss some of the materials which are ordinarily added to the stock in the beaters. The chief of these are clay, size, alum, talc, coloring materials, etc.

Clay.

Paper made of fiber alone is more or less transparent, the degree of transparency depending chiefly on the thickness of the paper, but also on the nature of the fibrous material itself, some kinds of fiber being more dense and opaque than others.

In order to overcome the transparency of thin papers such as newsprint and also to give the paper other desirable qualities (such as a better printing surface and a lessening of the friction when in contact with the type on the printing press), it is generally advisable to load such papers with some inert material.

The amount of clay or other filler varies with the kind of paper: book paper (in which clay is a very important ingredient) uses from 10 to 40 per cent, usually not more than 25 per cent; newsprint, cheap stationery paper, etc., rarely carries more than 5 per cent. All these figures are relative to the total weight of the paper. The great importance of clay in book paper is because of the necessity of properly printing high-grade half-tones and other cuts for illustrations.

Such inert materials used for loading are known as "fillers." The commonest of these fillers is Kaolin or China clay.

This substance occurs naturally, being a hydrous silicate of aluminum, formed by the weathering and disintegration of certain kinds of rock. It occurs throughout the world but until recently clay for the use of the paper industry has been procured chiefly from Great Britain. Lately deposits of clay suitable for papermaking have been opened up in the United States and Canada. The majority of clay deposits throughout the world are not suitable for the use of the paper industry because of the presence of impurities.

The composition of clay will always vary owing to the presence of impurities but a good average sample should run from 47 to 50 per cent SiO_2; 34 to 40 per cent Al_2O_3; 12 to 15 per cent chemically combined water. The usual chemical impurities are iron, calcium and the alkalies. Clay containing more than one per cent iron should never be used as iron will impart color to the paper. For making good white paper, clay should be perfectly white in color, very fine and free from grit.

The following table taken from Griffin and Little gives an analysis of four clays (presumably British), suitable for the use of papermakers:

ANALYSIS BY GRIFFIN AND LITTLE

	I	II	III	IV
Moisture, loss at 100° C.	0.30	10.15	7.09	9.10
Combined water, volatile at red heat	12.27	10.77	11.27	12.79
Silica (SiO_2)	47.56	42.72	43.50	41.16
Alumina (Al_2O_3)	38.12	33.44	35.48	35.84
Sesquioxide of iron (Fe_2O_3)	0.08	1.04	trace.	0.67
Lime (CaO)	0.39	1.61	0.17	0.42
Magnesia (MgO)	0.00	0.16	0.41	0.02
Alkalies	1.28	0.11	2.08	....
	100.00	100.00	100.00	100.00
Specific gravity of dry substances	2.8625	2.5585	.....	2.5451
Grit by flotation test (per cent)	0.65	6.83	.....	0.10

On page 318 is the analysis of a clay mined in Quebec, Canada, which is being used with satisfactory results by Canadian papermakers and a clay from the Aiken district in South Carolina which has also been found satisfactory.

Whether a clay is suitable for papermaking, or not, cannot, however, be decided by chemical analysis, although all clays considered for use should always be analyzed to prove the absence of chemical impurities in excessive amounts. The physical properties of the clay are equally as important as the chemical properties. These physical properties are the result of the geological history of the clay. A detailed discussion of this matter would

ANALYSIS OF CLAYS FROM U. S. AND CANADA

	Aiken, S. C.	St. Remi d'Amherst Quebec, Canada
Silica	45.67	46.13
Alumina	37.86	39.45
Iron oxide	1.48	0.72
Lime	0.05	none
Magnesia	0.01	none
Alkalies	0.80	0.29
Combined water	13.22	13.81
Per cent grit	1.88	not estimated

belong more in a work on mineralogy than in the present volume. However, the chief point is the presence of what the chemist calls "colloids" in the clay. This means that the fine particles of clay will remain in suspension almost indefinitely when the clay is mixed with water. It is the presence of this colloid structure that gives the clay the greasy, slippery, tenacious consistency when mixed with a small quantity of water, which is characteristic of all good clays. Further on we shall give some simple tests by which the papermaker can determine whether a clay is suitable for his use from the standpoint of physical properties.

American Clays vs. British Clays: There does not seem to be any good reason why American clays should not be more used in this country than they are. However, trade tends to follow beaten paths, and large tonnages of British clay were imported. English clays dissolve quicker and are generally thought to have a better color and a smoother handle.

According to T. Poole Maynard,[1] a chemist with experience in the clay industry, American clays are available in immense tonnages of superior quality to any now imported from England. Many large mills today use American clay exclusively.

The use of American clays is gradually increasing. In 1915 Georgia and South Carolina produced 92,000 tons of clay suitable for papermaking, and in 1916 125,000 tons. In 1938 the total tonnage of such clays produced in the United States was over 300,000 and in the same year more than 250,000 tons were imported from England.

Preparation of Clay: In preparing clay for the market, the crude product is thoroughly washed with water and the gritty impurities allowed to settle in large tanks. From these tanks the water is decanted off before the fine particles of clay have had time to settle. The clay is then allowed to settle in tanks from which the clear water is siphoned off. The thick, creamy white sludge containing the pure clay is then dewatered in filter presses and the cakes dried and prepared for shipment.[2]

[1] Paper before the Technical Association of the Pulp and Paper Industry, 1919.
[2] In England clay is not pressed hut merely drained, which is claimed to be the secret of the superiority of English clay.

Of course, the strength of any paper is weakened by putting in a filler with the fiber but since the surface, finish, feel and general characteristics of the paper are improved by the addition of fillers, it is generally advisable to do so. However, it requires experience and good judgment to determine in all cases just what proportion of filler should be used.

Clay is usually used as a filler in newsprint, magazine paper, and the cheaper grades of writing and book paper. The better qualities of writing and book paper are usually loaded with special materials such as agalite, calcium sulphate, pearl hardening, barium sulphate, etc.

For use in the beaters, the clay is usually made into a thin cream with water, this generally being done in a small tank fitted with an agitator. Some papermakers mix the clay with rosin size before adding it to the beaters, it being believed that this procedure aids in the retention of the filler by the fibers.

How to tell good clay: A good clay should feel smooth and soapy between the teeth and should not scratch a finely polished metal surface. The best test for clay is to drop a few lumps of the dried clay into a glass of water and without stirring observe the behavior of it. A good clay will emit numerous bubbles with a slight buzzing sound and as the water penetrates, will gradually break down into a fine powder which rolls off from the surface leaving the lumps until finally it is all broken down into a powder.

Upon stirring up the mixture with more water, pouring off the fine milk, adding more water, stirring and pouring off, very few particles of clay will be left in the glass.

If instead of forming a fine powder which rolls off the surface of the lumps, the lumps crack into small pieces as the water penetrates them and these small pieces crack again and so on, the clay is not satisfactory and will give rise to "clay spots" in the paper.

Before adding clay to the paper it should always be screened through a wire cloth to remove any impurities that may have been left in the clay in manufacture or that may have got into it during shipment and storage.

The thinner the clay liquid is and the longer it can be stirred, the better it will be. There being fewer lumps to screen out, the screening will be more rapid and easy, a finer wire cloth can be used for the screening, and it will flow better through the pipes. A thick mixture of clay and water of this kind is called "slip."

Furnishing clay to the beater: A convenient strength of slip for furnishing to a beater is made by dumping a cast of about 2400 pounds of clay into a tank holding about 2400 gallons, partly filled with water, stirring and adding water until the tank is filled. This gives a "slip" each gallon of which contains one pound of clay. By this means, it is very easy to gauge the amount of clay being furnished to the beaters.

A good arrangement is to make up the "slip" in a small tank or box above the beaters. Hot water slacks clay more readily than cold water and it is of considerable advantage to warm the water especially in cold weather. When clay is slacked in the above manner, in small tanks or boxes above the beaters, and when any size is being used in the paper, it is a good plan to use hot water for slacking the clay and to dissolve the size at the same time.

The alkali of the size causes the clay to slack more readily to a fine slip. Alum, however, should never be added when slacking the clay as it makes the clay flocculate together giving a slip of coarse consistency. Alum should, therefore, always be furnished separately and not mixed with the clay and water. Moreover, alum acts injuriously upon iron pipes, valves and agitators.

In mills where large quantities of clay are made into slip in large tanks and then pumped to the beaters, it is not advisable to mix the size with it, as it gives rise to much foam during the stirring and screening and when water is run into the tank for the next batch.

At frequent intervals samples of clay used should be sent to the laboratory, or to an analytical office, for chemical analysis and for physical and microscopical tests. Only in this manner can the mill be sure that the best quality of clay is being used and that too high a price is not being paid for the grade specified.

Clay requirements of different stocks: Soda pulp as a rule requires less filler than sulphite pulp because it is naturally bulkier and less transparent. However, with no kind of stock should excessive quantities of clay be used as it will dust off on the printing presses, contaminating the ink and giving poor results. The excessive use of clay is also a needless expense as the fiber will only retain a certain amount and a great deal of clay will be wasted in the white water if too much is added.

The proper amount to use for newsprint is generally about 5 per cent. The amount to be used with other grades of paper depends entirely on the effect it is desired to produce and must always be a matter of individual judgment and experience. In making newsprint, when a mill is well equipped with save-alls and facilities for utilizing the white water, it is generally cheaper to use clay liberally and groundwood more sparingly. The exact balance between clay and groundwood in newsprint must, however, be worked out as a matter of practical experience. In ordinary newsprint about one-half of the clay furnished is retained, but this varies considerably according to local conditions. The amount of size used has a direct effect on the retention of the clay, but ordinarily in making the newsprint, no size is used at all except on special orders. Alum also has an effect on the retention of the clay but it is not desirable to use too much alum because it exerts a hardening effect on the paper. Moreover, it is not economical to use 2 cents' worth of alum in order to save 1 cent's worth of clay.

The only source of loss in the use of clay is in the white water which is allowed to run to waste, and if it were possible to re-use every gallon of white water and have none go to waste, there would naturally be no loss of clay or of fiber. Many efficient devices are on the market for recovering the clay and fiber from white water. See page 477.

Some papermakers object to the re-use of white water, liking to use plenty of fresh water because of a fear that white water causes slime to accumulate. Some papermakers go so far as to use fresh water exclusively, permitting all the white water to go to waste after passing through a save-all for removing the fiber. This is rarely necessary except in a few mills where exceptionally fine grades of writing paper, etc., are being made.

It is our opinion that the prejudice against the use of white water is largely unwarranted and instead of avoiding its use we believe that as much as possible should be used. There is an opportunity at almost every mill to effect considerable saving of clay and fiber by careful attention to the disposal of the white water.

The following is a table based on tests at certain mills showing the retention of clay in hangings and newsprint:

Kind of Paper	% of clay furnished	% found	% retention
Hanging	13.00	7.81	60.08
Hanging	13.00	8.10	62.31
News	13.00	4.85	37.31
News	13.00	4.81	37.00
News	13.00	4.53	34.85
News	13.00	4.52	34.77
News	13.00	4.41	33.92

The hanging paper shows a fairly good retention but the retention in the case of the news is quite poor. We believe that a furnish of about one-half as much clay would give equally good results and would show a much larger percentage of retention.

In a certain mill the writer knows of 200 pounds of clay are used to a beater each round and out of each round they make 2150 pounds of paper. Consequently, 9.2 per cent is furnished, the per cent of clay found in the paper was 7.9, consequently the percentage of retention is 85.87 per cent. The cause of such a high retention was because this mill was very careful in the use of white water and in preventing clay going to waste. They also used quite a large amount of alum and the paper was very heavy.

Retention of Clay and Other Fillers.

Retention refers to the proportion of the filler added to the beater which persists in the finished paper. Retention is *promoted* by increase in slowness of stock, length of fiber, weight of sheet and *diminished* by increase in machine speed, solubility of the filler itself and the amount of filler used. Clay gives the highest retention of any filler, with agalite a close second and pearl hardening very low. Wilkinite, a colloidal clay, increases retention of all fillers, but is not itself a filler. Retention (in per cent)

$$=\frac{\text{Wgt. filler in paper}}{\text{Wgt. filler in beater}}\times 100.$$

Correct for difference in moisture content of filler in paper and original filler; also for chemically combined water; also allow for filler present in broken or waste paper in the furnish, and for filler content of white water.

These results are figured on the basis of the paper containing 10 per cent moisture. Average percentage of ash in paper containing no filler

EXAMPLE OF TESTS AND CALCULATIONS REGARDING RETENTION OF CLAY

Clay used, gave moisture and combined water	14.95%
Dry clay	85.05%
	100.00%

Ash (Clay) in 4 Samples:

	(1)	2.700% ash
	(2)	3.123% ash
	(3)	3.366% ash
	(4)	3.420% ash
which averaged		3.152% ash

was found to be 0.46 per cent. Hence percentage of dry clay in paper was 3.152−0.46 or 2.692 per cent. Calculating the dry clay to original clay used 2.692÷85.05=3.16.

Total production of paper was..........................	5,980,430 lbs.
3.16% of which is clay 188,981 lbs.	
Returned waste was	29,740 lbs.
3.16% of which is clay 939 lbs.	5,950,690 lbs.

Hence the clay in the paper made was 188,339
Actual clay used in one particular month was 365,974 lbs.
The percentage of retention was 51.46%.

The following table shows the percentage of clay used, the percentage found, and the percentage retained in a number of different operations.

Per cent clay used	Per cent clay found	Per cent clay retained
12.57	9.11	72.5
12.00	6.05	50.4
11.72	7.66	65.4
10.02	7.06	70.3
9.29	4.58	49.1
7.38	4.55	61.8
5.57	2.34	42.2

In order to determine the above values the following method was used:

1st. The weight of clay at each mill used for each month was reported and a sample sent to testing department.

2nd. The total weight of paper made each month and a sample of such paper taken every six hours was sent to the testing department.

3rd. The total weight of returned waste was reported.

4th. The total weight of paper made without clay, and a sample was sent to the testing department.

From these data the per cent retention was calculated as described above.

These tests show a shrinkage of about 10 per cent. The per cent of clay in each case is figured on 2 different bases.

1st on the basis of total groundwood and sulphite used.

2nd on the basis of all the ingredients used, giving the clay added.

Presumably the loss in weight is due to alum and size.

To get the retention, we add to the groundwood and sulphite the

TYPICAL MILL TESTS ON CLAY

First Test

3% of (finished product) of clay used.

Groundwood used (wet weight)	83,976 lbs.	(dry weight)	26,872 lbs.
Sulphite used (wet weight)	19,018 lbs.	(dry weight)	6,846 lbs.
			33,718 lbs dry

Clay used 2.4% of 1 equals	812	(2⅓% of total wt. of stock)
Alum	290 lbs.	
Size	174 lbs.	
Total	34,994 dry weight	

Paper made	27,515 lbs.	33,718
Waste and shavings	4,147 lbs.	1,276
Sweepings (wet)	95 lbs.	34,994 equals 110% of total stock
Total	31,757 lbs.	

Second Test

6% (finished product) clay used.

Groundwood (wet weight)	86,031 lbs.	32% dry	27,529 lbs.
Sulphite (wet weight)	22,148 lbs.	36% dry	7,973 lbs.
			35,502 lbs.
Clay used 5.2% of 1	1,881 lbs. (5% total weight)		
Alum	320 lbs.		
Size	198		
Total			2,899
			37,901 lbs.

Paper made	31,365 lbs.
Waste	4,126 lbs.
Sweepings	273 lbs.
	35,764 lbs.

amount of clay used, and then divide by the amount of clay which gives the percentage of clay used.

This ignores alum and sizings. After obtaining the per cent of clay used as above, we divided the percentage of actual clay returned by this and thus obtained the percentage of retention.

The retentions in the two cases were 62.44 and 63.00 per cent.

Other Loading Materials.

Talc: A naturally occurring mineral found in almost every state and in Canada. Chemically it is a hydrous magnesium silicate. Its most conspicuous property is its soft, greasy feel. Its use is not confined to papermaking, large quanttiies being used in the manufacture of talcum powder, rubber goods, etc. After being mined, the talc is pulverized so that it will pass through a 200-mesh screen and then bolted through fine cloth or graded with an air separator. Talc is not so much used as clay in paper but is necessary for some varieties of surface and is much used in paper coating mills.

Agalite: This is a filler chemically the same as ordinary talc, but of somewhat different physical structure, being prepared from a variety of talc that is more like asbestos. In fact, mineralogically the talcs and the various sorts of asbestos are very closely related. On account of its fibrous structure, agalite is a very useful loading material. Just like talc, however, it makes the paper loaded with it very greasy.

The terms agalite and talc are used very loosely and interchangeably by practical papermakers. Asbestine, French chalk, mineral pulp, etc., are all other names for the same thing.

Pearl Hardening: This is calcium sulphate (sulphate of lime, artificial gypsum, etc.), prepared artificially. It is much used as a filler in the better grades of paper. When properly prepared it is white and free from grit. The commercial article contains considerable mechanically contained water in addition to the combined water.

Crown Filler: This is another name for pearl hardening.

Ground Gypsum: Sometimes known as "terra alba." Chemically this is the same as pearl hardening, but it is made by grinding and bolting naturally occurring gypsum. It is not used so much as pearl hardening.

Satin White: This is an artificially prepared filler containing calcium sulphate and alumina. It is usually sold in casks or drums in the form of a paste. This filler gives a high percentage of retention owing to the alum it contains.

Precipitated Chalk: This filler is only used in cigarette paper which sometimes is very heavily loaded with it.

Size.

Size is any substance which is added to a porous or absorbent surface to render it less so. Sizing is by no means confined to the paper industry. A plastered wall is sized by brushing it over with weak glue or shellac, etc.

Paper needs to be sized to prevent the spreading of ink, to give it a good surface, to impart the proper degree of stiffness and rattle, etc.

The principle of sizing is to add some material that will coat fibers with an ink or moisture resistant layer, thus preventing ink or moisture spreading by capillary action, just as oil spreads upwards in a wick.

Naturally, various degrees of sizing are required. Blotting paper and filter paper are not sized at all, as it is intended that they should soak up liquids. Newsprint is sized very little—sometimes not at all—because the heavy viscid printing ink does not tend to spread much. Good writing papers require a lot of size because they are written on with fluid inks.

Several different materials are used for sizing. Glue or gelatine size and rosin size, however, are at present by far the most usual.

Glue or Animal Sizing.

This was introduced in the days when paper was still made by hand. It is still used in England and in certain mills in America making fine writing paper and drawing papers. This size is really a solution of gelatine and is often called "animal size" because it used to be prepared by soaking hides in water. In the old hand paper mills, and in some modern mills making fine papers the size was applied to the paper after the sheets were made, by dipping the sheets in a vat of the size. This operation is called "tub sizing."

In America today so-called animal sizing is usually done with solutions of commercial glue or gelatine and the paper is led from the machine through a trough or vat containing the size. These machines are usually called size presses and are placed after the dryer part of the paper machine or else the dryers are separated into two nests with the size press between them.

The drying of animal sized paper is an operation requiring great care. It must be carried out slowly and at a low temperature. Frequently such paper is "loft dried," i.e., the sheets are suspended on poles in a warm dry loft. This treatment brings out very fine qualities in the paper. When loft drying is not resorted to, sometimes special forms of mechanical dryers are used in which the paper is festooned in a blast of warm air, as in a coating mill.

Engine Sizing: This is the term applied to the addition of size to the beater where the stock is being prepared for the paper machine. This is the usual method of sizing for the majority of printing papers, bonds, etc. The size most usually added is rosin size.

Rosin.

Rosin is a resin obtained in the manufacture of turpentine spirits from crude turpentine, which is a natural product obtained from pine trees. There are numerous grades of rosin, these grades being determined by the color. The grades are distinguished by letters of the alphabet. Rosin is graded B, C, D, E, F, G, H, I, K, L, M. N, W-G (window glass), W-W (water-white). B is the darkest and W-W the lightest grade. Ordinarily the first three grades B, C and D, are not separated. The grades E, F and G are the ones usually employed for making size in the paper industry. The other grades are used in other lines of manufacture. Rosin is sold in rather peculiar units of 280 lbs. This is derived from the English gross ton. However, the 280-lb. bbl. includes the weight of the container.

Provided that the darker color is not harmful, it is better to use E or even D rosin than the lighter F and G as the sizing value is higher. However, D and G are the limits and should not be exceeded in either direction.

Rosin consists chiefly of a weak acid called abietic acid and will combine with an alkali to form a chemical compound, known as a resinate. In making size the rosin is made to combine with sodium carbonate or soda ash. Usually 58 per cent soda ash is used. A table telling how soda ash is graded will be found at the back of the book. Rosin and soda ash do not react until heated. When mixed and heated they combine, carbon dioxide gas being given off, which gives rise to foaming.

Making Rosin Size.

The usual method of making the size is to dissolve the soda ash in water in a kettle heated by a steam coil or a jacket. Sometimes the kettle is heated by direct steam, but this is not good as it is necessary to make allowance for the dilution from the steam in weighing out the materials for the size. When the soda liquor is ready, the finely powdered rosin is stirred in and the whole boiled for some time, after which it is diluted with water. Some size makers prefer to melt the rosin first and then slowly add the solution of soda ash in water. *Never add solid soda ash to rosin!*

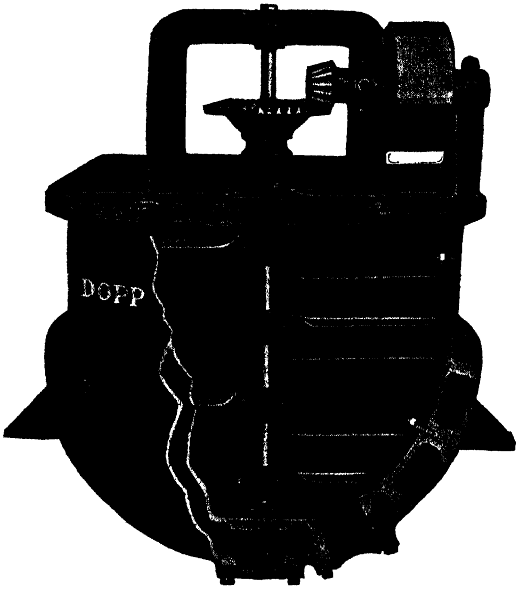


FIG. 140.—Type of kettle used for making rosin size.

Courtesy: Sowers Mfg. Co., Buffalo, N. Y.

The proportion of soda and rosin used varies. The maximum amount of free rosin can be obtained by using 9 pounds of soda ash and 100 pounds of rosin. Such size is rarely used. From 20 to 40 pounds of soda ash per 100 pounds of rosin is quite usual. The writer prefers 15 to 18 pounds soda to 100 rosin. The soda and the rosin never completely combine. That is, there is always free rosin and free soda in the size, even if just the right quantity of soda for the rosin is added. The amount of free soda and rosin decreases the longer the size is boiled. No rule can be given for the percentage of free or of combined rosin that a size should contain. It depends on the condition under which a size is to be used, the nature of the stock, the water, etc. A size that will work well in one mill may be useless for another.

Sutermeister [1] says that rosin size made by boiling 2000 lbs. rosin with 400 lbs. soda ash in solution analyzed as follows:

	Freshly prepared	Ready to use
Combined rosin	22.0%	30.5%
Free rosin	11.3%	15.9%
Combined soda Na_2O	3.0%	4.5%
Free soda Na_2CO_3	3.4%	1.2%
Water by difference	60.3%	47.9%

[1] Sutermeister, E., "Chemistry of Pulp and Paper Making," 2nd Edition, New York, John Wiley & Sons, Inc., 1929.

Sutermeister[1] says that size is best added to the beater after the stock and filler are in but before the alum. Still better sizing results are said to be obtained by putting the size in the beater with enough water to carry it under the roll and allowing it to circulate before the stock is added. This however causes so much foaming that it is impractical. If the size contains less than 35 per cent of free rosin it may be added directly to the engine or it may first be dissolved in lukewarm water. Hot water should never be used because it causes the free rosin to collect in lumps which make spots in the paper. There is probably not much to choose between adding directly to the beater or dissolving so far as efficiency of sizing goes but as the dissolved size may be strained through cloth it is preferable from the standpoint of cleanliness.

With high free rosin sizes some form of emulsifier should be used in order that the emulsion of free rosin may be so fine that none will settle out. The emulsifier is practically a steam injector which takes the hot size and sprays it suddenly into a large body of cold water. This prevents the free rosin from collecting in flakes and gives very fine particles in suspension. Some forms of apparatus are so arranged that the operator can control the output and obtain at will either a milky suspension of comparatively coarse particles or a semi-transparent, brownish one in which the particles may be as small as 0.002 mm in diameter. The concentration of the emulsion is said to have a large influence on the results and the upper limit for satisfactory work is variously given as a 2 to 3 per cent solution of rosin. The claims made for emulsification processes are more uniform, cheaper and better sizing and less dirt.

For an excellent discussion as to the varying views of eminent chemists on the nature of the sizing process consult Sutermeister.[1]

We understand that some of the best commercial rosin size is now refined and stabilized by putting it through a colloid mill. Such mills are also sometimes called "color Jordans."

After cooking until the lumps of rosin are dissolved and the batch is of a clear dark color, when the steam is turned off and the foaming subsided, a test is made as follows:

Take a ½ pint dipper of hot size and add in a pail a quart of hot water and stir until well mixed; now add cold water till the pail is nearly filled and stir again. The resulting liquid should have a white or yellow color and dissolve to a thin milk free from lumps, grains or sticky pieces of rosin.

If it does not readily mix with water and dissolve to a milk, but forms grains like corn meal, it must be again cooked, but the cooking must again be stopped when the test shows it to be done as further cooking injures the size. Rosin size should strain easily through a 60-mesh wire screen.

After it has stood for a day or two a black liquor separates which is brine and soda ash. This should be removed as it causes foaming on the screens. By longer standing and occasional poking with a stick more

[1] Sutermeister, E., *op. cit.*

liquor can be made to separate from it. Adding a little common salt will aid the separation.

Notes on Making Size.

1—Caustic soda is not so good as soda ash and should not be used.

2—Lime is harmful rather than good.

3—Brine improves size by helping eliminate the excess of soda.

4—Aging size is good for it separates more black liquor from it and aging can be hastened by using fresh brine.

5—Thick size should never be furnished to an engine. Thin size is made by dissolving one gallon thick size in four gallons water.

6—Heating size or the stock in the beater is detrimental to good sizing results and causes foaming.

7—Kerosene is bad for size and when used for keeping down foam should be used very carefully.

Process Where Direct Steam is Used.

The equipment consists of an iron tank heated by direct steam blown into it. In such a case there is water formed by the condensation during the cooking and care must be taken to use at first as little water as possible, for the reason that the weaker the solution of soda ash the longer it takes to cook the size. Therefore, only a sufficient quantity of water is run into the tank to just dissolve the soda ash used.

Soda ash must be dissolved: The water is first heated by steam by means of a steam pipe until the soda is completely dissolved and no undissolved lump should be left.

Rosin should be crushed fine: Rosin is next shovelled in, the finer it is crushed the quicker the cooking is completed. The cooking is continued as rapidly as possible without it running over the tank.

To prevent boiling water: It is a good plan to have a sprinkling can with cold water to stop the foaming and boiling water. After boiling until all the lumps are dissolved, try the Solubility Test.

Melted Rosin Process.

The following method of making size has proved very successful. The rosin is melted over night in a steam jacketed kettle. A strong solution of soda ash is made up and then added to the rosin a little at a time. At first the action is very violent, but it soon moderates. After all the soda is added the size requires very little boiling to be done.

When this rosin size is dissolved in a comparatively large amount of water the free and uncombined rosin does not go into solution but forms a sort of emulsion in the water, this giving the whole a milky appearance. This uncombined rosin attaches itself to the fibers of the paper.

However, when making high rosin size great care must be exercised to have it exactly right, or sticky, tarry masses of rosin will separate out that will clog tanks, pipes and pumps, make size spots in the paper, adhere to felts and wires, and cause all kinds of trouble. Many of the ready made sizes are of this free rosin variety, but they are usually made with care so that the rosin stays in solution.

Ready Made vs. Mill Made Size.

Ready made size is undoubtedly more convenient than making size at the mill, but it is much more expensive, and in spite of all the mystery surrounding the subject any practical papermaker should be able to learn to make size suitable for his particular class of paper after a little experimenting.

Various Kinds of Rosin Size.

The following are descriptions of some of the kinds of size the papermaker will find, or will be given recipes for making, in many mills:

Highest Free Rosin Size: An example of this is one of the ready made sizes which contains so much rosin that, in order to get it into solution properly, 50 gallons of water must be used to dissolve 1 gallon of the size. One third of the 50 gallons is boiling hot and the hot size is sprayed into this water by means of a steam injector. The other ⅔ of the water is run in cold. If care is not exercised the result is a sticky, unmanageable mass. There is no doubt that such size gives good results and is economical of alum, but it is troublesome and in the long run the economy is doubtful.

Second-Highest Free Rosin: There is another group of sizes on the market containing less free rosin and capable of being dissolved without the need of special appliances, but still requiring great volumes of water for solution and being very troublesome to handle.

Most Popular Size: The most generally popular size is that which contains a large amount of free rosin, but not so much but what the size will dissolve in any quantity of water.

Old-Fashioned Size: Many old-fashioned size makers still adhere to the practice of using excessive quantities of soda ash and cooking the size so thoroughly that all the rosin is converted into soap and no "free rosin" remains. They test by dissolving in water, and if the size gives no "yellow milk color" they cook again. This is very wasteful of soda ash and alum. Old-fashioned size makers call modern high free rosin size, "raw size."

Adding Size to the Beaters.

The size should be diluted with water before adding to the beaters. The most convenient proportion is 1 gallon of size to 4 gallons of water, if ordinary size is used. If a high free rosin size is used correspondingly more water will have to be added.

The proportion of size in a furnish will range from 0.20 per cent to as much as 3 per cent.

Size should always be added to the beaters before the alum—never after, or at the same time unless you are so unfortunate as to have a very hard water to deal with, when some of the alum may well be added first. The size should be furnished when the stock is thin.

If any quantity of size is kept on hand, the tank in which it is kept should be provided with an agitator. It is advisable to keep enough size on hand that the beaters will never be furnished from too freshly made size.

If clay is used, it is a good plan to mix together the size and clay before adding to the beater, and then to strain both. However, if the clay and water are mixed in a large tank and conveyed to the beaters by pipes this is not advisable. It works well when the clay is mixed with water in a small mixing tank above each beater.

Adding the alum before the size is properly dissolved is a frequent cause of size spots. These are frequently blamed on the composition of the size.

Foaming causes trouble if the stock is warm. Little trouble is experienced from this cause if the stock is beaten cold. In heavy sized paper it is sometimes advisable to mix a little tallow with the size during the cooking. This tends to prevent foaming. Some papermakers add kerosene to prevent foaming, but this is inadvisable.

Size in Newsprint.

Some papermakers claim that 1 pint of size to a 1000 lb. beater is of advantage in making newsprint. It helps the fiber to lie down in moist weather. It is also claimed that it aids the retention of clay in the paper. This is undoubtedly true if a large amount of size be added, but experiments have proved that the amounts usually added in making newsprint have no effect on the retention of the clay at all. Alum has much more effect in this regard.

It is an undoubted fact that the use of size in news causes trouble with foam, slime, etc., and as very good news can be made without size, it would seem better practice to leave it out rather than to put it in on the supposition that it may do some good.

General Considerations about Sizing.

Many conditions influence good sizing results. It is well known that free stock is more difficult to size than is slow stock. This is because the finer meshes of the slow stock retain the particles of rosin almost completely while the coarse meshes formed by the free stock permit much of the size to pass through and be lost. *Sizing is quite a sensitive operation* and almost any change in the conditions under which a sheet of paper is made will produce some effect in the sizing.

We have observed that a sheet which has been running for some time with satisfactory results as to sizing became "slack sized" when the machine was speeded up. The amount of size had to be increased 25 per cent in order to get the same result as before.

Also we noted in making hangings out of a coarse pulp especially ground for the purpose that much more size was required to produce the same result than when "news pulp" was used for the hangings. Having run out of the special "hanging pulp" news pulp was substituted and it was apparent that the paper was too hard sized and the amount had to be cut down considerably. As soon as regular "hanging pulp" was again used more size had to be used.

Grinding, beating, jordaning all have a decided influence on the quantity of size necessary to produce good results. It is also probable that *sizing* is influenced by the shake, suction, dryers, etc., and in fact almost by every step in papermaking.

In modern mills the chemists often check the size and alum furnished with a pH indicator.

Alum.

Alum—in the usage of the papermaker—does not mean the alum of the chemist, which is the crystallized double sulphate of aluminum and potash. Papermakers use the term alum to denote aluminum sulphate, $Al_2(SO_4)_3 18H_2O$. The true alum was once used in papermaking, but has been replaced by aluminum sulphate which is cheaper and stronger in alumina. The aluminum sulphate or papermakers' alum of commerce is not a definite chemical compound, different makers driving off different amounts of the combined water before the product is placed on the market. The best commercial product on the market today contains 22 per cent alumina, Al_2O_3, which is equivalent to 73 per cent sulphate of alumina, $Al_2(SO_4)_3$.

Commercial alum is generally prepared from bauxite, a naturally occurring hydrous oxide of aluminum. Pulverized bauxite is agitated with 50° Be. sulphuric acid in lead lined tanks. The mixture becomes very hot during the reaction, after which it is diluted with water, allowed to become cool and to stand long enough to deposit silica and other impurities. The clear liquor is then decanted off, concentrated with heat, and when thick

ANALYSES OF ALUMS

Selected from Griffin and Little (Except No. 4)

	(1)	(2)	(3)	(4)
Insoluble in Water	10.61	0.67	0.11	0.02
Alumina (Al_2O_3)	14.96	22.37	11.64	22.02
Iron Oxide (FeO)	0.13	0.46	0.06	none
Iron Oxide (Fe_2O_3)	1.08	0.08	1.17	0.01
Zinc Oxide (ZnO)	none	3.80	none	none
Soda (Na_2O)	0.57	none	4.75	0.72
Magnesia (MgO)	none	none	0.45	none
Combined Sulphuric Acid	37.36	45.28	35.98	45.36
Free Sulphuric Acid	1.08	none	5.13	none
Water by difference	34.21	27.34	40.71	31.87
Sizing Test (parts of neutral rosin size precipitated by one part of the alum)	3.47	3.64	3.19	....

Notes: In Sample (1) the high percentage of water insoluble material indicates that the raw material was not entirely dissolved by the acid. The free acid is also too high in this sample, and the iron. Such an alum is more suitable for water softening than for papermaking. (2) is a better alum but the iron is too high. (3) is a very poor alum, the alumina being very low and the percentage of free acid being abnormally high. (4) is one of the best commercial alums on the market today. The alumina is high, the iron almost negligible and no trace of free acid present. It is interesting to note that apparently a higher alumina content than that required for the neutral sulphate has no effect on the sizing efficiency of the alum, as (2) in which the alumina is very high is not appreciably more efficient than (3) in which the alumina is very low.

enough, run out onto marble slabs, where it crystallizes in a mass which is broken up, packed and sold.

As bauxite always contains some iron, the commercial alum is rarely free from iron. The iron is frequently reduced to the ferrous condition with zinc before the alum is crystallized, but this procedure is useless from the papermakers' point of view as the iron soon oxidizes again and colors the paper in which it is found.

A good alum should contain very little insoluble matter, not over one-half of 1 per cent. More insoluble matter indicates that the alum has been made in a hurried and careless manner.

Free sulphuric acid is objectionable in an alum. It decomposes the size, corrodes the wire, disintegrates the felts and attacks every pipe and vessel it comes in contact with. It is possible to obtain from the manufacturers alum quite free from free sulphuric acid and this should be insisted on.

Other things being equal, the important point about an alum is the alumina content, although the efficiency of the alum cannot be absolutely judged by this factor.

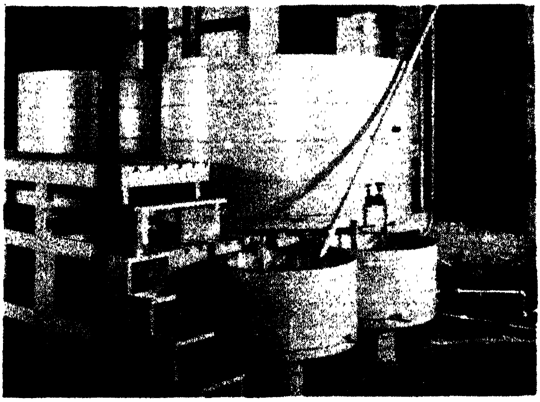


FIG. 141.—Cypress mixing and pump supply tanks for furnishing alum to beater room.

Courtesy: Kalamazoo Tank & Silo Co., Kalamazoo, Mich.

Furnishing Alum.

Sometimes dry alum is put in the beater, but it is better to make up a solution of alum and use that. The solution can be kept in a measuring box above the beaters and connected below with a lead pipe leading to the beater. The alum solution is run into the measuring box and thence into the beater. The solution may be of any strength, but 1 pound to a gallon is a convenient strength. The amount of alum furnished will range from 25 to 75 lbs. per ton of stock.

Function of Alum in Papermaking.

It is frequently said that alum is added to size the paper. That is not correct. The true purpose of alum is to precipitate the dissolved rosin in the size on the fibers of the paper. This is sometimes called "setting" the size. It also "sets" or "fixes" certain colors, making them stronger and brighter, as certain reds and blues. However, it weakens certain other colors, such as yellows and greens. If it is necessary to make a heavily sized yellow paper it is best to experiment until the exact amount of alum to set the size is found and then use care not to add any more than that as it will weaken the color. The same hint applies to many other colors. However, many papermakers have the idea alum strengthens all colors, and will tell you it keeps the color from washing out of the paper, and when they are making any highly colored paper they will be very liberal in their use of alum. This practice is based on no scientific reason, and in many cases is absolutely wrong. The dealers in colors can usually provide information as to how they should be used, and unless the mill is provided with a chemist competent to work such things out on a truly scientific basis it is always better to follow the color dealer's instructions in detail.

Too much alum renders the paper brittle, causes it to lose moisture rapidly, and is a cause of rapid deterioration. Sometimes excessive amounts of alum are added to impart a stiffness and rattle to the paper but this is bad practice as it will cause the troubles described above and the desired effect can be secured in other ways—e.g., by the use of silicate of soda, starch, etc.

Excess of alum is also hard on the wire and felts, especially the dryer felts. The rottenness of felts, frequently attributed to burning or scorching on the dryers is due to a large extent to the accumulation of alum. The combined action of the alum and the heat of the dryer will soon destroy the felt.

In addition to setting the size, alum has a clarifying effect on the water. If water is turbid due to the presence of clay, etc., it cannot be filtered bright as this slime will either pass through the filter or else will completely stop up the pores of the filter so no water passes through at all. Alum causes the dirt in the water to coagulate so that it falls down in granules, leaving the water above clear and bright. Now, in papermaking the alum exerts this same property and much clay and fine fiber that would otherwise be carried off with the water is coagulated and held in the web and is less likely to be sucked out by the suction boxes or to drain through the wire. This is why alum aids in the retention of clay, a fact that we alluded to when discussing the use of clay as a filler.

Hardening Action of Alum.

Alum tends to harden most organic substances. This is sometimes alluded to as the sizing effect of alum, but this is not correct, because sizing renders a paper impervious to moisture and while alum makes a paper hard and stiff it does not make it any more resistant to moisture than if none had been used. The general feel of such a paper is as if it had been sized, but it has none of the real properties of a properly sized paper.

It is sometimes desirable to make a very well sized soft paper, as for wall paper and hangings. In order to do this we use a liberal amount of size and less alum than is necessary to completely fix the size, letting some of the size wash out. This wastes some size and causes a little trouble with foam on the screens, but no other way of attaining the desired result has been devised. If enough alum is added to completely fix the size, the paper is too hard and brittle for satisfactory hangings.

Alum and Foaming.

Alum prevents to some extent the foaming caused by size, especially new size from which the liquor has not been well separated. In cases where an excess of alum is not objectionable this method of preventing foam may be permissible, but as a rule it is better to kill the foam with a spray of water or an air blast. There are also new efficient foam inhibitors which are complex synthetic organic chemicals.

Alum and Pitch.

Alum tends to keep the wire of the paper machine bright. This is because of a slight corrosive action on the wire, which is increased if the alum contains any free sulphuric acid. A wire will last longer if excessive alum is not used, but when pitch is present to any extent the use of alum to prevent sticking seems an instance of permitting a slight evil to cure a much greater one. However, the use of alum for this purpose should be with discretion as too much alum will have a very bad effect on the felts.

Alum and Water.

If the water used in the mill is hard, i.e., if it contains salts of lime or magnesia in solution, a larger amount of alum than usual will have to be used to properly set the size. This is because some of the alum is used up in precipitating the lime or magnesia salts, as previously referred to in this chapter. Some papermakers add alum in excess of the amount required to set the size purposely to secure this effect, as if the lime and magnesia compounds are present in the water when the size is added they will precipitate the size as a flaky precipitate of resinates of lime and magnesia which has no sizing value and simply wastes that much rosin as well as precipitating an insoluble powder that is troublesome in the stock.

When alum is used in this way the general practice is to determine in the laboratory the amount of alum needed to soften the water, and then add that amount to the beater before furnishing the size. Then, after the size is furnished, the amount of alum necessary to set the size is furnished.

However, a much more modern and efficient way of producing the same results is the installation of a water softening plant, if the mill is located in a district where the water supply is at all hard. Such a plant furnishes perfectly soft water for the paper mill and also for the boilers and, in mills where varieties of paper are being produced where hardness of water would have a serious detrimental effect, will prove economical in the long run. Efficient water softening plants that require little attention are offered by a number of firms and we will describe some of the leading types of such plants in a subsequent chapter when speaking of water supply.

Caution Regarding the Use of Alum and Other Chemicals.

Papermaking is largely a mechanical process and the quality of the finished product is dependent primarily on the character of the stock and the manner in which it is manipulated in the beaters and on the machine. The paper can be no better than the fiber (whether it be sulphite, groundwood, rag or anything else) which is put into it. Compared with these factors the quantity of chemicals added is insignificant.

When the quality of the paper is not what is desired the remedy will usually be found in the operation of the beaters or the machine (the shake, the dryers, the operation of the suction boxes, etc.), rather than in dosing the stock with chemicals or trying to make good paper out of poor stock by using clay, alum, silicate of soda, etc.

It is, of course, necessary for one to do everything possible to get the best results from a given stock and in some cases (e.g., where the wood pulp fiber is too coarse and hence the paper will not retain a good surface) it is all right to use chemicals liberally; but to make a regular practice of that, instead of getting to the root of the matter and finding out what is wrong with the stock or with the operation of the mechanical equipment of the mill, would be very bad practice.

It is a good rule that whenever the appearance of a sheet can be improved by mechanical means to do so rather than resort to the use of chemicals.

To Test How Much Alum is Necessary to Set a Given Quantity of Size in a Beater.

Furnish the engine as usual with everything except clay, color and alum. Have the stock rather thin, so that it will travel fast around the beater.

Dissolve 5 pounds of alum in hot water in a wooden pail, and pour the solution into the beater, allow it to mix for about 15 or 20 minutes and then test it as follows:

Have a small box made holding about a quart, and covered at the bottom with a piece of fine wire cloth. Fill this with some of the stock from the beater, and allow the water to run off till it looks clear, then catch about a half a tumbler full of it. Do not press the water out of the pulp, but let it drain off naturally; it will then be clearer. Add a little litmus solution to the tumbler, and if enough alum has been added the solution will turn red. If it is blue dissolve 5 pounds more of alum, add it as before and test at the end of another 15 or 20 minutes. Continue this until the clear liquid turns the litmus a distinct red.

When large quantities of size are used, testing after the addition of each 5 pounds of alum will be close enough. If only a little size is used, however, the alum should be added in portions of 1 pound at a time, in order to determine the proper amount with more accuracy.

The litmus solution is made fresh before the test, by dissolving a few lumps of the dry litmus in a half tumbler of hot water.

A piece of cheese cloth makes a good substitute for the wire screen. Do not squeeze the water out, however, but let it run naturally.

The amount of alum necessary to set a given quantity of size varies at different mills, owing to the different kinds of water. Also the quantity of alum necessary for 5 gallons of size is not five times as much as would be required for one gallon, because the water itself uses up some alum. Thus, for example, it might be found that when five gallons of size were furnished, 15 pounds of alum would be necessary, while when only one gallon of size was furnished, five pounds of alum might be required instead of only three pounds.

It will also be observed that when there is not enough alum to set the size, the water drawing away from the stock will have a milky appearance, while when enough alum has been added, the water will draw away quite clear. Clay would make the water a little milky, so it is best to leave out the clay in making these tests.

Two or three of these tests performed with different quantities of size will show once for all the quantities of alum required for different quantities of size at any one mill, and any more alum which might be added is wasted in case there is no other object in adding alum except that of setting the size.

Silicate of Soda.[1]

For many years some papermakers have used silicate of soda [2] in the beater to produce certain results in the sheet. The papers in which it has been used have run from bonds to supplement stock and from blotting paper to glassine. When used under varying conditions, its effects in the beater will vary greatly. However, tests extending over a long period of years have shown that under proper conditions the following results can be obtained.

1. *Improved finish:* Perhaps the first thing which will be noticed in a silicate-sized paper is the smoother finish and better feel. If the sheet has been inclined to be fuzzy, the loose fibers will be bound into the sheet.

2. *Increased strength:* This may be apparent in the Mullen test, the Elmendorf tear test, the tensile strength, or the folding strength. Many mills have used silicate sizing because of its effect on strength, some of them to overcome temporary difficulties and some continuously. The increase in pop test has averaged about ten per cent, running much higher in some cases and not being apparent in others. The increase in fold is particularly notable as general opinion has been that silicate would have the opposite effect.

3. *Firmer sheet:* This may be recognized in thin papers by the increased rattle and in heavier papers and boards by the stiffness. The finding that silicate-sized sheets lie flatter is undoubtedly connected with this firmness.

[1] Contributed by William Stericker, Development Chemist, Philadelphia Quartz Company.
[2] Vail: Paper, Oct. 26, 1921.

4. *Increased hydration:* The degree of hydration is increased by the presence of silicate in the beater if the beating time is held the same. In mills where this is not desirable, the beating time may be decreased. For example, one mill found it possible to get as good results in 3.6 hours with silicate as in 4.1 hours without it. The saving in power paid for the silicate. In other cases the power consumption on the Jordans has been decreased.

5. *Size for printing inks:* Ordinarily, sizing is spoken of in connection with resistance to water or aqueous inks. Printing inks have oil or varnish bases and silicate sized paper furnishes an excellent surface for them. This is particularly advantageous in multicolor printing. The absence of fuzz and loose fibers which "pick" or clog the plates is an additional argument for silicate.

6. *Size for aqueous inks:* Silicate sizing alone has little effect on the resistance to water but, in combination with rosin or special sizes, it improves the resistance. In a number of cases the saving in rosin size has been sufficient to pay for the silicate used.

7. *Starch retention:* The use of silicate with starch increases the retention of the latter. This is particularly marked when the starch is swollen with silicate before it is added to the beater.

8. *Short fibers:* The silicate precipitate not only lays the fuzz but holds short fibers which might otherwise escape in the white water.

9. *Filler retention:* In a similar way fillers, such as clay, are held in the sheet.

10. *Improved color:* Whenever sodium silicates are used with materials which are basically cellulose, whether it be in the laundry or the paper mill, whiter products result. If blue dye has been added, it may be necessary to reduce the amount, thereby effecting a saving. Furthermore, samples of paper made with silicate have been found less likely to yellow with age than the same paper without silicate.

11. *Increased ash:* In higher priced papers the increased ash may pay for the silicate.

To improve a sheet of paper by the use of silicate of soda, it is necessary to choose conditions which will produce the desired result. Fundamentally, silicate has three actions when added in the beater: (*1*) It affects the hydration of the pulp. (*2*) It forms a precipitate with alum or some other agent. (*3*) It affects the dispersion and subsequent retention of fillers.

During beating and refining a change takes place in the cellulose aggregates which is called hydration. It is well known that alkaline materials aid hydration. Silicate, however, has a greater effect than equivalent amounts of other alkalies. During beating silica is taken up by the fibers. This may be due entirely to adsorption on the cellulose in a way similar of the beater and the Jordan a deeper seated change is taking place. Samec [2] of sodium silicate. There is, however, a possibility that under the action

[1] John D. Carter, Ind. Eng. Chem., *23*, 1389 (1931).

of the beater and the jordan a deeper seated change is taking place. Samec[1] believes that silica is an essential constituent of naturally occurring cellulose. It probably is largely removed in chemical pulping but under the conditions stated it may again enter into combination with the cellulose complex. The maximum hydration takes place when the beater is in an alkaline condition.

Precipitation of silica by papermaker's alum (aluminum sulphate) depends very largely upon the pH of the stock. If silicate is used in the beater solely to increase hydration, it makes very little difference how much alum is added. If maximum precipitation is desired, sufficient alum must be added, preferably late in the beating process, to bring the pH to about 4.5. Lower pH's require excessive amounts of alum and do not increase the precipitation. In fact, there is some tendency to decrease the amount of material held in the paper. The behavior of silicate and alum in the presence of paper stock is shown more clearly in Fig. 142.

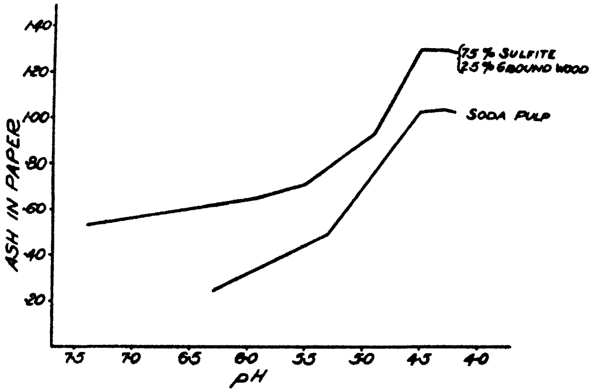


FIG. 142.—Behavior of sodium silicate and alum in the presence of paper stock.

Courtesy: Philadelphia Quartz Co., Philadelphia, Pa.

Time: In order to get the best results, the silicate must have time to react with the fiber before the alum is added. In experiments using the same amount of alum, the same pulp, and the same procedure, except that in one case the pulp was beaten with the silicate fifteen minutes and in the other one hour, the same pH resulted but the ash was increased 12 to 15 per cent on longer beating with sulphite or soda pulps and 4 to 9 per cent (SiO_2 5 to 13 per cent) with a mixture of 75 per cent groundwood and 25 per cent sulphite. Increasing the beating time before the silicate is added does not increase the precipitate. We, therefore, conclude that the silicate should be added early, preferably when the beater is furnished, to get the maximum effects both in hydration and ash.

After the alum is added sufficient time must be allowed for the precipitate to form. Usually there is ample time in the stuff and machine chests. In fact, where there are facilities for insuring even distribution, good results may be obtained when the alum is added after the Jordan.

[1] See M Samec's chapter "Colloid Chemistry of Cellulose," in Vol. IV of Jerome Alexander's "Colloid Chemistry, Theoretical and Applied," particularly p. 10, Reinhold Publishing Corp., New York, 1932.

Time of Alum Addition: When alum and silicate solutions were mixed before the pulp was added, the retention of the precipitate was much less. Beating the pulp with alum before the silicate was added gave about the same results. The ash retained was 20 to 30 per cent less and the difference was practically all in the amounts of silica present.

Kind of Pulp: As might be expected, the kind of pulp has an effect on the retention of the silica. There is slightly less retention with kraft than with soda or sulphite. There seems to be an impression that silicate is of no value in part rag paper. This does not agree with the results obtained. Improved finish, resistance to erasure, and resistance to typewriter ink were clearly evident on a "bond" paper made with 50 per cent rag stock. Various rag content papers used in printing show the advantages of silicate enumerated above. At the other extreme, many results on which this discussion is based were obtained on paper containing 75 per cent groundwood and 25 per cent sulphite. There may be a slight reaction with the ligneous materials but papers containing groundwood are regularly made with silicate in the furnish.

After the pH has once been brought to the required point and the silicate and alum have had an opportunity to react, dilution may raise the pH without dissolving the precipitate. Thus one mill has obtained good results with a pH of 4.5 in the beater and 6.5 in the head box.

Two types of commercial sodium silicate solutions have been widely used in paper sizing. One of these is a 39 per cent solution of $Na_2O:3SiO_2$ (42° Bé). The other is a 31 per cent solution of $Na_2O:4SiO_2$ (33.5° Bé). The former contains approximately 30 per cent SiO_2 and the latter, approximately 25 per cent SiO_2, but because it precipitates better with less alum, the latter is often preferred. When the silicate is used solely for its effect on hydration, as in a blotting paper mill, the more alkaline silicate is probably preferable.

Retention of Fillers: Silicate is often used to deflocculate clay for use in the beaters. If it is correctly precipitated afterward, the retention is increased as it is with other fillers. We may look upon this as the action of the gelatinous precipitate holding the very fine particles of filler on the fibers. Therefore, the best conditions for the retention of fillers are the same as those for the silica precipitate.

Starch.

Various starches are used in the paper industry, such as corn starch, wheat starch, potato starch, etc. Starch is used for its hardening and stiffening action; also because it aids in the production of certain highly finished surfaces when the paper is calendered.

Some papermakers add the starch directly to the beaters and others mix it with the size. It seems to exert certain beneficial properties on the rosin of the size, enabling the particles of rosin to become better attached to the fibers of the stock.

According to J. Traquair [1] corn starch is not the best to use, a mixture

[1] Technical Association Papers, 1918, p. 43.

of starches being better, and 1 lb. starch should be boiled with 2 gallons of water and the mixture kept at a little less than the boiling point for from 15 to 20 minutes, after which the starch is ready to be added to the beater. According to this authority the retention of starch is about 50 per cent.

However, starch is not much used in papermaking, its use being confined to certain high class writing and book papers, also a little being used in cigarette paper.

There are various prepared starches in use made by treating ordinary starch with alkaline and acid solutions. Undoubtedly many of these are of use in making high grade papers, but in general their use is prohibited by the expense.

Colors.

It is hardly within the province of this book to deal at great length with so special and highly technical a subject as the coloring of paper, a branch of papermaking where personal experience is specially necessary. However, some general remarks may prove helpful.[1]

The color room should adjoin the beater room; but should be entirely separate, with a north light, if possible. A good scale with capacity up to 25 lb. and also a laboratory balance for weighing from $\frac{1}{32}$ oz. to 1 lb. are essential. Have a hot-plate for drying samples. Enameled steel storage bins and lockers are advisable: also enameled pitchers and scoops. This room should be kept locked when not in use to avoid accidental contamination of colors. There should be a drain in the floor and it should be flushed frequently. No iron or steel pans or scoops should be used.

Color is almost always added to the stock in the beater, that being the chief time during the papermaking process when there is an opportunity to color the fibers.

The coloring of paper has never received the same attention that the coloring of textile fabrics has. It is unusual to find men around a beater room who are as skilled and expert in the use of colors as the average textile dyer. The average papermaker regards color as a minor item in his responsibilities.

However, almost all paper has at least a little color added to it. The bleach is seldom relied on to give a satisfactory white color. Even newsprint has added to each beater usually a gill or two of blue and red to improve the appearance.

The color of the stock in the beater is usually deeper than it will be in the finished paper. One method of matching the color is to reduce the sheet to be matched to pulp, then making the pulp in the beater the same color. By squeezing dry a handful of stock from the beater some idea can be gained as to how the color will be in the finished sheet.

An experimental beater and a frame for making sample sheets by hand will be found useful in every mill where colored papers are being made. In general, the reliable dealers in colors and dyes can be depended on to

[1] Consult Mathews: Application of Dyestuffs, John Wiley & Sons, Inc., New York; also get literature from Dupont Co. and other dye manufacturers.

give excellent help and advice in matching colors. Many of these firms maintain experimental paper beaters and machines for testing out their colors and solving their customers' problems.

The coloring materials used in the paper industry may be divided into *pigments,* or mineral colors (however a few pigments are non-mineral in nature), which are distinguished by being insoluble in water, and *dyestuffs,* mostly artificial in origin and usually spoken of by the general title of "aniline dyes."

Pigments color the stock by becoming enmeshed with the fibers in the beater. The size and alum helps the fibers to retain the pigments, which adhere in small particles to the surface of the fiber. Pigments do not penetrate the substance of the fiber as do dyestuffs. There is probably no chemical action between the cellulose of the fiber and the pigment, whereas in the use of dyestuffs the combination seems to be more chemical than mechanical.

The percentage of retention of a pigment, and therefore the degree to which the paper is colored, depends on the manner of sizing, the amount of alum used, the specific gravity of the pigment and the nature of the stock. Slow stock gives a higher retention than free stock. Also the operation of the paper machine, and whether or not suction couch rolls are used affects the retention of pigment.

Pigments, if used in any quantity, have exactly the same action as clay. In fact, they may be considered as colored clays. Just as too much clay will weaken the paper, so will too much pigment. Many pigments contain grit. All pigments to be used should be passed on by the laboratory to ascertain that they are free from grit, which will cause pin holes in the paper and also will injure the wire and felt and the calender rolls. Add lampblack to the beater tied up in a paper bag, otherwise your beater room will be full of soot.

Some of the commonest pigments are ultramarine, Prussian blue, chrome yellow, red oxide, yellow oxide, umber, lampblack, etc. All of these vary in their fastness to light and to alum. For the action of alum on colors, see the section of this chapter dealing with alum.

Owing to their being more powerful, more varied and easier handled, dyestuffs have largely replaced pigments. Moreover, they have no effect on the strength of the sheet.

Dyestuffs: Whether one speaks of aniline dyestuffs, synthetic dyestuffs or dyes, coal tar dyes or colors, etc., it is all the same product that is meant. They are all made from derivatives of coal tar by a series of complicated processes that is one of the triumphs of applied chemistry. The first such dye was invented by Sir William Perkin in 1856, since which date thousands of others have been invented.

Different manufacturers sell their dyes of different strengths. They are practically never placed on the market full strength. They are almost universally sold on the basis of samples. The names given to these dyes have no logical basis. Each manufacturer will give his dyes some individual name. Letters placed after the name of the dyestuff generally imply a certain shade, for instance R placed after the name of a blue means that it has a reddish shade.

Dyestuffs are divided into: (1) Basic dyestuffs, (2) Acid dyestuffs, (3) Direct dyestuffs, (4) Vat dyestuffs.

Basic dyes are not very fast to light and are hard to use unless perfectly soft water is at hand. With hard water they give the paper a spotty or mottled appearance. These dyes require no alum to set them. Auramine is a typical example of these dyes.

Acid dyes must be set with alum. They are faster to light than basic dyes. Unlike basic dyes they will resist comparatively high temperatures without change. They also work better if the water is at all hard.

Direct dyes do not require any alum or other chemical to set them. They do not work well with hard water. They enter into direct chemical combination with the fiber and so are suitable for use with unsized paper, such as blottings. They are faster to light than either the basic or acid colors. These are the dyes that are known in the textile industry as cotton dyes.

Vat dyestuffs are little used in the paper industry. They are practically pigments of synthetic origin. Vat dyes are more expensive than the others. They were originally sold only in paste form—a nuisance to use—but now are available in powder form under such names as Haloponts, etc.

Notes on Coloring Paper with Dyestuffs.

Test dyes to ascertain that a mixture is not being used. Mixtures do not give uniform and satisfactory results. A simple test for a mixture is to take a pinch of the dyestuff on a knife or coin and blow it sharply onto a piece of filter or blotting paper dipped in water containing a little acid. If the dye is a mixture usually spots of individual colors can be seen where the tiny separate particles fall.

It is better to dissolve the dyes to a liquid or to a paste before adding them to the beater. Dry dyes added to the beater are not so effective as some of the dyestuff is wasted and the effect is not so even.

Basic colors and acid colors should never be used together. They tend to coagulate each other.

Basic colors should not be mixed or used together with direct colors. Solutions of basic colors should never be boiled. In fact the temperature had best not exceed 150° F.

Acid colors can be used with direct colors, but not with basic colors.

Direct colors can be used with acid colors, but not with basic colors. They should be mixed at temperatures below 150° F.

Excess of alum is bad for all colors. Just the right amount to use should be determined.

Intense blues, especially ultramarine, will usually fade on calendering and in storage.

Good results can sometimes be used when a very full shade is desired by first dyeing the stock with an acid color and then submitting it to a second dyeing with a basic color. This will give a better color than could be obtained with an acid dye alone, and it will be faster to light than if a basic dye alone were used.

In coloring mixed stock, such as groundwood and sulphite, sometimes the groundwood will take the dye before any sulphite does, producing a mottled stock. This can be prevented by dyeing the groundwood first in a separate beater and then mixing it with the sulphite which has already been dyed.

Mottled papers, for instance, mottled blottings, are made by dyeing the stock strongly in two or more separate engines, then mixing just before the stock goes on the machine.

In purchasing colors adulteration should always be guarded against. Little risk is incurred if the colors are bought from reliable manufacturers, but as colors are extensively handled by jobbers, etc., large amounts of highly adulterated colors get on the market. This is possible because of the high concentration of the synthetic dyes and also because of the temptation offered by cheap colors. As a rule the best colors will be found the most efficient in the long run regardless of price. Also there are slight but important differences between dyes for paper and for textiles even when the name is the same.

The principal adulterants are dextrine, salt, sugar and Glauber's salt. None of these is harmful, except in that the customer is paying for their weight at the price of a dyestuff.

Several American firms are now manufacturing dyestuffs suitable for the paper industry quite equal to anything previously manufactured in Germany. In fact it is stated that as a result of tests some of these dyestuffs are better. It is very essential that the American dyestuff industry should be supported and if the textile, leather, paper and other dye-using interests will cooperate there is no reason why we should not always have satisfactory domestic sources of every essential dyestuff.

Color Formulas.

Color formulas for the beater room are usually given in grams per 1000 lb. of stock, admittedly a mongrel unit, but a useful one. In matching colors two strips of blotting or filter paper are useful. Make up solutions of 1 part dyestuff to 1000 parts water. Remember 1 cc. water weighs 1 gram. Note time of immersion with a watch, also time of drying, and temperature. So-called "daylight lamps" are a great convenience—in fact indispensable in a plant making colored papers. If depending on actual daylight beware of casts from nearby brick or painted walls.

Stock Chests.

In the basement of the beater room are a number of stock chests. These are for receiving the stock from the beaters preparatory to sending it to the Jordans or other refining engines, or to the paper machines. There are also other stock chests for receiving stock to be furnished to the beaters. Some of this stock is deckered stock received direct from the sulphite mill and some of it is stock produced by disintegrating laps of kraft or other pulp

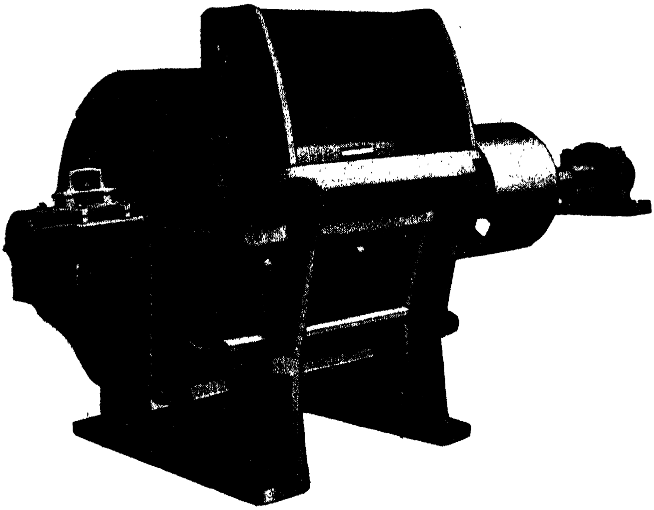
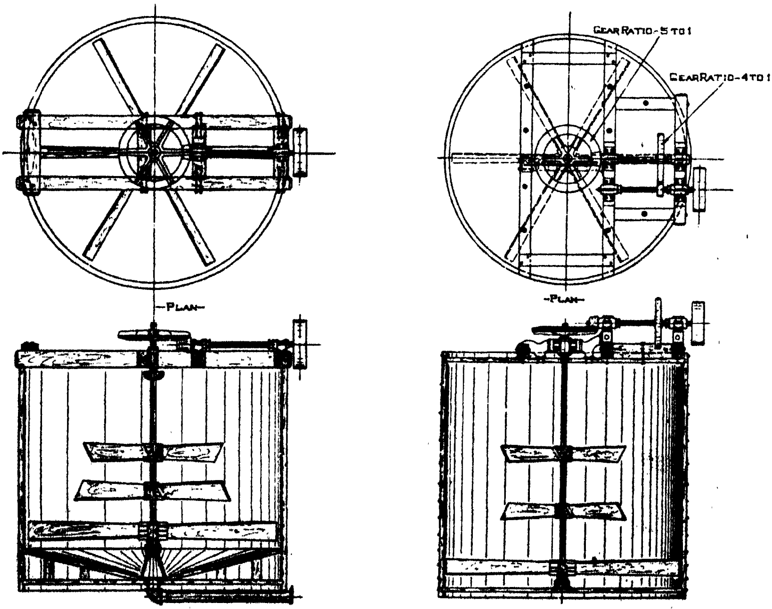


FIG. 143.—Shredder for disintegrating frozen or dried pulp laps.

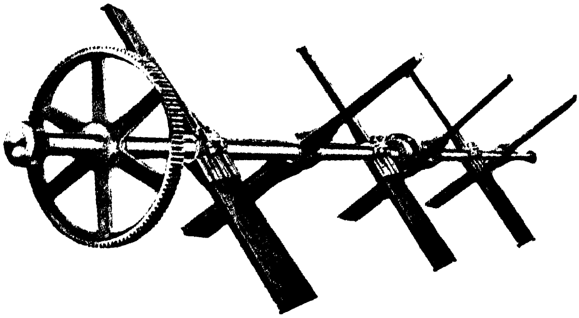
Courtesy: Mitts & Merrill, Saginaw, Mich.



Courtesy: Noble & Wood Machine Co., Hoosick Falls, N. Y.

FIG. 144.—Plan and elevation of two typical vertical stock chests.

with shredders and pulpers. Some lap stock is too hard and dry to feed to the beaters as lap stock and has to be mechanically disintegrated before being furnished. This is usually done with shredders and pulpers.



Courtesy: Noble & Wood Machine Co., Hoosick Falls, N. Y.

FIG. 145.—Type of agitator used in horizontal stock chest.

These chests vary in size according to the room available, or the size of the plant, but an average storage chest will hold approximately 2.5 to 3 tons of air dry stock. These chests are always provided with agitators to keep the stock of uniform consistency and to drive an agitator of the usual type in such a chest as we have described requires about 4 hp.

The stock is pumped from the storage chests to the beaters by a centrifugal pump and it is generally advisable to get this pump down as low as possible so as to get all the head available and also to have the suction

Courtesy: Kalamazoo Tank & Silo Co., Kalamazoo, Mich.

FIG. 146.—Glazed tile drainer tanks for paper stock 19 ft. diameter by 25 ft. high with stainless steel perforated drainer bottoms.

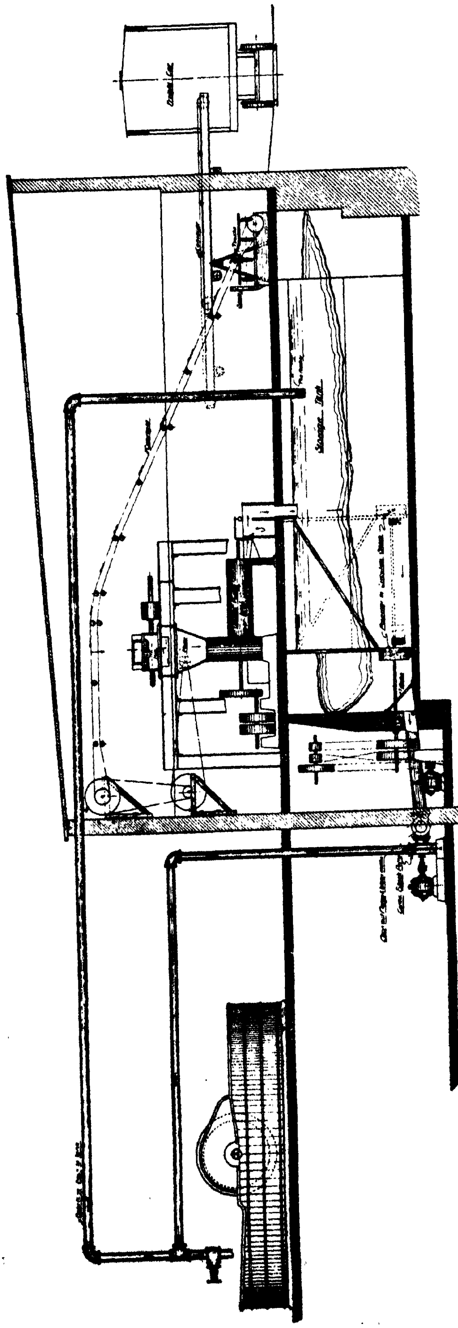


FIG. 147.—Diagram showing a complete installation for preparing kraft or dried or frozen pulp laps for the beater. The installation consists of a Mitts & Merrill shredder, Lannoye pulper and the necessary conveyors, tanks and pumps.

pipe as large as possible. A 6-inch pump should have an 8-inch discharge pipe and, if possible, a 12-inch suction. The power required to drive such a pump with piping as described with a head of not over 20 feet will be approximately 20 hp.

The stock usually gravitates from the beaters to the storage chests from which it is pumped to small chests located just above the Jordans. This is usually done with a duplex or triplex plunger pump. It is good practice to have this pump of sufficient capacity to do the work at a low speed. For a machine of from 30 to 45 tons capacity a 12×12 triplex pump is a very efficient size. This pump running at a speed of approximately 25 r. p. m. will deliver from 30 to 45 tons per 24 hours with a power consumption of about 15 hp. against a 25 or 30 foot head. The suction pipe should be at least 14 inches in diameter with a stock gate in the line, also a "tee" placed near the pump to enable the operators to clean the suction in case it clogs.

The Jordan Engine.

This machine, which was invented by Joseph Jordan at the mill of S. D. Warren Co., Cumberland Mills, Maine, in 1860, consists essentially of a conical cast-iron shell, the inside of which is fitted with long, narrow steel bars, and rotating inside this conical shell is a conical casting, called the "plug" or "runner," the outside surface of which is fitted with long, narrow steel bars, or "knives," each resembling, more or less, the runner of a skate, although only about ¼ inch high and about of the same width.

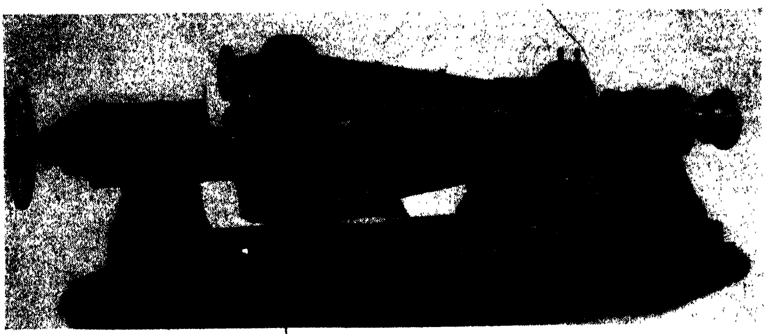
The runner is journaled to rotate about its long axis, and—like the beater roll—can be adjusted to clear the inside plates of the shell by a very minute distance. This adjustment is performed by means of a hand-wheel and screw. The runner makes from 300 to 350 revolutions per minute. *The Jordan must never be allowed to run without stock passing through it as it will very rapidly heat to a dangerous degree.*

The bars, or knives, both on the shell and the runner are accurately ground, so that when the runner is properly adjusted, each knife cuts its entire length.

But this contact of the runner with the inside knives is not a direct or right-angle cut. The bars are so arranged as to deliver a *shearing* cut to the material, in somewhat the same fashion that the blades of a *lawn-mower* are obliqued against the bed-plate. These engines are massive affairs, weighing several tons, and requiring a driving-power of from 75 to 250 hp, depending on the grade of paper being made. Kraft, rag and jute stock take considerably more power than any other kind ordinarily met with, on account of their long fiber and heavy consistency.

The Jordan engine gives the paper-stuff the last refining touch before it goes to the paper machine. Each little bundle of fibers, which would otherwise clog and mar the final result, is separated and distributed throughout the material in such a manner as to make the whole stock consistent and homogeneous.

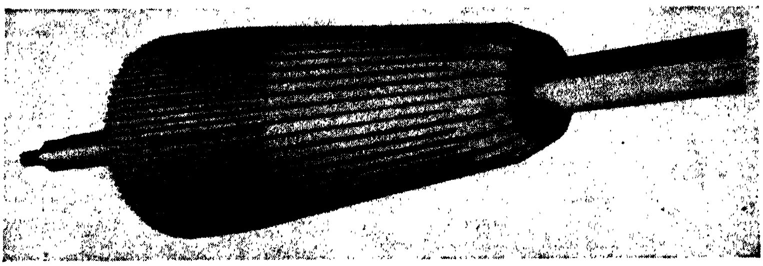
The material is forced into the small end of the cone, and out through the other end, having been compelled to pass through the very small space between the plug and the shell, and between the whirling knives. From the large end of the Jordan it passes down to a second stuff-chest, quite similar to the one that receives the stuff from the beaters, and is maintained in suspended state until the paper machine is ready for it.



Courtesy: E. D. Jones & Sons Co., Pittsfield, Mass.

FIG. 148.—Typical Jordan engine.

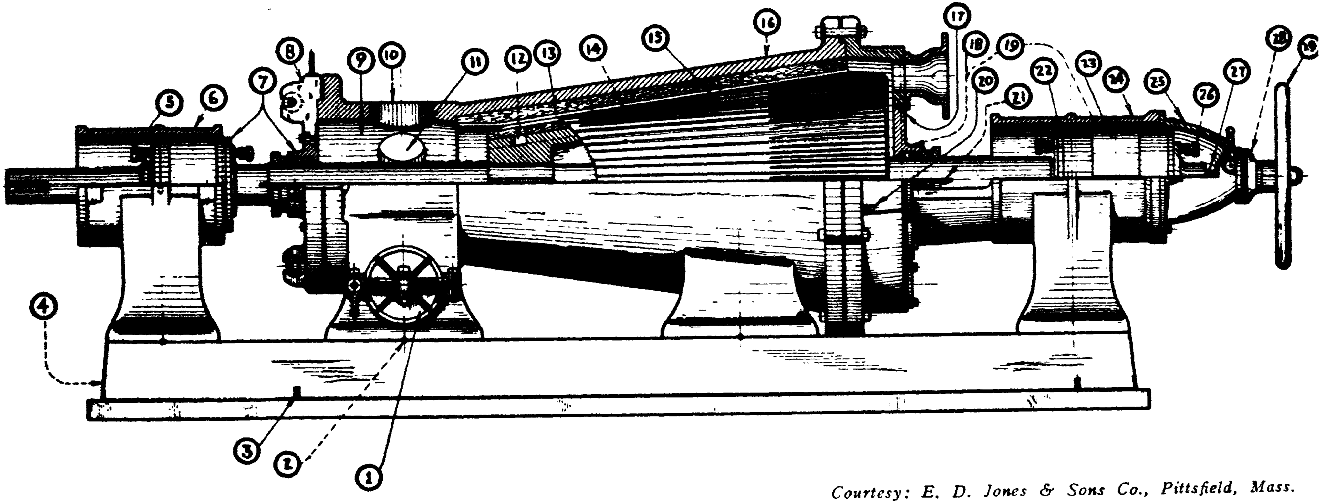
Sand Trap: At the inlet to the Jordan a sand trap should be provided to keep sand and grit and also foreign matter such as nails, screws, pieces of iron, etc., out of the Jordan. On account of the nature of the Jordan such material would soon play havoc with the machine. It is important that these traps should be kept cleaned out, otherwise they are of no use. Sometimes a powerful magnet is built into the sand trap to retain pieces of iron. This is a very useful device.



Courtesy: International Nickel Co., Inc., New York.

FIG. 149.—Jordan "plug" or "runner" removed from engine showing Monel metal knives.

Split-Shell Jordans: A recent improvement in Jordan construction is making the shell in two halves, an upper and a lower, meeting along a horizontal line. The shell, heads and packing boxes are split, so that the top half of the shell can be lifted off when it is necessary to make repairs to the engine. In this way the plug can be refilled, without being removed, by



Courtesy: E. D. Jones & Sons Co., Pittsfield, Mass.

FIG. 150.—Diagram showing construction of typical Jordan engine.

1. Quick opening bottom clean-out doors.
2. Doweled for permanent alignment.
3. Setscrews to permit easy leveling of base.
4. Deep heavy box shaped base; no weak sections machined top and bottom.
5. Breathers for bearings.
6. Radial guide split to facilitate disassembly.
7. Packing box and bearings remain on shaft.
8. Small head split and detachable from packing box.
9. Deep throat entirely smooth; no sharp corners.
10. Large inlet drilled for standard pipe connection.
11. Top-side handhole for inspection and grinding.
12. Bandless plug bars supported full length by plug body.
13. Shell fillings; greylock or double wedge assembled type.
14. Plug and shell bars machined both edges.
15. Choice of fillings to meet every condition.
16. Heavy semi-steel body.
17. Packing flange hole large enough to draw back head over thrust bearing.
18. Packing box detachable from back head.
19. Packing box and bearing remain on shaft.
20. Setscrews for backing off heads.
21. Packing box swing studs to allow easy packing.
22. Cartridge type bearing mounted in cylindrical guides.
23. Bearings never require adjustment.
24. Bearings protected from water and grit by cylindrical guides.
25. Smooth end piece with built-in sturdy quick acting lock.
26. Breathers for bearing.
27. Adjusting screw on center.
28. Rugged built-in machined and chrome plated double indicator counting full turns of handwheel and fractions to nearest 1/100 turn.
29. Large handwheel.

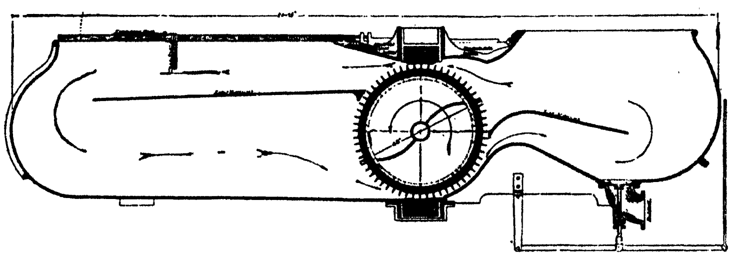
merely rotating it. The top segment of the shell is provided with lugs and eye-bolts to facilitate lifting it. The two halves are carefully machined so that they come together with a water-tight joint and fasten with bolts. This type of engine is very handy when space is at a premium as it can be placed close to a wall or in any other position without allowing end room for drawing out the plug.

Marshall Engine.

The Marshall engine is another refining engine, more used in England than in America, but very useful for making certain classes of paper. It is especially good for preparing long, strong stock for thin, tough papers. It is quite similar to the Jordan, except that after the stuff has passed between the cone and the shell, it is caused to pass between a revolving and a stationary disc, both being provided with knives or bars. The revolving disc is attached to the end of the plug and the stationary disc is fastened to the inside of the shell head. The disc has a brushing action on the fibers much like the action of the roll in the beater, and the stock emerges from the machine free from chips and bundles of fiber and of uniform consistency.

Miller Duplex Beater.

This beater is designed on the principle of effecting two beating operations for every circulation of the stock through the tub. As the largest part of the power required in any beating engine is the power for circulating the stock, the above method would be a distinct advantage provided that it did not involve too complex a mechanism. The builders of the Miller beater seem to have solved the engineering problems involved very nicely and numbers of these beaters are giving very good service.



Courtesy: Downingtown Mfg. Co., Downingtown, Pa.

FIG. 151.—Diagram showing construction of Miller duplex beater.

The cut represents a section of the Miller beater, showing the submerged roll and the front and rear midfeathers dividing the tub into upper and lower sections, through which the stock is circulated by contact with the roll in both sections, which greatly increases the rapidity of the circulation and makes it impossible for the stock to settle or lodge in any portion of the tub. The location of bed-plates both below and above the roll doubles the beating capacity of the engine. The roll is carried in double lighters in the usual manner. The top bed-plate is likewise carried on double lighters, which are connected to and controlled by the roll lighters in such a manner that the top plate is raised and lowered twice as fast as the roll, thus preserving an equal distance between the roll and both plates. In addition to being used for various sorts of paper stock, this beater has proved very efficient in beating cotton fiber for use in making smokeless powder. This beater can be equipped with one or more cylinder washers just as in the case of the usual type of beater.

Umpherston Beater.

In the Umpherston type of beater the stock is caused to pass below the floor and backfall on its return path to the front of the roll. This machine is very economical of floor space and it is also supposed to give very perfect circulation with somewhat less expenditure of power than the usual

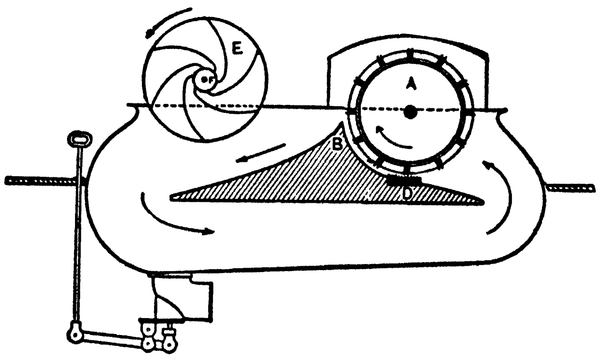


FIG. 152.—Diagram showing principle of Umpherston beater.

From "Outlines of Industrial Chemistry," Thorp, Macmillan Co.

type of beater. However, although many of these machines are in successful use, as is also the case with numerous other specially designed beaters, the ordinary type of beater will be found in the majority of mills. The Umpherston beater can be equipped with cylinder washers in the same manner as any other beater. The illustration shows an engine with one washer.

Continuous Beating.

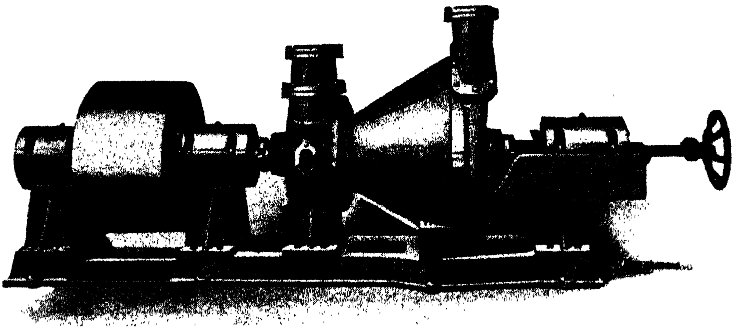
The intermittent nature of the beating operation causes a certain waste of time, power and stock, as well as a duplication of equipment in some cases. Various efforts have been made to get around the filling and discharging of beaters and to devise a continuous beating process. Provided that such a system could be worked out in a practical manner many mills could reduce the amount of beating equipment required by a large amount since under the intermittent system the beaters are idle as far as production is concerned a large fraction of the time. Also in some operations, for instance the reduction of waste paper, owing to variations in kind of stock, strength and other conditions, some of the stock is reduced before other portions are ready to be discharged from the beater and the portions done first are beaten too much before the others are properly disintegrated.

The Bird Continuous Beater Attachment is typical of such appliances and is intended to enable any ordinary beater to be operated continuously. It consists of a specially constructed cylinder, which is placed in the beater like a cylinder washer, with holes of a proper size in the face and on the end next to the midfeather. The end next to the side of the beater is open for the discharge of the beaten stock which has been extracted through the holes in the cylinder. A drain is cut into the side of the beater to which can be fitted a dam which will regulate the level of the stock.

Various other devices of the same kind have been experimented with from time to time. They have found their chief application in working up waste paper, etc., for various kinds of boards. If the beating operation is to be rendered continuous it is more likely to be finally accomplished through the introduction of refining engines similar to the Jordan and Marshall engines than by adding attachments to ordinary beaters. However, under certain conditions such appliances as the one described above can prove very useful.

Claflin Continuous Beater.

The Claflin engine affords a means of making the beating operation continuous, which is an advantage from many points of view. At the same time the Claflin accomplishes everything that the Jordan engine can do. Consequently a suitable installation of Claflin engines may take the place



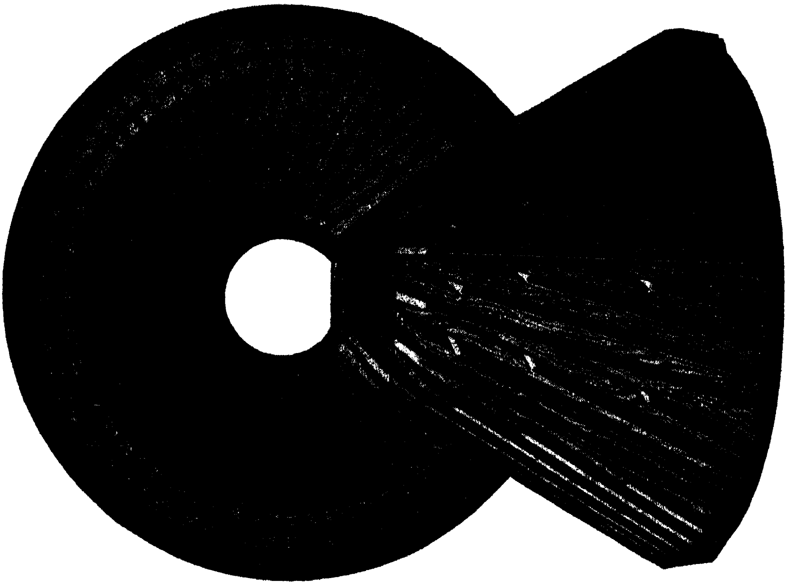
Courtesy: Claflin Engineering Co., Lancaster, Ohio.

FIG. 153.—Claflin continuous beater.

of a combination of beaters and Jordans. This substitutes one type of machine for two, cuts down the paper consumption (since the Claflins require less power than Jordans) and at the same time affords a continuous process.

Claflins are most usually installed for preparing stock requiring severe beating treatment, for instance kraft stock intended for the manufacture of high grade bag and wrapping paper.

The construction of the Claflin engine will be apparent from the illustrations. The cone is much more obtuse than in the Jordan engine, which accounts for the lower power consumption. The arrangement of the knives is also special with this engine and has been carefully planned so as to yield the same thorough brushing out of the fibers obtained in ordinary beating engines when operated in the proper manner.



Courtesy: Claflin Engineering Co., Lancaster, Ohio.

FIG. 154.—Internal view of shell and plug of Claflin continuous beater, showing arrangement of knives and fillers.

The Fritz Refiner.

This beater consists of a series of stationary and movable discs. The machine itself stands approximately 13 feet high, and 3 feet in diameter. It has ten sections, one over the other, so that as the pulp is pumped in at the top it flows by gravity from the top section down through, and out at the bottom section. Each section contains a movable and stationary disc. The movable discs have 59 bars 9 inches long which taper from $\frac{5}{8}$ inch up to $\frac{7}{8}$ inch at the outer edge of the disc, while the stationary plates which correspond to a bed-plate in a beater, have 52 bars 9 inches long of the same width as those in the movable part. The discs travel at a speed of 300 r.p.m.

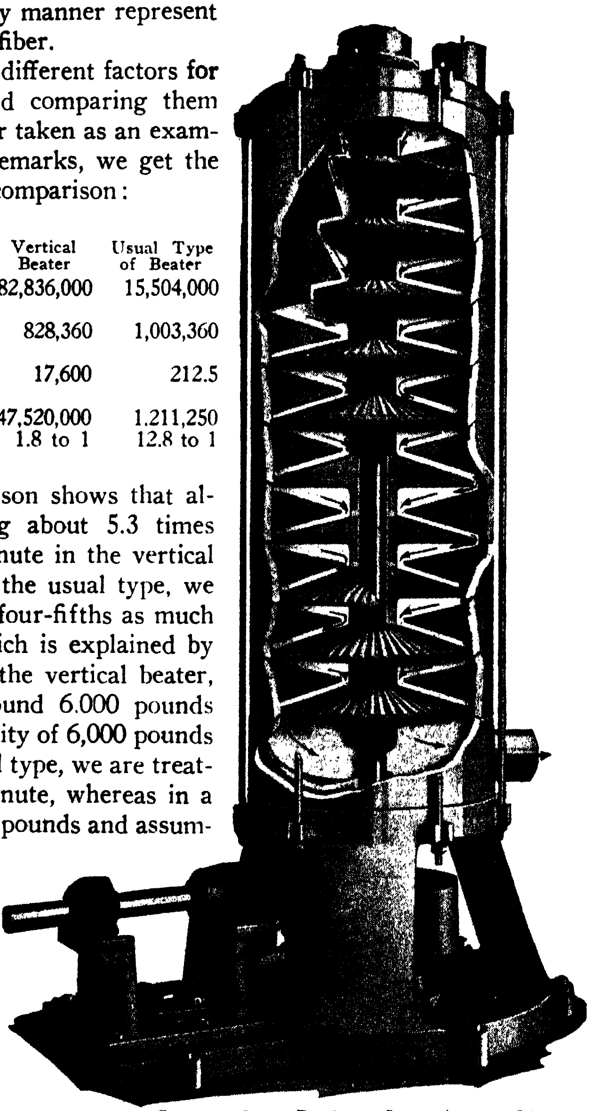
It has been found possible to obtain the same strength development on bleached sulphite stock with the vertical beater with approximately one-fourth the amount of power necessary in an ordinary beater. This is not, however, the only advantage to be gained, for several tests show that it is possible to develop the strength without shortening the fiber. This, of course, means that we are getting true hydration rather than a cutting action. This is borne out by the fact that the slowness tests show very little increase, although the strength has been developed. This may seem strange at first, but when we consider that all of the instruments used for measuring slowness cannot and do not differentiate between fine stuff and wet stuff it is not unusual that the slowness in this case does not increase to any great extent, for without any slowness readings taken on stock beaten in the customary manner represent very largely length of fiber.

In figuring out the different factors for the vertical beater and comparing them with those of the beater taken as an example in the preceding remarks, we get the following interesting comparison:

	Vertical Beater	Usual Type of Beater
Inch cuts per minute	82,836,000	15,504,000
Inch cuts per pound of stock	828,360	1,003,360
Wet beating per inch per revolution	17,600	212.5
Wet beating effect per minute	47,520,000	1.211,250
Numerical factor	1.8 to 1	12.8 to 1

The above comparison shows that although we are getting about 5.3 times more inch cuts per minute in the vertical beater than we are in the usual type, we are only getting about four-fifths as much cutting per pound, which is explained by the larger capacity of the vertical beater, which is normally around 6.000 pounds per hour. With a capacity of 6,000 pounds per hour for the vertical type, we are treating 100 pounds per minute, whereas in a modern beater of 1,800 pounds and assuming a two-hour beating time, we are only beating 15 pounds per minute. On the other hand, we find that we have about 83 times as much wet beating per revolution and about 39 times as much wet beating effect per minute.

The numerical factor is, as you will re-



Courtesy Love Brothers, Inc., Aurora, Ill.

Fig. 155.—Diagrammatic view of Fritz vertical refining and hydrating machine showing jack drive arrangement for which direct connected motor located in base of machine can be substituted.

member, the inch cuts per minute divided by the inch beating effect per minute, and it is found from the above that we have in the vertical type a numerical factor of 1.8 to 1, whereas in the usual type we have 12.8 to 1. The ideal numerical factor for wet beating would, of course, be 0 to 1, or when you were not getting any cutting.

The above factors show why we are able to get real wetness and retain the length of fiber so that a well-closed sheet can be made with a longer fiber which will result in a sheet free from fuzz, having a better tear and filler retaining ability along with other minor desired results, with, as already stated, one-fourth the power.

In a recent test, nine tons of bleached sulphite were run through this beater and stored in a large tank from which it was pumped to the beaters, where, with the roll way up, the size, clay, alum and dye were added as quickly as possible. The average time in the beater was 30 minutes so that it is reasonable to assume that very little, if any, beating was done. The stock was then refined in a Jordan and made into paper with the following results:

	Vertical Beater	High Speed Beater
Strength	26.3	24.3
Tear	70.0	66.5
Tensile	19.0	16.6
Size Test	2'04"	1'29"
Ash	4.5	5.5
Weight	45 pounds	45 pounds

These results prove that we have retained length of fiber while hydration for the bursting, tearing and tensile strength are all greater for paper made from the vertical beater. Samples of the paper itself show that we were able to get a good formation along with the other improvements.

During another test the same stock was passed through the vertical beater twice. On the first time through, a strength increase of 15 per cent resulted, whereas the second treatment gave a total of 32 per cent in strength. In a modern high speed beater, one hour and a half actual beating time would be necessary to accomplish the same results. Allowing for filling and dumping of the beater, we would probably have a total time of about two hours. This test shows the possibility of hooking one or more of these beaters in tandem and getting any degree of hydration desirable.

The Bauer Refiner.

The Bauer single or double disc refiner described in detail in Chapter 10 is also extensively used for preparation of stock either as a substitute for, or in conjunction with, beaters and Jordans. As a general thing the double revolving disc can be used to produce stock wherein the freeness is high for a given Mullen and where hydration is required, the single disc is recommended. In either case it is claimed that stock prepared by the disc machine can be brought to the same condition or strength with from 50 per cent to 60 per cent of the power required on beaters and Jordans. In some cases, particularly where the beating operation is extraordinarily long because of a desire to keep from cutting the stock, disc preparation can save even more of the power because disc action does not cut the stock as does the beater, so that there does not have to be the same sacrifice of effectiveness to quality. Stock preparation with the disc machine also goes further than in other types of apparatus because the disc machine has a field peculiarly its own, in what might be called "stock pre-preparation." For instance, in a kraft mill this machine will take mill cooked bag stock kraft pulp from the deckers, and, by applying approximately 3 horsepower per ton, will rub out most of the multiple fiber bundles and black strings which customarily produce so much dirt and so many black specks, fine though they be, in kraft paper.

In stock preparation, particularly where we mean full preparation of the stock, the power required per ton will vary with the type of pulp and the products required. In kraft pulp, for instance, some krafts have an initial Mullen of 35 to 40 per cent; other krafts better cooked have an initial Mullen of 60 to 70 per cent. With a raw cooked kraft it may be very difficult to raise the Mullen the 60 or 65 points required to bring it to a 100, but the sheets have much different properties than if a softer kraft were the starting point. Whatever the type of pulp used, the power required to give any desired Mullen rise will be less with the disc than with the beater and Jordan and this saving may amount to 40 to 50 per cent.

The disc machine has another special application in pre-bleaching refining. In this application stock is passed through the disc machine at the rate of from 50 to 100 tons per day per unit for the purpose of defibering the few multiple fiber bundles that may be present, and of pliabilizing all the fibers so that they may be more easily permeated by the bleach liquor.

Special Engines and Attachments.

Great ingenuity has been lavished on new types of beating and refining engines, mainly with the following ends in view: saving of power; improvement of the stock produced; saving in floor space. Many of these machines have never attained wide use. Some of the most important are described in detail in this chapter largely because the writer happens to have been familiar with them and not necessarily because they are superior to other machines not so described. The following is a brief summary of some others that will be encountered in modern mills:

Horne beater: The beater roll is at one end of the vat and completely submerged with the idea of improving circulation. It is used considerably where mixing of stocks is required.

Marx beater: Has two rolls in order to increase roll action, and two bed-plates. Each roll has its own lighter bar, and often one roll is a special one, for instance a stone roll.

Rabus beater: Very much like the Horne; tub arranged for closed circuit, with open midfeather; channel deepened to aid flow of stock; useful for waste paper stock for boards, etc.

Emerson beater: There are two parallel midfeathers, with the roll between them, to avoid the tendency of the stock to lie dormant near the midfeather. The tub is of special rectangular shape to permit this arrangement. The roll is mounted on a spindle spanning the tub. The stock passes under the roll in the central channel, over the backfall, divides into two streams, which unite again at the front of the tub.

Stobie beater: A radically novel type of engine: an open tub used as a mixer for the furnish, feeds into a chest with a powerful agitator, from which a centrifugal pump feeds the stock at a consistency of 2.5 per cent to fire-hose nozzles which shoot it at a pressure of 75 lb. per sq. in. at a serrated steel baffle. It is only suitable for such materials as sulphite, soda and groundwood. It can not be used for long fibered stock. It permits very close and constant control, also very great power savings.

Vortex beater: Designed for rapid filling; lap stock can be furnished in bundles intact. The tub is circular and there is a powerful motor-driven rotor operating within a bowl-shaped stator which serves as both bed-plate and midfeather, and can be regulated to govern the refining action; economical of both power and floor space.

Niagara beater: Like a Hollander, but has specially designed channels for stock circulation; roll virtually submerged because of the great cascade of stock over the backfall; notably reduces time required for beating; great difference in width between channel at front and roll sides of tub.

Shartle attachment: Perforated casting to replace backfall in beaters for board stock, etc. Perforations are so arranged as to discharge stock under backfall as fast as it reaches a desired fineness; beater thus becomes a continuous machine; otherwise quite like ordinary Hollander except that tub is usually of concrete and often set almost flush with the floor.

Bird attachment: For the same purpose as the Shartle, but a revolving perforated drum removes the beaten stock; especially suitable for roofing felt, etc. The drum is mounted in the channel opposite the beater roll.

Griley-Unkle attachment: Much like the Shartle, but the perforated plate is located in the hood of the beater in front of the beater roll, centrifugal force propels the stock against the sceren, and a shower of water carries away the sufficiently beaten stock; useful for waste paper reduction.

Kingsland refiner: A predecessor of the Jordan consisting of a plate rotating between two fixed plates, the rotating plate having blades on both sides. No longer used but interesting as having been the first engine of its type and having inspired the now almost universally employed Jordan. Kingsland was a New Jersey papermaker and his machine was patented in 1856.

Pope refiner: Much like the Kingsland but only one working surface and operated at extremely high speeds and with very close clearances; impractical in general use but the same idea is employed in the modern "colloid mills" and "homogenizers."

Wagg Jordan: Designed to offset uneven wear of bars due to variations in peripheral speed of plug due to differences in cross-section of the conical plug. The Wagg filling consists in setting the bars in pairs, instead of evenly spacing them, the two bars of a pair being very close together so that if the front bar wears out the rear bar of the pair is protected from erosion and preserves the original condition.

Morden refiner: Like a vertical Jordan operated at extremely high speeds with a circulating pump for the stock.

Haug refiner: A special refiner of the Jordan type used on screenings, raw kraft pulp, etc.

Rod mills: This is a tube mill, the same as used in ore-reduction plants for mining operations. It is a strong horizontal steel cylinder half filled with steel rods. The most usual size is 12 ft. long and 6 ft. diameter, operating at about 15 r.p.m. and requiring about 90 hp. Very fine results have been achieved with hard kraft and with waste paper stock. Sometimes these mills are rubber-lined. The stock enters one end and leaves the other, so they can be used in a continuous operation.

There are dozens of other such ingenious engines, some utterly fantastic and some very useful for special purposes. Before this book is printed a dozen new ones will doubtless have been announced There are abundant data in the paper industry journals regarding the engines mentioned above and the new ones that appear. One should not scorn these attempts at improvement as the Jordan engine was once just such an innovation and traditional papermakers were quite sceptical of its utility on any large scale.

Power for Beater Room.

Proper drive for the equipment of the beater room involves quite a problem in mechanical engineering. With the success of the resultant sheet of paper depending directly upon correct pressure and duration of beating, and with a number of different grades of stock being carried to completion in a number of different beating and Jordan engines, it is impossible to use a centralized power-plant. The conditions are quite different from those in a factory where all the machines are driven all the time and are all shut down together when the whistle blows.

In the beater room machines are shutting down and starting at all hours of the day and night, and with a central source of power, a great deal of power would be constantly going to waste. The best procedure is to install a large electric generating plant and then drive the beaters, Jordans, agitators in stuff-chests, stuff-pumps, etc., by *individual electric motors.*

Maintenance of Beater Room Equipment.

Beater Roll: The beater roll is made up of a number (generally four), of cast-iron discs arranged on a shaft. Two of these discs are at the two sides of the roll and the other two are near the center. The periphery of these discs is slotted straight across at stated intervals (usually about four inches apart), and into these slots the knives are driven. The knives have slots in each end, forming, when all the knives are in position, a complete circle of slots, one on each side of the roll. The outside discs have annular grooves located in a line with the base of the slots. The knives are driven in so that the lugs on the knives register with this groove. After the knives are all inserted a wrought iron ring, which fits the groove, is heated to redness and driven into this groove and allowed to cool and shrink, making a shrink fit, gripping each lug of the knives on both ends of the roll. After the knives are thus inserted and fastened, wooden filling pieces, with a driving fit, are put between each knife, and driven home by placing a wooden driver on the wooden fillers and hitting the driver with a sledge. Care must be taken to insert all of the wood fillers and to tap them down gently at first all around the roll. This is to avoid tipping the knives, and to bring an equal strain on each and every knife.

These knives (which are often called fly-bars or roll-bars) are slightly thicker in the center than at either edge, so that the swell in the center of the knife helps to hold the wood filling in place, since the wood is driven in beyond the swell. In addition to this the knives are scored slightly so that the wood when it becomes swollen with water fills the scorings. All this is done to prevent the woods from coming out and to hold the knives in an upright position.

After the knives are inserted, as above described, it will be seen that no matter how accurate the widths of these knives may be, that there is bound to be a slight variation in their height, making an uneven periphery. Thus when the roll is let down onto the bed-plate there will be found to be one or two high spots on the cutting surface and the roll will strike the bed-plate unevenly. As it is necessary to have the roll run absolutely smooth when resting on the bed-plate, the roll and bed-plate must be ground in to fit and produce smooth running. When the roll is on the bed-plate and in proper order it will hum as it revolves and there will be no knocking or rasping.

Bandless Beater Rolls: Several manufacturers of beating engines are equipping their beaters with bandless beater rolls. In these rolls the knives or fly-bars are held in position by a specially shaped slot. The knives are so made that the section in the head fits the dovetail slots. Between the heads the knives are of standard section. For this type of construction the following advantages are claimed: To fill the roll it is not necessary to take the roll out of the lighters; new bars are put into the slots with one end dovetail lug outside and next to an outside head; then with a hammer or a jack the bar is moved endwise into position. The wood filling is then put in and the roll is ready for use. However there is some danger of the knives becoming rusted and stuck in the slots so that a great deal of trouble is had in getting them out.

Grinding a Roll In: To grind a roll in, a dam is erected of boards in front of the roll and in the space between this dam and the backfall water and sand are placed. The roll is lowered carefully onto the bed-plate and allowed to revolve so that the high spots will just touch the bed-plate. The roll is lowered as fast as the grinding proceeds, the progress of this operation being judged by the sound which is helped by placing a smooth stick against the bed-plate and the other end against the ear. This makes it easy to tell if the grinding is going on in a satisfactory manner. When this grinding process is completed the roll is ready for use.

In running the beater extreme care must be taken that no foreign matter gets in with the stock, as even a nail would nick the knives and a bolt or larger object would seriously damage the knives and bed-plate.

When feeding laps the roll should always be raised from the bed-plate, about an inch, to avoid jumping the roll as the laps pass through. Laps should be opened out before being placed in the beater, as this makes it easier for them to pass the roll and also lessens the risk of foreign substances being put in with the laps. Also they disintegrate quicker.

Beaters intended for fresh stuff should never be used as broke beaters. The broke is hard to disintegrate and also is likely to contain pieces of metal such as bolts, nuts, tools, etc.

Beater knives should be inspected carefully to see if acid contained in the stock is wearing them thin. Sometimes beater knives are worn to a knife edge in this manner, under which circumstances they should be replaced.

In the course of time beater knives, bed-plate and the inside of the beater itself will acquire a certain smoothness from the constant polishing of the circulating stock. It is very valuable to preserve this and no scraping or rough handling of the interior of the beater or washing with strong alkali or acid should be permitted.

Bed-Plate: The bed-plate of the beater consists of a bank of knives and wooden fillers arranged alternately. The knives and fillers in the center are short and those at the two edges are longer, so that the top surface of the bank is a concave trough which is parallel to the bottom of the beater roll, so that every one of the knives in the bed-plate will cut. This bank is fastened together by bolts running straight through and fitted with nuts countersunk into the outside pieces of wood. Sometimes instead of being set parallel with the roll-bars, the knives are set at an angle so as to deliver a shearing cut when they come in contact with the knives of the beater roll. The whole bank of knives and fillers is set in an iron trough which has a lip perforated with a hole at its outer edge. This trough is set right across the path of the beater roll, its outer end coinciding with an opening in the shell of the beater. When it is desired to repair the bed-plate a bar is inserted through the hole in the lip of the iron trough and it is drawn right out, the beater-roll, of course, being raised during this operation. When the beater bed-plate knives wear down, the bed-plate is withdrawn in the above manner and shims inserted under the bank of knives and fillers, raising it the required degree. This operation can be repeated until the knives become worn down to such an extent that it is necessary to renew them.

Jordan Engine: Generally the first intimation that the knives of the Jordan plug are worn down appreciably, is the falling off in delivery of the stuff through the engine, owing to the loss of impelling effect on the stuff on account of the knives becoming flush with the wooden fillers. Also the whining sound characteristic of the Jordan when the knives are in good order will be reduced. Also there is a characteristic sensation produced when the hand is placed on the shell of a Jordan, the knives of which are cutting properly, which is not met with in a Jordan the knives of which are worn down. This can easily be ascertained by trial, and will assist materially in judging of the necessity for repair.

When the delivery of the Jordan falls below requirements, the plug has to be taken out. If it is found that the knives are in good condition and that all that has happened is that the knives are worn down flush with the wood filling, then the wooden filling between the knives can be chipped out. This is done with a chisel. The shell of the Jordan is treated in the same manner as the plug. One chipping is all that a Jordan will stand, as if this operation were repeated so much of the wooden fillers would be removed that the knives would not have adequate support.

Owing to the acid in the stock, the knives will gradually wear very thin, and will become quite useless. At this stage they must be replaced. Also they must be replaced if they have become hacked or nicked by foreign matter getting into the Jordan.

Jordan Outlets: There are three outlets on a Jordan—bottom, side and top. The outlets are situated on the big end. They are supplied with handhole plates when not in use. Only one at a time is used. Usually the top outlet is the one used. The lower ones would be used in the event of making free stock requiring little refining in the Jordan. The use of the upper opening backs up the stock in the Jordan, holding it in the engine for a longer time. This effect can be increased by having a valve on the outlet and throttling the discharge. If the plug is set so that the knives are not in actual contact and the stock is throttled so that it will pass through the engine very slowly it will be found that the fibers are rubbed against each other. This is what is called stuffing a Jordan. It is an excellent way to produce a long, strong fiber, such as is noticed in strong kraft paper. When the Jordan is stuffed, it will be noted that the characteristic whining persists only so long as the engine is full of stock. If the stock is allowed to run out the whining will cease, showing that the knives are not actually in contact.

High Speed Re-designed Beaters.

Of recent years, a great deal of discussion has taken place in regard to the merits and demerits of rebuilt high speed beaters. There has been a lot of favorable comment on the improved action of some of the new types; on the other hand, it is claimed that it will be a long time before any real improvement over the standard Holland type can be made.

In the Holland type of beater the circulation of stock in the tub is from 4 to 5 feet per minute, while in the high speed type a circulation of as high as 12 feet per minute is obtained. The tubs are made larger, which means more production with the same floor space and higher densities of stock resulting in increased capacity.

Re-designed beaters have a higher backfall and a sloping bottom leading direct to the dumping valve. Fillets are placed in all corners of the tub so that no stock can lodge in any place. A smooth uninterrupted flow of stock to the dumping valve and a more rapid circulation of the stock are thus insured. Some of these changes result in false economies. Increasing the speed of the beater-roll takes more power, possibly more expense per ton, than is gained in making such changes; therefore, careful consideration must be given to calculations concerning increases or decreases in cost and quality. All such changes must be commensurate, i.e., reducible to a common measure. An increase of 12 cents per ton in power cost and only 10 cents per ton increase in benefits may result.

The first consideration before changing the speed of beater rolls is the quality of paper to be made. Newsprint needs no hydrating or cutting, as the quality of this paper is determined in the making of groundwood, supplemented by mixing with a small percentage of sulphite. Running this mixture through refining engines makes it ready for the paper machine. Wall paper is also in this class.

Cutting stock in a beater is one thing; hydrating stock in a beater is another. A careful blending of these two operations is necessary in a large majority of papers. Hydrating stock is a slow process and the best results are obtained by the use of thick and dull beater-roll bars and bed-plate bars. The fibers are squeezed and mashed without cutting, first gently with a gradual increase of weight on the fibers, by lowering the beater roll at measured intervals. Much depends upon the judgment of the beaterman, for it is a matter of skill gained by experience.

Stock for blotting papers require no hydration. Stock for Glassine requires all the careful hydration that can be given to it without cutting the fibers. Blotting paper stock represents the extreme limit of freeness and Glassine stock is the extreme limit of slowness. In the enormous range between these two extremes all kinds and qualities of paper stock are prepared. Various kinds of paper requiring extreme freeness or draining qualities, such as filtering paper for chemical laboratories, must have this quality and yet the stock must be cut very short so that the sheet of paper may be closed tight and even. Such stock must be very clean and the paper opaque.

Going up the line of the many qualities of paper, in all cases the density of the stock in the beaters must be maintained uniform, otherwise the stock may develop uneven qualities. Every beater may produce a different quality. The danger of uneven quality of stuff increases when using several beaters. The speed of the beater-roll, the number of fly bars, thickness of the bars, number of bed-plate bars and thickness of the cutting edges, the rate of circulation of the stock, etc., should be carefully checked so that the same quality of paper may be duplicated at any time.

Well hydrated stock is of value in most ordinary papers. It increases filler carrying capacity and imparts character and strength to the finished paper.

Mechanical engineers when recommending changes and improvements for paper mill machinery do not always understand in detail the service required of such machinery. Certain paper mill executives were persuaded that valuable floor space in the beater room might be conserved by supplementing a direct sprocket chain drive from a motor sprocket to a beater roll sprocket and using a short horizontal drive placed on the same floor with the beater, allowing distance enough to permit the beater roll to be raised and lowered and to permit the roll to jump as it often does when furnishing pulp laps or waste paper. The executives and the mechanical engineer however overlooked the most important point of this installation. One day this beater-roll became plugged and stopped. The motor did not stop. The sprocket chain did not break, with the result that the beater-roll jumped out of its journals, pulled the motor from its foundation, wrecking the motor and coils, ruining all of the bars in the roll and bed-plate, wrecking the beater curb and damaging the beater-tub badly. Scraps and splinters of the wreck were thrown across the beater room endangering the lives of workmen. It cost the company several thousand dollars to make repairs and change four beaters back to their original drives.

Long horizontal belts make the best drives for beater rolls for the reason that the rolls must be raised and lowered in the process of furnishing pulp and waste papers which will not pass between the roll and bed-plate when the roll is down on the plate. If the material being furnished for any reason stops circulating, it is necessary for the beaterman to start the circulation by using a beater paddle. In doing this the beater roll is snubbed and often stopped for an instant. In such an emergency the long horizontal driving belt will slip and prevent damage. When furnishing raw material to beaters for reducing to suitable fibers for the making of paper, the beater must first be filled about one-half full of water. The beater-roll should then be raised from the bed-plate several turns to prevent the roll from jumping when laps of pulp or waste paper are furnished. This material must circulate in the beater until it is thoroughly soaked and gently pulled apart. More water may be added if necessary as the pulp becomes thicker until the correct density is reached. When the pulp has become thoroughly separated and is circulating smoothly, the beater-roll may be lowered at intervals permitting each adjustment of the roll to remain in the changed position long enough for the stock to circulate several times before lowering the roll again. The object of this treatment is to avoid cutting the fibers in flocks or until they are carefully separated and drawn out, and thoroughly hydrated. The last half hour with the beater-roll on the bed-plate will usually make the fibers short enough to finish in the Jordans or other refiners.

SPECIFICATIONS FOR BEATING ENGINE

from

(Name of Firm)

(Address)

Roll.

Of cast iron, ...diameter, ...face; to be balanced, and the inside well painted. To have ....heads finished to an exact diameter, so as to give each bar a solid bearing on every head, accurately fitting slots to receive the bars and no wedges to be used for supporting or holding same in place. Each head to be bored a driving fit and firmly keyed to the cast iron shaft; the outside heads finished on their outer faces, provided with suitable "banger irons" made of wrought iron and fastened with countersunk head machine screws.

Shaft.

Of cast iron, ...diameter where the heads are located, finished the entire length, tapering towards the ends; provided with a finished brass cap on the front end. Wrought iron collars at the location of the back side and midfeather, and a ....collar at the location of the front side. ....for driving cylinder washers.

Bearings.

Front ....diameter, ...long; back ....diameter, ...long. Type, babbitted, water jacketed. Corners rounded.

Fly Bars.

Of ...., in number, ...wide, ...cut, ...shoulder, ...back, projecting .... beyond the filling, planed true on both edges, placed in position in the roll and securely banded with .... wrought iron bands shrunk on. The spaces between the bars to be filled with oak, carefully fitted and securely driven; then the ends of the bars, filling and the outer faces of the bands are to be finished true and the roll accurately balanced.

Pulley.

Of cast iron, ...diameter, ...face, ...bore, of the double belt type, turned with a suitable crown and accurately balanced. Placed .... from the inside of the tub. Speed ............R.P.M.

Lighters.

Of cast iron, moulded from our heavy patterns, with steel shafts for operating both ends of the rolls simultaneously; the cross shaft passing above the tub. The posts supported by the harness or foundation, the bases .... square, the chaps of .... and the hand wheel of ....; the hoist of the worm and gear type. To have a quick lever relief hoist.

Bed-Plate.

Elbow style, ...wide, ...sheet steel cuts, ... outside bars, ...hard wood filling, planed true on the bottom and firmly keyed into the plate box with hard wood keys.

Plate Box.

Of cast iron, finished all over, properly fitted to the bed, projecting outside of the tub sufficiently to admit of easily drawing the same.

Tub.

............long, ...wide and ....deep at center, inside dimensions; side, ends and midfeather made of ...., bottom of ...., all dressed two sides, jointed, grooved and splined, staves hollowed and rounded. The top capped with a cast iron rim securely screwed to the woodwork with countersunk head iron screws; each end to have two flat wrought iron bands. The planks forming the bottom, sides and midfeather to be securely rodded and joint-bolted together. Back side supported by .... heavy cast iron braces; back end, front side, covered with 2" Gulf Cypress.

Rub Plates.

Placed on the front side and midfeather, extending from the high point of the backfall to the extreme front of the roll, from the top of the tub down to the bed, set into the woodwork flush, securely fastened with countersunk head .... screws and made of ...., ...thick.

Corners.

Of ...., located where the sides, ends and midfeather join the bottom.

Protecting Bands.

Of 1½" × ¾" half round iron, fastened to the staves with countersunk head iron screws, located between the two regular flat bands.

Bed.

To have patented backfall; the bottom made of .... timber; the crown of ....

Plating.

To extend from the extreme high point of the backfall to the back side of the plate box, from the front of the plate box to the low point of the apron (where there is an apron) otherwise for a distance of 18". To be of ...., ... thick, securely fastened to the woodwork with countersunk head .... screws.

Curb.

Heads of ...., packing boxes of ...., cover of ...., fastened to the heads with round headed .... Of our patented type, provided with adjustable oak doctor, cast iron deflector and protector.

Spatter Boards.

Of ...., made in .... pieces; fastened together with heavy strap hinges of brass.

Valves.

Of cast brass; ....emptying, ...wash-up.

Hydrant Valves.

Of cast iron and brass; ....

Cylinder Washers.

.... in number, shape ...., diameter ...., face .... Heads of ...., buckets of ...., sash of ...., brass wire cloth ...., reinforced by 30 mesh. No. 18 cloth; the edges and joints protected by strips of sheet brass, all fastened to the woodwork by copper tacks. The discharging, hoisting and driving apparatus complete, of cast iron, moulded from heavy and improved patterns. The shafting throughout of steel. The water-spout supported independently of the main shaft; the water box fitted to receive a 5" cast iron flanged drain pipe. The main driving gears 2½" face, ¾" pitch.

Floor Plates.

Of cast iron throughout, for the support of the lighter posts, one single plate being required for each pair of posts, the raised surfaces at the ends for the support of the posts being machine finished, the intervening space between these raised surfaces having a drip pan bottom and ribbed edges, the bottom slanting to a 2" drain hole located at the center; we to furnish the tap bolts, drill and tap the holes for fastening the posts to the plates, you to set the plates, furnish and install the bolts for fastening them to the floor system.

Stock Guides.

Of cast iron, fastened with brass screws to the midfeather and front side on the inside of the engine directly in front of the roll, for the purpose of guiding the stock away from the midfeather and front side.

Piping.

All piping of every name or nature not specified as being furnished by us is to be furnished and installed by the Purchaser.

Finish.

The woodwork throughout thoroughly ....outside, ...inside, with .... coats of pure .... The iron work to have .... coats of pure lead paint and oil on all unfinished exposed parts. Machined parts well slushed before shipment.

Workmanship and Material.

All workmanship first-class in every respect and materials of the best of their several kinds for the purposes intended.

Note.

The assembling and erecting of the tub and of the parts which attach thereto is to be done at the Purchaser's mill rather than at our shops.

The various parts of the complete engines are to be shipped in as much of a knocked-down condition as in our judgment may be best.

Conditions.

The date agreed upon for the shipment of this machinery is made in good faith; it is contingent, however, upon the non-occurrence of strikes, accidents and other delays unavoidable or beyond our control.

Title of Machinery.

The title to this machinery shall not vest in the purchaser until it is fully paid for; the fact that said machinery may attach to realty by any means whatever, shall not be considered as making it a part of such realty, but till fully paid for, the same shall be and remain personal property and the purchaser agrees to execute or cause to be executed, acknowledged and delivered to us, all legal instruments necessary and appropriate to preserve our title therein. If a note or notes of the vendee or any other person is or are accepted, the title to said machinery shall not pass from us until such note or notes, all extensions and renewals thereof and interest thereon, shall have been paid in full, and if default is made in payment of the contract price of said machinery, whether evidenced by note or otherwise, the right is expressly reserved and given for us to enter the premises where said machinery may be, and remove the same as our property. The taking of security other than provided for shall not operate as a waiver of our statutory lien, and consent is given, that we may, without notice, accept security and thereafter increase, diminish, exchange or release the same.

Acceptance.

Where the payments are contingent upon the dates specified in the contract for shipment, completion of erection or starting of the machinery, and should it be impossible or impracticable to ship, erect and start said machinery on these dates, owing to conditions over which we have no control, then shall this machinery and work be accepted and paid for as agreed in the contract, all providing that we are ready to ship, erect and start machinery on these dates, the payments being deferred or extended only by the additional time that we require to fulfill our contract.

Safe Keeping.

The purchaser shall become responsible for the safe keeping of this machinery and shall insure same for our benefit, as our interest may appear from the time it shall be shipped from our works.

Agreements.

There are no understandings or agreements not expressed herein and nothing is included that is not particularly mentioned.

Payments.

The contract price of any unpaid part thereof, shall draw interest after due, at a legal rate until paid, and when the time of payments extends beyond thirty days, such deferred payments shall be evidenced by a negotiable note or notes at our option.

Erection.

We will deliver F.O.B. cars ....
.... (Address) .... you to unload same from cars and place in Engine Room of your mill, after which we will send .... competent .... to .... the .... It is agreed that all labor and materials relative to the harness, floor system, leaders or pipes of any kind, pulley curbs, belts, grinding of rolls, holding-down bolts or any other kind of labor and materials which do not strictly belong to the engines, is not a part of this contract and is to be done and furnished by you, without expense to us. Price per day of ten hours for the Superintendent ...., for additional mechanics .... The charge to include time occupied going to and returning from your mill as well as while there. You are to pay all traveling expenses, board, lodging and transportation of tools both ways, also furnish all millwrights and laborers (without expense to us) that our superintendent may deem necessary in order to erect the machinery with the least possible delay.

JORDAN ENGINE SPECIFICATIONS

from

(Name of Firm)

(Address)

TYPE.................... SPEED.................... WEIGHT.................lbs.

R. P. M..............................

DIMENSIONS OVER ALL. 14'-10⅝"×3'9"

HEIGHT TO CENTER OF SHAFT. 2'-6"

Plug.

Of cast iron, 4'-3¼" long; 2'-10¾" and 1'-8" diameters, respectively, at the large and small ends, over bars. To consist of a taper shell, moulded from a heavy pattern, the center bored out and provided with a hub at each end. The casting to be trued up from the inside and machined to proper dimensions on its outer face; the hubs bored, splined and firmly keyed to the shaft by fitted taper keys, the latter being forced into position by hydraulic pressure. To have five (5) raised surfaces with finished slots to receive the bars. To be balanced.

Shaft.

Of hammered iron, turned all over true to sizes; 4 13/16" diameter at the pulley fit and bearings, bossed at the locations of the sleeves and plug. To have standard splines, provided with machine-finished keys for fastening the pulley and plug in position. At the back bearing there are to be five (5) taper grooves to take the end thrust.

Sleeves.

Two (2) in number, of seamless brass tubing, ¼" thick, shrunk on the shaft at the location of the packing boxes, extending from the ends of the plug to the nearest bearings and finished on their outer surfaces.

Plug Bars.

.... in number, of Open Hearth Jordan Steel; 2 11/16" wide, ..., 51¼" long, ... thick, ..., 28" long, ... thick, planed to a width, placed in position in the plug and securely banded with five (5), ½×⅝" wrought iron bands shrunk on. The spaces between the bars to be filled to the proper height with dry oak, carefully fitted and well driven. The plug then to be accurately balanced.

Shell.

Moulded from heavy patterns, of cast iron, bored to a true taper inside and the ends squared up; the heads counter-bored to fit, drilled to interchangeable templates and fastened in position with standard tap bolts. To have four (4) wrought iron guide bars of 1"×⅝" iron, bent to proper shape, placed quartering and lengthwise and cap-screwed to the inner surface. To be provided with packing boxes and glands where the shaft passes through the heads; these to be finished in the usual manner. To have two (2) supporting brackets each side. The small end projecting beyond the plug about 14", having an 8" inlet at the top, a hand hole with cover on one side and a sand trap with clean-out hole and cover at the bottom. The outlets to be 6" in diameter and four (4) in number, three (3) to have plain caps and the fourth a 6" wrought iron pipe flange with standard thread.

Shell Bars.

Of Open Hearth Jordan Steel; type, ... in number, 16½" long, 1¾" wide, ... thick, planed to a width, placed in position in the shell, filled in between to the proper height with dry oak, carefully fitted, each section being securely keyed. The filling to be made with two (2) chippings.

End Adjustment.

To be made in the usual manner by a hand wheel, screw and nut; the latter being fastened to the under-side of the back bearing.

Bearings.

Three (3) in number, length 15", of the ring oiling, water-jacketed type, with slush cups and vertical adjustment; oil rings of composition, finished all over. The bases and sides machined and babbitted; one being fitted to the shaft grooves.

Guides.

Two (2) in number, of cast iron, fastened to the two (2) heads of the shell; the inner surfaces to be machine finished.

Stands.

Five (5) in number, of cast iron, two (2) each for the support of the guides and shell and one for the out-board bearing; all of the box type with machine-finished tops and feet, fastened to the base by tap bolts; the tops provided with clamping and tap bolts.

Base.

Of cast iron, moulded from a heavy pattern, thoroughly braced and cross-ribbed, provided with a solid top except where the pulley is located, sloping to a drain outlet at the back end, which is equipped for a 2" standard pipe flange. To have pockets on the ends, so that bars may be used for moving the engine, also, eight (8), $\frac{3}{4}$" anchor bolt holes. Both the top and bottom to be accurately planed.

Sand Box.

Of cast iron, of neat design, placed on top of and fastened to the shell at the feed end, provided with an 8" inlet and discharge and a cross partition or dam, dividing it into two (2) chambers; the first having a clean-out hole and cover on the side. To have a 6" vent pipe, 30" in length, equipped with a cast iron cap.

End Adjustment.

Made in the usual manner by a hand wheel, screw and nut; the latter being fastened to the under-side of the back bearing and the screw being connected through a train of machine dressed spur gearing, a shaft running lengthwise of the Jordan, supported by bearings attached to the base, the outer end being threaded and engaging a nut fastened to the bottom of the motor base, so that the same end motion which is given by the adjusting screw to the plug is also transmitted through the spur gearing, shaft and nut to the motor frame.

Couplings.

Of the flexible insulated type, one-half ...., bored, fitted keywayed and keyed to the end of the plug shaft; the other half whole, bored and keywayed to dimensions to be furnished by the Purchaser, we to furnish the key.

Motor.

Furnished by the Purchaser without expense to us and without pulley, outboard bearings or sub-base. The end of the shaft next to the Jordan Plug to project sufficiently to receive a one-half coupling; to be provided with a coupling fit and keyway. The base to have two planed surfaces in place of four; each of sufficient length and width to support the motor and to comply with our requirements. These to be finished on the bottom, outer edges and the ends. Holes to be drilled and tapped in the outer edges and the ends to receive $\frac{3}{4}$" tap bolts, to which will be attached castings which we will furnish. On the bottom of the frame there must be a raised flat surface, size about 5"×8"; to be planed, to have a counterbore in the center $3\frac{1}{4}$" diameter, $\frac{1}{4}$" deep, to have four $\frac{3}{4}$" holes drilled and tapped to receive four tap bolts which, in turn, will fasten a nut to the frame. We will furnish the castings, the nut and all tap bolts above referred to, but they will be attached to the motor base and frame by the Purchaser at his Mill.

This proposal is made with the understanding that the motor purchased will not be higher than .... from the base to the center of the shaft, that the width from out to out of the feet will not exceed ....; otherwise an extra charge will be made and the amount of same will depend upon the increased dimensions if the motor is over and above those specified.

Jordan Base.

Of cast iron, moulded from a heavy pattern, thoroughly braced, and provided with a solid top sloping to a drain outlet at the back end, which is tapped for a standard pipe. Top where the stands are located, the bottom and the ends to be accurately planed, one of the latter being drilled and provided with bolts for fastening it to the motor base.

Motor Base.
Of cast iron, moulded from a heavy pattern, thoroughly braced, and provided with a solid top. Top and bottom as well as one end to be accurately planed, the latter being drilled to receive the bolts which clamp it to the Jordan base. To be provided with our special arrangements for the support of the motor and easy adjustment thereof.

Notice.
The purchaser must advise the manufacturer of the motor and before contracting for same, in reference to all the special arrangements required and as outlined above.

Conditions.
The date agreed upon for the shipment of this machinery is made in good faith; it is contingent, however, upon the non-occurrence of strikes, accidents, and other delays unavoidable or beyond our control.

Title of Machinery.
The title to this machinery shall not vest in the purchaser until it is fully paid for; the fact that said machinery may attach to realty by any means whatever, shall not be considered as making it a part of such realty, but till fully paid for, the same shall be and remain personal property and the purchaser agrees to execute or cause to be executed, acknowledged and delivered to us, all legal instruments necessary and appropriate to preserve our title therein. If a note or notes of the vendee or any other person is or are accepted, the title to said machinery shall not pass from us until such note or notes, all extensions and renewals thereof and interest thereon, shall have been paid in full, and if default is made in payment of the contract price of said machinery, whether evidenced by note or otherwise, the right is expressly reserved and given to us to enter the premises where said machinery may be, and remove the same as our property. The taking of security other than provided for shall not operate as a waiver of our statutory lien, and consent is given, that we may, without notice, accept security and thereafter increase, diminish, exchange or release the same.

Acceptance.
Where the payments are contingent upon the dates specified in the contract for shipment, completion of erection or starting of the machinery, and should it be impossible or impracticable to ship, erect and start said machinery on these dates, owing to conditions over which we have no control, then shall this machinery and work be accepted and paid for as agreed in the contract, all providing that we are ready to ship, erect and start machinery on these dates, the payments being deferred or extended only by the additional time that we require to fulfill our contract.

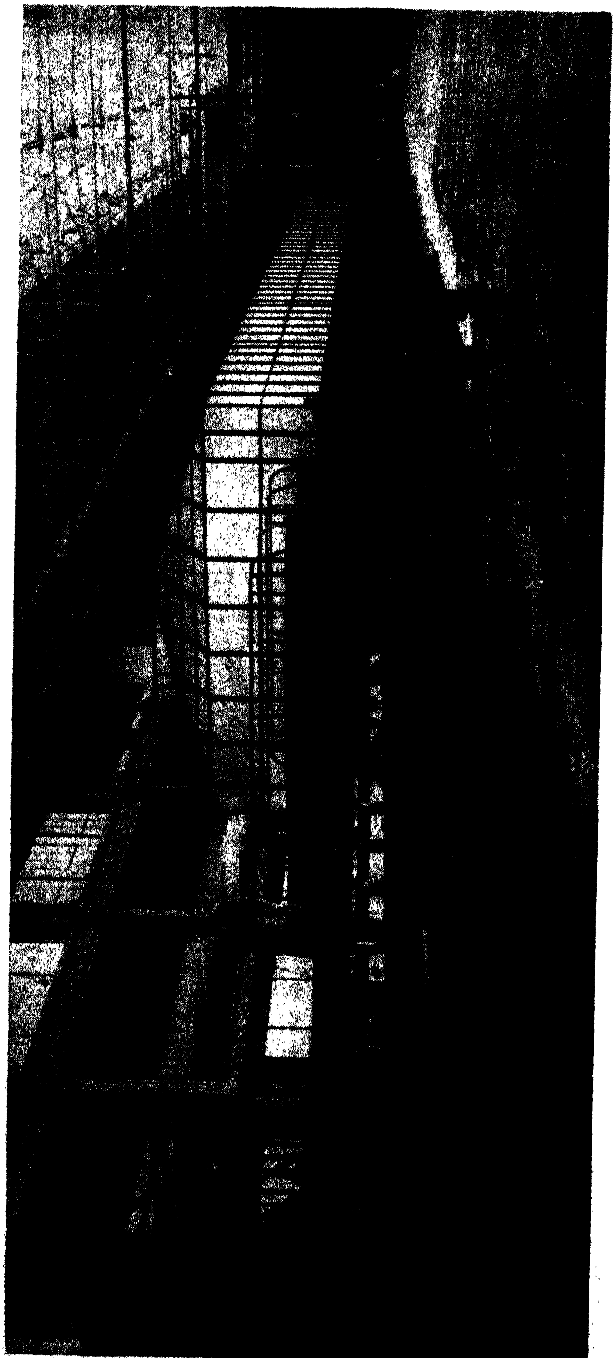
Safe Keeping.
The purchaser shall become responsible for the safe keeping of this machinery and shall insure same for our benefit, as our interest may appear from the time it shall be shipped from our works.

Agreements.
There are no understandings or agreements not expressed herein and nothing is included that is not particularly mentioned.

Payments.
The contract price of any unpaid part thereof, shall draw interest after due, at a legal rate until paid, and when the time of payments extends beyond thirty days, such deferred payments shall be evidenced by a negotiable note or notes at our option.

Finish.
To be assembled in our shops and shipped whole. To have three (3) coats of pure lead paint and oil on all unfinished, exposed parts; machined parts well slushed before shipment.

Workmanship and Materials.
All joints machine-dressed and bolt holes drilled. Workmanship first-class in every respect and materials the best of their several kinds for the purposes intended.



Courtesy: Pusey and Jones Corp., Wilmington, Del.

FIG. 156.—Large modern high speed bag paper machine viewed from wet end.

13. The Machine Room

The Machine Room is the name commonly given to the building housing the papermaking machines together with the equipment for driving them, for supplying stock to the machines and steam to the drying equipment.

There are two machines ordinarily used for making paper, the *Fourdrinier machine* invented by Louis Robert in France in 1799 and commercialized by the brothers Fourdrinier in England in 1804; and the *cylinder machine* invented by John Dickinson of Germantown, Pa., in 1809. Despite its slightly earlier invention the Fourdrinier machine was not introduced in America until about 1836 when one was set up at Saugerties, N. Y.

When the words "paper machine" are used without qualification an ordinary Fourdrinier is usually meant; and such is the usage of this book.

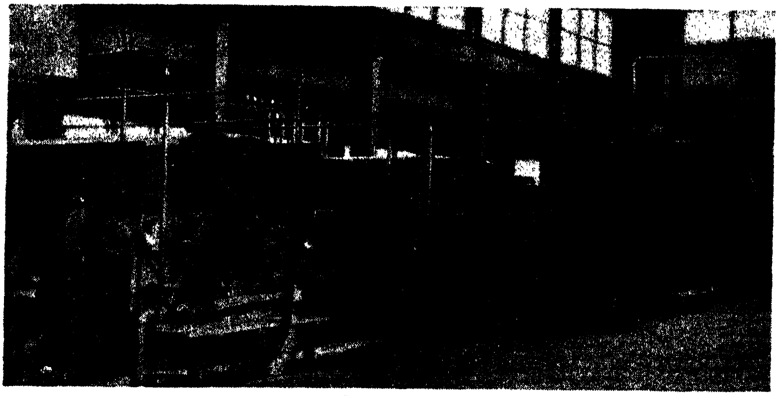
Various modifications of the Fourdrinier have been developed for special purposes such as the Harper Fourdrinier for tissues; the Yankee machine for glazed papers; and combination Fourdrinier and cylinder machines for duplex papers. The cylinder machine and all these Fourdrinier variations will be discussed later. Meanwhile we will consider in detail the ordinary Fourdrinier machine.

Although there are numerous firms manufacturing Fourdrinier machines of excellent design and construction, and although each of these firms has introduced certain special features which they think tend towards efficiency and perfection, yet the general principles are the same—i.e., the same essential parts are found in all the different makes—and the descriptions in this chapter will apply to any make of machine. Paper machines are not built standard and carried in stock like grinders or beaters. They are designed and built special for each case in accordance with specifications drawn up by the buyer, models for which will be found at the end of this chapter.

The Fourdrinier machine consists essentially of a device for allowing carefully screened pulp of constant consistency to flow onto a horizontal wire screen, hereafter called the "wire," made in the form of an endless belt and traveling constantly away from the point where the pulp flows on it. The water in the pulp drains through the wire, this drainage being assisted by suction boxes applied under the wire at certain points. At the end of the wire farthest from the point where the pulp flows on it, is a pair of rolls between which the film of fibers from the wire passes. At this point the film of fibers still contains much moisture, so it is passed through other felt covered rolls, which press more water out of it. Next it passes through a long series of steamheated iron cylinders, always supported by a layer of felt which travels with the paper, and these cylinders drive out all the remaining water except a small percentage always present even in paper commonly considered quite dry. Finally the paper passes through polished calender rolls to give it a "finish" and onto reels where it is wound up.

The foregoing description gives little idea of what a complex and intricate mechanism a Fourdrinier machine is, and of the necessity of having every part in perfect running order, and perfectly adjusted to every other part if satisfactory work is to be done.

Before reading the subsequent sections of this chapter, in which it will be attempted to outline the practical details of Fourdrinier machine operation, the reader is urged to study carefully the diagram of the Fourdrinier machine between pages 370 and 371, learning carefully the name and location of all the various parts. After studying this diagram it would be highly advantageous, if opportunity presents, to study a machine in actual operation, identifying the various parts of the machine and carefully noting their functions.



Courtesy: Bagley & Sewall Co., Watertown, N. Y.

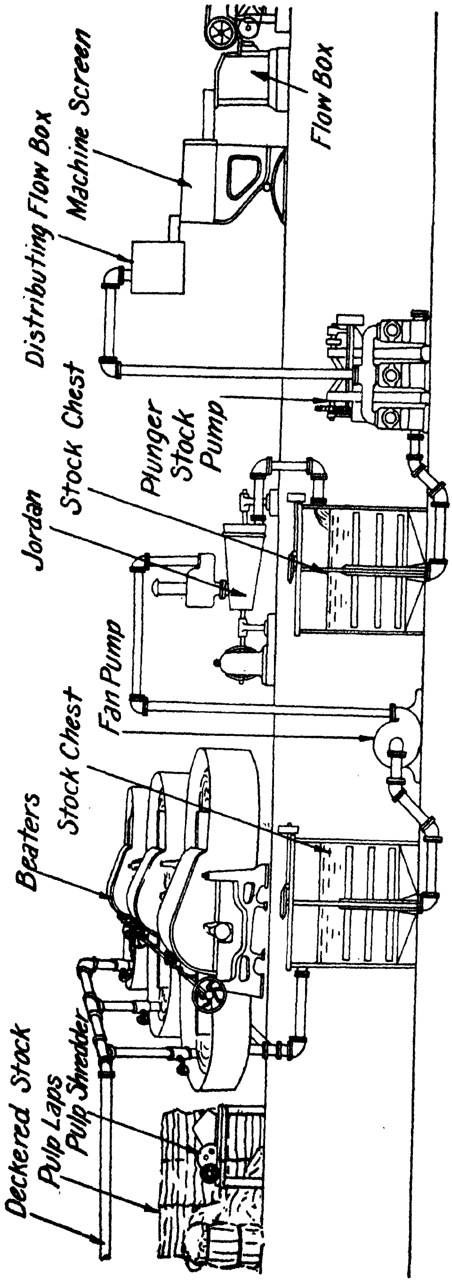
FIG. 157.—Fourdrinier end of press section of paper machine.

Screens.

Before being allowed to flow onto the wire of the machine the stock is given a final screening, through screens much finer than any previously employed, in order to remove every possible trace of dirt, slivers, etc.

The screens (which in Europe are frequently called "strainers") most commonly used for this purpose are flat diaphragm screens [1] (although rotary screens are coming to be preferred), the screening surface of which consists of a number (usually 12) of flat metal plates perforated with slits. These plates form the top of a shallow box, tray or vat, the bottom of which is made up of diaphragms which serve to suck the stock through the screens. These diaphragms are actuated by devices known in papermakers' lingo as "trotters." These trotters are simply arms attached to the

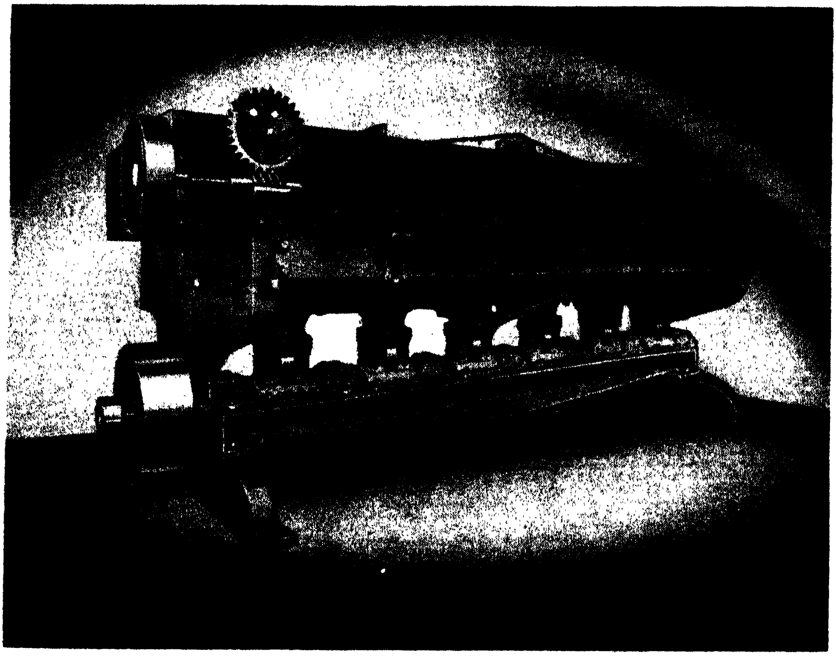
[1] About 1895 throughout America the diaphragm screen replaced the "knocker" or Gould screen previously in almost universal use, very efficient on rag stock but very noisy.



Courtesy: Socony-Vacuum Oil Co., Inc., New York.

FIG. 158.—Diagram showing delivery of stock to paper machine.

under side of each diaphragm and bearing at their lower extremity a toe-block, usually of maple, which rides on a cam having three or four drops to the revolution. The cams are mounted on a shaft making about 125 revolutions per minute and are arranged so the diaphragms are not in step, i. e.,



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 159.—Modern "packer" flat diaphragm screen equipped with roller shoe drive.

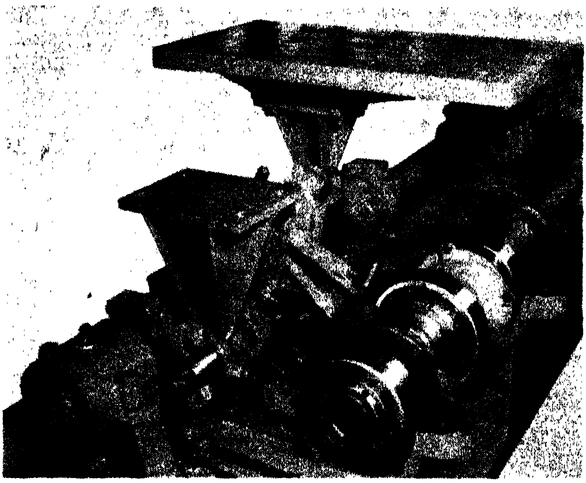
so one is up when the others are down or in intermediate positions (like pistons in a four cylinder automobile engine). The toe-blocks are removable, as they wear out and have to be replaced. The diaphragms are attached to the frame of the screen by means of a leather or rubber flap which is sufficiently flexible to permit of the up and down motion of the diaphragm, and at the same time affords a tight joint.

Dunbar drive: Recently greatly improved flat screens have been developed actuated by an eccentric antifriction bearing on the drive shaft which replaces the arrangement of cams described above. This actuates a lever and pitman arrangement as shown in the illustration. This type of drive is said to effect power savings of from 50 to 75 per cent, to eliminate almost all vibration and noise, and to reduce greatly the maintenance cost of the screen installation.

The size of the screen is such that it takes regular size plates 12 in. by 43 in. The screen is so arranged as to have sufficient outlet for its capacity. The size of the slots in the plate is governed by the kind of paper being made, ranging anywhere from 8 to 18/1000 of an inch in width.

Paper containing a large percentage of sulphite, kraft or any long-fibered stock will naturally require a screen having larger slots than paper made from a shorter-fibered stock. Sometimes the screens contain two different sizes of slots.

For instance, if a slot 12 or 14/1000 is a little too small to pass the paper stock, three or four plates may be taken out and replaced by 16 cut plates, for instance, at the upper end of the screen where the stock enters the screen through a large pipe or flow-spout. This pipe is usually equipped with a quick opening valve so each screen can be operated exactly according to its capacity. The stuff goes into the upper end of the screen and flows toward the opposite end and the rapid action of the pulp when it



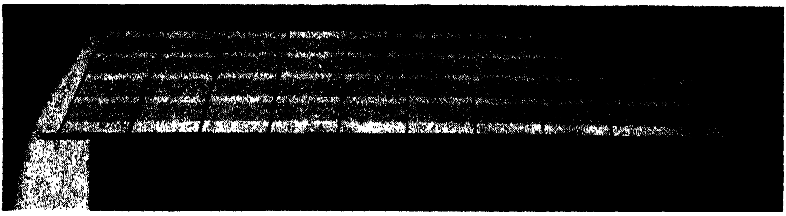
Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 160.—Dunbar patented eccentric drive for flat screens.

strikes the screen does not permit of the stuff standing on the 16-cut plates. However, a good portion goes through, but dirt and shives will not go through an account of the rapid stirring and agitation, so that the 16-cut plates help deliver the stock through without in the least increasing the dirt or shives in the paper.

Chromium Plated Screen Plates: Since time immemorial, ordinary bronze flat or curved screen plates had been standard in this operation, with the result that fine precision-sawed slots soon became worn, ragged and irregular. This condition effectively precluded consistent control of pulp size. The irregular slots also passed quantities of dirt and soon became so clogged as to require frequent cleaning during daily operation, in addition to the customary weekly shut-down, in order to operate at even approximately normal capacity.

Electrodeposition of chromium on screen plates, especially in the interior of the slots, provided them with a new, hard, smooth, and long-wearing protective coating. Despite the immediate success of this application, the difficulty of adequately throwing the chromium plate into the slots continued to be a technical plating problem. To overcome this, a new, patented, screen plate slot design was developed by plating engineers. Not only did this simplify plating problems, but it also alleviated to a remarkable extent the paper mills problem of reduced screening capacity through clogging of the slots. This in turn permitted increased and uniform production



Courtesy: Wm. A. Hardy & Sons Co., Fitchburg, Mass.

FIG. 161a.—Slotted screen plates, spot welded, the slotted sections being made from Monel metal or stainless steel sheet by gang sawing with an especially designed machine.

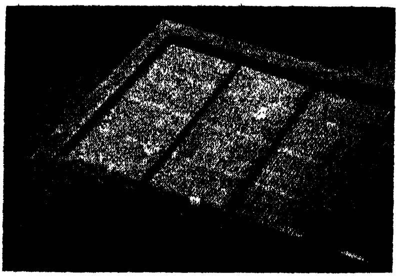


FIG. 161b.

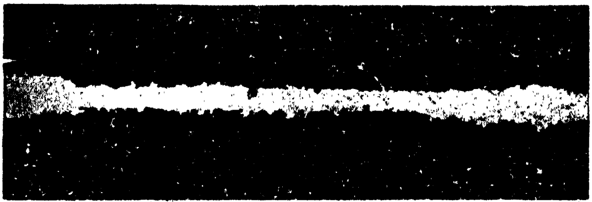
Under side of stainless steel screen plates showing slotted channels and supporting frame.

Courtesy: Wm. A. Hardy & Sons Co., Fitchburg, Mass.

schedules, resulting in definite operating cost reductions. Chromium's extremely low coefficient of friction has made possible the use of much narrower slots—some as fine as 0.005 in. (0.13 mm.) without measurable loss of capacity, resulting in a still finer finished sheet of paper. Many mills have benefited materially by being able to reduce slot sizes with chromium and thus make better paper without expensive or extensive equipment changes.

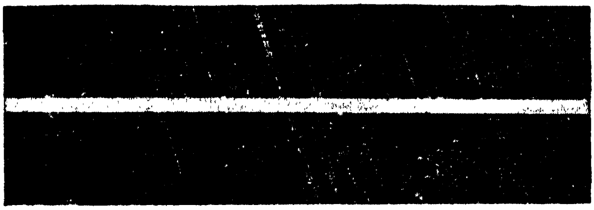
Operation of Diaphragm Screens: It is sometimes advisable to dam up the stock as it flows onto the surface of the screen plates by putting in cleats running crosswise of the screen, thus compelling the current as it flows over the dam, to zigzag and retard. In these cases it is arranged to have the fine plates at the dry end of the screw, or zigzag path, so that the large particles of dirt and shives are carried forward with the flow of the stock and finally come to rest at the dry end. If these plates were coarse the dirt and shives would finally jar through and get into the paper.

The screen is also equipped with adjustable dams at the outlet, so that the water and stock can be backed up under the plate at the desired distance from the plate. There is a point that is just right, which can be determined by experimenting a little with the dams. If the stock under the plates is kept at too high a level, i.e., too near the plates, the oscillation of the diaphragm will cause the stock to back up through the plates. Moreover, the long fibered stock might weave into cobweb-like particles. The slots in the screen plates are quite large on the bottom side and V-shaped, thus furnishing large grooves into which the stock would be continually beaten by the up-and-down motion of the diaphragm, and thus the process of weaving, alluded to above, set up. The cobweb-like accretions would



Courtesy: Chromium Corp. of America, New York.

FIG. 162a.—Ordinary bronze screen plate after ten months' service (magnified ten diameters). This plate was recut twice. Note ragged edges and widening of slot as well as roughness of surface.



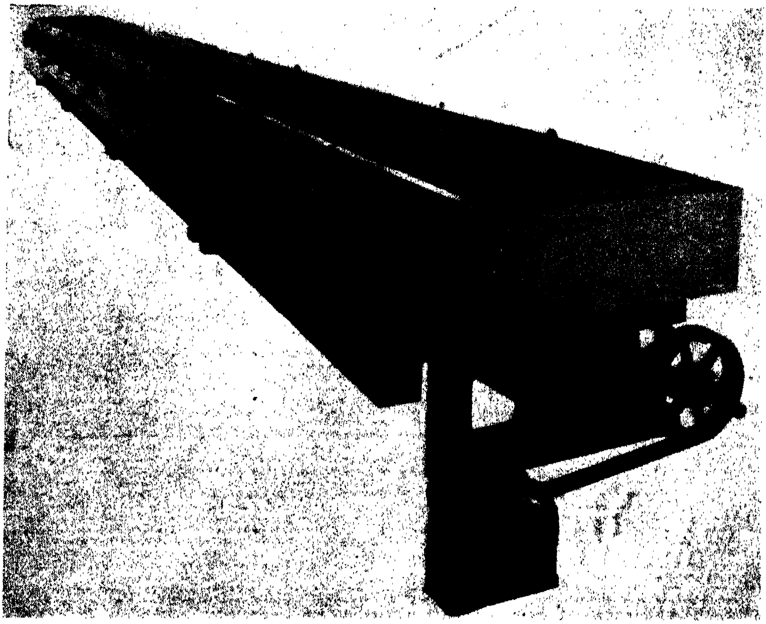
Courtesy: Chromium Corp. of America, New York

FIG. 162b.—Chromium-plated bronze screen plate after 24 months' service. Note complete preservation of slot accuracy, absence of wear of slot edges and smoothness of surface.

finally get so large and heavy that they would drop off and float out through the screen outlet onto the wire. These larger particles are almost sure to break the paper down on the wire, but if any of the smaller of them do pass, they make a large blotch in the paper, which is usually wet and spoils that portion of the sheet. Consequently, great care must be exercised in adjusting the dams and thus regulating the height of the stock under the screen plates.

A good way to decide the adjustment of the dams when the screens are in use is to stand up above the screens and watch their operation, gradually and carefully lowering or raising the dam as may be required. Care must be taken during this adjustment not to flood the wire when lowering the dam, or to cause any considerable removal of stock when raising the dam. Either of these courses would result in breaks in the paper. If the lowering or raising is done ¼ inch or less at a time the adjustment can be made and the proper height of the dam arrived at without stopping operations and without any injury to the paper that is being made.

Screen plates should never be walked on, especially with hob-nailed shoes, as the bars will become bent, thus opening the slots to an inordinate width, for instance, a slot intended to be 14/1000 of an inch will become possibly 24/1000 and will then let through coarse shives and dirt. If it is necessary to walk on the plates at at all it should be done by stepping on the toes and soles of the shoes and not allowing the heels to touch, but it is much preferable that the plates be not walked on at all.



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 163.—Typical flat screen with wooden frame as supplied to Maine book paper mill.

When the slots in the screen plates become filled with stock, the best way to clean them is to draw them out separately with a tool furnished by the screen plate makers, which is just small enough to go into the slot and pull out the fibers that have been caught in the slots and thus plug them up.

Some mills allow the machine help to use a wide, thin piece of rubber belting nailed to a handle, with which they clear the slots by pounding the belt on top of the plates. If this is allowed, great care should be exercised. Some predetermined thickness and weight of this slapper should be decided upon and the job should be entrusted to a careful workman. Otherwise the bars of the screen plate are sure to become bent just as if they had been walked on.

The screens should be taken up and washed thoroughly as often as is necessary. It is usually customary to wash the screens once a week by rinsing and scrubbing off all the slime that may have accumulated under the vats during the week. If the slime is allowed to accumulate for any length of time, it gets so thick that it will drop off from the walls of the vat and come through on the wire. Slime has no fiber to speak of and consequently a hole is produced in the paper just the size of the slime spot. It may not actually make a hole until the paper reaches the calenders, but it is sure to spoil the paper. Furthermore, it is likely to cause a break, and in addition, the slime spots often stick to the wire, causing a hole in the paper the size of the slime spot every time the wire makes a revolution.

The screens, in order to work properly, must be attended to just as faithfully as any other part of the machine. The toe-blocks of the trotters should always be kept tight and sufficiently long that they ride the cam, dropping into the depressions and riding over the top of the cam in a smooth way. Sometimes these toe-blocks get worn so short that only the very top of the cam touches the toe-blocks. Under these conditions no vibration is produced in the diaphragm at all. If one diaphragm is out of action in this way, it reduces the screening capacity of the equipment just 25 per cent, if there are four diaphragms to a screen.

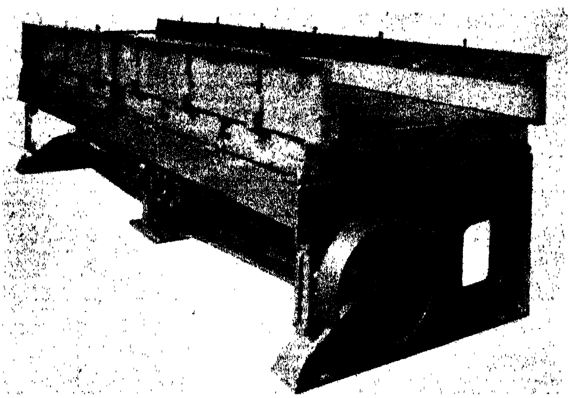
In the event of there being more than one screen serving the machine (as is usually the case) it is necessary to watch carefully the operation of the screens with reference to the stock supplied them, and each valve should be opened or closed in proportion to the capacity of the screen it is feeding. If there is any difference in the capacities of the screens, it is probably due to the cams or toe-blocks being worn, or some other thing affecting the oscillation of the diaphragm. Always try to have the diaphragm operate with a smooth motion which will produce an intermittent suction under the screen plates. The suction is to draw the fibers through and the pressure caused by the upward movement of the diaphragm afterwards releases the fibers on top of the plates, so that the plates will not become sealed. This is why a steady suction down through the plate (such as that produced by a vacuum pump) would not do; a suction of this kind would soon seal the slots in the plate.

Another point worth bearing in mind is that large particles of fiber, dirt, shives, and slivers are inclined to float, and if careful judgment is exercised, most of these can be floated to the dry end of the screens where they can be removed with a wooden or rubber-edged shovel.

The screen plates should never be scraped with metal harder than they are themselves. This produces rough, burr-like projections on the plates and prevents the fibers from dropping through the slots. In other words, clean, smooth slots of the right size should be maintained and care taken that nothing is done to get them out of this condition. In taking up a screen for a general washing, if chain falls are used or rope tackle, care must be exercised not to drop any of these articles on the screen plates, for they are sure to be bent.

It is customary, and quite desirable, in almost all flat screens, to supply a shower of water to drive and float the material toward the dry end of the screen. These showers are usually provided by a shower-pipe extending crosswise of the screen at some advantageous point, and the needle streams that come from the shower-pipe are inclined at such an angle as to sweep the plates in the most efficient manner. With some grades of paper white water is used for the shower, while with other grades nothing but clear fresh water is used.

When the screen plates are put into a screen extreme care should be taken to see that they fit perfectly on the wooden sills of the screen body. Every screw should be driven home so that the plate will lie perfectly flat and be perfectly water-tight all around the edges. Where the sills have become worn, a thin sheet packing or gasket is sometimes used. The continued use of a screen vat necessitates screen plates being taken out and put in, time after time. The screws go back into the same hole every time, on account of the holes being drilled through the plate by a template. The holes in the sills will finally become so worn that the plates will rise or unseat every time there is an upward stroke of the diaphragm, thus letting through an immense amount of dirt. The only cure for this worn condition of the sills is to renew them. Sometimes as a temporary makeshift, the holes can be plugged, but this is not generally recommended.



Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 164.—Flat screen with cast bronze screen vat. Bolts which hold the plate fasteners are located outside the screen chamber leaving the interior entirely free from obstructions.

There are several screwless screen plate fasteners on the market. These have devices by which the plates can be clamped down and fastened in tightly without screw holes. The Witham screwless screen plate fastener is typical of these devices. The plates are beveled, and beveled cleats of special form hold them in position, obviating the use of screws entirely.

Another point in connection with screens, worthy of consideration, is that the upper part of the screen body, carrying the plates, should always be carefully screwed or clamped to the screen vat and packing used to prevent this joint from leaking stock. The screens are sometimes placed in such a manner that it is hard for the workmen to get at the clamps to unscrew them, and in order to get them apart, the help sometimes use hammers, bars or weights. After releasing them a few times in this manner, the fastenings become useless. Good fastenings with proper packing will always keep the screen body tight, if treated with care. Leaks through the joint between the upper and lower parts of the screen body are bad because they reduce the suction under the plates, and maintain an untidy and wasteful mess of stock on the floor.

Some machine tenders have the erroneous idea that having the screen plates cut as fine as possible makes paper cleaner, their theory being that the finer the slot the less the large particles, such as shives and dirt, will go through. This idea of course is all right up to a certain limit, but where screen plates are so fine that they need constant stirring, it is detrimental to making clean paper.

The slots in the plates must be large enough to permit of the stock going through readily without being stirred. For instance, if 14 cut plates were being used and it were necessary to stir the screens constantly to get the stuff through, it would be far better to change these 14 for 16 cut plates. The exact limit must be determined by the kind of paper and the amount of work screens are required to do.

It is very poor judgment to equip any paper machine with a scant screen capacity, because the necessity of stirring the screens frequently not only delivers a lot of fine dirt through into the paper, but it also interrupts the weight of the paper. When the accumulated fiber in the screens is released by scraping, the weight of the paper increases. Since the drying is properly set for a certain weight of paper, the increase in weight will make the paper wet. When the screens are filling up the result following would be exactly the reverse. In other words the paper would become too light and dry. This would necessitate constant changing of the steam pressure in the dryers and would give all sorts of different weights to the paper, change its texture, change the moisture contained in the paper and cause no end of trouble. The screens must be adequate for the supply of the machine and the plates must be of such cut as will permit all of the stock to go through without constant stirring and attention.

As before stated, the best condition is to have the stock flow into the upper end of the screen and go through without stirring and have the large particles of dirt and shives flow out onto the opposite end of the screen onto dry plates, where it can be carefully removed with a wooden pointed scoop.

Rotary Screens.

Some papermakers prefer rotary screens to diaphragm screens because they believe that the advantages of this type of equipment more than outweigh the somewhat increased complexity of the mechanism.

The advantages claimed for rotary screens over diaphragm screens are as follows: With a fixed flat bed screen plates cannot be maintained at a uniform or constant degree of cleanliness for flat plates accumulate dirt; they fill up and foul until it becomes necessary to wash up. Consequently, there is a period just before washing up when the stock is dirty. By building the screen plates in cylindrical form, as in the rotary or revolving screen, it is possible to keep the plates clean all the time by a continuous shower.

Several makes of rotary screens are now on the market which have proved very satisfactory in operation. These are of two types; inward flow screens and outward flow screens.

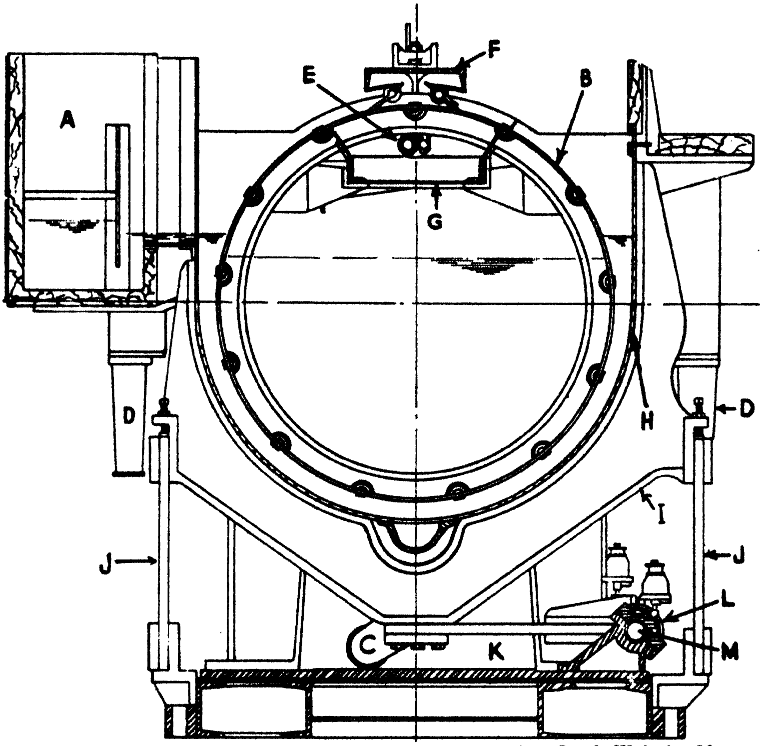
Courtesy: Bird Machine Co., South Walpole, Mass.

FIG. 165.—Two views of Bird inward flow rotary screen.

The modern rotary screen is designed to deliver a large volume of clean, uniform stock to the paper machine wire and in order to accomplish this objective the following factors must be provided in the design of the screen. These are (1) the width of the slots in the screen plates; (2) the total screening area (combining the slot width with the total length of slots); (3) screening action, by which is meant the proper control of the forces assisting the stock through the slots; and (4) proper removal of rejects. These factors are inter-related and no one of them can be neglected if the highest screening efficiency is to be attained.

Delivery of stock of maximum cleanliness calls for the use of the finest possible screen slots practicable for the grade of stock being screened. Slots as fine as .007″ are being used on some stocks and slots of .010″ are quite common in modern practice, this being much finer than was commonly employed a few years ago. The successful use of such fine cut screen plates has been made possible by the proper combination of the aforementioned screening factors. Total screening area must be sufficiently ample to permit the use of these fine plates with a controlled screening action which assures a gentle assisting force sufficient to help the fibers through the slots but not force the dirt through with them.

Typical of modern rotary screening equipment is the Bird Inward Flow Rotary Screen. The movement of the stock through this screen is clearly illustrated in the accompanying cross section view. The stock is fed to the flow box A which extends the full length of the screen. As the drawing shows, the flow box is equipped with a baffle to even out the flow to the screen itself. Stock is delivered to the screen in a quiet and even flow. It passes into the area between the revolving screen cylinder B and the vat H. From here it proceeds through the screen plates which form the shell of the cylinder and then through the open end of the cylinder to the flow box of the paper machine.



Courtesy: Bird Machine Co., South Walpole, Mass.

FIG. 166.—Cross-section of Bird inward flow rotary screen.

Dirt or any other foreign material larger than the screen slot itself settles to the bottom of the screen if it is heavy or floats on the top of the pond between the vat and screen cylinder. The heavy material is removed continuously through drain C and the light dirt is removed continuously through outlet D. These light and heavy rejects contain good stock and are therefore conducted to a small auxiliary screen or other means provided to separate the good stock from the rejects, the good stock being returned to the papermaking system.

As the screening cylinder revolves it is cleaned continuously by shower pipe E. The shower guard F is used to prevent splashing and to collect some of the water which is driven through the screen slots. On the inside of the cylinder and below the shower is a pan A which collects most of this water and removes it from the screening system.

The body of the vat H is made of copper and is supported by two semicircular brackets I. These in turn are supported by four vertical springs J, and connected to the bottom of each bracket are shake arms K attached to eccentric housing L. Eccentrics mounted on the shaft M provide a horizontal movement to the vat. This exerts the gentle force necessary to flow the fibers through the screen slots.

The cylinder is driven separately through a motor and worm gear reduction unit. The eccentric shaft M is driven through a motor and V-belt drive. A flexible connection is provided between the stationary end frames and the moving vat.

The practice of replacing old screens with modern screens having the capacity to permit fine cut screen plates plus efficient screening action has been exceedingly widespread and has resulted in remarkable reductions in dirt count, often 50 per cent or more. In addition to the efficient removal of dirt, the screen performs a valuable function in combing out the fibers before they go onto the paper machine wire and delivering to the machine a homogeneous mixture of stock and water free from lumps, strings and slime.

This is a very satisfactory screen for all grades of stock except those containing long, slow working fibers such as the stock for bonds, ledgers, writings, etc., which usually contain a large proportion of rag stock.

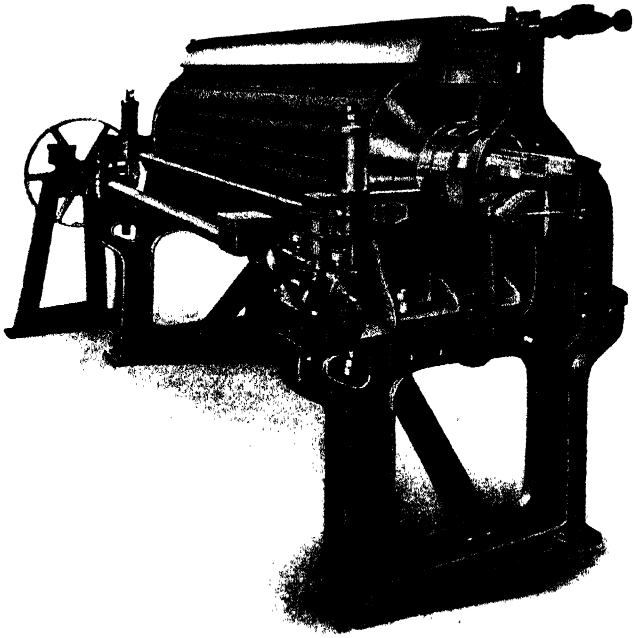
The inward flow type of rotary screen permits of greater capacity than the outward flow type and consequently is desirable wherever it can be used. It is suitable for newsprint, book paper, sulphite and mixed bonds, bag and wrapping papers, groundwood, and sulphite box board, chip board, roofing felt, rope, jute and sulphite specialties, etc.

The Walpole Outward Flow Rotary Screen: This screen is specially adapted to stock containing long, slow working fiber such as is used for high class rag papers. It is an adaptation of the Wandel[1] screen. The following is a description of the construction and operation of this screen: In construction the Walpole screen consists of a cast-iron vat and frames amply heavy to stand up and give long service. The vat is lined with copper or Monel, which prevents corrosion and discoloration of the stock. The cylinder plates are made of specially rolled phosphor bronze. The cylinder heads are of cast brass finished to offer a smooth surface to the stock. All fittings which come in contact with the stock are made of copper or Monel.

The stock is spouted into the cylinder through a hollow journal at the end; it drops to the bottom of the cylinder, passes through the slots into the vat, and thence to the paper machine. The rejections and impurities are carried up with the revolving cylinder and are washed out through the discharge pan by the shower. The cam shaft fitted with a six-pointed, round-faced cam at either end imparts an easy shake to the cylinder. This light,

[1] Developed in Germany by Christian Wandel about 1860 and formerly much used in this country in the old rag paper mills, but seldom seen today.

but positive vibration shakes out the massed fibers and effectively puts them through the screen plates well brushed out and ready for the paper machine. The only moving parts are (1) the cylinder, (2) the pivoted bearings which support the cylinder, and (3) the cam shaft. One pulley 24×4 inches constitutes the drive, which requires but 1 hp.



Courtesy: Bird Machine Co., South Walpole, Mass.

FIG. 167.—Walpole outward flow rotary screen.

The Bird Centrifiner.

To meet the modern demand for cleaner and cleaner paper, mills making high grade papers such as ledgers, writings and bonds, and specialties such as insulating papers, often treat their stock centrifugally in order to separate dirt according to its specific gravity as well as according to its size as is done in screens. This centrifugal treatment is called centrifining and it makes it possible for the papermaker to get an exceedingly sharp separation and positive removal of both the very fine, heavy dirt and metal particles and the very light dirt and rubber as well.

The Centrifiners are placed just ahead of the paper machine and the stock passes through three separate centrifugal compartments, each having a different centrifugal force. Uncentrifined stock passes from a gutter through a feed tube into the first revolving compartment. The stock flows upward passing into the second compartment at the top. It flows downward and into the third compartment at the bottom. Passing upward again it enters the skimming ring. Heavy dirt is thrown out in the baskets successively, the finest being caught in the last compartment. The skimming ring traps and holds the lighter-than-fiber dirt which may be removed continuously by a skimming tube device.

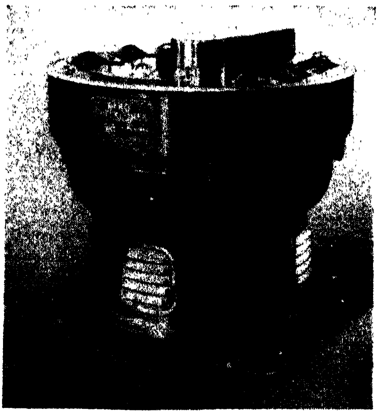
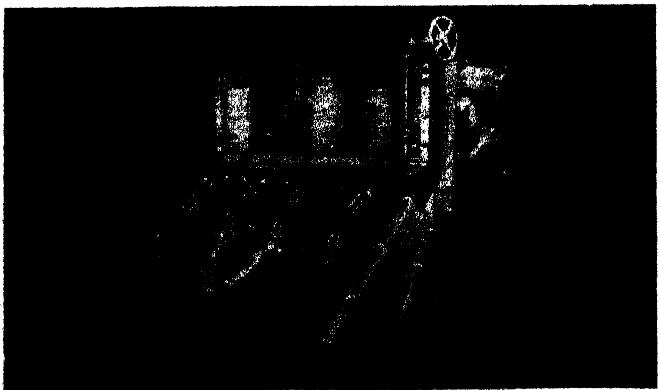


FIG. 168.
Bird Centrifiner.

Courtesy: Bird Machine Co., South Walpole, Mass.

Head Boxes.

The head box, or flow box, of a Fourdrinier paper machine is usually constructed of from three to four inches of hard pine or cypress plank, and perfectly tight. These boxes are usually strengthened with iron rods. The design of the head box should be such that it will deliver the entire flow of water and pulp mixture from the screens onto the apron and wire thoroughly mixed and not rushed on with any undue pressure which would



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 169.—Bertram flow distributor attached to Fourdrinier head box.

create currents and boiling action. Also the stock should come up to the last opening and be delivered onto the apron in a smooth sheet of stock, the full width of the machine. This stock should be thoroughly mixed, the fibers drawn out and separated.

When a head box is so constructed that one can see streaks of water and streaks of stock flowing onto the wire, apparently separated, arousing the homely expression that one can see a streak of fat and a streak of lean, meaning by this that the stock is not thoroughly mixed, it is not of the right construction and should not be used.

A head box usually has two or more compartments. The stock is usually delivered at the back of the box, taking it directly from the screen spout. Sometimes it is put into the box at the top, and allowed to fill the first compartment, striking against the partition and coming up and over the edge of the last partition and onto the apron.

The size of this head box is determined entirely by the volume of stock and water that has to be handled. Different conditions require a little different construction to meet them. Sometimes it is necessary on account of the location of the screen to enter the stock down low where it first goes into the head box. In this case the first partition next to the intake goes clear to the bottom and the stock in this case has to flow over the top of the first partition and underneath the next one. All of this is meant to spread the stock, to produce the mixture uniformly or draw it out as mentioned above. There is also provided an overflow at the back side of the flow box so that in the event of a gush of water caused by the screens filling up, by the uneven flow of pumps or by opening valves at the intake of the screens, etc., this overflow will pass from the end of the head box around into the pump box and to the screens. A gush of water distributed in this way will not as a rule cause any breaks or trouble on the machine, if it is worked carefully.

If the wire should stop (from the breaking of a belt or the slipping of a couch roll or for any reason) so that the stock must be shut off suddenly before the machine can be closed down in the regular way, the outlet to the apron would have to be shut off quickly while the stock was still flowing into the screen and head box. This overflow would take care of the most of this violent gush of water and flood the wire but little. The head box is also usually equipped with a lip at the outlet where the stock is distributed onto the apron and this lip can be raised by means of hinges on the under side. This lip is called the apron-board and carries the apron across the breast roll. When a wire has to be put on, this hinge on the apron-board permits swinging it back out of the way, thus giving ample room to take out the breast roll without difficulty.

Apron.

The apron is a shallow, flexible flap, over which the stuff flows onto the wire, thus bridging over the open space between the breast roll and head box. The apron is usually made of rubberized cloth. The slices, which are metal dams with perfectly level under edges, set vertical to the surface of the wire, dam back the stock, filling the apron with water containing pulp fibers and this is called the pond. The slices are raised one inch or less from the wire so as to allow all the water and fibers to flow onto the wire. The force with which the stock comes out of the pond and under the slices is in direct proportion to the height of the water in the pond. This head is regulated by the supply of stock and also by the height of the slices from the wire. Without changing the stock supply, the slices can be lowered, reducing the area of the outlet, which results in backing up the stock in the pond to a greater height. This performance has the effect of giving the stuff more speed as it is delivered to the wire. Reversing this process gives the opposite results. These changes must be governed entirely by the kind of paper being made. The stuff must be delivered to the wire at as near the speed of the wire as possible. The slices, in conjunction with the shaking of the wire, are what spread the fibers evenly and uniformly.

The slices when set very low catch the fibers and turn them on end, causing the sheet to have a broken, unfelted appearance. This is more noticeable when working long stuff, and it is the cause of the wavy streaked appearance of thick sheets. The thicker the sheet the more shake is required to felt it and when making a thick paper, such as certain bag and wrapping papers, for which the stuff has been made long, the slices will have to be raised so that enough water may be worked in to assist in closing the fibers.

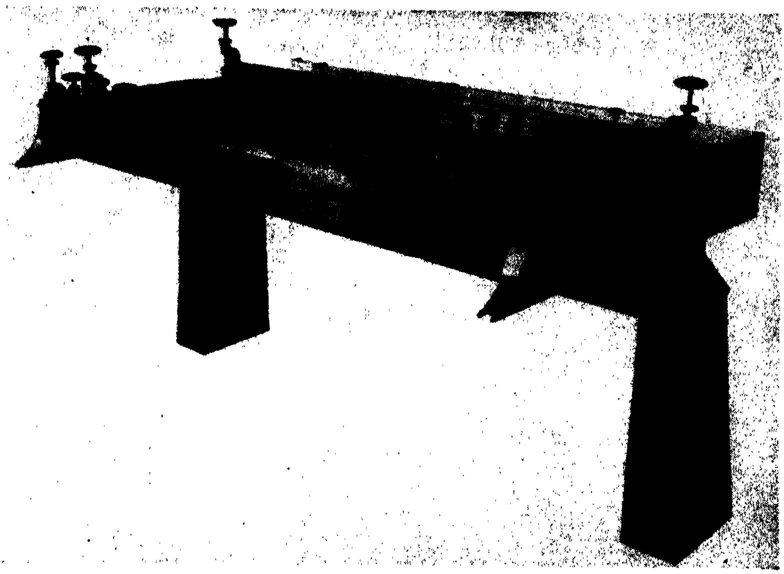
In starting a run the lower edge of the apron should be within about an inch of the first slice. This distance may often have to be varied later, depending on the particular kind of sheet being produced. When making a thin sheet from free stock, where there is difficulty in carrying the water nearly to the suction boxes, the moving of the apron clear down to the first slice will assist. Conversely when making a thick sheet from slow stuff the apron should be pulled back, possibly as much as two inches, depending on conditions to be met.

Slices.

The slices, of which there are usually two, are sheets of brass, ordinarily from 6 to 12 inches wide and about ½ inch thick. They are placed across the wire vertical to the surface of the wire. They are made in two sections which slip by each other in such a manner that the length of the slice may accord with the width of the sheet of paper being made. When the length of the slice is determined, the sliding device is held firm by thumbscrews. A device is also provided for up and down adjustments so as to regulate the even distribution of the stuff on the wire.

As previously mentioned, when speaking of the apron, in making all grades and weights of paper, the slices should be so adjusted that the speed of the wire and that of the stock will be as near equal as possible. This result is obtained by the pressure of the head behind the slices (assisted by the pitch of the wire in some machines). Some machines, especially modern high speed news machines, give a high degree of pitch to the wire, sometimes the difference in elevation of the two ends of the wire being as much as 18 inches.

Slices are carried high on free stuff in order to supply the great amount of water needed in free stuff to properly close it on the wire before it reaches the suction boxes. On slow stuff the slices must be carried close to the wire in order to reduce the quantity of water. This is due to the comparatively small amount of water that will drain out of slow stuff on the wire. In most cases when making heavy paper, the slices are carried close to the wire, excepting when the stock is free, when they must be properly raised to close the sheet. The slices are a very important factor in making a paper that must be close and uniform (in looking through). Generally speaking, when making the lighter weights of paper, the best results are obtained by only using one slice, especially if the machine is running more than 200 feet per minute; otherwise the sheet is likely to be blemished with bar marks running across it. When using two slices, the first slice should



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 170.—Neilson patented slice which combines the desirable features of a sharp edge, straight lip slice with the adjustable features of a curved lip inlet.

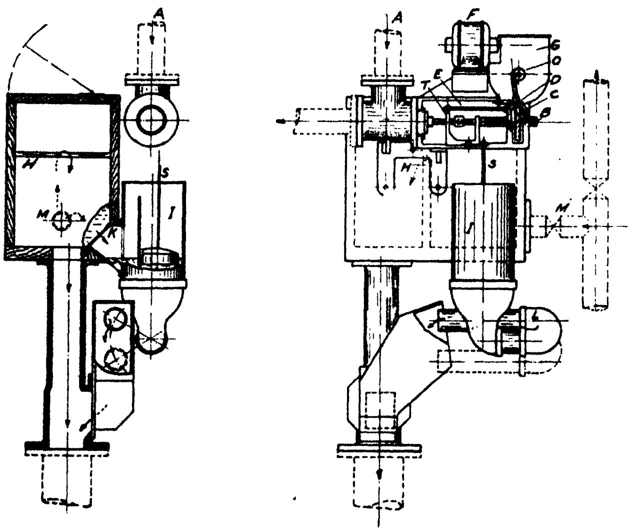
be twice the distance from the wire of the second one. This causes a current between the two and insures a thorough mixing of the fibers just before they pass the last slice. The width of the deckle also influences the position of the slices. The slices on a narrow deckle must necessarily be carried higher than on a wide deckle; in fact, the whole matter may be summed up as a question of obtaining the proper head behind the slices to equalize as nearly as possible the flow of stuff with the speed of the wire.

Consistency Regulators.

It was early noticed by paper makers that as consistency increased, there was more resistance to flow through pipes. Pipes of larger size were required, or greater head was needed through pipes of a given size. Below 1 per cent consistency, the frictional resistance is relatively low. From

$1\frac{3}{4}$ per cent to 5 per cent, the friction increases rapidly as the ratio of stock to water increases. This is the customary range at which stock is handled. For high density bleaching at 10 per cent to 18 per cent no suitable consistency regulator has yet been designed.

For uniformity of "basis weight" and quality, consistency control is desirable for bleaching, for slush beater furnish, for uniform jordanning and at the paper machine stuff box. Variations in consistency arise from two chief sources, slush storage and dumping beaters. No thickening apparatus is able to deliver stock to slush storage within the desired degree of accuracy. Unless unusual precautions are employed, there are considerable variations in the beater chest from one beater to another. Stratification will occur in stock storage chests where there is inadequate agitation, and this will also cause consistency fluctuations.



Courtesy: Trimbey Machine Works, Glens Falls, N. Y.

FIG. 171a.—Diagram showing operation of Trimbey consistency regulator.

The first devices seeking to maintain uniformity on the paper machine might be classed as automatic volume controls. When the stock became thin, the flow would be increased, and conversely the volume would be reduced when the stock became heavier. Most of the early regulators accomplished this to a certain extent either with restricted orifices, or with floats which would directly actuate volume control when consistency changes occurred. It may be said that these early regulators partially compensated for consistency variations, but left much to be desired. However, if the consistency coming to the stuff gate could be kept uniform, there would be no need for these volume control devices.

It is quite evident that the friction of stock flowing in pipes increases with consistency. Also, if a constant volume of stock is to pass through a pipe of a given size, it will require a greater head to maintain the same flow as the consistency becomes greater. Using these principles, Trimbey designed the first true consistency regulator in 1915. In place of a straight pipe, a goose-neck and return-bend were used for increasing the sensitivity to consistency changes by contracting and bending the flow lines. This arrangement is so sensitive to consistency changes that an increase of ¾ of 1 per cent will raise the level in the cylinder one foot.

The Trimbey Consistency Regulator, as illustrated in Fig. 171a, consists of a vat with an overflow dam and orifice, and a friction cylinder controlling the action of a motor driven water valve. A continuous sample enters "M" and supplies a constant volume to the cylinder "I" through the plate orifice "K." The excess overflows at "H." Friction in "I" and its outlet pipe "L" maintain a constant head as long as the consistency remains uniform, but this head changes decidedly with minute changes in density. Thinning water from a constant pressure supply is connected to the automatic dilution valve "A." From the valve "A," the water is con-

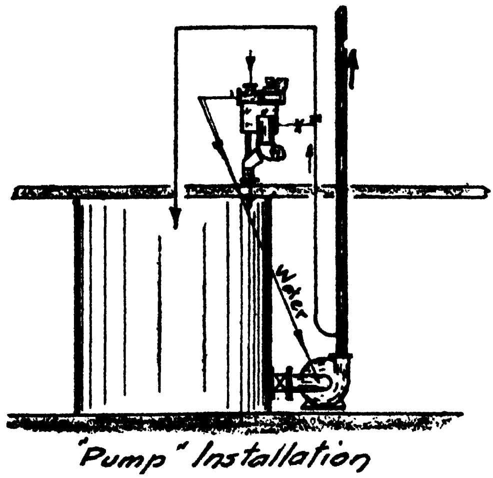


FIG. 171b.
Diagram showing connections for Trimbey consistency regulator.

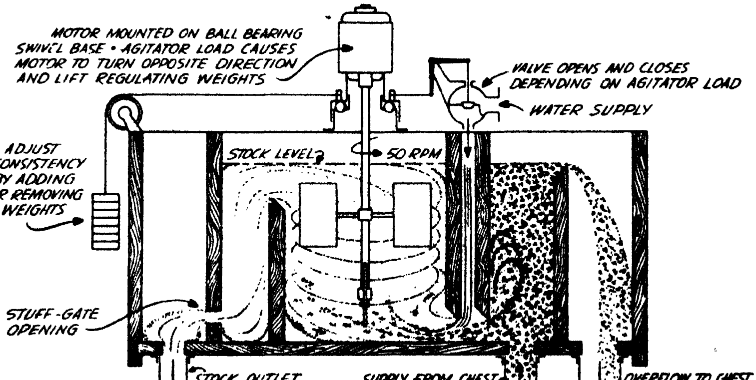
Courtesy: Trimbey Machine Works, Glens Falls, N. Y.

nected to the suction side of the centrifugal pump (furnishing stock to the Regulator). A pawl "D" connected to float stem "S" by link "E" and safety stop "T" is actuated by motor "F" through gear reducer "G" by an eccentric "O" and engages either side of a double faced ratchet wheel "C." This ratchet wheel operates the valve "A" through stem "B." Safety stop "T" disengages this pawl when the limits of valve travel have been reached.

Stock in storage chest must be somewhat heavier than is desired for regulated stock. The regulator will then automatically add at the suction side of the stock pump, the necessary thinning water to reduce it to the desired density. While only a portion of the stock goes through the regulator cylinder "I," all the stock pumped is controlled. When the sample is too heavy, the head within the cylinder rises, the float and float stem rise, causing the pawl to engage the ratchet and open the water valve. If the stock becomes too thin, the reverse action takes place. When the stock is of the desired consistency, the pawl is neutral with the water valve remaining unchanged and open a greater or lesser amount as may be required.

We wish especially to call attention to the fact that in the illustration, the thinning water is added at the suction side of the stock pump. It is, therefore, thoroughly mixed with the stock while going through the pump. The stock sample line is shown in Fig. 171b, extending six feet above the regulator vat, to insure more rapid circulation and greatly reduce any time lag between the addition of water to the pump, and the flow through the regulating cylinder "I." The sensitivity of the regulator is within 0.02 to 0.03 of 1.0 per cent and it can be controlled within limits of .1 of 1.0 per cent above or below the control point, providing, of course, that the supply is at least as heavy as the control point.

In the case of a plunger pump, the dilution water must be added and mixed in the regulator vat itself, because a plunger pump provides no mixing. Consequently, the size of the regulator vat is increased to handle the full capacity of the pump. This type of installation gives an even closer consistency control, because the time lag between the addition of dilution water and its effect on the regulating cylinder is materially reduced. In the same manner as in the pump type installation, only part of the stock passes through the regulating cylinder, but it is a true representative sample and does control the consistency of all the stock delivered by the pump.



Courtesy: Process Controls, Inc., Leroy, N. Y.

FIG. 172a.—Diagram showing operating principle of Meyers consistency controller.

The Meyers type of regulator is based on the power necessary to drive a modified agitator in a vat of pulp. The mechanism is so adjusted that when the torque goes above a certain point, dilution water is added, and if it falls below a given point, water is shut off. Those regulators that employ some outside power to regulate the water valve are to be preferred because any sticking or binding of the dilution valve will not destroy the sensitivity of the instrument. This type requires that dilution water be added in the supply pipe or the vat itself for best results. Addition at the inlet to a centrifugal pump would cause excessive hunting because of the rapid action of the dilution valve. The De Zurik regulator is similar in operation but has a multi-blade agitator.

Another type, the Poirier, seeks to maintain basis weight on the paper machine not only by adding water, but also by automatically changing the size of the stuff gate opening. Stock is fed from one chamber with a fixed head through an adjustable torturous passage into a float compartment with a stuff gate at its bottom. The friction of stock flowing through this torturous passage is enough to give a lower head in the float compartment. Difference in level in these two compartments becomes greater as the consistency increases. The float is linked so that it directly operates both the dilution valve and the gate opening.

The Sall consistency regulator, developed by Ekstrom in Sweden, comprises an indicator, impulse transferrer and regulating device. Fig. 172b shows a typical installation frequently used to control the consistency of stock ahead of paper machines. In other installations, only a sample of the stock is used for regulating purposes. The arrangement with a float is very sensitive and so the friction of the mechanism here is brought down to a minimum and the work the float has to do is almost negligible. The slightest variation in consistency will be felt by the regulator and immediately corrected. The Sall regulator can be installed and used at any place in a pulp or paper mill and can with different indicators regulate consistencies from 0.6 per cent to 12.0 per cent.

The indicator regulates the consistency of stuff by adding water in sufficient quantity to the stuff before it reaches the regulator. The standard indicator consists of a patented float device placed in an indicator box of patented design. This indicator box takes the whole quantity of the stuff or part of it. Fig. 172b illustrates a design of the indicator box frequently used for instance to keep the stuff on paper machines at a uniform consistency. This type of indicator box is used in cases where the consistency of the stuff has to be regulated from 1.5 per cent to 4 per cent. For stuff of lower or very high density other types of indicators are used. According to the illustration the control takes place between a stuff chest and the machine (paper machine, etc.) to which the stuff is pumped from the stuff chest. In this case the whole quantity passes through the indicator box, the size of which depends on the quantity of the production. (For about 275 gallons of stuff per minute the length, width and height of the box are about 4 ft. 7 ins. × 2 ft. × 3 ft.) The stuff first passes the inlet compartment (2), which is connected with the level compartment (12), from where part of the stuff passes through the outlet (3) to the float compartment (4). By means of a balance (7) and rods (8 and 9) the float is connected with a movable guide (10) fixed to the impulse transferrer. The remaining stuff passes from the inlet compartment to the level compartment where a constant level is maintained by the surplus stuff continually passing the overflow (5). The surplus stuff joins the stuff from the float compartment and returns to the stuff chest. From the level compartment the stuff is let out through the pipe line (11) to the machine (paper machine, etc.). Since the consistency of the stuff and the pressure in the level compartment are kept

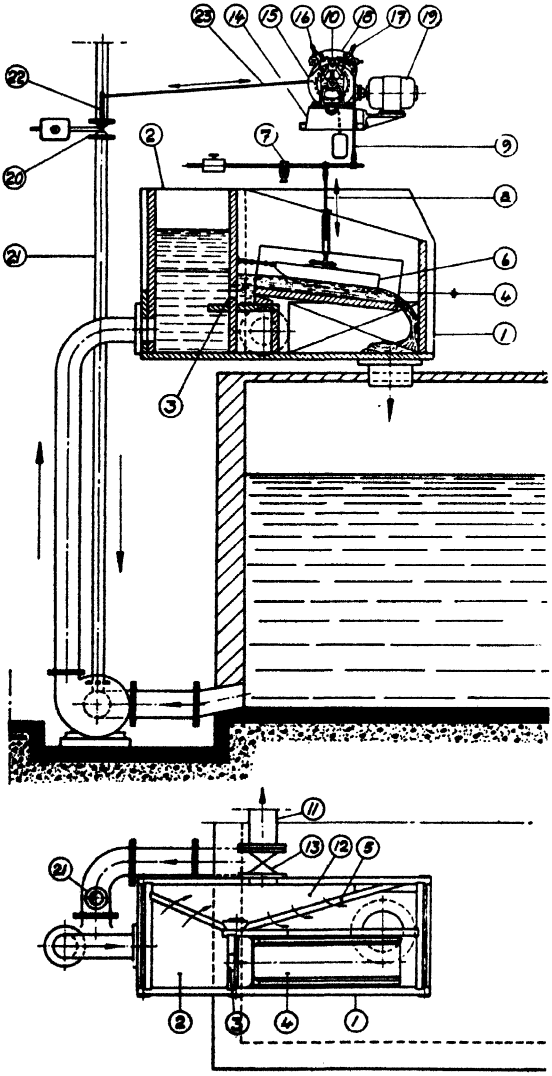


FIG. 172b.
Diagram showing operation of Sall consistency regulator.

Courtesy: Bird Machine Co., South Walpole, Mass.

constant a uniform quantity of stuff will pass through the pipe line to the machine at a certain position of the valve (13).

The patented impulse transferrer (14) is composed in main of a friction grooved wheel (15) and two pawls (16 and 17) of a patented special design. The pawls are fixed by means of links to a movable rod (18) driven by an electric motor connected to the impulse transferrer, the speed of the motor being reduced by a gear. The movable guide (10) which is connected to the impulse device, controls the engaging of the pawls with the grooved wheel. As soon as one or the other of the pawls engages the grooved wheel, the regulating device, in this case a butterfly valve (20), reacts to this movement, it being connected to the friction clutch belonging to the impulse transferrer by means of a chain wheel and chain.

The impulse transferrer and motor should be mounted on a common soleplate, carried on brackets, or on a wooden floor of 2″ thick planks which can be placed above, alongside, or under the indicator box.

The impulse transferrer which is chiefly of phosphor bronze, requires a space of 20 ins. × 20 ins. including the motor.

In most cases the regulating device is composed of a butterfly valve (20) of a special design connected between two flanges in the diluting water pipe line (21). The spindle of the valve has a lever (22) fixed to it, which is connected to the impulse transferrer by means of a chain (23). Where it is not suitable to draw the diluting water pipe line to the regulator, the chain is connected with a wire which can be drawn over pulleys if wanted. The valve is controlled by the impulse transferrer so that a smaller or greater quantity of diluting water is added, depending on the consistency of the unregulated stuff. In the illustration the controlled quantity of diluting water is let into the suction pipe of the pump.

Consistency regulators have many uses besides their application to paper machines. They are employed in bleaching systems; on deckers and washers; in the lines leading to Jordans and various sorts of refiners; in screening systems and wherever accurate control of weight of stock in proportion to volume of liquid is an essential.

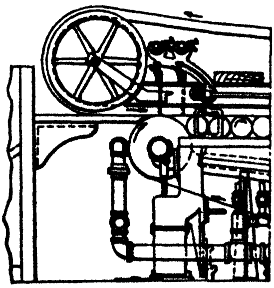
Breast Roll.

The breast roll is a hollow bronze roll, usually from 18 to 24 inches in diameter, with forged steel journals. In modern machines ball bearings

Fig. 173.

Breast roll end of Fourdrinier part of paper machine.

Courtesy: Socony-Vacuum Oil Co., Inc., New York.



are usual. As the breast roll is *driven by the wire* lightness, balance, ample lubrication of the bearings are all necessary. The ample girth is to relieve the strain on the wire. The breast roll is *never crowned* as this would stretch the wire. It is provided with a doctor. The journal protrudes at the end of the roll so that a *"porter bar"* can be slipped over it for use in removing and replacing the breast roll when changing the wire. Driven breast rolls have been experimented with, but are not advisable, in the writer's opinion, because of the great difficulty of synchronizing the speed with that of the wire, which takes its speed from the lower couch roll.

Fourdrinier Wires.

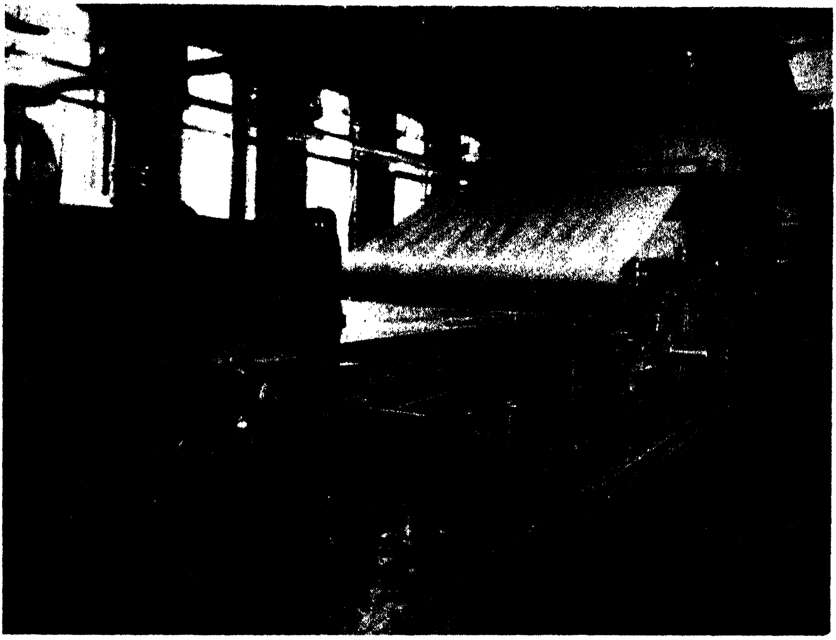
The strands of the Fourdrinier wire are made of especially annealed copper or brass, very finely drawn and woven into a web usually from 60 to 70 *mesh,* the term mesh referring to the number of wires to the inch, 60 to 80 being the most ordinary number as can readily be determined with an ordinary ¼-inch linen tester. Much finer wires are used for some special papers, such as cigarette paper. The wire is joined at the ends making an endless belt of wire cloth. Wire analyses used to show ordinarily 80 per cent copper and 20 per cent zinc. Today phosphor bronze is more generally used, especially on high speed news machines.

The pulp fibers must be thoroughly crissed-crossed and interwoven on the wire while they are being formed into the film or web. This is the only place on the paper machine where the fibers can be interwoven and properly felted so consequently everything must at all times be in first class condition. To assist in interweaving the fibers a shaking or sifting motion is imparted to the shake rails which carry the tube rolls and wire. This is known as the "shake" of the wire. Assuming that there is only 15 feet to 20 feet of making up surface (this length depending on the machine) on the wire, and with the machine running, let us say five hundred feet per minute, it is evident that only a very small part of a minute is allowed for forming the paper. The speed at which the machine is to be driven, and the nature of the stock to be worked, must always be taken into consideration when specifying the length of the wire to be used. For the proper working of short, soft, greasy stuff at the correct speed, a long wire is an advantage, thereby giving more time to allow the water to be taken out; but for fine, long stuff, not too soft, worked at a moderate speed, a short wire will be best suited. The speed must also determine the amount of pitch or inclination to be given to the wire.

In the case of high speed news machines (as mentioned above) running constantly 800 feet a minute or more, the wire may be raised at the breast roll end as much as 16 or 18 inches to give the necessary speed to the stuff. If the stuff were moving slower than the wire, the sheet would be rough and not properly felted and if the stuff should run faster than the wire it would accumulate in puddles causing streaks.

It will be noticed that when a wire after running sometimes becomes slack on either of the edges, it is generally the back side, if the water for the wash roll enters at the front side, and vice versa if the water enters from the back. The reason for this is that the small holes in the water pipes are apt to become choked at the end farthest from the inflow, and the wire owing to its being dryer is strained in its passage over the rolls.

Apart from this the wash roll should have a suitable doctor and a good strong shower in order that any pulp, which would become lodged in the meshes, may be washed out. Attention to this and also to thoroughly washing the wire, when shut down for any length of time, will keep the meshes clear, lessen the strain on the suction boxes, and improve the appearance of the sheet, in addition to prolonging the life of the wire.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 174.—Fourdrinier machine adapted to the manufacture of tissue paper viewed from wet end and showing "Yankee" dryer in background.

Having the wire too slack is another very frequent source of "snap-offs" or crackings and breakings in the sheet between the dryers and calenders. When the wire is too slack the seam of it is apt to crease the paper when passing under the couch roll, but in such a way that it is scarcely noticeable, unless the machine tender knows where to look for it. This is most liable to happen when making a narrow sheet of heavy paper, and the first thing a machine tender should do when he is at a loss to account for such breaks, is to hold a light under the web between the under couch roll and the wet felt roll, so that he may make sure if any creases are there. If the wire is causing creases they will appear like small black streaks running a little way in from the edge. Tightening up the wire a few turns and putting more weight on the couch roll will cure this.

Causes of Wire Deterioration.

(1) The destructive action of the couch roll through actual wear.

(2) The pitch pressed into the wire.

(3) Foreign substances passing through.

(4) Cleaning the wire with acids.

(5) Breaking of jackets.

(6) Accumulation of stock on the wire, breast rolls and carrying rolls through the use of imperfect deckle straps and carelessness and above all the operation of imperfect shower pipes with inadequate pressure. This may be corrected by concave deckles and installation of shower pipes delivering a continuous and unbroken spray of water at from 20 to 30 pounds pressure.

(7) Improper bearings on rolls and unbalanced rolls.

(8) Rolls out of alignment.

(9) Imperfect guides and guide rolls.

(10) Deep pond over the apron and heavy load on the wire. Except for high speed machines with inclined wire there seems to be no adequate means for relieving this load.

(11) Floods on the wire.

(12) Improperly dressed suction box covers.

(13) Inefficient management has a direct bearing on shortening the life of the wire. Lack of inspection, lack of cooperation, lack of incentive, contribute to a large extent to shortening the actual life of a wire.

(14) The importance of protecting the wire from injury in the store room until it is put on a machine is frequently underestimated. Unless there is a hearty cooperation and a real sense of responsibility there is likely to be trouble.

(15) Changing of wires. It is necessary that the proper facilities should be at hand when changing a wire. All parts of the machine should be thoroughly washed, cleaned and freed from slime and dirt. No foreign material or pulp should be left on the rolls, for this will cause ridges. Make sure before starting that the wire is perfectly straight, that the suction boxes are smooth, and that there is no greater tension on the wire than is absolutely necessary.

Putting on a new wire.

The wires necessarily being very fine and delicate, extreme care must be exercised in their handling, which should always be done by competent experienced workmen. A bruise or kink in these wires soon causes them to wear or break through, seriously shortening their service.

Defects in their manufacture should be observed, if possible, before they are put on the machine, and the wire should then be rolled back on the poles, boxed up and the manufacturer promptly notified of its non-acceptance. Slack edges, slack centers, poor seams and loops in the filling, known as slack shots, are all objectionable features. It is advantageous to have some smooth clean place in which to open up these wires, and have them inspected by a man who is competent to judge them, before they are put on the machine.

Wires should never be too tight when started, as they are thoroughly stretched before leaving the factory, and any undue strain on them shortens their service. On large machines the mere weight of the stretch roll is generally sufficient at the beginning, it not being necessary to screw it down.

It should be remembered that the strands of a Fourdrinier wire are not elastic, that is when once elongated by stretch they will remain so. Consequently, *the wire should never be stretched, when not in motion,* as this would lead to a permanent stretching locally whereas if stretch is applied slowly during one or more revolutions of the wire the stretching effect will be distributed evenly over the whole surface. Great care must be taken that the Fourdrinier part is thoroughly in line and level. If any of the rolls, especially the breast roll, is out of line a fractional part of an inch, a great deal of trouble is caused and the wire is liable to be run into a wrinkle. All the wire rolls should be of sufficient size and strength to prevent their springing at the center, as this usually results in a straight wrinkle in the wire which soon cuts through and destroys it.

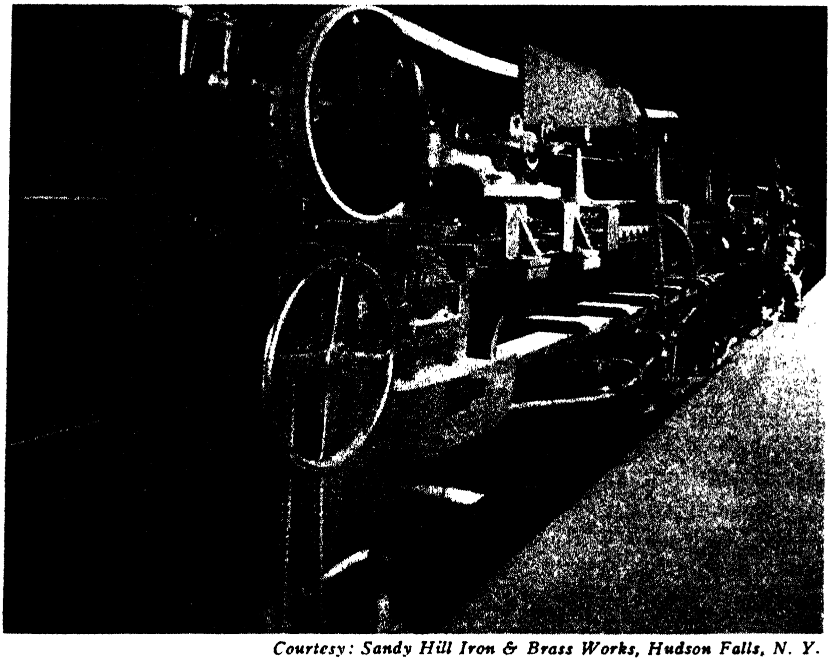
Starting a new wire.

Great care must be exercised in starting a new wire, first being assured that everything is in proper condition before striking in the clutch, which operation should be performed very gently. A clutch should never grip so hard that the wire is started with a jerk. It is found to be a very good plan to turn the wire around slowly, at least once or twice, before the couch is set down, thus getting the wire in proper alignment before starting up. The stretch roll must not be fastened down until after the top couch roll is lowered into place.

Suction boxes should be thoroughly dressed (see page 407) so that the covers are smooth and level; all rolls should be properly cleaned; wire guides should be properly adjusted. The seam of the wire should be watched closely so that neither end will run ahead of the other, but should line up with the suction box or a parallel roll. If the apron is held in place by copper tacks it is very essential that no tacks should be left around in any place where they can get into the wire. All particles of hard material must be brushed and rinsed off before the wire is started up.

The breast roll should be supplied with a doctor, or shoe, which is simply a level edge pressing firmly on the roll, to prevent stuff collecting on it. In addition to this there should be a strong shower of water passing through and in front of the roll and over the lip, so that all particles of stock may be washed away. There are different designs for these showers and doctors. In some cases a straight piece of square-edged board covered with felt is wedged between the end of the save-all and the breast roll; in other cases a wooden doctor leans on the roll and scrapes off the stock, which collects and passes into the save-all, and under which is the shower above mentioned; anything which the doctor does not remove the shower will.

If for any reason the wire is stopped and the stuff shut off, the shake should also be stopped, as there is danger of shaking the wire into a wrinkle when it is not loaded with a sheet of paper and held down by the suction boxes. If anything happens making it necessary to strike the wire out immediately without first having a chance to shut off the stock, such stock should be thoroughly rinsed from the wire before attempting to start again. The weights should be removed from the couch levers, and by all means the suction should be broken, where the stock has sealed the wire over the top of the suction boxes. This can be done by rinsing, or by rubbing the fingers across the top to break the suction.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 175.—Wire screen of Fourdrinier machine showing deckle straps.

Care should be taken to let up on the guard-board screws before striking the wire in, as many times the couch roll jacket is torn off by neglecting to do this. The guard-board should never be let down onto the jacket until after the weights have been applied to the couch rolls, as there is always slack enough in the couch roll boxes so that if the guard-board is let down before the weights are applied this slack is taken up in the boxes and the guard box will necessarily have to carry the weight of the weights on the levers. In setting the guard-board, great care should be taken to lower it horizontally, never allowing one end to go down before the other, as in this way the jackets would be torn off the couch roll.

If the wire does not guide properly when started, there is sure to be some good reason for it, and the Fourdrinier part should be very carefully examined. No attempt should be made to guide the wire by weighting one set of the couch levers heavier than the other. It frequently happens that the suction boxes will control the guiding of the wire. It may run all right without any stock, but as soon as the sheet is put onto the wire and the suction boxes take hold, the wire may hang to one side or the other very strongly. Sometimes this can be averted by giving the suction box-heads a little air, or swinging one end slightly out of alignment.

A guide roll located between the last suction box and the couch rolls, and on a level with the suction box, is intended to keep the wire running in proper alignment. This guide roll is controlled by an automatic device called the wire guide, which tends to correct immediately any tendency of the wire to get out of alignment. The guide roll is rubber covered, and the wire makes quite a sharp bend from it down to the lower couch roll thus allowing the guide roll to get a good grip on the wire.

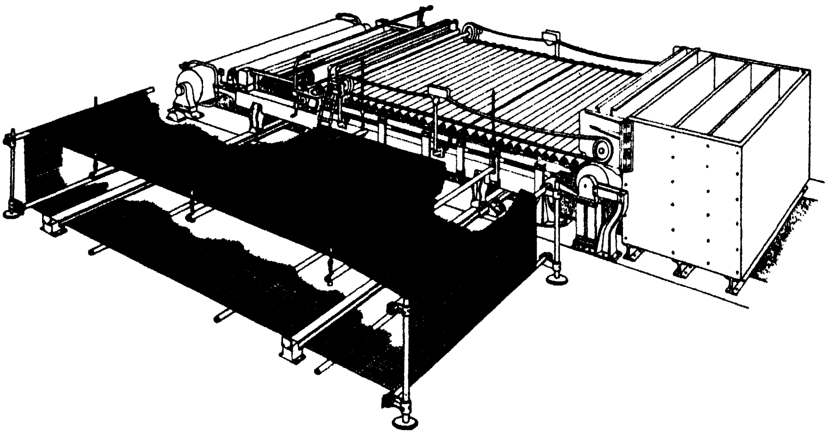
Care must be taken that good showers are furnished for the carrying or wash roll directly under the couches. The shower must strike the top side so that it will beat off the stock as it follows down around the wire. A good doctor also must be provided for this roll.

Stock should never be allowed to pile up in the save-all high enough to touch the wire. The cleaning of the stretch roll is another important feature. This should be well provided with good showers so that all particles of fiber may be rinsed away from the wire and the roll.

Removable Fourdrinier Part.

The wire is mounted on a wire carriage, as shown in Fig. 176, and all the inside wire supporting poles are inserted in the carriage inside of the wire loop. Next the carriage is moved down the aisle and the wire poles are inserted in the proper place so that the loop is formed as shown in the sketch. Then the remover beams are swung into place inside the loop and the *entire* Fourdrinier section from the breast roll to, but not including, the suction couch is rolled out into the wire loop. The horn or yoke which is shown surrounding the couch roll is then attached to the Fourdrinier rails and the end wire poles are inserted in this loop which forms a loop in the wire extended to go over the suction couch roll when the Fourdrinier part is rolled back into its operating position.

The advantage of this new arrangement is that the wire can be strung in the aisle while the machine is still making paper. Then when everything is ready, the machine is shut down and the Fourdrinier part rolled out into the wire loop and at the same time the pit under the Fourdrinier can be washed out, ready for the Fourdrinier to be rolled back into position. There is less danger of injuring a wire with this arrangement as the wire is not handled except when it is installed in the wire carriage, whereas with the other arrangement the wire bundle must be unrolled on tracks over the Fourdrinier pit. With this equipment a wire can be changed in less than an hour.



Courtesy: Beloit Iron Works, Beloit, Wis.

FIG. 176.—Beloit patented removable Fourdrinier part.

Shake.

There is much dispute as to whether Fourdrinier machines should have a shake or not. A shake is a device whereby the entire breast roll end of the wire is slightly swayed from side to side—the amount of sway being very slight—only $\frac{1}{4}$ to $\frac{3}{4}$ inch. Modern high-speed news machines usually have no shake. This is probably correct as it permits much heavier and more massive construction. But for slower, narrower machines making wrappings or bag paper or high-grade book or bond it is the writer's opinion that a shake is most highly desirable. Also at least one progressive machine builder has designed a wet end with a shake that operates with perfect satisfaction even at such high speeds as 1200 feet per minute and up to 350 shakes per minute.

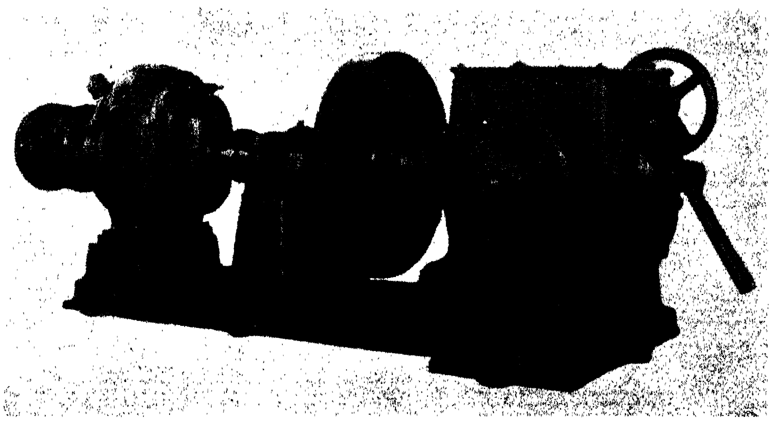
The Modern Shake and Its Effect on Papermaking.

Improvement in the formation of the sheet on the wire has been given much attention in recent years. While "paper is made in the beater," is an old and true papermaking phrase, properly beaten paper can be spoiled on the wire. Also, stock which is just off the proper degree of preparation in the beaters, can be made into specification paper if the papermaker has proper devices to control his formation.

Among these devices is the Bertram shake head.

Fig. 177 shows a typical arrangement of the device adaptable for any Fourdrinier, new or old. Its notable features are that it may be adjusted to sixteenths of an inch in the throw or oscillation of the Fourdrinier and that it will give any variation in the number of shakes per minute within the range of usual papermaking practice.

Other features are that the shake motion with the use of this shake head is positive. If set for three-eighths of an inch throw, for example, the Fourdrinier or table roll frame moves over exactly that amount, and back the same distance. There is no "bunt," or extra and unpredictable motion, nor will this "bunt" ever develop during the reasonable life of the shake head. Reference to the interior of the shake head as shown in Fig. 177 shows that this must be so. Instead of the small pin against which the eccentric motion of the older types of shake were carried, the large block, which is seen to be circular on the outside with a rectangular hole in its center carries on its large circumference the thrust of the oscillating Fourdrinier.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 177.—Bertram shake head.

The adjustment of the length of throw of the shake is made by the handwheel shown at one end of the shake head. This is readily accessible to the papermaker. By means of it a throw of one-sixteenth of an inch may be obtained, or this can be increased to seven-eighths of an inch in a fraction of a minute. Moreover, the shake need not be shut down to make this adjustment. Both the machine and the shake may be running when the adjustment is made. As the papermaker becomes accustomed to the use of this type of shake he can watch his sheet on the wire and bring the sheet to any point which his judgment of its appearance deems desirable.

The adjustment of the frequency of the shake is made just as readily. The type of shake shown is driven by an alternating current motor through a variable speed changer. The small handle shown is used to adjust the frequency which may be carried from one hundred to five hundred shakes per minute in less than one minute.

On both the length of throw adjustment and the frequency adjustment are indicating devices. A satisfactory combination of the two for any grade or weight of paper may be noted on the production report. When this order is run again, the shake may be set at the determined points and further adjustment is likely to be at a minimum.

Purchasers of paper who have modern testing instruments available buy their paper on strict specifications. These specifications may be met or missed where the paper is formed on the Fourdrinier. The shake is one of the most important factors controlling formation. The Bertram shake gives the papermaker a precision instrument for controlling his formation and being sure of meeting specifications at the point where the paper is made, instead of waiting for a test of the finished sheet.

Deckles.

The deckle straps on a Fourdrinier paper machine are made endless, of soft rubber; $2 \times 2\frac{1}{2}$ inches square being a common size. They run over flanged pulleys like an endless horizontal belt, the upper strand being supported by the flanged pulleys, and the lower strand by the wire which carries the strap along with it caterpillar fashion by friction. These deckles are set at a width corresponding to the width of the pond, slices and apron, and on this depends the width of the sheet being made. The length of the deckle is from the pond to the third suction box. The flanged pulleys are made to move in or out—narrow or wide. When they are moved the deckle strap moves with them. In this way the width of sheet is determined. These straps are very easily injured. The slightest crack or bruise on the edge will cause the paper to break at the couchers, presses, dryers and calenders.[1]

The deckle straps, as they lie flat and square on the wire, prevent the fibers from spreading—they act as dams $2\frac{1}{2}$ inches high, holding the stuff on the wire. The edges of the web are moulded against the straps as the straps, wire and stuff are all carried forward together. In order to mould a square and safe running edge, the water must be extracted so that the fibers are dry enough to stand up, after leaving the straps. It is for this reason that two or three of the suction boxes are placed under the straps. Modern high-speed machines usually have six suction boxes, three placed under the straps and three between the straps and the couch.

Deckle straps should be handled with extreme care when putting on a wire or making other repairs; avoiding having the strap come in contact with any sharp edges of any kind. They should never be tied up out of the way with a sharp string; a broad piece of wool felt should be used for this purpose.

[1] Note the deckle straps in Fig. 175, and Fig. 205.

Spare deckle straps should be kept immersed in water and never should be wound up in a tight roll. New deckle straps should be unpacked as soon as received and laid in a vat of water. If necessary for any reason to keep a deckle strap out of water for any length of time its position should be changed each day, as they rapidly harden and become rigid in whatever shape they are left in. Should a strap become nicked on the edge, or otherwise injured, it should be replaced and sent to the factory to be reground. No oil or grease should be allowed to come in contact with the straps, as, like all rubber goods, they are easily ruined thereby.

Tube or Table Rolls.

The Tube Rolls [1] are a number of parallel rolls of steel or brass tubing designed to support the wire by forming a level table on which the wire runs. Hence they are often called table rolls. The tube rolls are small, rarely more than 2 inches diameter, although on modern very wide machines tube rolls as large as 6½ inches diameter have been used. Their journals are supported in bearings adjustably attached to the shake rails. Those at the breast roll end, and under the pond and slices, should be somewhat larger than those forming the balance of the table to prevent springing under the excess weight of the pond. If a tube roll gets out of order it should be replaced at once, as the wire running over a stationary roll would soon wear a flat place on the roll. The machine tender should also look out for rolls with sprung journals, as these will cause the roll to be off center with the result that it produces an elevation in the wire, each revolution puddling the stock and causing thick streaks in the paper. If a roll can't be kept running it is always best to lower it out of touch with the wire until it can be replaced by another one. The tube rolls do more than support the wire: they carry off water by friction from the under surface of the wire. For this reason they are a much more important element in the paper machine than is often realized.[2]

Guide Roll and Wire Guide.

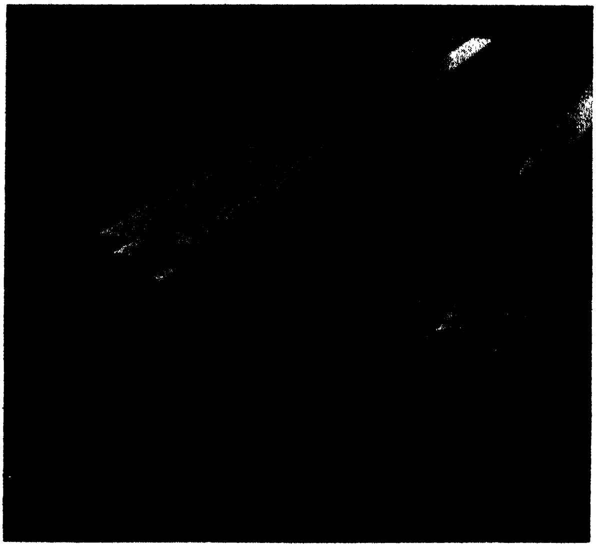
The guide roll is located right back of the couch rolls.[3] Actuated by an automatic device it can move forward or backward at the front end, thus keeping the wire traveling true at all times. Each machine builder has a patented wire guide system of his own, but they all work on the above principle and are essential.

Suction Boxes.

Suction boxes are long, narrow, brass boxes fitted with wooden (maple or mahogany) covers, perforated with round, one-half inch holes or other openings, so arranged that every particle of paper that passes over

[1] Note the tube rolls in Fig. 174, and Fig. 205.
[2] Note the table rolls in Fig. 205.
[3] For details on the couch roll see page 410.

them comes in direct contact with the suction without breaking the paper. In Europe these are often called pump boxes. The holes frequently flare a little from the under side so that accumulations of slime, etc., will tend to drop out. To the under side of each suction box is attached a set of pipes, leading to a vacuum pump regulated by valves, so that the vacuum can be regulated on each individual box. Furthermore, plungers are attached at the ends of these boxes which can be moved in and out in accordance with the width of the sheet. As the layer of fibers in water touches the machine wire there is approximately 99½ per cent water, but as the layer of fibers passes over the box on the top side of the wire, water is drawn out through the suction holes and pumped away, leaving about 90 per cent of water in the thin sheet before it passes between the couch rolls and on through the press rolls and dryers.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 178.—Kamyr patent rotary suction box, especially efficient on heavy board machines.

At least two, and sometimes eight or more, suction boxes are used. Using too few boxes with too high a vacuum on them is very hard on the wire. About 10 inches vacuum on the mercury gauge is the highest that should be permitted and less than that is better practice. Recently oscillating suction boxes have been introduced:[1] this prevents scoring of the suction box tops and lessens wear on the wire, but it involves another moving part on an already complicated machine. To maintain the vacuum rotary and hytor pumps have largely replaced the old-fashioned recipro-

[1] Invented by Louis Jurgeson of Grand Rapids, Minn., who sold his invention to Beloit Iron Works, who use it on all their high speed news machines.

cating vacuum pumps. If the latter are used they should be equipped with air separators as the suction boxes draw in air with the water in relatively large amounts.

When a suction cover is dressed it should be done after the cover is screwed on the box, the whole box being removed and supported on two horses at each end, just as it is supported in the machine. Otherwise the top of the box will appear true until placed on the machine when it will be found to sag slightly in the middle. The millwright should use a jointer, not a jack plane, and an accurate straightedge.

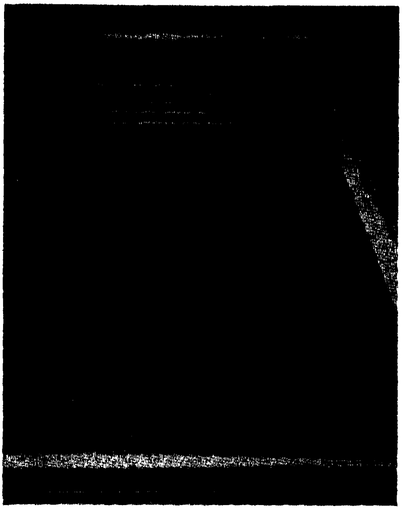


FIG. 179.
Three Monel metal suction box covers for Fourdrinier board machines.

Courtesy: Charles Mundt & Sons, Jersey City, N. J.

Dandy Rolls.

The function of the dandy roll is to smooth down the surface of the sheet while it is still in formation and capable of being moulded. Moreover, the dandy roll is used to watermark the paper, in grades where a watermark is desirable. Recently other means of watermarking paper have been devised but watermarking with dandy rolls is still the general practice. The usual purpose of a watermark is to identify the paper of a given manufacturer. It is usually a name or a trade-mark, although watermarks for purely ornamental purposes are sometimes employed. Every postage stamp collector knows how important watermarks are in identifying different issues of stamps.

The dandy roll must be light in construction and yet rigid enough not to spring. It must be sufficiently open in construction that it will not fill up, since if even a spot on the dandy is filled up it will lift the paper at that point. There is no shaft running through the center of the dandy. It is a fabricated roll, being made up of comparatively heavy wire, supporting lighter wire outside. The journals are attached to discs at each end.

The dandy roll is usually placed between the suction boxes. If a machine has six suction boxes under the wire, four are behind the dandy and two are ahead of it. The four behind prepare the sheet for the action of the dandy and the two following suck it dry ready for the couch rolls.

The dandy should never be placed right over a tube roll. It should be placed between two tube rolls, but the distance between centers should never be so great as to allow any sagging of the wire under the dandy.

The dandy is usually supported in "U" shaped bearings in such a manner that the weight of the dandy always rests on the paper. It must never drag on the paper.

The circumference of the dandy is so calculated that the watermark will register in just the right place on the sheet. That is, if one is making note paper or typewriter paper of a certain size it is desirable to have the watermarks come so that when the sheet is cut up the watermarks will be in the center of the sheets and not at the edges or chopped up by the cutting. It is possible to do this with wonderful precision. The paper on which the postage stamps of many countries are printed is so made that when the sheets are printed one watermark comes exactly in the middle of each stamp. Shrinkage of the paper has to be considered in this connection.

In a mill making fine writing paper or government papers for bonds, postage stamps, documents, etc., a large assortment of dandy rolls has to be kept on hand. Some of these rolls are very expensive, especially in connection with intricate watermarks (for instance the large coat-of-arms of the United States used on some government stationery) and this is an important item in such mills. Of course, many mills not making any watermarked paper use dandy rolls for smoothing out the sheet, but such dandys are much simpler and less expensive than those used for watermarking.

If, on looking across under the wire, directly beneath the dandy, the wet streak always present under the dandy at the point where it touches the paper, does not run right across the sheet, it is an indication that the dandy is not pressing hard enough on the paper at the side where the sheet is dry, that is, it is riding in the journals, which must be adjusted to correct this defect.

The dandy is usually kept clean with a shower from a pipe supported by the supports of the dandy roll. Back of this shower is a wiper which keeps the dandy smooth and free from stock so that when it comes in contact with the paper it is perfectly clean. Some dandy rolls have internal showers, which is done by running a shower pipe through hollow journals.

It is easy to tell when the dandy needs a thorough cleaning, because it begins to pick up the sheet persistently. When this occurs the dandy must be taken off and cleaned. The right way to do this is for the machine tender to stand at the front end of the dandy and the back tender at the back end. They carefully lift the dandy from its bearings, and if this is done quickly and skilfully the paper will not be broken. Then the machine tender up-ends the dandy and places it on a pair of supports on the floor convenient to the machine. The roll is now scrubbed with dilute vitriol (sulphuric acid) care being taken that this acid is not too strong. A little acid should be added to water in a pail. It can then be tasted by sticking one's finger in it, and if it tastes about as sour as lemon juice it is all right to use. The acid is applied with a wire scrubbing brush in a thorough but careful manner. Finally, the dandy roll is thoroughly washed off with clean water. A steam hose is sometimes of benefit in cleaning a dandy roll.

When clean, the dandy is replaced in the same manner as when it was removed, care being taken to give it a little twirl in the direction of the movement of the wire when it is placed in the journals, and if this is done properly the paper will not be broken. Of course, it is always advisable to see that the dandy is clean before starting the machine, but if it becomes dirty while running the cleaning can be carried out in the above manner in about fifteen minutes.

Sinclair Open End Dandy Rolls.

Important recent improvements in dandy roll equipment are the open end dandy roll which is an old idea adapted to modern needs, and the Sinclair single pedestal stand, a combination of all the functions necessary for the good operation of a dandy roll in a compact workable unit. The present day rolls have the additional function of necessary brackets to oscillate the water shower that runs on the inside of the dandy roll as well as the steam shower. The steam shower inside these rolls is very useful but the steam must be used with moderation.

The dandy roll is of machined spiral double truss construction. Various meshes of wire cloth are used in covering these dandy rolls depending on the type of paper to be made. For news there is a special flat bronze material and for book, flat bronze as well as lightweight Monel wire cloth. All these coverings are designed to reduce to a minimum any wire mark occurring from the dandy roll. The seams employed in joining this wire cloth are a special wireless all-brazed seam, which eliminates the stock filling up in the seam, always one of the difficulties encountered with the sewed or stitched joint. These modern open end dandy rolls are built for all types of machines, from those manufacturing special lightweight cigarette paper up to and through all grades of paper made on Fourdrinier machines including kraft and news running at high speeds.

The distance between the wire cloth covering and the inner frame structure of these Sinclair rolls is the greatest yet attained in any dandy roll structure. This condition permits the water accumulating on the inside of the roll to flow between the longitudinal rods and the covering, eliminating the possibility of filling in this area, and consequently bar marking the paper. These rolls can be built either crowned or straight and are mechanically perfect in regard to trueness and balance.

Couch Rolls.

As the web of paper is carried with the wire after passing over the suction boxes, it passes between couch rolls where it is further squeezed to take out more water. These rolls are from 20 to 36 inches in diameter, both upper and lower couch rolls being the same. The bottom couch roll is made of brass carefully ground to a smooth and true surface. Around this roll the wire passes. The top couch roll is made of the same material but is supplied with a seamless tube made of wool called a jacket. A large amount of pressure is put on top of the couch roll by means of levers and weights. This jacket is put on dry, sewed around (generally with sisal cord) at the ends and shrunken in with hot water. The shrinking should be begun in the center working toward each end.

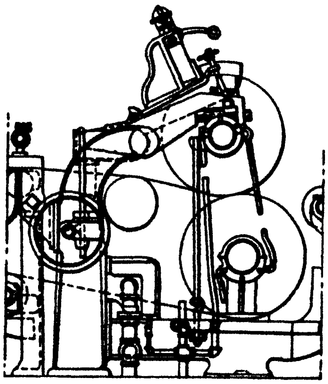


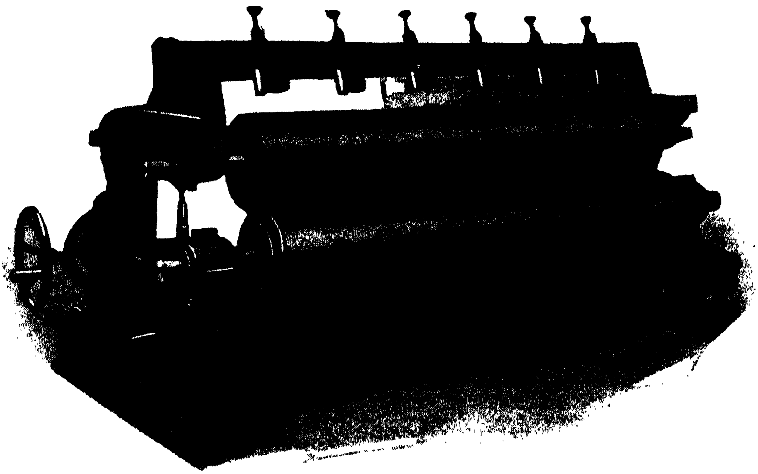
FIG. 180.
Couch roll screen of Fourdrinier machine.

Courtesy: Socony-Vacuum Oil Co., Inc., New York.

The bottom roll is connected with a clutch to a driving cone or is driven by an electric motor in the case of modern sectional electric drive and serves to drive the entire Fourdrinier part.

The top roll, which is driven by the bottom roll via the wire and the forming sheet of paper, contains numerous perforations through the shell which serve to let out any water, stock that may press through the jacket, and lint from the inside of the jacket which would otherwise create lumps which would be very harmful because of the pinching effect on the paper. These lumps would also be an obstruction to the guard-board lip as the roll revolves.

Guard-Board: The Guard-board is made from a heavy cypress or hard pine plank from 18 to 24 inches wide and 4 inches thick and trussed on the back side—also over the top. It is supported at each end by brackets extending from the upper couch roll housing. It bears a maple lip about one inch thick beveled down to about ¼ inch on the lower edge. This lip is attached to the guard-board with iron brackets. Springs are provided between the lip and the brackets allowing for some up and down motion. This lip presses on the couch roll jacket at such an angle as to press out moisture and retard any pulp or particle of dirt, but not at such an angle as to chatter. Immediately in front of the guard-board lip is a shower-pipe extending across the couch roll to facilitate the removal of pulp and dirt, keeping the jacket clean. The lip touches the roll at a point back of the center making a shelf for water to rest in. Just in front of this shelf is a wiper consisting of a strip of felt hanging from a wooden bar extending right across the roll. This wiper assists in the maintenance of the pond of water.



Courtesy: Pusey and Jones Corp., Wilmington, Del.

FIG. 181.—Couch roll showing Gately patent spring guard-board.

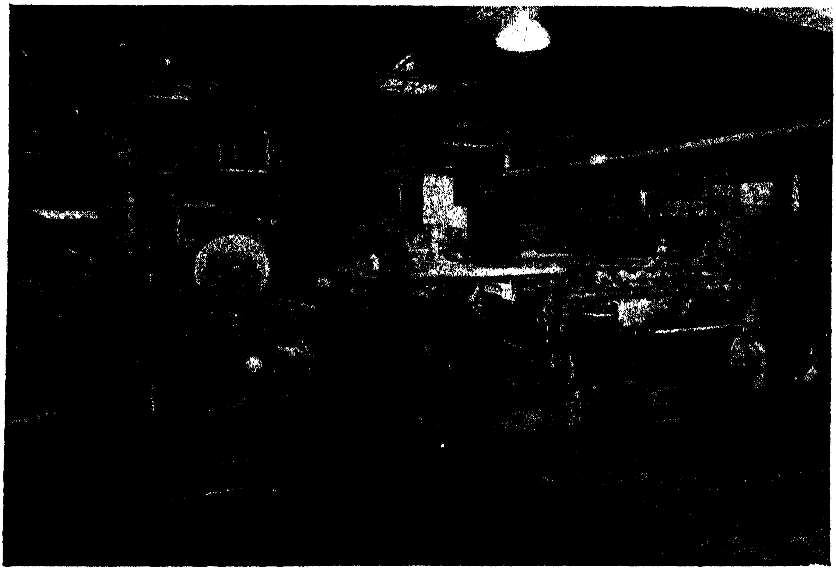
Couch Roll Jacket: Either through faulty construction, pulling, shrinking or stretching, the couch roll jacket will sometimes give poor service in several different ways.

The most common of these troubles is for the jacket to stretch in the center, owing to the center constantly traveling faster than the two ends because of the slight crowning of the bottom roll.

If faults of this kind develop it does not necessarily indicate that the jacket is of faulty manufacture. The best possible jackets can give poor results if the weights on the couch roll are not kept even at the two ends, if the guard-board presses unevenly or for many other reasons.

If the jacket should stretch in the center, the slack will generally remain in one position, a little behind where the upper and lower rolls meet, and unless the slack is excessive no harm will be done. If the slack becomes excessive, the machine must be shut down and the couch roll lifted, just as if a new jacket was to be put on, and then the jacket pulled forward and the ends re-sewed to take up the slack.

It should be noted that the center of the top couch roll is set back from 4 to 8 inches from the vertical line running through the center of the lower couch roll. This is so the wire, and consequently the paper forming on it, will be gently squeezed against the roll before being subjected to the heavy pressure where the two rolls meet. If the film of pulp in water were suddenly subjected to the full force of the pinch



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 182.—Suspension type Fourdrinier machine showing couch and wire screens.

the paper would be "curdled" or "crushed" and the forming of the sheet interrupted. Moreover, this arrangement gives a straight fall-away for the water squeezed out by the rolls which would have to run around the circumference of the lower roll if their centers were set in a straight line.

Stretch Rolls.

This roll is located inside the wire back of the couchers. It is usually about 10 inches diameter of either steel or brass. It can be moved vertically up or down by a handscrew. The tension of the driven lower couch roll will ensure that the upper part of the wire (that on which the paper forms) runs tight. The return half of the wire is more or less loose. As the wire grows older it slacks up a little. This slack can be taken care of with the stretch roll. That is the true purpose for which the stretch roll is provided. However, extreme care should be exercised not to put too much tension on the wire. It is very easy to ruin a wire utterly in this way.

Press Rolls.

The first press comes next to the couch rolls. The bottom rolls are made of iron covered with an inch of rubber, the surface being ground perfectly round and true and slightly crowned. On top of these rest wooden rolls from 24 to 30 inches in diameter. Between these rolls runs an endless woolen felt (sometimes known as a wet felt to distinguish it from dryer felts that will be dealt with later on) which runs over a system of supported rolls and a stretch roll to keep it taut. The web of paper is taken off the couch roll, and much of the water is taken out by squeezing through this massive wringer.

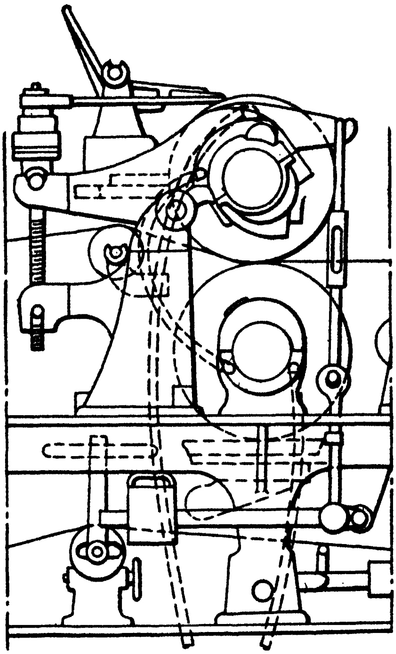


FIG. 183.
Press roll section of Fourdrinier machine.

Courtesy: Socony-Vacuum Oil Co., Inc., New York.

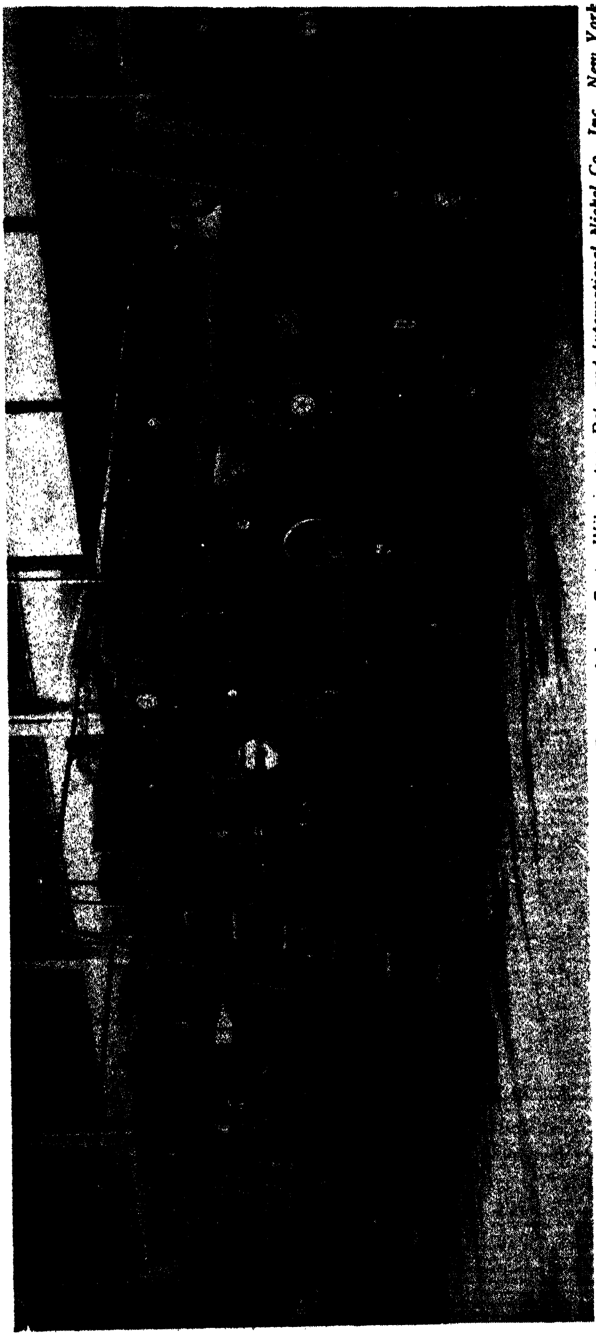
Press rolls are very essential indeed. The web of paper runs through each set of these rolls and the top roll is connected upon each journal with compound levers. On these levers are heavy weights and, as the rolls are naturally springy, there has to be sufficient crown put on them to offset the spring so that every portion of the surface that comes in contact with the sheet will be perfect.

There are several reasons for the crowning of press rolls, the most important of which is the necessity of weighting the ends of the rolls with heavy weights. This in itself would cause the rolls to pinch on the ends, thereby pressing more water from the paper at this point than in the center of the rolls. To avoid this the bottom roll is ground with a crown or, in other words, it is of larger diameter in the middle with a gradual tapering toward the ends. Then again, suppose that no weight were used on the ends of the press rolls, and the rolls were finished perfectly straight, resulting in an even amount of water being pressed from the sheet at all points. Now take the paper over the dryers and by drying soft you will find the edges of the paper dry and the middle part wet. This is caused by the dryer being hotter on the ends than in the middle, this condition being due to the deckles which do not entirely cover the face of the dryers, thereby leaving an uncovered space at each end on which the heat is unchecked. You, therefore, must go back and put a crown on the press rolls to overcome this difficulty. There are no definite standardized formulas which give the proper amount of crowning for the rolls. This is determined by experience only—by flexibility of the rolls—the width—the hardness of the rubber—the peculiarities of the machine as a whole. The metal rolls require less crown than rubber because they have less "give" to them. There are some machines which have peculiarities such as non-uniform temperatures on the face of the dryers, formation of sheet, removal of water by vacuum system, which must be met and overcome by crowning the press rolls. As a general rule the first press should have about 10/1000 of an inch (in circumference) more crown than the second press. The only real way to ascertain the proper crown for the roll is by observing the sheet of paper when it is just a trifle on the damp side. If the middle of the sheet shows up damper than the edges, then the press rolls need more crowning, provided you are making an even level sheet on the wire. If the edges are damp and the middle dry then you have too much crown on the roll. When making such observations be sure that the presses are set evenly on both sides and have the levers all in same position.

The second press is the same as the first, and also the third. Paper should leave the third press about 35 per cent dry, and more than that if possible. Even then this leaves 65 per cent of the total tonnage of water necessary to evaporate in the sheet. Often the top roll of the third press is bronze covered.

Suction boxes similar to those beneath the wire are placed under the felt, just in front of the pinch of the press rolls so the sheets gets the benefit of the suction just before it passes through the final squeezing of the press rolls. These suction boxes also prevent the paper from "blowing" which is the paper-makers' term for air getting between the felt and the paper and forming wet wrinkles when squeezed out by the press rolls. The suction boxes guard against this by removing the air. They also keep the felt clean, sucking out excess water.

The top roll of the first press is sometimes offset from 3 to 4 inches for the same reason that the upper couch roll is (see page 410). It is also desirable to have the top wooden rolls a little longer than the bottom rolls to prevent the edges of the felt from curling.



Courtesy: Pusey and Jones Corp., Wilmington, Del. and International Nickel Co., Inc., New York

FIG. 184.—Press screen of modern high speed bag paper machine showing Monel covered steel rolls 240 inches wide.

Press Roll Doctor.

Each top press roll is provided with a doctor-blade either of gutta percha or of maple wood, and even this is usually protected from direct contact with the roll by pieces of wool felt under the edge.

If stationary, the doctor would scar the roll, scraping grooves into it. This doctor is a very important part of the Fourdrinier as it removes the constantly accumulating wet broke from the press and also miscellaneous matter that would mar the paper. It also helps keep the felt clean. Accordingly, to prevent the scarring alluded to above the press roll doctor is vibrated by a special mechanism that ensures this vibration being "out of step" with the rotation of the roll. This is driven by a worm from the press roll journal, and there are quite a number of patented variations of the mechanism and of the doctor blades themselves, such as the Vickery doctor illustrated. These are also used on breast rolls, dryers, calenders and super-calenders for similar reasons.

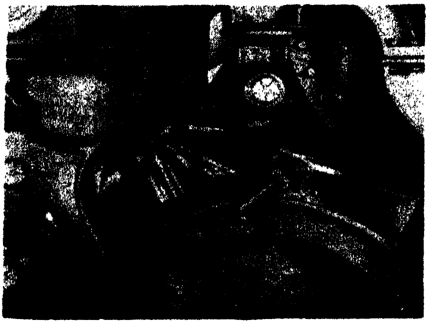


FIG. 185.

Vickery vibrating press roll doctor.

Courtesy: Bird Machine Co., South Walpole, Mass.

Roll Doctors.

It is considered good practice today to doctor the surfaces of paper machine and calender rolls as an easy and inexpensive means of avoiding breaks and shut downs and securing more uniform paper finish. Flexible doctors are now available and are engineered for every type of roll, including press rolls, wire rolls, breast rolls, dryers, calenders and super-calenders.

Typical of these is the Vickery Doctor which is constructed to provide a free rather than a rigid blade, mounted so as to obtain longitudinal flexibility in order that the blade can maintain contact with the roll along its entire length, and radial flexibility for light but uniform contact. This blade is provided with a support which gives the correct and uniform pressure over the full width of the roll.

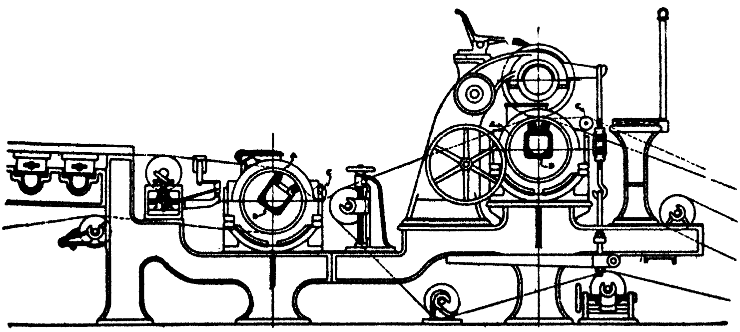
Suction Rolls.

Suction rolls [1] are specially designed rolls to take the place of the couch roll or one of the press rolls, and which are intended to remove

[1] Invented by Wm. Millspaugh of Sandusky, Ohio, and first placed in operation at the mill of the Hammersley Mfg. Co., Garfield, N. J., on a machine making "greaseproof" in 1908.

water from the paper by suction in the same manner as it is removed by the suction boxes, at the same time these rolls performing the usual functions of an ordinary couch or press roll. With the operation of wider and faster paper machines great interest has arisen in these rolls and many modern paper machines are equipped with them.

Since modern paper machines operate at very high speeds it is necessary that the water should be taken from the paper rapidly and efficiently, and paper machine designers have sought to improve on the older types of machine which depended for the removal of water on the drainage through the wire, the action of the suction boxes and the mechanical pressure of the couch and press rolls. Moreover, the removal of the water must be done carefully; there is a limit to the force that can be exerted by the couch and press rolls without breaking or crushing the newly formed web of paper.



Courtesy: Sandusky Foundry & Machine Co., Sandusky, Ohio.

FIG. 186.—Diagram showing construction and operation of suction couch and press rolls.

In the ordinary couch roll the pressure is exerted on the line where the top roll comes in contact with the bottom roll, giving a very high pressure at any particular point in this area of contact. As the water is squeezed out of the paper at this point there is bound to be some disarrangement of the fibers of the paper. When this effect becomes excessive it is the cause of crush marks, felt marks, etc. The suction roll pressure is distributed over a much greater area, that area being the whole surface of the roll.

The stationary suction chamber is connected to a powerful rotary vacuum pump, usually located in the basement and driven from the constant speed line. The contact between the suction chamber and the inside surface of the revolving shell is made with special hydraulic packing. A deckle arrangement is provided for adjusting the length of the suction area to accommodate any width of sheet made on the machine.

The suction couch roll eliminates entirely the use of the old top couch roll with its felt jacket and guard board, both of which require constant attention and are responsible for many of the machine tender's troubles, such as crushing, wet streaks, wire marking, pick-ups, accidents to wires, etc. The suction couch roll does not displace all of the regular flat suction boxes on the wire. In many cases the number of flat suction boxes used may be reduced, or what is equivalent, the degree of vacuum carried on them lessened. The degree of vacuum that may be maintained at the suction couch roll in operation largely depends upon the weight and character of the paper made. Likewise the percentage of water that may be removed by the couch roll also varies, but to a larger extent this is proportional to the degree of hydration which the stock undergoes in its preparatory treatment. This accounts for the

Courtesy: Sandusky Foundry & Machine Co., Sandusky, Ohio.

FIG. 187.—Suction couch roll on Fourdrinier machine.

fact that on extremely slow stocks like greaseproof and glassine, the paper may be delivered from the suction couch roll as much as 25 per cent bone dry, whereas with quickly beaten stocks like news, the amount of water taken out may not quite equal or at least exceed that possible to take out with top and bottom couch rolls. On such papers, made from the free stocks, the suction couch roll must be supplemented with the suction press roll in order to effect increased dryness in the paper.

The use of suction rolls admits of widely varying weights of paper being made on the same machine. There seems to be no limit in the direction of heaviness to the papers which can be made on suction roll equipped machines the weights ranging from 300 pounds. It has been advanced by some paper makers that the suction couch roll would tend to remove filler from the paper, but this has never proved a serious difficulty in mills where the device is in constant use.

The suction press roll is quite similar to the suction couch roll, except that it is surmounted by the usual top press roll. The suction press roll is usually inserted in the first press. In addition to assisting in the removal of water from the sheet, it prevents the paper from sticking to the top press roll, a difficulty frequently encountered, because of the positive action of the suction of the bottom roll which holds the paper to it. Moreover, the air passing through the felt, on account of the suction, tends to keep the felt open and clean, lengthening its life.

It is the writer's opinion that the chief merit of suction rolls is that a greatly increased degree of suction can be obtained, without adding to the wear on the wire, as would be the case were this suction applied with flat suction boxes.

The first cost of suction rolls is a large item, but there seem to be so many advantages connected with their use, the speed of the machine can be increased with safety, breaks can be reduced, felts made to give longer service, etc., that they would seem to be an excellent investment.

Suction Dual Press Section.

The Dual Press consists of three rolls set horizontal to each other, in which the first roll from the wet end is a rubber covered suction press having a box with a 4-inch wide suction area. The second roll is a "Stonite" covered roll. The third roll is an ordinary rubber covered roll having a hardness of about 35 to 40 point.

The horizontal center line of these rolls is very little higher than the horizontal center line of the couch roll on the wire, thus the operator is really looking down on its operation and can readily see what is going on.

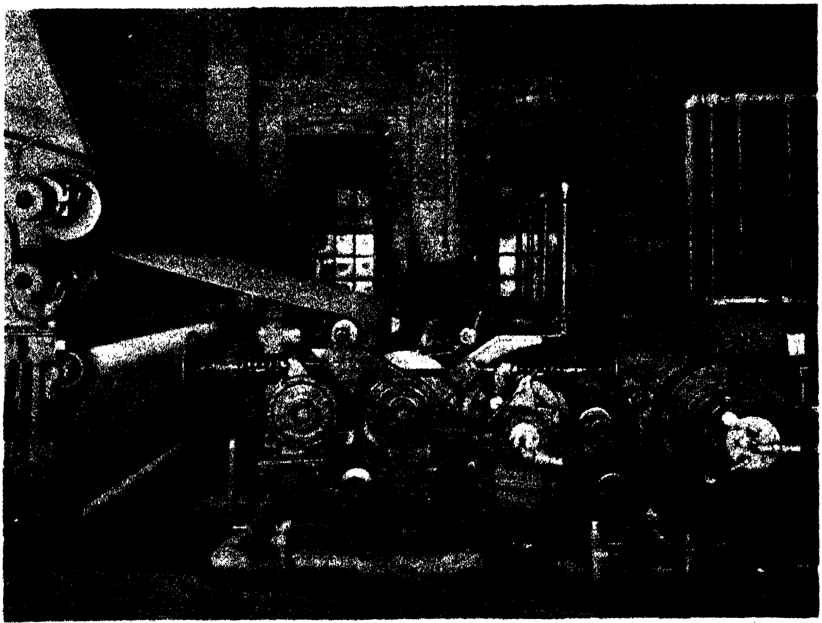
Mechanically, the center roll is in a fixed position while the suction roll on one side and the press roll on the other side are held against the center roll by calibrated spring pressure having geared hand wheels for adjustment, the two outside rolls being hinged on the base plate. These outside rolls are so hung that by releasing the spring pressure they fall away from the nip of their own weight, a stop being provided so they will not drop back too far. A graduated scale along the springs shows the operator where he has the pressure set.

Instead of two drive stands on the back side of the machine, one each for first and second press, there is only one drive stand connected direct to the suction press roll and with a cone pulley and belt arranged as a helper drive to the second press roll. This, of course, when set needs no adjusting until such time as a roll diameter is changed by being ground. In some of our later installations the new Texrope adjustable sheaves have been used, requiring even less room than the cone pulley arrangement. Since both of the driven rolls are movable, swinging in an arc from the sill plate, the connections from drives to these rolls are through a heavy duty type of universal joint used quite largely in machine tool practice.

The vacuum connection to the suction roll is taken in the inside of the machine to a pump located in the basement and it, of course, is flexible.

The two wet felts used, run vertically to the mill basement floor, requiring only three felt carrying rolls for the first felt and two for the second press felt. Two of these rolls are automatic guide rolls and are located on the sill plate in easy access to the operator and where they may readily be seen. Since the felts run open like a belt very little guiding is necessary.

The two tail felt rolls, mounted preferably in weighted arms, are located on the basement floor and are slightly wormed. These act as the stretch rolls also and since they are mounted in weighted arms a constant and uniform tension is maintained at all times during the life of the felt. Of course the operator may change this tension by changing weights should he so desire. On the whole less tension is used. We have noticed that felts do not narrow up.



Courtesy: Beloit Iron Works, Beloit, Wis.

FIG. 188.—Beloit horizontal dual press section.

All rolls in the Dual Press equipment are mounted in suitable heavy duty ball or roller bearings. This, of course, reduces power and adds very much to cleanliness and smooth operation.

In operation instead of a long draw from the first press over at least two paper rolls into the reversing second press with danger of innumerable breaks in the paper and considerable stretch in the wet web of paper, we now have the sheet going through the first press nip and adhering to the bare center roll as it is carried around underneath half the center roll diameter into the second press nip and the sheet is quickly parted from the felt, adding to its dryness. There is no chance for stretching the sheet and a break in the paper web is impossible. It is entirely automatic in carrying the paper through both presses without any handling. The paper is taken from the top of the center roll after passing through the second press roll nip to the smoothing press, over a water marking device or to the dryers, as the case may be. This center roll of course, is provided with a doctor preferably of oscillating type.

The center roll corresponds to what is normally the top press roll and it has twô driven roll nips to drive it. This eliminates any desire or need for what is known as a top roll drive. While the second press nip employs plain rolls, since they set horizontally to each other, and the paper is passing vertically, the water pressed out here falls naturally out of the nip into a save-all pan instead of wanting to carry through the nip as is true in the conventional horizontal nip.

The paper is drier through the two nips of the Dual Press than it was formerly through two conventional presses, at least 2 per cent and some grades very much more. The water falling vertically out of the second press nip accounts for some of this gain in dryness. Since, on the whole, much lower nip pressures are used on the Dual Press, this is of course in line with the effort today to obtain bulk on many firnishes. In not reversing the sheet we do not lose finish or aggravate two sided finish.

There has been found little need to change felt grades. Perhaps a slightly more bulky felt but free and open may be more desired for the suction press nip. The normal basement will give a felt length of about 40 feet and we keep both first and second press felts the same length. In some cases they have been interchanged. With the fewer felt rolls and no hitches, the felts run longer, and they stay cleaner; conditioners or suction cleaning devices may be used with the equipment but they are not essential.

Little space is needed for this equipment. Very little more than the three roll diameters is required for the Dual Press Section. At least four 48-inch diam. Dryers can be added in the space saved on a conventional two press machine, or a wire may be lengthened and additional dryers also added to meet the particular need of a given machine.

While the above has applied to Fourdrinier operation, the Dual Press is also applicable to heavier sheets.

In the Tissue field, substituting a drier for the center roll gives a very compact piece of equipment for the manufacture of both flat and crepe tissues.

Smoothing Roll.

This roll often called a Lump Breaker which is placed on top of the suction couch roll on a Fourdrinier machine not only breaks or flattens down any lumps of fiber or shine spots which occasionally form in the stock by gently pressing the sheet, but also serves to set the fibers together into a more compact formation. This roll also promotes the value of the suction because of the gentle pressing of the sheet at a point where it is wet and yields most readily to the gentle and even pressure of the lump breaker surface. It also serves to set up the sheet into a better formation with less porosity The gentle pressing of the sheet at this point also promotes the action of the first press. It becomes a valuable "make ready" for the vigorous pressing the sheet must get before it reaches the dryers. The smoothing roll promotes the fiber structure of the paper; also, develops more suction by its gentle pressure applied at a point where the fibers are moist and yielding.

Smoothing Presses.[1]

Many modern paper machines are equipped with smoothing presses. This device is not strictly a press. Its function is not to press water out of the sheet, which is the purpose of the true presses. It is intended to smooth and flatten the sheet after it comes from the presses before

Courtesy: Pusey and Jones Corp., Wilmington, Del.

FIG. 189.—Smoothing press.

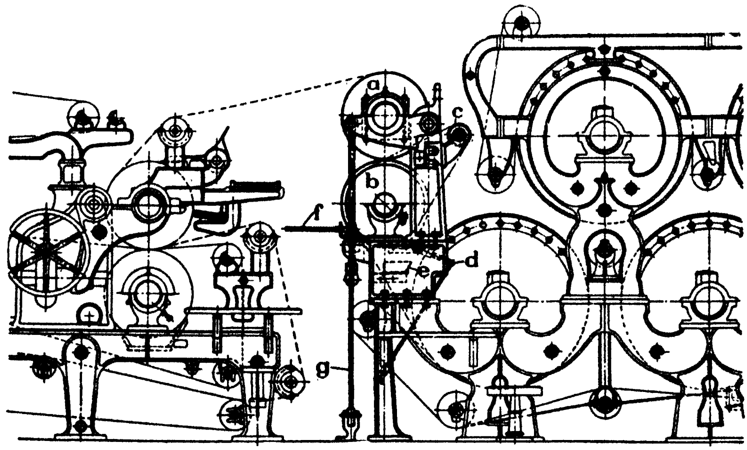
it goes to the dryers, removing all wire and felt marks. Many such marks are easier to remove at this stage of the formation of the sheet than later after the paper has dried.

The upper of the two smoothing rolls is covered with rubber, somewhat softer than ordinarily used on ordinary press rolls. The lower

[1] Not to be confused with the smoothing *roll* or "lump breaker" described above.

roll is provided with a gun-metal jacket which is ground very smooth. This roll has little or no crown; the upper roll is crowned somewhat more, but still very little.

The damp web of paper (at this point it contains from 60 to 70 per cent water) usually reversed at the last press, so that the wire marks are underneath, is led over and around the upper rubber-covered roll, and passes between it and the gun-metal roll underneath, whence it passes to the first dryer. The passing of the paper around the greater part of the upper roll tends to make the pull on the paper stronger in the middle than on the edges, thus avoiding tearing of the sheet.



Courtesy: Puscy and Jones Corp., Wilmington, Del.

FIG. 190.—Diagram showing installation of smoothing press.

The success of the smoothing rolls is largely dependent on the care with which the upper roll is made. Exactly the right density or hardness is necessary if the perfect smoothing action is to be obtained. It is also very important that the smoothing action of the press should be uniform across the whole width of the sheet. There is an arrangement of weights and levers for adjusting the pressures.

The smoothing press increases the strength of the paper due to the fact that it is smoothed before entering the dryers. It smooths the fibers in the sheet, thus allowing closer contact with the surface of the dryers, eliminating air-spaces between paper and dryer, and thereby enabling the paper to be dried better with the same amount of drying surface, or with a lower temperature in the dryers, which is beneficial to the paper. It yields a paper requiring less calendering and one which retains its finish better when glazed on the calenders only. Such a finish is not affected by the atmosphere. It obliterates all wire and felt marks at the moment when the sheet is most sensitive to mechanical finish.

Smoothing presses are chiefly useful in connection with the manufacture of good book and writing papers at moderate speeds. They are also useful in the manufacture of blottings and some specialities such as vegetable parchment.

Wet Felts.

The process of making papermakers' wet felts, so far as the technical operations are concerned, is very much the same as that of making any woven woolen cloth, especially bed blankets.[1] A papermakers' felt is in reality a blanket and not a felt in the strict sense of the term, the latter being a sheet of wool fiber so felted or pressed together as to present a smooth surface but having no threads.

In making papermakers' felt long, staple, strong wool is carded and spun into two kinds of yarns—the first being used for warp or threads lengthwise of the felt and the second for the filling or cross threads. The warp gives the strength and necessary pulling qualities lengthwise. The filling makes the surface of the felt and from these filling threads the nap is raised.

The seam of the felt is made by hand. A long fringe of warp is left on each end when the piece of cloth is woven. The felt being placed on a table with the two ends together, the joiner ties a knot in the ends of the two exactly opposite threads and draws one out; the other following is drawn in and takes its place. This operation being repeated first on one side and then on the other makes a perfect hand-woven seam.

The felting, fulling or thickening of the cloth then takes place and finally the raising of the nap. The coarseness of the yarns, as well as of the wool, varies with the kind of paper to be made.

The writer does not know who first discovered the use of woolen blankets as related to paper making, but they have always played an important part, not only in machine-made paper, but in hand-made paper as well.

The wool fiber among all textiles is the only one against which a wet sheet of paper may be pressed to remove the water and from which this water may again be removed by pressure. It is the only fibrous material which will pick up a sheet of wet paper from some other carrying medium and deliver it again to any desired point without injuring the sheet and with no particles of the paper stock adhering to it.

At first the two ends of a piece of felt were carefully sewed together to make the carrying belt for a paper machine; later the possibility of weaving the seam by hand and so joining the two ends to make a perfect endless belt, was realized, and on this as much as on the endless Fourdrinier wire, modern papermaking depends.

Felts are of almost as many varieties as there are kinds of paper made; but, as a basis, it may be said that they are all made of strong fibered wools, varying in coarseness with the paper to be made. The main object

[1] Dryer felts, to be discussed later, are not really "felts" at all: they are a kind of heavy duck woven from cotton.

to be gained is a felt of the greatest possible strength and resistance to friction, together with a texture so loose as to admit of maximum removal of water from the sheet of paper. Serving as a belt or carrying apron, it must be smooth and even in surface; must run straight and true; the edges must be firm and it must hold the desired width while running day after day under the varying conditions on the paper machine. It must be remembered that one of the chief characteristics of wool fiber is that it shrinks or felts together. This felting or fulling must be so supplied to the paper felt that it will not shrink more after being put on the machine.

Most felts which are used for finer papers have a nap to prevent the paper from being pressed against the threads and thus an impression in the paper being formed.

On the earlier types of machines, which were narrow and ran at slow speeds, there were only two presses. The first press of about 24 feet in length and a second press usually 12 feet in length. With the development of the Fourdrinier machine, extra width was added and speeds increased and it was found desirable to have both first and second press felts much longer, and finally, a third press, and in some cases a fourth, was added.

The invention of the Harper Fourdrinier machine also necessitated the use of very long felts, and as cylinder machines became adapted to the making of heavy boards and papers the felts were increased in length to take the paper from the additional cylinders.

While, as has been said, a woolen felt will carry the sheet of wet paper without the paper stock adhering to it, a certain amount of the stock, or of the filler run with the paper, is gradually taken up by the felt, necessitating washing either with a shower of water constantly pouring on the felt at a point where the felt may also be freed by being beaten with a driven cylinder with blades, or by shutting the machine down and removing the felt, or by washing on the machine by the method decribed later.

Another addition to the modern machine which has helped felts materially is the suction box. This helps to remove the water and to dry the paper, and without it the fast speed of the modern Fourdrinier machine would be impossible. Even more is this true of the even more modern suction couch and press rolls. There is much difference of opinion as to whether a suction box made of a plate with round perforations, or one with long slits with rounded edges, causes less wear on the felts through friction. The felts are finally worn out by friction and by the action of the water in which they are constantly run; the water must of necessity finally rot the woolen fiber. This is consequently a fixed condition so that the life of a felt depends very largely on the amount of friction to which it is subjected. This friction comes not only from the suction boxes but from the felt carrying rolls and from the presses through which the felt runs. The old-fashioned, iron bottom press rolls have been superseded by rolls covered with soft rubber.

This one fact has caused the saving of an immense amount of money to paper manufacturers. The best practice today is to cover the bottom press roll with a coating of from $\frac{3}{4}$ to 1 inch of a comparatively soft rubber composition. As the roll wears and becomes uneven it should be turned down again; it is false economy to run rolls on which the rubber has worn down so thin and become so scored by wear that the friction on parts of the felt is very much increased.

The second cause of friction, which always materially shortens the life of felts, is the felt carrying rolls. Wooden rolls will not keep their shape in the extreme lengths of the modern machine and iron rolls, whether galvanized or not, soon become rusty and pitted so that even the small friction necessary to pull them creates a grinding effect on the surface of the felt which soon removes the fiber and injures the fabric. Many experiments have been made toward obtaining rustless felt rolls but the best modern practice is to have the rolls covered with brass or made of Monel or some similar corrosion-resisting metal. Stainless steel has recently been used for this purpose.

In size, felts on the modern machine have gradually increased to lengths of forty, fifty and sixty feet. Here also, there is a great difference of opinion, but at the present time the majority of Fourdrinier machines are being built for first press felts varying in length from forty to sixty feet—the second and third press felts a little shorter in some cases than the first.

As has been said, the quality of felts used, varies with the paper to be made. Different papermakers (and in fact felt makers as well) have varying ideas as to the exact quality required for each particular kind of paper, but in general the following statement might be made.

Adapting the felt to the machine and the product.

For Fourdrinier machines the felts must vary in quality depending on whether the paper to be run is news, manila, book, writing, etc. All must have the quality of openness and free running and must be capable of running the longest possible time without washing, which is usually done by relieving the pressure on the press rolls and guiding the felt into the center until it forms a long rope which is pressed between the rolls as the machine runs slowly.

The felt on the second press is sometimes of the same quality as that on the first, but usually heavier, while third press felts are still heavier. The relative length of service of the first, second and third press felts on fast running machines seems to depend on the amount of work in drying the paper that each is made to do. In other words, the heavier the pressure on the felt and the heavier the suction, the shorter its life. Necessarily with the great increases of speed met with in modern Fourdrinier machine operation, the service required of felts has become much more severe. At the present time a great strain must be put on the felts lengthwise—in other words they must be run very tight—to keep them open, and admit of the high speed.

For tissue paper very fine felts with no nap are required and owing to the peculiar conditions on tissue machines, the thinness of the paper and the necessary thinness of the felt, as well as the fact that felts become filled with stock quickly and require constant hard beating, the felts probably cause more trouble on these machines than any other.

Harper Fourdrinier machines require felts somewhat stronger but the same in general character as ordinary Fourdrinier machines running the same grades of paper.

Large cylinder machines running board on several cylinders, if the board is to be of high finish, require felts of great longitudinal strength to carry the strain of the cylinders and squeeze rolls and yet of sufficiently fine warp to give the required finish to the board.

Wet machines running pulp (for these also require carrying felts) should have very strong, coarse felts, thicker and heavier, with looser weave in the case of sulphite; closer and firmer, but still strong and open, in the case of groundwood.

These varying conditions, and this increasing severity of service, have presented a great problem to the felt manufacturer. He has constantly been obliged to change his felts to meet new and changing conditions and in many cases he has not been informed of contemplated changes until the felts he has been supplying have been blamed for not meeting conditions for which they were not designed, and of which he had not been informed.

Care of Felts.

The life of a felt depends very largely on the treatment it receives at the hands of the machine tenders. To meet the conditions under which it is used, it must necessarily be a comparatively delicate woolen fabric, easily torn or injured, and yet it must do the work of an endless belt running constantly at a high rate of speed between heavy rolls, carrying a great weight of paper and water, and with constant liability to injury from unforeseen causes. There is no point in paper making where care and watchfulness count for more than in the treatment and use of felts. Felts in the stock room should be carefully watched and kept free from moths by the application of para-dichlorobenzene crystals, naphthalene or tarred paper; they should be kept free from all dirt and grease. The room should be dry and yet not hot.

Great care should be exercised in starting felts on the machine, since many felts are ruined by careless starting, whereas if a little precaution had been taken they could be made to give full and satisfactory service. The amount of service that can be obtained from a felt varies so greatly with different conditions that it is impossible to lay down any rule for this. Felts on two machines running side by side will sometimes differ 50 per cent or more in the amount of service given and the amount of paper made. It is possible for a felt to be injured in so many different ways that the felt itself should not be considered defective until every possible source of damage on or about the machine has been investigated and, in case the papermaker becomes convinced that the felt is defective in some way, it should never be sold or destroyed, but should be held until the manufacturer has been informed of the supposed defect. Felt manufacturers invariably make it a rule that felts claimed to be defective must be returned for their inspection and this rule is certainly a just one.

The treatment of worn out felts is always an important subject for consideration by the papermaker. In most papermaking communities there is a demand for these old felts for use as blankets from people living in the vicinity. The felts should be carefully washed and cleaned, put in as attractive shape as possible and in a place where they can be easily inspected. Some of the poorest in which the fiber has become very rotten and threadbare can be disposed of only as waste material, but the heavy second and third press felts, and all felts that have been taken from the machine because they have been damaged, should be sold for blanketing at prices depending on the quality. This is an important source of saving to the papermaker and the careful handling of old felts may mean the reduction of cost by many hundreds of dollars in a large mill.

Felts should be thoroughly inspected before being put on paper machines. The rolls, boxes, and journals should be thoroughly cleaned. The press rolls should be lifted high enough to give the felt plenty of clearance for passing under the roll. All felt roll journals should be exercised so that the sharp ends of the journal do not cut the felt when passing through it. After all the rolls are in proper place and before letting down the press rolls, the felt should be straightened out as smoothly as possible, and in proper alignment with the machine. The top press roll may then be lowered onto the felt. The stretch rolls should be strained up only tight enough to take care of the slack in the felt. There should be a man on either side of the felt and in front of the press rolls to pull out any wrinkles that may pass between the rolls when first starting the felt.

Before applying any water, the felt should be run around and gradually strained up, but not too tight, as the application of the water causes it to full up, or shrink. This application must be very carefully done; *one should never permit a solid stream from the hose to be used,* by holding it over one point as the felt runs around, causing a wet streak in the center, as this method usually results in spoiling the felt. In fact, such methods sometimes cause a felt to run in a straight wrinkle its whole length, caused by this portion of the felt fulling up, or shrinking in the streak where the water was applied. The only proper way to wet down a new felt previous to putting on the web of paper, is to apply the water through a shower pipe, preferably across the full length of a roll, so that the water may be evenly distributed as the felt runs around, the object being to give the felt an even amount of moisture its whole width so that when it passes between the press rolls its every fiber will be made moist and it will thus shrink evenly.

Proper attention should be given to the seam in the felt, that it may run as nearly straight across the machine as is reasonably possible. It will be found that presses on account of their many rolls, no matter how perfectly constructed, during a large number of revolutions will gradually lead the seam ahead or allow it to fall behind at one place or another. The only method of eliminating this trouble is to see that all the rolls are properly turned true in a lathe; this includes the press roll, as the crowning of the bottom press roll is sure to run the seam ahead in the center if such influence is not offset by the balance of the carrying rolls.

A seam that runs very crooked has the effect of pulling the warp in certain places to such an extent as to close up the meshes of the felt, thus allowing it to be filled up with the fine pulp in this particular streak, and finally, to mark the paper; this produces what are known as "crush marks." The running of one side of the seam ahead of the other, presenting a diagonal appearance across the felt, can be corrected by the stretch roll. This should be attended to, as, if the felt is left with one side running several inches ahead of the other, it is very difficult to guide and liable to run into wrinkles and thus be injured.

The cause of one side of the seam traveling ahead of the other is that it does not have so far to travel around the circumference of the group of rolls in the press; hence the side of the seam in advance should be strained up so that the circumference will be increased.

Stretch roll arrangements are so constructed that the front side must be thrown out of gear in order to increase or diminish the circumference of one side. This makes it possible to operate only the back side of the stretch roll, so that if the front side of the felt seam is running ahead of the back side, the back side of the stretch roll should be slacked up thereby decreasing the circumference, allowing the back side of the felt seam to catch up to the front. If the seam runs in the reverse manner the process of adjusting should be reversed.

There is such a difference in the shrinkage of woolen felts that it is impossible to lay down any rules by which to be guided. It is usually the best practice to always use one kind of felt, of course, being sure that a felt is chosen that is best adapted to the grade of paper being made. Some felts will shrink in length without appearing to become narrower while others will narrow up and stretch out in length.

Defects in the manufacture of felts are troublesome to papermakers. A felt often gives unsatisfactory service in spite of all the care and proper treatment that can be given. Many felts develop "bad spots"—that is, spots that will crush the paper, varying in size from a silver dollar to five or six inches in diameter. There appears to be a slack place in the weaving, leaving this particular place more closely woven, and causing the felt to "bag." Such places invariably crush. The writer knows of no cure for this, and such a felt should be condemned, as it is the direct fault of the manufacturer.

Other felts develop into straight wrinkles in spite of the usual care in starting them when new. This is often, though not always, due to their manufacture; but it can be stated that if proper care is adhered to as above described and the felt wrinkles straight around, the blame can be placed with the manufacturer. Such felts should be carefully removed from the machine and put in safe keeping, subject to inspection or investigation by the felt manufacturer.

Many felts are ruined through carelessness of machine operators. It is not an uncommon occurrence to see third hands or machine helpers when picking paper from the first press, throw it into the second press in large wads. This should never be done as it always results in injuring the felts especially if the weights are left on. The leaving on of the press lever weights when putting paper on the felts is careless negligence, and should not be permitted.

Felts should be supplied with automatic guides to keep them in the middle of the machine and in proper alignment. This is especially true of first, or wet felts. Second press felts can usually be guided by means of a hand guide.

Copper tacks commonly used around the paper machines should be used with discretion, as one of them will ruin a felt in short order.

Wooden rolls having worming or listing tacked on them should be very carefully scrutinized when changing felts and tacks liable to work out removed or driven in.

Felts should never be run after becoming filled up; and under no consideration should the help be allowed to scratch the felt with wire brushes when it becomes filled up as this destroys the nap, rendering the felt unusable; whereas, if a felt in this condition is promptly washed, either on the machine or off, its life can be extended to a reasonable length.

The abuses mentioned have occasionally been practiced by unscrupulous machine help to aid them through their respective tours so that the work of washing or changing would fall to the workmen on the next tour. This is a narrow view of the matter, as such a method of procedure is detrimental to the production of the machine and to the company.

The application of soda ash water to avoid washing felts thoroughly, should never be permitted. If the judgment of the machine help could be depended upon, the judicious use of a small amount might be permissible under certain conditions; but the ordinary procedure is to put from a pint to a quart of strong soda ash into a pail of water, boil this by means of a hose, and dump it upon the felt—grit, settlings and all. There are specially compounded cleaners available today that are much safer to use.

On the latest modern fast news machines it is not considered economy to spend much time in darning holes in felts, as in only unusual cases can this be done with any degree of saving. If, for instance, a felt should become torn when new, a careful and expert workman can often close the break with a fine cambric needle and soft silk thread so that it will run for sometime provided such breaks are not allowed to run until the edges become frayed out.

Soft woolen yarns, however, are used to a considerable extent on groundwood and sulphite wet machine felts as the imprint of the mending does not affect the quality of the product. The mending of a felt with woolen yarn should be done very similarly to the darning of a stocking—the threads should be properly crossed at the right intervals imitating the weave of the felt just as nearly as possible. The presence of knots and other hard particles of yarn should be avoided.

Each press in the paper machine should do its share of the work, the web of the paper never being allowed to pass one press without its proportional share of the water being taken out at this point, otherwise the second press levers must be loaded down to make up for what the first press did not accomplish. Presses should be kept in proper condition to allow the top press roll to rise and fall in proportion to any differences in the thickness of the material passing between it and the bottom roll. The levers should never be allowed to bind but should always remain flexible.

One side of a press should not be weighted to any extent heavier than the other. It sometimes happens that a little more pressure is necessary on one side to dry out the web evenly. In such cases it will usually be found that one or the other of the press rolls needs regrinding, or that the top roll is not in strict alignment with the bottom.

Save-alls under presses, and spouts leading from them to carry off water pressed from the sheet, should be kept free, so that such water will not run onto the felt. This would soon fill up the meshes with slime and cause the felt to crush. In rinsing up the machine around the presses care must be taken not to rinse grease and oil onto the edge of the felt.

If a felt becomes bare and napless from the fact of its having been in service for a considerable time on one side, it may be turned over, thus giving the benefit of the other side of the nap. Felt should never be put on a machine with the nap runing the wrong way—it should be passed through the rolls so that the nap will be smoothed down.

Felts speedily become worn out if they are not allowed to dry when the machine is shut down. This is one of the reasons for washing of felts on the machine. They cannot dry. The mechanical flaws of felts are very numerous and one of these is excessive tension. This tension, however, can be helped to a marked degree by proper choice of bearings and lubrication for the various sets of rolls.

Automatic Felt Washers.

At the present time there have been placed upon the market machines which make it possible to wash the felts without the customary shut downs, and also give the felts an increased life. One of these machines is the Bennett Felt Cleanser. The washer consists of two rolls and steam pipes, the rolls controlled by means of a lever. The operation is of the simplest nature. Whenever the felts are to be washed steam is turned on and the steam pipe is pressed down against the felt. In a few seconds the felt is thoroughly cleaned of all dirty substances. This method is thorough and

FIG. 191.
One efficient type of felt conditioner.

Courtesy: Bird Machine Co., South Walpole, Mass.

avoids wrinkles and creases so common to the present hand manipulation of felt washing. Moreover, the life of the felts is greatly increased and old felts (which under the old system seemed to have lost all their nap) when submitted to this washer take on a new life with the reappearance of nap that seemed to have been all worn off.

Continuous Automatic Felt Conditioning.

It is virtually standard practice today to keep press felts in uniform condition to perform their function and this is done by means of the felt conditioner which consists of one or more conditioning boxes mounted on a slide supported by bearings on each side of the paper machine. Each conditioning box is engaged through its mounting with a screw operated by a driving and reversing mechanism driven from the press roll shaft. To each conditioning box is connected a hose to supply warm water and another to a vacuum supply. The conditioning box travels across the working face of the felt and during its travel warm water is forced through the felt from a nozzle and pulled back again by vacuum, thus cleaning the felt and treating the threads so that the felt does not become flattened and hardened. Felt conditioning effects important operating savings by eliminating midweek shut downs otherwise necessary to wash and rope dirty felts. Conditioned felts mean maximum water removal at the presses instead of at the dryers where it costs a great deal more.

Adjustment of Paper Machine Wet Presses.

If a sheet of paper from the Fourdrinier wire reaches the wet presses well formed and uniform in thickness, it should weigh the same across the entire width of the sheet. If weigh sheets are taken from both edges and the center and do not weigh the same, the difference in weight is frequently found to be caused by uneven pressing, so that either the center or edges of the sheet contain slightly more or less moisture. The remedy may be the adjusting of weights on the press levers.

The top roll of any wet press invariably crowds endwise and against the journal housings and prevents freedom in the rise and fall of that end of the top press roll.

This condition should not be tolerated. Top press rolls must respond freely to the weights carried on the press levers if even pressing is to result.

Press rolls that are slightly crowned in the center are more apt to crowd endwise than a perfectly straight roll. If the lever weights are removed from either end of the press, the top roll will tip slightly toward the end of the roll with the weights still in place; and when the weights on the unweighted side are replaced the top press roll is very likely to remain, to some extent, in the tipped position caused by the removal of the lever weights from the opposite end, thus causing the sheet of paper to run wet over about one-half its width. If the weights on the first press were removed and replaced, as above explained, the second unchanged, the third press would very likely correct the uneven pressing done on the first press. If this were allowed to continue, the wet side of the sheet would soon cause the second and third felts to fill up rapidly on the wet half of the sheet of paper. The only permanent remedy is first to see that the top and bottom press rolls are perfectly parallel with each other. Secondly to remove and replace lever weights simultaneously so that the roll may respond freely its entire length of pressing surface.

The advent of automatic pressure control for wet presses as developed by the Taylor Instrument Cos. has had a far reaching influence on the uniformity of the moisture content in a sheet of paper. It not only extends the life of felts, it also promotes even drying the entire width of a sheet of paper. There can be more damage done to a good sheet of paper on dryers than almost any place on the paper machine for the reason that it is next to the last important part of the whole process. You may have good pulp, good preparation of the stuff, good formation and a perfectly good sheet of paper up to the dryers and still after that point the paper may be utterly ruined. An evenly pressed sheet of paper promotes even drying, lending strength, durability, finish and a general pleasing character to the sheet. Therefore, automatic pressure control is a very valuable asset.

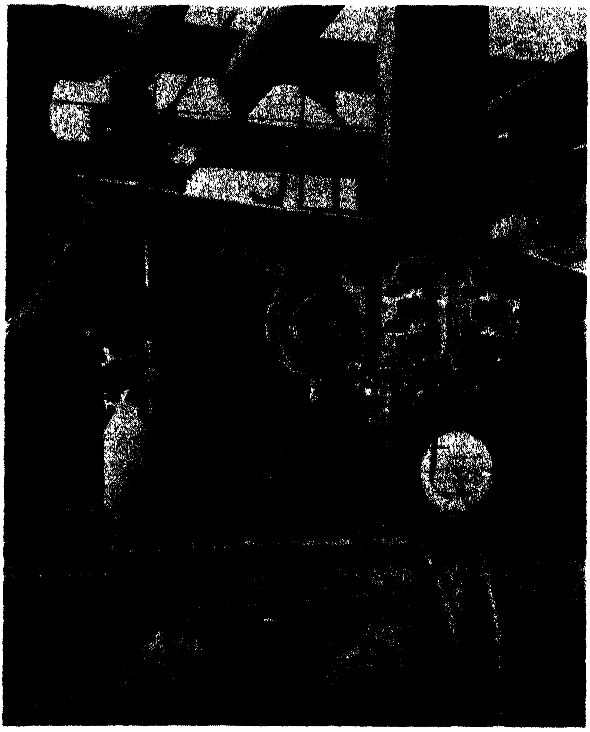
Taylor Press Roll Load Recorder.[1]

The design and construction of the weight and lever arrangement on the press section of even the comparatively new paper machine are relatively crude from a standpoint of design and workmanship, creating possibilities of great variations in the pressure exerted on the two ends of the press because of the terrific friction built up at the several points of contact between the tension rods, fulcrum arms and fulcrum points. This is shown by even a casual check of the method following in anchoring the short fulcrum arm to the press frame and the crude and unfinished contact between the tension rod supporting the short fulcrum arm and the extension piece from the top roll bearing.

[1] For the following details about the Taylor Recorder the author is indebted to Mr. C. D. DeMers of Taylor Instrument Companies.

In a paper[1] read by Dr. E. A. Rees, director of the research department of the F. C. Huyck & Sons Company, the following statement is made:

"Every practical running condition operates with the sides of pressroll unevenly weighted to a more or less degree. Even with the weights placed at the same notches on the lever arm, we have found differences as great as a ton on the two sides of the pressroll. Binding at the contact points of the fulcrum always occurs, and the effect is exaggerated many times by compounding."



Courtesy: Taylor Instrument Companies, Rochester, N. Y.

FIG. 192.—Taylor press roll load recorder.

The recorder, installed as shown in Fig. 192, is a bi-record of two-pen type. The load element, as shown, is made a part of the tension rod between the top roll bearing and the short fulcrum arm; this on both ends of the press. As the weights are adjusted the pens record the pressure exerted on each end of the roll, enabling the machine tender to adjust the weights so that even pressures are carried when such are required or to adjust them so that just the proper weights are carried on both ends to suit the operating conditions of the machine.

[1] Paper presented at the Spring Meeting of the Northern New York Division of the American Pulp and Paper Mill Superintendents Association, May 18, 1934, at Cornwall, Ontario, Canada.

In adjusting the weights so that uniform pressures are carried on both ends of the roll, it is only necessary to set the weight on one side to a point found suitable to any operating condition and basic weight, and then adjust the other weight so that the second recorder pen is recording the same weight as that of the first adjustment.

On starting up after the installation was finished the machine tender was told to disregard the instrument entirely and to adjust the weights in the usual manner, which in the case of that particular sheet being made at that time was a 50-pound weight 6 inches from the end of the lower fulcrum lever on both ends of the press. On checking the record it was found that one pen was recording 1,900 pounds and the other pen recording 2,500 pounds, a differential of 600 pounds, although the weights were adjusted in the usual manner and to the best judgment of that particular operator.

As it was desired to carry approximately 2,500 pounds on each end of the pressrolls at that time, the weight on one end, the end that had been recording 1,900 pounds, was moved out to a point where the record showed 2,470 pounds, at which time the weight was 2½ inches from the end of the lower fulcrum arm as compared with 6 inches from the end of the opposite fulcrum arm.

Percentage of Water Removed at Successive Stages of Manufacture

	Newsprint (600 ft. per min.)		Book (300 ft. per min.)		All sulphite (400 ft. per min.)	
	Solids	Water	Solids	Water	Solids	Water
Mixture from beater.....	3–3.5	97–96.5	4	96	4	96
Mixture going on wire...	1.5–0.6	99.5–99.4	1	99	1	99
Entering couch rolls.....	10	90	8	92	12	88
Leaving couch rolls......	13–15	87	17	83	25	75
Leaving last press.......	26–30	74–70	29	71	40	60
Leaving dryers..........	91–97	9–3	91	9	93	7

In the operation of a paper machine it so happens that the cost of removing water increases tremendously as the sheet passes from one succeeding method to the other. By far the largest amount and at the cheapest cost is removed at the wire. The pressing method in turn removes water much more cheaply than the dryers.

An average cost of removing water at the wires of a modern high-speed news machine is 2.6 cents per ton of water. The cost of removing it at the presses averages about 15 cents per ton, while the cost of removing water at the dryers will average close to $1.68 per ton of water removed. This ratio of ten to one between the cost of pressing water from the sheet at the press section and evaporating it at the dryers shows the tremendous possibility for economy in consideration of the fact that a reduction of 1% in water content of the sheet leaving the press to go through the dryer section shows a reduction of approximately 5% in the cost of drying.

Further, just as long as a press is operated without the maximum permissible weight, by which we mean the maximum weight that can be exerted on the pressroll without damage to sheet, felt or roll, then just so long will that particular machine be handicapped in an effort to produce a product at the minimum conversion cost and the plant as a whole be penalized by an extreme and unnecessarily high drying cost.

An old and a more common source of trouble, due to uneven weight adjustment, results in an over or underdried edge and a cockled or grainy sheet. If a machine tender adjusts the weights uniformly in the belief that uniform pressures will result, when in reality there may be a difference from 5 to 1,000 pounds in the pressures exerted on the two ends of the pressroll, it is reasonable to expect that the paper will be improperly dried when it leaves the machine—that is, the overpressed edge will be overdried, or the underpressed edge will be underdried.

I have asked papermakers these questions and have been told that when the paper is found to be running wet on one edge and overdried on the other the weights are adjusted to take care of this condition and that it is the duty of the machine tender to check the drying and to adjust the weights accordingly, but the fact remains that on one of the first installations of this recorder we asked the operator to adjust the weights in the usual way for an average running condition and he did adjust the two weights on the same relative points on the lower fulcrum arm and the machine ran that way until the back tender reported that the sheet was running wet on one edge. Upon checking the recorder we found a pressure of 1,900 pounds on what was the wet edge, and 2,500 pounds on the overdried edge.

Through the use of a technique developed in years of practice the average papermaker can do a real job and as a general rule produces a very good sheet. But it is rather too much to expect that with the great many other duties a part of his daily work he can give the close attention necessary to the drying conditions on the dryer and to constantly be readjusting the weights without the use of some indicator or recorder that will show the results of these many adjustments.

On some machines it is the usual practice to have to carry more or less weight on one particular end of the press section. This may be caused by a faulty slice adjusting arrangement, or some peculiar condition of stock flow in the head box or cylinder vat, perhaps by a feature of the drying condition in the dryer, or by any of the many other possible sources of variations in sheet formation; and knowing what un-uniform weights have to be carried, a record of the weights carried is even more essential as a means of checking this critical phase of press operation.

If the machine has no unusual characteristic and both the wet and dry ends are normal, in the usual sense of the word, then a record of pressroll pressures showing that uneven weights had to be carried in order to properly dry the paper, the plant executive would know that at some point on the wet end of the machine something was out of adjustment. Perhaps the high pressure showers used for cleaning the wires were partly plugged.

Perhaps the weights on the couch roll were not properly adjusted, perhaps the suction on the suction boxes was low, perhaps the felts were dirty and filled with clay, alum size or some of the other constituents which make up part of the many different grades, or something may have happened to the pressroll head and the roll was not responding to the pressure exerted on the top roll bearing; but whatever the trouble was the fact that uneven weights had to be carried to properly dry the paper would be an indication that something was wrong and steps could be taken to correct the trouble or arranged to do so at the first opportunity.

If steam flow meters are used for recording the steam flow to each machine, you will undoubtedly note that as the weights on the major presses are carried consistently below a definite point the steam consumption will have a tendency to rise, and that as the press weights are carried to your predetermined maximum the steam consumption will drop relatively.

If the record of steam flow was high and that of press weights showed that the maximum pressure for that particular grade was being carried, it would be obvious that there was something radically wrong in that the felts were not removing water at their normal capacity, or possibly the condensate system from or the steam supply to the dryers was at fault.

Dryers.

The purpose of the dryers is to remove by means of heat the 65 per cent or more of water still left in the paper after it has passed through the presses.

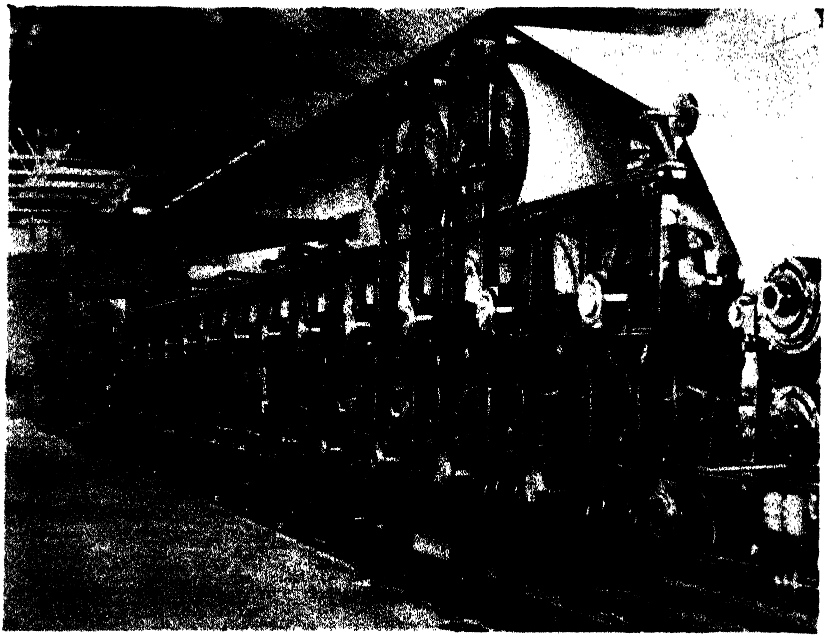
The dry section of a paper machine consists of a series of cast-iron cylinders usually erected so there is a double row of them, one on top of the other, and geared so they will all move at the same speed. Heat is supplied by steam piped into these cylinders; the water of condensation is removed by various devices.

The dryer cylinders are of cast iron, turned perfectly true on the surface and polished. The most ordinary size is 4 feet diameter. The castings must be perfect, as the presence of flaws, sand holes and other defects often found in large castings is dangerous, there often being a considerable pressure exerted on the dryers to provide the necessary degree of heat. The cylinders should be bored out smoothly so that the shell is of a uniform thickness throughout its circumference. Dryers not bored in this manner often contain considerably more metal on one side than on the other, which condition causes them to be out of balance and renders necessary the bolting on of a large piece of metal so as to offset the extra weight opposite. Moreover, varying thickness in the cylinder causes variation in the drying effect, owing to the great amount of heat necessary to bring the thicker metal up to the same temperature as the thinner.

Dryers should be turned on the outside and polished as bright and smooth as possible. The presence of tool marks or blemishes of any kind is fatal to the finish of the paper.

Arrangement of Dryers: The most usual arrangement of the dryers is that already alluded to, viz., in two rows, one above the other. With such an arrangement each tier usually has one long dryer felt. The majority of dryers in America are arranged in this way.

European machine builders have inclined more towards separating the dryers into two, three or more nests, each nest having an independent dryer felt. This permits of driving the different nests of dryers at slightly different speeds, which is sometimes an advantage for the following reasons: The dryers are all of equal diameter and connected together by a train of gears having equal numbers of teeth. Therefore, the speeds of the



Courtesy: Rice Barton Corporation, Worcester, Mass.

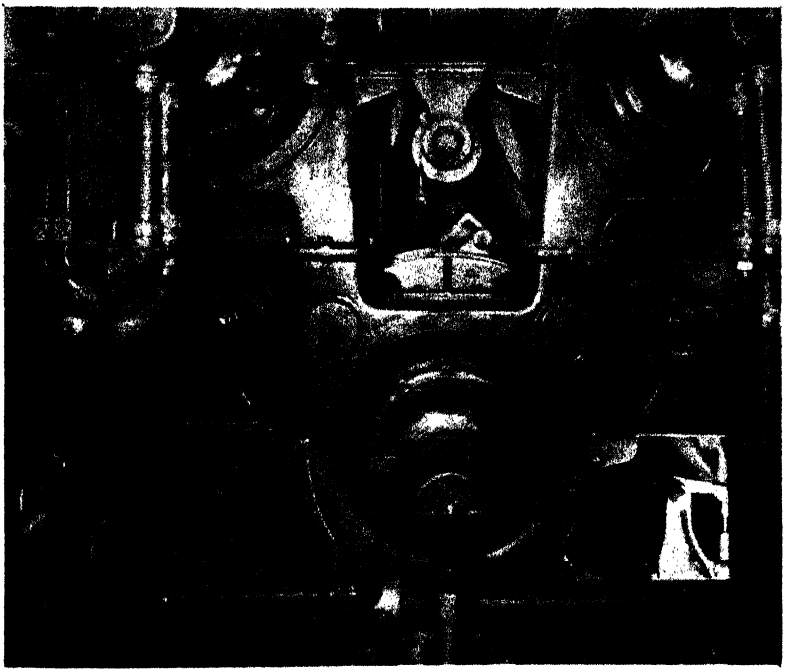
FIG. 193.—Front view of modern dryer section. Note break for size press to left.

surfaces of the dryers must be equal. The paper, however, is shortening as it dries. If the paper were to slip to an equal degree on all the dryers this shortening would be of no consequence at all, but since the condition of the surfaces of the dryers is never quite the same for all of them, the paper, as it shortens, slips a little more on one dryer than on another and is thus subjected to a certain amount of stretching. It is claimed that the loss of strength in certain fine papers due to this cause sometimes amounts to as much as 20 per cent.

Furthermore, each of the long felts comes in close contact with the wet paper coming from the presses and absorbs moisture, which shrinks it for a time. In shrinking the felt holds the paper alternately more and more tightly against the surface of the dryers, but as the wet paper and the partly wetted felts move on through the dryers they dry more and more, the paper tending to shrink and the felt tending to stretch out.

In making ordinary grades of paper these disadvantages in the American method of arranging dryers do not become of importance and machines making newsprint, a comparatively delicate kind of paper, run at very high speeds without breaks for days at a time.

However, the European practice of dividing the nest of dryers into several groups, capable of variations of speed has some advantages in making fine papers, because it really permits the paper to shorten as it dries. It does not lend itself so well to rapid production of large quantities of



Courtesy: Beloit Iron Works, Beloit, Wis.

FIG. 194.—Back side of dryer section of tissue machine showing chain drive.

paper and where the dryers are split into nests in America it is usually to insert a press for animal sizing between the two halves of the dryers . . . . or else to provide for a *breaker stack*, which is a calender [1] stack placed at this location so as to partially calender the paper while it still contains approximately 50 per cent of moisture. Stacks of this sort are used chiefly in making "English Finish" printing papers. The objective is not a high gloss, but rather an extremely uniform printing surface. The theory is that while the paper is still plastic it is possible to effect a readjustment of the fibers from thick to thin spots. There is quite an active controversy among

[1] The construction and operation of calender stacks is described on pages 453-455.

makers of such papers as to the relative merits of breaker stacks and smoothing rolls. Many make good use of both devices.

Frequently the dryers are arranged in three tiers instead of two. This permits of some economy in space and also conserves heat to a certain extent.

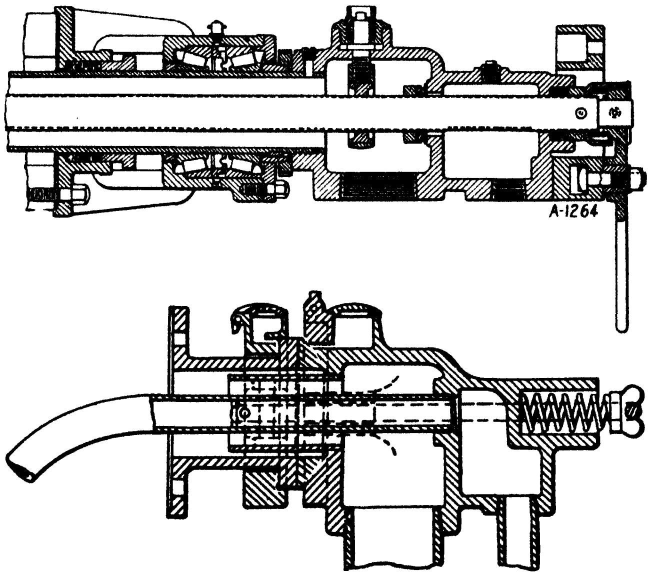
Some installations of dryers have been made where the dryers are stacked up, one above the other, in two vertical stacks. This is very economical of space, but must be a very troublesome arrangement. The dryers have to be reached with iron ladders and the handling of broke and the making of adjustments and repairs on such a set of dryers must be a matter of great difficulty. However, for drying thick, heavy paper such dryers would have the advantage of conserving the heat units to a maximum extent as the heated air from the lower dryers would aid in the drying of the paper on the upper units.

Another similar device is the placing of the dryers in a gallery supported over the wire, couch and presses. This is solely to economize space. The best proof that there is little real necessity for all such innovations, and that the conventional arrangement of paper machine parts is best in the long run, is the fact that such peculiar installations are so rare. As a rule paper mills are built, in America at least, in localities where space is not at a great premium and where the usual form of paper machine is by long odds the best.

Heating of Dryers: The dryers must be piped in such a manner that the sheet of moist paper will not be scalded when it starts through the dryer. This is accomplished by having the first dryers next to the presses considerably cooler than those further along. In this way the temperature and the drying effect are raised gradually. There must be drying capacity enough to dry the paper at the required rate of speed without the exertion of undue force. If the sheet is seared or scalded at the beginning of the drying operation it traps moisture in the top of the sheet, thus requiring a great deal more steam to dry it, besides destroying some of the qualities desired in the paper.

There are different opinions as to the best methods for removing the condensation water from the dryers. It is very necessary that this water should be removed rapidly and regularly. Some operators favor syphons and some dippers. It is objected to the syphons that they have a tendency to trap air in the dryers; the syphon pipe is supposed to be sealed in the water lying in the bottom of the dryer. A machine standing idle over Sunday becomes cold. Upon starting on Monday morning when the steam is admitted, the cold air is forced to the front, sometimes remaining in this condition for hours. This makes the front side of the dryer cooler than the back, causing an irregularity in the drying of the paper. Many schemes for extracting this air have been tried. Some operators put a small valve on the front end of each dryer to let out the air, just as air is let out of a steam radiator in a house heating system. It is also contended that syphons are wasteful of steam.

When systems of dippers are used, the dippers are necessarily bolted to the interior of the dryer cylinder and revolve with it. Water is dipped up at every revolution of the dryer and spills into the pipes and passes out. It is held by some that this method causes a waste of steam, since, as the dryers revolve, the dippers are at the top one-half of the time, and then being exposed to the direct pressure of the steam inside the dryers, it is supposed that the steam blows straight through and out of the drip pipes. Dippers have been developed for the modern high speed machines that operate perfectly even at upwards of 1,000 r.p.m. Machine builders place a trap on



Courtesy: Socony-Vacuum Oil Co., Inc., New York.

FIG. 195.—Sectional view of steam joints of dryer rolls showing plain and anti-friction types.

the inside of the dryer intended so that the drip pipe is never empty. Some of these traps are more efficient than others, while the dipper is exposed to the pressure of the steam.

Whether syphons or dippers are used they should be kept in the best of condition. The pipes entering the neck of the dryer should never be permitted to rub against the dryer, forming holes, as in this way the efficiency of both parts of the apparatus is impaired. Under such conditions the steam is blown in and out of the dryer before it has done its work. The presence of holes in these pipes also prevents the removal of water. Dryers are often half full of water when the pipes are in this condition.

Dryers cannot be maintained in proper efficiency without constant and intelligent supervision. If the dryers drain into a hot well and this hot well is not drained over Sunday and remains sealing the pipe from the dryers, the dryers will suck the water up as they cool and become full of cold water by Monday morning. This is typical of the large number of small points that have to be constantly remembered and cared for in connection with dryers. Proper steam traps kept in good order are important.

The piping of the steam to the dryers cannot receive too careful attention. Piping dryers on a paper machine is a piece of work that varies markedly from ordinary piping for steam radiation, coils and other apparatus to such an extent that an ordinary piper or piping contractor should never be permitted to introduce his own theories or ideas, but should be guided entirely by the judgment of some persons thoroughly experienced in the art of drying paper. Nearly all mills have different conditions which must be considered.

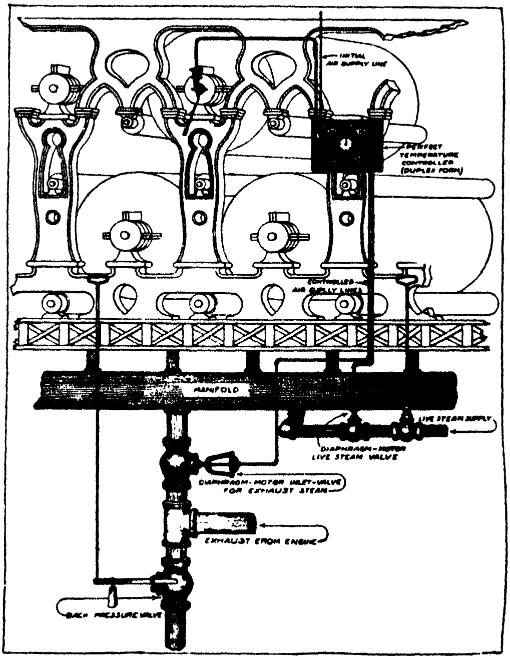


FIG. 196.
Witham system of automatic temperature control for dryers.

The writer has seen dryers piped up at the wet end from the exhaust of the steam engine attached to the machine, and the dry end piped up with a 1½ or 2-inch steam line direct from the boilers, carrying from 90 to 100 pounds pressure and only equipped with an ordinary valve, the degree to which this valve should be opened being left to the judgment of the ordinary machine help. It is obvious that such an arrangement as this can cause all kinds of trouble. In the first place, there is constant danger of blowing the dryers to pieces. In any case, the live steam lines will counteract the engine exhaust, causing back-pressure which slows down the engine and consequently the machine.

The paper is taken from the last press (either second or third) and carried around the dryers, under the bottom and over the top, and being threaded in this zig-zag manner the web of paper is held tight against the cylinders. When the web has passed the last dryer there is but from 5 to 10 per cent of moisture in it.

Automatic tighteners should be provided so that the sheet will at all times be hugged tightly against the hot surface of the dryers to prevent it from cockling, uneven shrinkage, and to insure even drying.

Dryer Felts.

Dryer felts [1] are among the most difficult of paper machine accessories to manipulate. They are made of very hard and firm material—do not stretch like woolen felts, except by wetting and drying. If by any means they become wrinkled, such wrinkles are usually there to stay.

All rolls and dryers over which these felts must run should be absolutely level and in line. Rolls, whether of wood or iron, should be absolutely true.

Dryer felts should be equipped with an automatic tightener roll. They are subject to such a variety of conditions on account of the heat of the dryers, the moisture of the paper, the speed of the machine, etc., that it is very necessary that this take-up roll should be very sensitive, to respond to all the variations.

Carrying rolls not in proper alignment with the dryer felt are sure to cause the felt to travel from one side of the machine to the other, and in many cases to wrinkle. Corner rolls, especially, must be in perfect adjustment.

Dryer felts should be equipped with automatic guides which will respond readily to the slightest variations of the felts.

Old-time papermakers often believe in pulling wrinkles out of dryer felts which is bad practice, and after these felts become wrinkled straight around their entire length, they believe in steaming or wetting the wrinkle. They have many other notions equally as bad, but the only sure and true way to take care of these felts is to have the rolls properly lined up and level and have them round and true.

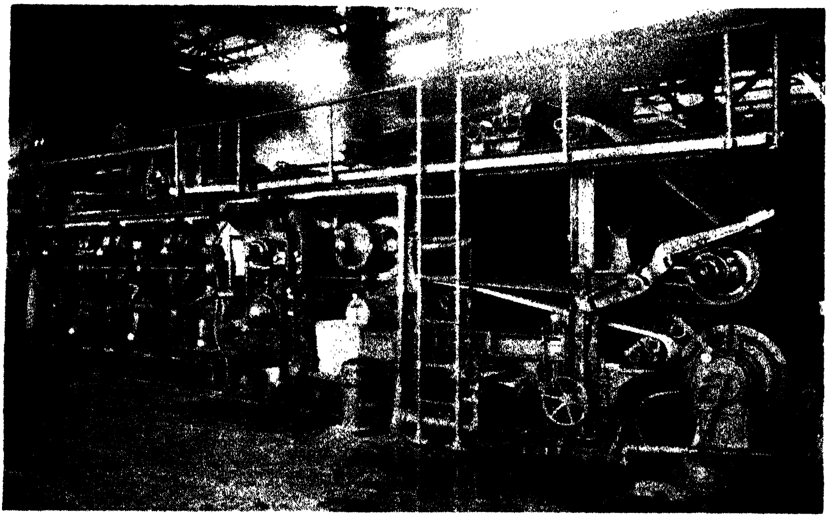
The best results are obtained with reference to the widths of dryer felts, by having them overhang the dryers on either edge from 2 inches to 4 inches, as they then run much more steadily on the machine. These edges not coming in contact with the dryers on account of their overhanging, have a tendency to shrink a little more than the remaining part of the felt, and thus act as a resistance against any influence to move them from one side of the dryers to the other.

Replacing Dryer Felts: If the machine-tender will give a reasonable amount of his attention to the condition of the felt he will be forewarned as to its giving out, so that a new felt may be in readiness to put on, as the new felt is led across the dryers by tying or stitching one end of it to an end of the old. If the dryer felt should break apart without being observed by the machine-tender, it would probably catch and wind around one of the dryers, or possibly run off the machine entirely.

[1] These are really not "felts" at all, being a kind of heavy duck woven from cotton, but by papermakers' general usage are called felts.

If the former should happen, it would be a hard matter to remove the felt from the dryer, as it could not be unwound, but would have to be cut off in pieces. Furthermore, the losing of a felt from the dryers often results in breaking or disabling the machine.

In putting a new felt on the machine, the dryers should be stopped and the old felt cut straight across that portion nearest the second press; the new felt can then be laid on the floor between the second press and the dryers if the bottom felt is to be replaced, or laid across the doctor of the second press of the top one. The new felt should be seamed to an end of the old, where it has been cut, to that portion which carries around the dryer. A man should be stationed on either side of the felt to help feed it along and keep it in alignment with the machine, being



Courtesy: Beloit Iron Works, Beloit, Wis.

FIG. 197.—Combination "Yankee" machine for both light and heavy weights, showing pre-dryers and suction press rolls. This machine is also equipped with suction couch roll and after-dryers which do not appear in illustration. Pick-up felt is raised out of operating position as machine is run on heavy weights at time of taking illustration. When a light weight sheet is run, the top roll is brought down on the suction roll and the vacuum is shut off, then the pick-up felt removes the sheet from the wire in the usual manner and the suction roll merely acts as a plain bottom couch roll with the exception that the holes in the shell carry away a quantity of water, similar to a grooved bottom couch.

careful that it does not get tangled up; while two or three men should take the remaining end of the old felt and pull it along as fast as it comes off. The old felt can sometimes be so led off from the machine as to be able to put it on one of the reels and wind it up in a roll, a strong friction being applied so that the felt can be pulled off without the aid of men; but unless conditions are very favorable, it is best to run it off onto the floor into snug folds.

When starting to lead a new felt over the dryers it is also necessary to have a reliable man to operate the dryer friction so that the felt may be led very slowly and carefully over the dryers. When the felt has nearly reached its length, care must be taken not to run it too far, but to stop the dryers at the proper time so that both ends of the new felt are in proper place to seam. It must be borne in mind that if the felt is run 3 or 4 feet farther than it should be it is very awkward, and perhaps impossible to join the two ends of the felt without going over all the dryers and rolls and pulling back the felt by hand, to a convenient place where the seam can be made.

Felt Seams: There are several different methods of joining the ends of these felts when putting them on the machine. The lap, or what is sometimes called the boot-leg, seam gives good results. This is made by bringing the two ends together and stitching a seam evenly across, through both plies, from 2 to 3 inches back from the ends. Slacking the stretch roll back as much as possible and removing a roll or two usually gives slack enough to do the seaming. Such a seam usually comes next to the paper; this answers very well for news, hanging, bag or Manila papers.

The seam above mentioned is likely to give better results if one ply is cut slightly shorter than the other—perhaps 1½ inches—so that the two ends will not come squarely together, thus reducing the abruptness of the two thicknesses. In cutting the felt, both ends should be drawn up as tightly as possible, after the stretch roll has been slacked back, and a roll removed, and tacked to a straight edge usually kept for this purpose, care being taken that both edges of the felt are in perfect line with each other. The ends may then be cut off, making necessary allowance for the lap in the seam, care being taken that each end is cut to follow a thread. The seam can then be made.

Fine book and writing papers being more sensitive to clumsy or thick seams, it has been found best to use in this connection the seam made by butting the two ends of the felt together and putting in what is called a herring-bone stitch. This method does away with the objectionable thick seam above described.

In adjusting the stretch roll care must be taken not to run one end of the roll very far ahead of the other, as it must be remembered that a dryer felt is of a very unyielding nature—not at all like a woolen felt, which stretches out and has a flexibility which yields to the tension of the rolls. It must not be expected that the seam of the dryer felt will run absolutely at right angles with the machine. If one end of the seam is a little ahead of the other, but the felt runs smoothly over the dryers and rolls, it should be allowed to remain so, there being no cause for worry. It is time enough to change the stretch roll when the felt shows signs of wrinkling over the corner and loop rolls. These present the sharpest angles for the felt to pass over, and are the places which should receive attention when a felt shows signs of troubling.

Dryer felts should be strained up tight enough to prevent the paper from cockling, but never tight enough to leave the imprint of the weaving of the felt in the paper, or to cause the felt to wrinkle. A little careful observation will teach the machine-tender about where the tension of the felt should be. The use of an automatic tightener is supposed to regulate the tightness of the felt under various conditions.

The weight of the canvas from which these dryer felts are made should depend very largely upon the conditions to be met with on the various machines.

Guide Rolls: The guiding of the felt and the position of the guide roll should be calculated in a way that they may have the greatest control over the felt. If two carrying rolls be placed 12 ft. apart, it is always best to take the guide roll at least 8 ft. toward the roll, following the direction in which the felt is traveling. It sometimes happens that the guide rolls are placed 3 or 4 ft. nearer the roll in the reverse direction, giving a very short draw from the roll as the felt approaches the guide roll. The short distance between the roll and the guide roll, coupled with the unyielding nature of the felt, makes it impossible for the felt to respond quickly to the guide roll. Immediately after passing the guide roll, the felt has a long stretch to travel before passing another roll, the result being that it is very likely to drift back again, thereby losing a part of the distance which it has been brought by the guide roll. The reverse condition would operate more satisfactorily; that is—if the roll be placed as above described, so that the long distance between the back roll and the guide roll would yield more readily to the influence of the guide, the short distance between the guide and the roll ahead of it would have a tendency to hold the full amount that has been gained by the guide roll. It may be said that this plan is applicable to any felt.

Briefly—the guide roll should be placed so that the felt may be easily turned to one side or the other, and the roll following should be near enough to hold all that the guide roll has accomplished.

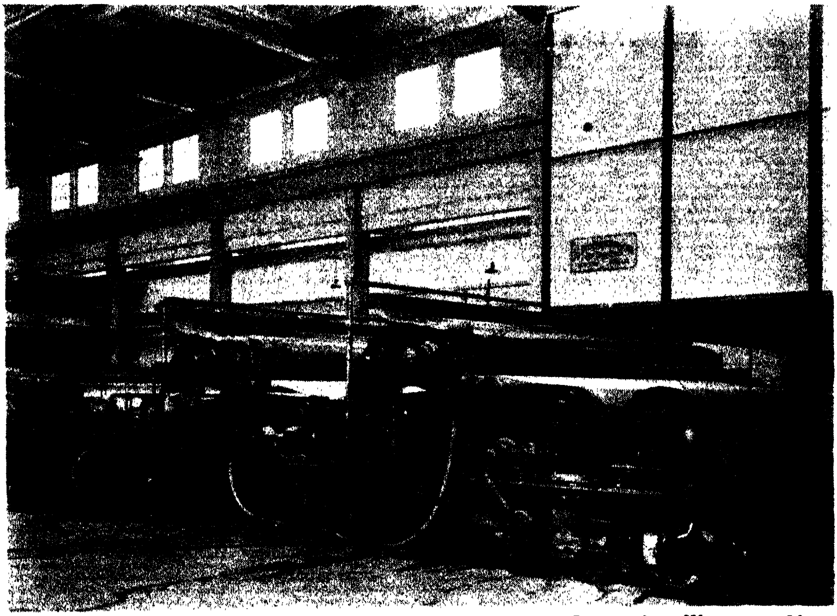
Automatic guides should be of such a type, and so delicately adjusted, that the least pressure on the edge of the dryer felt will be sufficient to turn the guide roll without turning the edge of the felt. The guide roll should never be placed between two rolls very near together, or so high that the arc of contact of the felt on the roll shall prevent the guide roll from swinging easily, or shall bind it in any way. The felt should run over the top of the guide roll, inclining downward slightly on either side.

Water should never be allowed to drip on the top dryer felt. The steam and condensation should be extracted from the hood over the machine, if there is one, in such a manner as to prevent any dripping. This subject of ventilation is discussed in detail in Chapter 17. The chemicals, especially alum, contained in paper stock, rot a felt out very quickly if the drip be ever so slight; they also cause wet streaks in the paper, which are very objectionable, even if they are dried out before finally reaching the reel, as other portions of the paper must necessarily be over-dried in order to eliminate the moisture in these particular streaks.

Care must be exercised in rinsing up around the press nearest the dryers, that no water be spattered on the dryer felt, as this also has a tendency to rot the felt and thus shorten its service.

The careless use of spears for removing paper that has become wound around the dryers should not be permitted. There is a temptation for machine help to assume too great risk, the spear being frequently caught between the dryer and the felt, and taken around the dryer, which results in tearing holes and sometimes destroying the felt. If the dryers become clogged with paper, they should be stopped long enough to cut it straight across, and started very slowly so that the paper may be rolled up and removed without danger or injury.

The dryer felt running next to the press nearest the dryers, should always be protected by a good strong guard. The space between the dryer felt and this press is so limited that there is great danger of machine operators getting caught between the felt and the first dryer.



Courtesy: Rice Barton Corporation, Worcester, Mass.

FIG. 197a.—Modern high speed machine showing pony dryers.

Pony Dryers.

Pony Dryers are drying cylinders, similar to those that dry the paper, but smaller (usually 24 to 30 inches in diameter), running in roller bearings and not connected with the ordinary dryer drive, being revolved by the friction of the felt. They are so placed as to dry the felt as it passes back from the last dryer to the first so that it will be in condition to give maximum efficiency at the wet end of the dryer. These pony dryers are especially useful when pushing a machine to the limit of its capacity.

It will be appreciated that if moisture were allowed to remain in the felt each time that it made a revolution this condition would gradually build up a moisture content in the felt that would result in it finally running very wet, even at the dry end.

Dryer Felt Rolls.

These rolls are made of iron or steel pipe from 6 to 12 inches in diameter, depending on the width of the machine. They are not turned down as this would reduce the thickness of the metal too much in certain portions of the pipe and slight irregularities in surface are unimportant since, owing to there being a number of these rolls, the irregularities will correct each other. These rolls are usually heavily galvanized.

Dryer Gears.

Dryer gears should be cut so as to be smooth running and avoid backlash. A jerky condition on any of the dryers would put undue strain on the paper in places which might break it and in any case would be detrimental to the quality by straining the fibers apart.

They should be split gears to facilitate the changing of broken gears.

Machines have 25 or more four-foot dryers; it is customary to drive them with two pinions. These pinions have to start the dryers from a standstill and when the clutch is thrown in there is a terrific lifting tendency on the dryers immediately surrounding these pinions. This should be guarded against by having very strong holding-down caps over the journals on the back side. If the dryers lift they may break not only their own gears but many of those around them. Machines are frequently erected without these holding-down caps but we would advise that they be supplied and demanded in specifications for new machines.

The Operation of the Dryer Section.

Automatic temperature control of paper machine dryers comes the nearest to a perfect drying system of any method yet devised, for the reason that it controls the actual heat of the dryers instead of the steam pressure, which may be affected by variations that may develop in each dryer. Whether the heat is produced from live steam direct from the boilers or exhaust steam from the engine which drives the paper machine makes no difference, nor if the drying of the paper requires both live and exhaust steam, since it is the actual temperature of the dryers that is governed by an automatic temperature controlling device. If both live and exhaust steam are used the instrument may be adjusted to use all of the exhaust steam first and then if more heat is needed to augment with live steam. There are other very good steam pressure controlling devices for drying paper, but pressure does not always mean "heat" as applied to paper machine dryers. Exhaust steam from the engine which drives the paper machine will not quite dry the paper and boiler pressure steam must be used more or less at a pressure of say 150 pounds to be mixed with exhaust steam equal to the back pressure allowed on the steam engine which is from 5 to 10 pounds. The sum total of this mixture must be "heat," whether it is latent heat from exhaust or saturated steam, or direct from the steam boilers at 150 pounds pressure.

Paper machine dryers may well be thought of as surface condensers. The heat value of the steam inside of the dryer is reduced in direct proportion to the amount of moisture contained in the sheet of paper that covers it.

If a section of dryers with 25 bottom and 25 top dryers, making a total of 50 in all, in good draining condition, is drying a sheet of 35-pound paper satisfactorily at a machine speed of say 700 feet per minute, it will be found that an accurate and consistent flare of heat is developed in the dryers, beginning with the first dryer at a temperature of say 100 degrees F. and finishing with the last dryer at a temperature of say 200 degrees F. This condition of drying will prevail by virtue of the elements employed, viz., the sheet of paper is uniform in thickness and it passes over the dryers at a definite and regular rate of speed. It contains a definite and regular amount of moisture, say 57 to 60 per cent. The first dryer warms the sheet, the second warms it still more and the third more yet. The sheet does not reach the evaporating point until it has passed several dryers, each dryer in its turn heating the sheet within its capacity until it reaches a dryer where evaporation of the moisture in the sheet begins, and where steam can be seen rising from the paper. The evaporation becomes more intense as the paper passes over hotter driers until it reaches the point of correct dryness.

It will be seen from the above that the combination of the definite thickness of paper containing a definite amount of moisture passing over a definite number of dryers heated to a definite temperature at a definite speed makes its own nearly perfect chart. The main steam supply should enter the machine manifold pipe at the calender end of the dryers. This will give the first dryers next to the presses some advantage for the reason that the steam will be somewhat reduced in pressure and heat by the time it has passed a majority of the steam pipes from the steam manifold to the individual dryers, thus assisting in preventing surface scalding and curling of surface fibers.

If a paper machine is equipped with say 50 dryers—25 bottom and 25 top—each dryer must have a steam supply pipe entering the center of each dryer through a universal steam joint and each one of these pipes is connected at the lower end to one large steam header or reservoir which serves as one common supply to all 50 dryers. The size of each of the 50 intake pipes is mathematically determined from the diameter of the dryers and the drying capacity needed, and is coordinated with the speed of the machine and the weight of paper. Liberal allowances must be provided for flexibility. The capacity of the steam header or reservoir must be of liberal size to serve the 50 dryers with the same common pressure. The best and most satisfactory results are obtained by entering the steam header at the dry or calender end with exhaust steam from the steam engine. If steam is needed from high pressure lines to boost the heating capacity of the exhaust, this steam should by all means enter the same end with the exhaust steam, so that both pressures will travel in the same direction. Putting the exhaust steam in one end and putting the live steam in the opposite end destroys even distribution of steam in the dryers. Furthermore, this plan creates fluctuating back pressure on the steam engine and upsets the general scheme of straight line temperatures in the dryers. Paper machine dryers, as previously pointed out, are very similar to surface condensers, especially the first five or six dryers at the wet end next to the last wet press. The paper leaves the last press with a moisture content of 57% to 60%. This wet blanket of paper has the effect of cooling the first few dryers. Steam does not begin to come from the paper until it is warmed through and further on becomes hot and then evaporation of moisture in the paper begins and continues until the paper is dry.

There are many excellent papermakers who have never had the opportunity to learn even the elementary principles of steam engineering. Moreover there are very few who have the natural ability or desire to learn; so, *do not* install too many mysterious automatic valves in pipe lines which serve the paper machine dryers with steam and provide the means for extracting the condensation. Stick closely to the natural way. The writer recommends the use of syphons for extracting condensation from the dryers into the drip line, connecting a small horizontal reciprocating vacuum pump to the end of the drip line and regulating amount of suction needed by opening or closing a hand valve in the suction pipe. In this way the discharge of the syphon pipes in the dryers will be assisted, the suction preventing back pressure in the drip line. Each dryer is supplied with steam by means of individual vertical pipes connected to the center of the dryer at the upper end and connected to the steam pipe, called the steam header, at the lower end. Most machines have a hand valve in each one of these individual supply pipes, so that the steam may be closed or partly closed from entering any one of the dryers.[1]

Some machines are connected for steam at the wet end of the machine next to the presses. Others are connected at the dry end at the last dryer. These different connections are made for the reason that nearly every papermaker has a different theory, all of which are well intended. The exhaust steam from the steam engine which runs the machine is scarcely sufficient to dry the paper, unless it is very thin paper, tissue, etc. Therefore, the exhaust steam must be augmented with steam from the high pressure lines. The effect of scalding the paper on the first few dryers is to sear the surface and to trap or seal water in the center of the sheet, injuring the finish and making it difficult to complete the drying. Paper should be first warmed through and brought gradually to final drying temperatures. The dipper or bucket principle of water extraction from dryers is that dippers are bolted close to the inside sur-

[1] I am well aware that this advice will be disputed by enthusiasts for various automatic steam supply and condensation removal systems. I realize there is much to be said for such systems, but do not consider them practical for the average American mill.

face of the dryer and have a scooping effect, dipping water at every revolution of the dryer, and spilling it into a pipe connected to a hood or bonnet which covers the center outlet from the dryers and is intended to prevent steam from blowing straight through into the drip line.

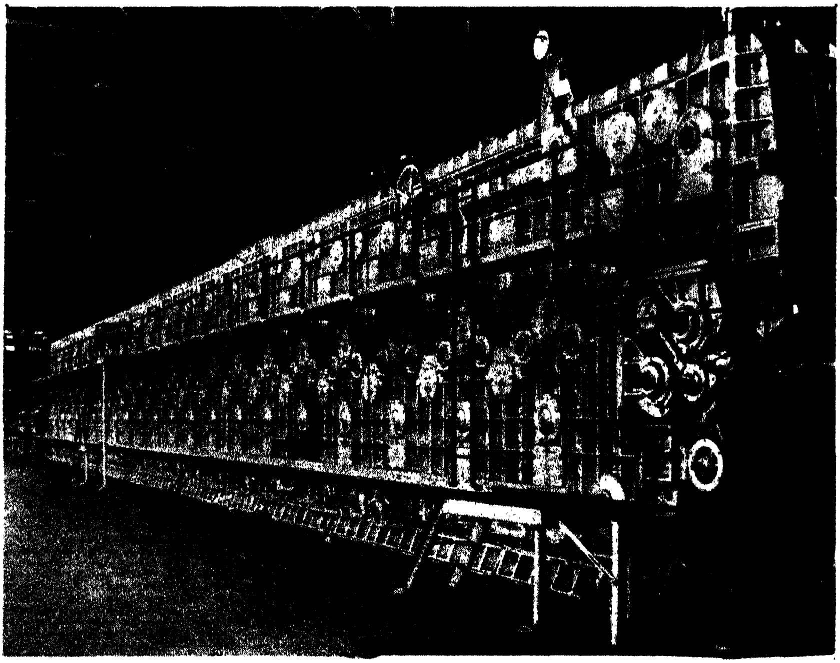
A dryer felt if used wide enough to overhang the dryers about 2 or 3 inches on each end and well started and broken in, ordinarily gives very little trouble. If it gets wet and is allowed to run in a wrinkle, it becomes very difficult to handle. The best way to straighten out wet wrinkles in a dryer felt is to break the paper at the presses, slack up the dryer felt, stop the dryers, pull out the wrinkles, tighten up the felt and run it over the hot dryers until it is dried out before again putting over the paper. Any time spent pulling on a wet dryer felt wrinkle while running is time lost. The 2 or 3 inches overhang of the felt helps to guide it. Uneven pressing causes the paper to wrinkle on the dryers. Wet dryer felts are also caused by water dripping from the hood. Neglected press rolls will do the same thing; also, overtaxing the dryer felt capacity and poor ventilation. The remedy is to stop the water dripping, grind and adjust the press rolls, increase the dryer felt capacity, and improve the ventilation.

Paper will cockle because of stuff formed in lumps, wild formation, long fibered stuff, pressing in streaks and slack dryer felts. The remedy for this is to improve the sheet formation, grind and adjust the press rolls, tighten up the dryer felts, and shorten the stuff. *Shortening the stuff should be the last resort.* The tightening of the dryer felt will usually correct mild cases of cockling.

Some of the most important points concerning paper machine dryers: The customary diameter of paper dryers is 48 inches. The length is determined by the width of the machine. They are placed level and parallel to each other and spaced to give room for felt rolls. Dryers are ground and polished on the surface and carefully balanced. They are equipped with dippers or syphon pipes for extracting water. The extraction of water by syphon consists of forcing the condensate by means of internal pressure up and out of the small pipe which enters the hollow backside journal of the dryer. The syphon pipe is permanently fixed with the open end extending down as near the bottom of the dryer as will permit of clearance and is supposed to be sealed in the water at the bottom of the dryer. The pressure in the dryer is supposed to help force water through the syphon pipe, which flows to the drip line, and ultimately to the hot well. Proper traps, possibly one to each dryer, prevent steam blowing through. The efficiency of this method is largely dependent upon back pressure in the drip line, the help of vacuum pumps, etc. The discharge end of a drip line should not be immersed and sealed in water, because the cooling down of the dryers over Sunday or any other shut-down will create a vacuum that will pull back into the dryers all the water within reach of the sealed end. The drip line valve should not be closed during extended shut-downs to prevent syphoning because the vacuum will still exist. Just what damage this might do is problematical, but why invite trouble, when there is a simple and correct installation? A straight away drip line slightly pitched toward the hot well with the discharge end of the line spilling into a well which has no back pressure; or better still, if the well carries a vacuum, vacuum pumps and condensers are used on drip lines.

The Minton Vacuum Dryer.

This is a patented dryer section which is being used by various builders of modern high speed machines with great success. The entire standard dryer section, including rolls and felts, is enclosed in an absolutely airtight chamber. At one end of this chamber is an ingenious seal or trap



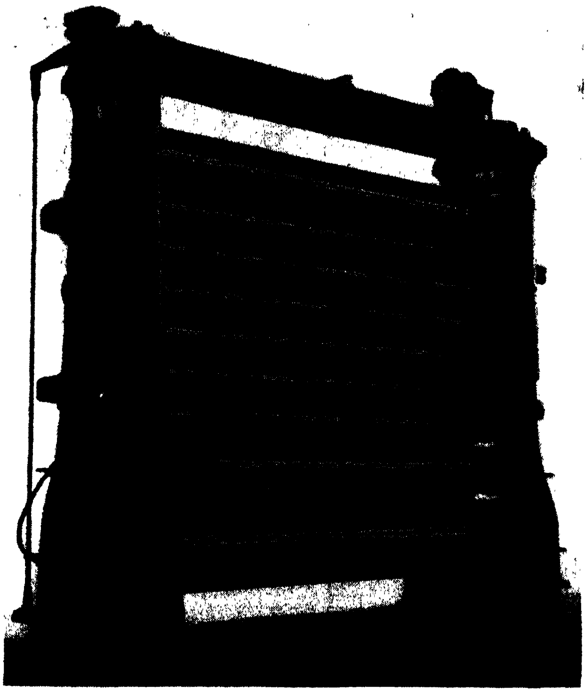
Courtesy: Rice Barton Corporation, Worcester, Mass.

FIG. 198.—Minton vacuum dryer section.

which allows the wet paper to pass through but does not admit any air. There is a similar contrivance at the rear of the chamber which allows the dry paper to emerge without breaking the vacuum. A powerful vacuum pump and an efficient condenser maintain a vacuum in this chamber just as in a tray drying chamber for chemical products. Ordinarily a vacuum is maintained at about 28 inches and the efficiency of the unit depends mainly on the very cleverly devised seals at each end of the chamber. Doors and glass windows are provided at frequent intervals so that the passage of the paper can be observed from the outside, the interior of the dryer being lighted with electricity. As in the case of any other vacuum dryer the operation can be performed at a lower temperature. The drying conditions can be immediately and accurately governed by the operator and are entirely independent of the weather. The wear of the felts is much less than in the case of an ordinary dryer and, of course, the consumption of steam is much less. On the other hand, the first cost of such an installation is obviously quite high.

Calenders.

Calender rolls are cast and chilled and must be of fine grain and perfectly free from blemishes of any kind. They have to be most carefully ground and polished. They are mounted in housings, there being gen-



Courtesy: Lobdell Car Wheel Co., Wilmington, Del.

FIG. 199.—Stack of chilled nickel-chromium cast-iron calender rolls.

erally from seven to eleven in a stack, the whole stack being driven by the friction of the bottom roll. The size of the calender rolls depends on the width of the machine. The bottom roll is crowned and is usually from 24 to 25 inches in diameter on a 156-inch machine. On small machines the bottom roll may be only 18 inches in diameter. The roll next to the bottom is smaller than the bottom roll, but larger than any of the succeeding rolls. All of the remaining rolls are of uniform size except the top roll, which is somewhat smaller than the second roll but larger than any of the intermediate rolls.

The paper enters at the top of the calender stack, being carried across from the dryers and under a spring roll which absorbs any tension due to uneven pull between the dryers and the calender stack.

The number of rolls in the calender stack which the paper is made to pass between is variable and depends on the finish desired to attain. Sometimes more than one calender stack has to be used to get the desired result. On some water-finished paper three stacks are used, one small and two large. The small stack is placed next to the dryers and is called the breaker stack.

The rolls must be kept in perfect alignment and, in order to preserve this alignment, an excellent foundation (concrete to rock or something equally massive) is required. Brass friction rings are provided to take care of the ordinary amount of endwise crowding normally present, but if this crowding becomes excessive the cause should be investigated. It will frequently be found that the cause is a worn journal box, or if the stack is equipped with compound weighted levers, these levers may be pressing unequally on one of the two sides.

In making water-finished paper very great pressure is applied by means of weights and levers and in order that the application of this weight may not cause pinching at the edges of the sheet, all the rolls as well as the bottom one must be slightly crowned according to the weight carried.

Calender Doctors: Calender stacks should be equipped with doctors, one doctor to each roll. These doctors are thin steel blades which are pressed against the rolls by springs. They are beveled so as not to scratch or score the roll or to cause any perceptible amount of friction. The function of the doctors is to keep the rolls free from little specks and scabs of paper, lint, dirt, etc., which would all tend to produce calender spots on the paper. Also they prevent the paper from running around the roll when it is put through the stack.

When a wet end goes through the calenders the rolls become covered with scabs. Sometimes the doctors will not remove these. To get the calenders clean the doctors should be released and the accumulation of lint, paper and dirt thoroughly cleaned out. A little kerosene is now sprinkled on the calender rolls. When the paper starts going through, a little water or kerosene can be sprinkled on the paper. This will usually loosen all the scabs, but if not, the back tender or third hand can remove the obstinate ones with a calender scraper. The paper going through the calenders while this is being done should not be allowed to go on the reels but should go into the broke.

All calender stacks should be provided either with a hydraulic lifting equipment, or a threaded lift operated by a hand-wheel, with which to lift any number of rolls in order to remove wads of paper that may become caught between the rolls.

Air is blown against the calender rolls to keep them cool and to insure even expansion from what heat is inevitable. It will be realized that in such large, heavy masses of metal as calender rolls the expansion and contraction would be more or less uneven. This would tend to press the paper harder at some places than at others making it thinner and weaker there. When a roll shows soft spots a strong air blast should be directed against the calender rolls just at that point, as this part of the calender roll must have become overheated. Overheating frequently occurs at the ends of the rolls. Sometimes the paper comes from the dryers more perfectly dried at one place than another, thus carrying more heat, and this tends to heat the calender rolls unevenly.

Every roll in a stack of calenders when running will crowd to one side or the other of the stack, with an end thrust against the housings, so friction rings are used on the ends of the roll journals to take the wear; inside of the calender frames, a continued endwise thrust will wear deep circles in the frames preventing the free up and down motion which the rolls must have to permit paper to pass between them. Otherwise a wad of paper frequently plugs and stops the rolls from turning. This same crowding influence also prevails on all wet presses.

Calender rolls must be in proper alignment to prevent crowding endwise. The bottom calender roll must be crowned to offset sag and the amount of crown determined by the number of rolls used in the stack and the amount of weight carried on the levers. A high machine-finished paper usually requires slight crowning of some of the intermediate rolls to get uniform finish. It is sometimes necessary to cool the last two dryers (top and bottom) for better finish in which case both top and bottom dryer felts must not cover over one-half of the dryer. If the felt covers two-thirds or more of the surface of these two dryers, the paper will wrinkle because of the reduced circumference of the cold dryers.

The Taylor Calender Roll Pressure Indicator.

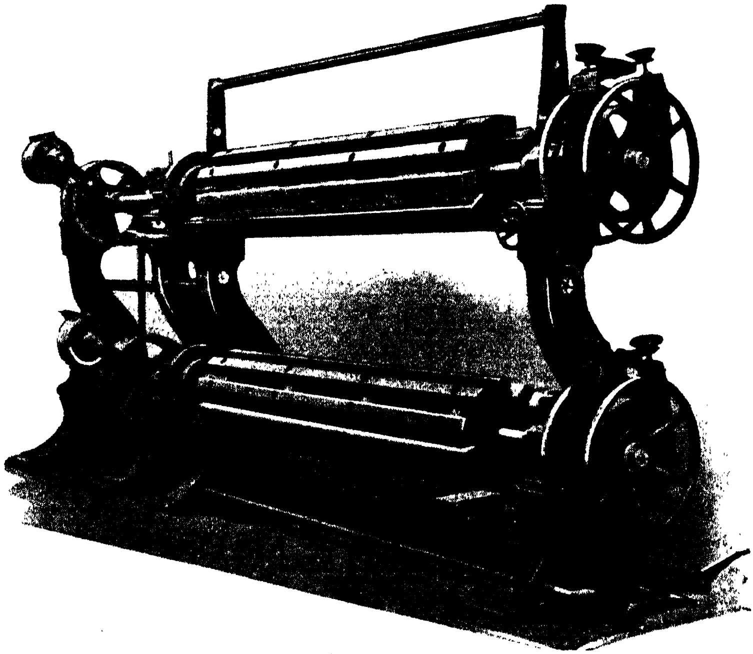
Friction at various points in the weight and lever arrangement makes it impossible by "blind" adjustment of the weights to exert equal pressures upon both ends of the calender roll. Pressure variations as high as 12,000 to 15,000 pounds between the two ends of the roll are common when the weights are adjusted without some means of measuring the actual pressures applied.

Non-uniform calender roll pressures cannot produce a uniformly finished sheet. Excessive roll pressure increases power consumption and materially shortens the life of the intermediate cotton rolls where used for certain finishes.

The Taylor Load Indicator for calenders and supercalenders accurately measures and indicates the pressure exerted upon both ends of the calender roll. By eliminating all guesswork in making weight adjustments the operator is able to maintain a uniform nip pressure across the entire width of the sheet, thus assuring a uniform finish. Once the required roll pressure is established for any given finish, it can be readily duplicated. The elimination of excessive roll pressures reduces power consumption and prolongs the life of certain intermediate rolls. Over a period of 8 months the use of this instrument has saved the price of two intermediate rolls on one machine.

There is a tube system for each end of the roll. The combined length of connecting tubing of both tube systems is 50 feet, thus permitting the instrument to be conveniently located for observation when making weight adjustments, 35 feet being the maximum length of the longer tube system. The instrument's well opened 5-inch scale with bold figures and graduations, together with the two pointers in contrasting colors, enables the operator to make accurate observations from a distance.

The load or pressure-sensitive element is installed in the compression pin between the top lever and the top roll bearing at each end of the roll and measures in pounds pressure the actual load exerted on the top roll bearing by the weight and screw arrangement. Where it is desirable to have a permanent record of the roll pressure to certify that the required calender roll pressure has been maintained for a given finish a recorder can be attached. One of these Taylor indicators is shown in Fig. 230, Chap. 14, attached to a supercalender.



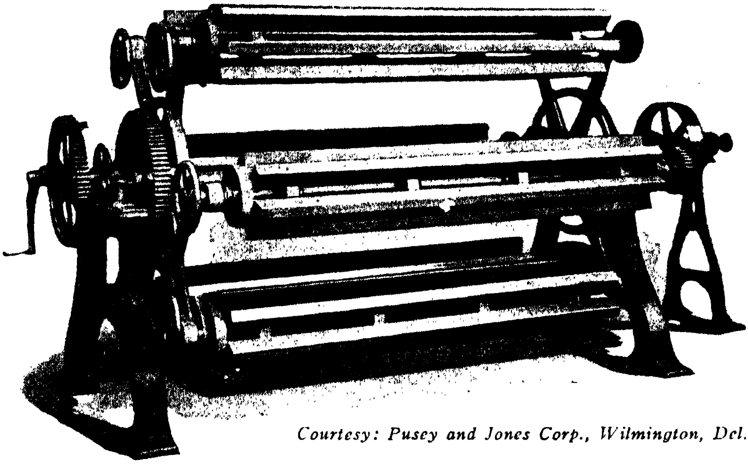
Courtesy: Pusey and Jones Corp., Wilmington, Del.

FIG. 200.—Two-drum vertical reel.

Reels.

There are two different types ot reels—stack reels and revolving reels. Stack reels are put one on top of the other in a vertical frame —usually two reels to a frame, sometimes three. The frames are so constructed as to permit the reels being taken out, after they are filled for the purpose of rewinding. After the reels are removed from the stack they are placed on a separate set of stands for rewinding into smaller rolls or for cutting off into sheets. When the paper is being unrolled the tension is regulated by brakes which on modern equipment are water-cooled and automatically regulated.

It is extremely dangerous, especially in case of high-speed news machines, to allow one reel to be winding up and another reel unwinding in the same stack, because if a man's hand or arm gets caught between the two reels he may be drawn in and killed. This accident is unfortunately not uncommon in paper mills.



Courtesy: Pusey and Jones Corp., Wilmington, Del.

FIG. 201a.—Four-drum semi-automatic revolving reel, of type used with moderate speed, medium width machines.

Revolving reels consist of a set of reels arranged in the form of a cylinder. It is really a reel of reels. The housing carrying the reels revolves so that by the time one reel is filled another is in position to take its place, and similarly by the time one reel is almost unwound another full reel is in position for unwinding. These reels are specially adapted where the paper is taken from the reel to be cut into sheets.

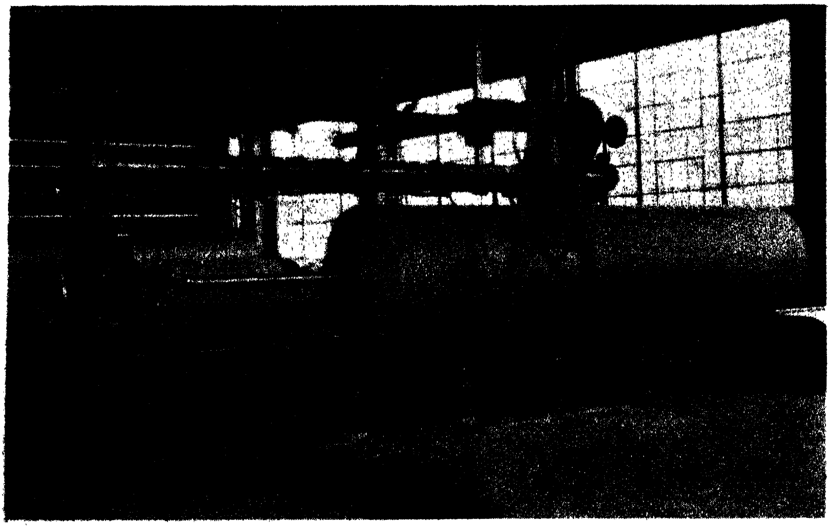
The stack reels are driven with a clutch and a friction belt is provided so the speed of the reel can be controlled, both in winding when care must be exercised not to break the paper, and in unwinding when friction must frequently be applied to keep the reel from going too fast and allowing the paper to become slack.

The revolving or cylinder reels are driven by a gear arranged so that the gear for each reel meshes into the driving gear when the reel reaches a certain point in its revolution. These reels are also provided with frictions for the same purposes as in the case of the stack reels.

"English" reels are driven by the friction of the paper itself against a large drum revolving by mechanical drive. These reels make very tight and uniform rolls.

Winders.

The winder is a machine for taking the paper from the reels and winding it in rolls of any desired size and at the same time cutting the paper into any desired width, which it does by means of knives that press on the paper as it is moving from the reel to the winder. There are a great many makes of these winders in use. This equipment will be described in detail in the chapter on the finishing room.

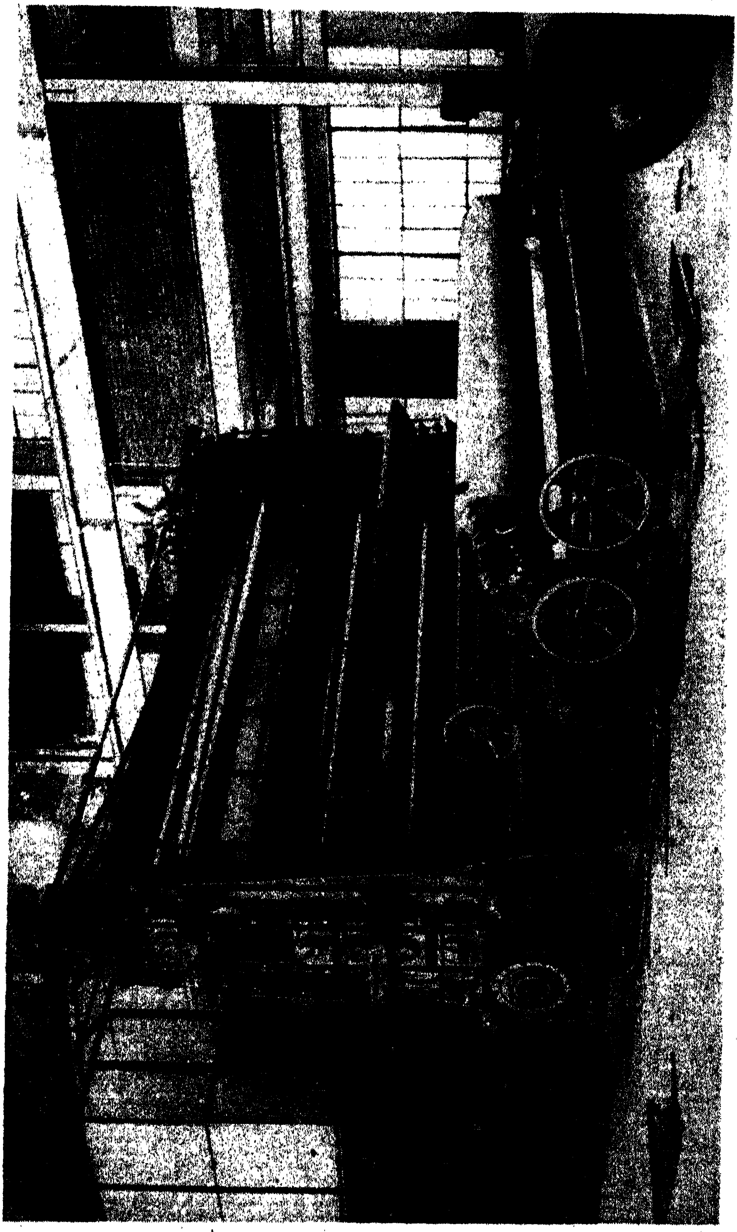


Courtesy: Beloit Iron Works, Beloit, Wis.

FIG. 202.—Improved type of winder: after finished roll of paper is made, kicker roll pushes roll of paper from the operating position over the winder drum onto a travelling conveyor operating across the front of the winder, the entire series of operations being controlled by electricity and there being absolutely no strain on the winder shaft.

The Cylinder Machine.

The cylinder paper machine differs from the Fourdrinier machine chiefly in the means by which a sheet of paper is formed. Instead of a level Fourdrinier wire on which the stuff flows and spreads evenly into a uniform sheet of paper, the formation on a cylinder machine is accomplished by means of a cylinder mold surface-covered with fine wire cloth which revolves in a vat of thin paper stock. The fibers are attracted to the face of the cylinder mold by suction by which means a uniform sheet of paper is spread evenly over the entire width of the cylinder mold which is covered with fine mesh Fourdrinier wire. The paper thus formed is picked up and carried to the first press by means of a long wet felt which passes between the top and bottom press rolls. From this point the remainder of the cylinder machine is usually quite like the Fourdrinier



Courtesy: Farrel-Birmingham Co., Inc., Ansonia, Conn.

Fig. 202a.—Dry end of modern Fourdrinier paper machine showing calender stack and winder.

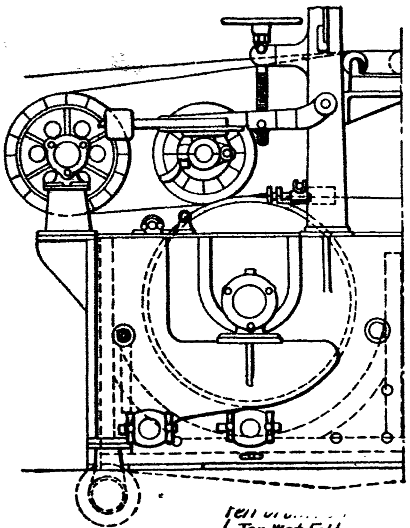
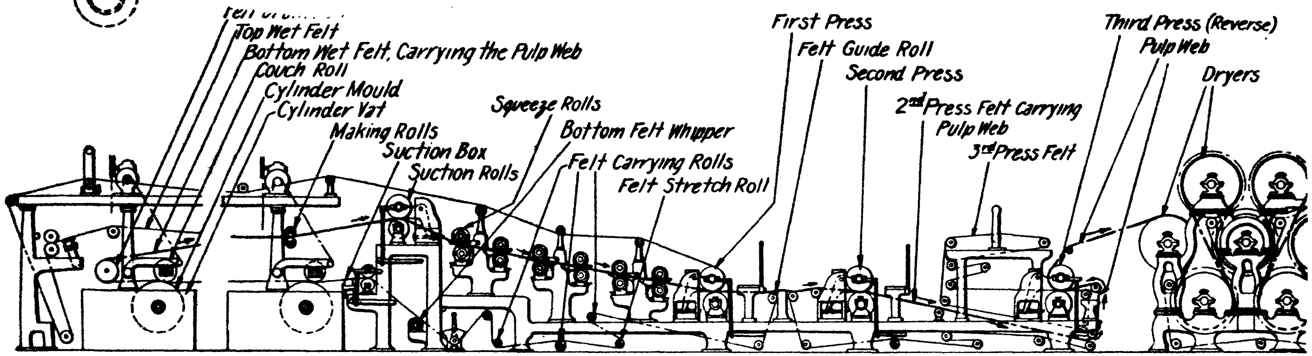


Fig. 203.—Cylinder machine from wet end, only two cylinders being shown.
Courtesy: Socony-Vacuum Oil Co., Inc., New York.

Details of vat part of cylinder machine.



except that the dryers are usually arranged three or more high in two, three or four vertical stacks. Also in the case of cylinder machines used for making glazed paper or board there is frequently a large "Yankee" dryer or "Flying Dutchman." The skill required to operate successfully a cylinder paper machine is different but no less than is required to operate a Fourdrinier machine. The formation principles are very different and can only be learned by experience. A Fourdrinier machine tender cannot run a cylinder machine; neither can a cylinder machine tender run a Fourdrinier machine. The cylinder machine by virtue of its construction makes a conspicuously distinct grain in the paper under the influence of the suction. The explanation is as follows: If a cylinder mold 48 inches in diameter and ten feet long were placed in a horizontal position in a cylinder vat with the cylinder equipped with deckles on each end so that both ends of the cylinder will be open, and then the vat is filled with water, the water will soon stand at an equal level both inside and outside of the cylinder and yet no water will have entered the open ends of the cylinder. At the front end of the cylinder vat is a gate which slides up and down and is operated by a float in a separate compartment at the end of the vat. The level of water in this compartment is identical with the level of the water on the outside of the cylinder mold. A float is placed in this compartment which is attached to a stem in turn attached to a sliding gate which opens or closes in direct proportion to the height of the water in the vat and on the outside of the cylinder. If the height of the water increases the float rises and opens the gate at the end of the cylinder correspondingly and corrects the water level. The machine tender regulates the height of water in the vat by shortening or lengthening the stem between the float and the gate to a normal height, usually so that the cylinder will be immersed about three-fourths of its diameter. Riding on top of the cylinder, is a rubber-covered couch roll. Around this couch is a long wool wet felt. The couch roll is hung by its journals from what are called couch arms suspended in a way that permits the couch to rise and fall with uneven degrees of paper thickness. This is so that the felt around the couch which must run on the paper will have the correct amount of pressure to transfer the web of paper to the felt perfectly and without distorting its formation.

There is usually a shower to clean the wire of the cylinder mold before it re-enters the bath of stock in the vat. The clearance between the mold and the inside of the vat may be anywhere from three inches to eight inches depending on the stock. Similarly the wire on the cylinder mold may be anything from 30 to 60 mesh.

The press part of the cylinder machine is the same as in the Fourdrinier machine except that the paper usually first passes between six or more "baby" press rolls, necessary to prevent "crushing" of thick boards and papers. The top "baby" press rolls are rubber-covered and the lower ones of metal, and the pressure can be regulated very accurately.

When starting a cylinder machine the first thing to do is to furnish the screens, head box and cylinder vats with water. When the water reaches its normal height, paper stock is admitted to the screens and to the cylinder vats. The suction causes the fibers to cling to the cylinder and the water is drawn through the meshes of the cylinder cover into the inside of the cylinder, leaving the fibers clinging to the outside surface of the cylinder mold. This yields the desired formation of a sheet of paper which is picked up by the wool wet felt and carried to the presses and on over the dryers, calenders and thence to the reels and winder or sheet cutter. The water drawn through the screen cover on the cylinder mold is regulated by the float above described. By opening the gate the water flows from the center of the cylinder into a pump box and the pump returns this suction water back to the screens to mix again with the stock. The suction water may be diverted for other purposes if all of it is not needed in the screens.

A much greater variety of thicknesses of paper may be made on a cylinder machine than can be made on a Fourdrinier machine. The range of thickness is from the thinnest tissues to the thickest building board, wall board, box board, or roofing paper and every weight between these two extremes. In the foregoing description of a cylinder machine one cylinder only has been considered. In making extremely thick board as many as six or eight cylinders are used depending on the thickness required. Each one of the six or eight cylinders forms a thick sheet and each sheet is couched from the cylinders beginning with the first cylinder picking up each succeeding sheet and pressing them together in plies while the sheets are still wet. By the time this thick board reaches the cutter it would be difficult to separate the plies for the reason that they have been firmly pressed together or "laminated." One long wool wet felt serves all the cylinders. Lined board is made by using a better stock in the first and last cylinders. This procedure lines both sides of the board with a better grade of paper and of a different color if required and permits inferior material to be used in the middle of the board or paper. The *first* and *last* layers are called "liners" and the intermediate layers are called "fillers." Cylinder machines with only one vat are used for making tissue paper and also stock for asphalt saturated roofing and other such specialties. Some of these single vat machines now have molds upwards of six feet in diameter, but the usual diameter is less.

The influence which causes the fibers in the cylinder vat to cleave to the surface of the screen covering on the periphery of the cylinder, thereby forming a sheet of paper, in the language of the papermaker is called suction, but it is not suction in its correct sense because there is no actual vacuum on the inside of the cylinder mold. It is more like the action of a screen. By pouring water filled with pulp fibers through a fine screen, the screen will catch the fibers—which cannot be called suction. This is just what happens continuously in the case of the cylinder mold with a surface covering of fine Fourdrinier wire. It is much like water running over the crest of a dam. If a screen were placed across the crest, the water would run through but the screen would catch everything that could not pass through the mesh. The difference in the height of the water on the inside and outside of the cylinder constitutes a miniature dam. If more suction is needed it may be increased by *reducing* the height of the water on the *inside* of the cylinder mold: if less suction is required the water on the inside of the cylinder is *raised,* reducing the height of the dam.

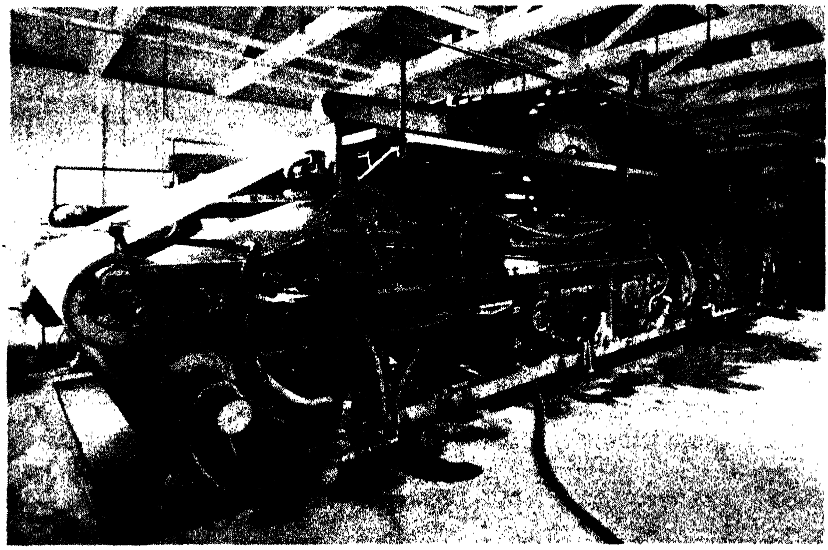
The distinct grain usually found in paper made on a cylinder machine mentioned in the beginning of this chapter is caused by the influence of the current of water flowing through the screen covering of the cylinder, like water running over the crest of a dam. Logs running over a dam invariably go over the dam endwise. Similarly fibers are drawn endwise on to the surface of the cylinder mold which causes the distinct grain which runs lengthwise of the finished paper. The longer the fibers the more pronounced will be the lengthwise grain. There is no "shake" in the cylinder machine as in the Fourdrinier. That is why it is so satisfactory for tissues that require little strength. Many schemes for criss-crossing the fibers to reduce this grain tendency have been used with considerable success, such as agitators and baffle boards of various shapes placed in various parts of the cylinder vat thoroughly to mix the fibers, but these agitators and boards cannot be placed so near the cylinder face as to distort the formation of the sheet. Therefore, the current influence predominates finally because even one inch distance from the cylinder face gives plenty of room for fibers to be drawn to the cylinder lengthwise.

Combination cylinder and Fourdrinier machines are used for making double faced paper such as the familiar red and black paper for camera films. The wet felt of the Fourdrinier part is arranged so as to pick up the thin film of colored tissue from the cylinder machine and together they pass through the remaining presses, the dryers and the calenders.

Harper Fourdrinier Machine.

The Harper Fourdrinier machine closely resembles an ordinary Fourdrinier machine with the entire portion preceding the presses turned around end for end. In other words the wire is traveling away from the presses, instead of towards them. The paper formed on the wire is carried back from the couch rolls on a long felt (which is carried on rolls high over the wire), which supports the paper until it enters the presses and sometimes even until it enters the dryers. The dryers are reduced in number often no more than six being required.

The chief usefulness of this machine is due to the fact that the paper is constantly supported by a felt, or some other surface, there being no gaps to bridge, as between the couch rolls and presses in the ordinary Fourdrinier machine. This renders the Harper machine valuable for making very delicate papers such as tissues, cigarette paper, crêpe papers, etc. Since this kind of paper requires very little pressing, there is frequently only one set of press rolls on such a machine. The excessively long felt often 100 feet in length, is one of the undesirable features of this machine. In the first place, it is very expensive and, secondly, it is very hard to keep free from injury. This fact, together with the upkeep of the Fourdrinier wire, makes the Harper a very expensive machine to maintain. Consequently its use is restricted to those kinds of



Courtesy: Beloit Iron Works, Beloit, Wis.

Fig. 204.—Harper Fourdrinier machine.

paper that cannot well be made on any other machine, as outlined above. Of recent years many Harper machines have been turned around and converted into ordinary Fourdrinier machines largely due to the introduction of suction couch and press rolls.

Yankee Machine.

The essential difference between a Yankee machine and a Fourdrinier, Cylinder or Harper is the method used in finishing or surfacing a sheet of paper and the drying.

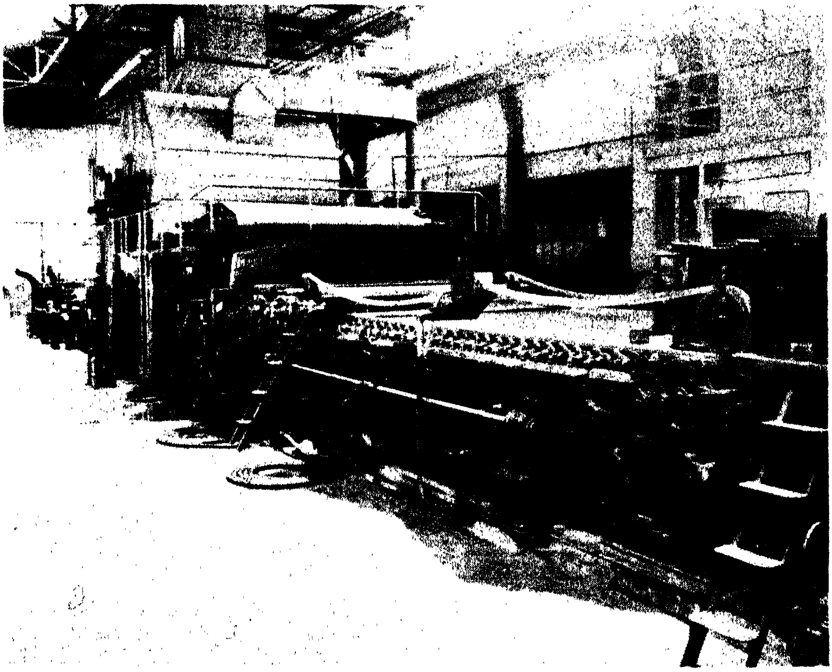
The Yankee machine has one very large dryer, sometimes considerably more than 10 feet in diameter, while the ordinary machine dryers range from 3 to 5 feet in diameter. The large dryer which is used on Yankee machines has a very highly polished surface, and against this surface a set of press rolls runs, the top press roll coming in contact with the surface of the dryer.

The press rolls are permanently fixed and the dryer is screwed back against the surface of the press roll by means of screw gears and hand wheels. This is so that when the paper passes between the rubber covered press rolls and dryer it can be pinched very hard.

There is also usually a dryer felt covering the big Yankee dryer the same as it covers ordinary dryers, care being taken to get all of the drying surface possible within the radius of the dryer.

The making up part of the machine is precisely the same as any other machine, namely straight Fourdrinier part, wet part of Cylinder machine or wet part of Harper Fourdrinier machine.

Sometimes there are small intermediate dryers and the big Yankee dryer is placed at some advantageous point in the section of dryers. The object of all of this is to give the sheet of paper a glossy finish on one side only.



Courtesy: Beloit Iron Works, Beloit, Mich.

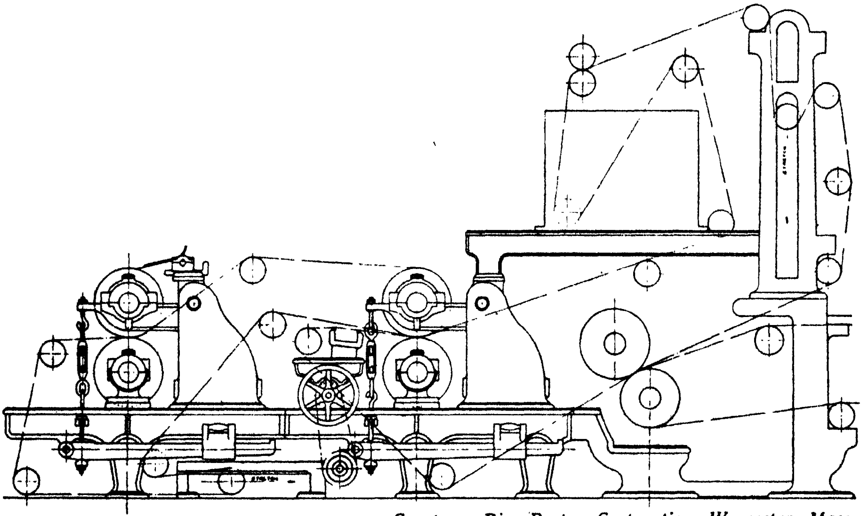
FIG. 205.—Standard "Yankee" Fourdrinier machine looking from wet end towards the big dryer.

The speed and production of the machine is limited to the capacity of the big dryer. For instance, if the machine was running a little faster then the big dryer would dry the paper alone, smaller dryers would be added either before or after the sheet passes the big dryer, usually before.

This leaves the right amount of moisture in the paper to iron nicely as it goes over the dryer. If the sheet of paper is too wet it does not give the desired surface or dryness and if it is too dry it takes away the excellent polish obtained. The idea is very similar to laundry work: ironing a shirt bosom, for instance. It has always to be sprinkled to a certain degree of moisture before flat irons are applied. This is the principle of the Yankee machine.

The Yankee machine is necessarily slow running and yields a low production and, as before stated, it is limited on account of operating the large dryer.

There can be the same number of presses and the same apparatus to form the sheet and get it ready for this dryer, as on any other machine. There are seldom any calenders on a Yankee machine, because when a sheet of paper goes over the big dryer it is supposed to be finished.



Courtesy: Rice Barton Corporation, Worcester, Mass.

206.—Diagram showing Edwardes attachment to standard Fourdrinier machine for making tissues by simplifying the transfer of light weight paper from the wire to the dryers, the paper at all times being supported by a carrying felt as shown in the diagram.

This machine gives an excellent shiny surface to the paper which cannot be obtained by ordinary calendering but it only gives the surface to one side of the sheet, the sheet of paper being hugged so tightly against this dryer by the dryer felt and moved so slowly, that by the time it goes over the dryer once it is ready to reel up nicely finished.

There are a great many uses for this paper, such as for the lining of duplex paper bags with the shiny side inward. It makes a very satisfactory appearance for a bag containing cereals of any kind, coffee, teas, confectionery, etc. Tissue paper is sometimes finished in this way, especially that used for wrapping confectionery goods. It is also used for paper for druggists' purposes. It may be used for blank leaves in technical books, novels, etc., where a nice finish is desired. Paper napkins and towels and all sorts of paper used for similar purposes may be made and finished on a Yankee machine.

The Yankee machine is adapted for thin and medium weight papers only, ranging from tissues to not thicker than 35 or 40 pound paper.

The reason for this is also on account of the limited production and slow running of such a machine, because all of the finish that it can possibly get is while the big dryer is making one revolution.

The reason for putting the big dryer at the dry end of the ordinary dryers is so that the ordinary dryers can be tempered so that the paper will come to the big dryer with just the right amount of moisture to give it the ironing effect. The whole machine must be run entirely in accord with the big dryer and its conditions, drying capacity, etc.

It is very essential that the surface of this dryer be kept absolutely clean. In many instances the dryer is supplied with some sort of a polishing apparatus like a revolving buffer or oscillating doctor, which is equipped with soft material that will not scratch the surface, as the finish of the paper depends entirely on the surface of this dryer. Any scratches or creases caused by ordinary doctors dragging on the surface will show up in the paper after running over this dryer.

A typical Yankee machine has no additional dryers, but these modifications can be applied in case of necessity to come nearer to the requirements for certain grades of paper.

Machine Drive.[1]

The general practice, long known as the Marshall drive or "train," is to drive all the moving parts of the machine from a variable speed line shaft situated in the basement under the machine room. This shaft extends the length of the machine and is usually driven by a belt from a steam engine or electric motor. Turbine-driven reduction gears have been tried in a few instances. Owing to the length of this shaft it is not advisable to have the engine or motor direct connected to it, and should this arrangement be installed for any reason it is necessary to introduce a flexible coupling between the engine and the shaft.

Steam engines are generally used in preference to motors since the exhaust steam is afterwards used in the dryers. Turbines might seem advantageous for this purpose, as they would deliver exhaust steam free from oil, whereas oil separators have to be installed between the engine and the dryers. However, where turbines have been used other facts have developed that militate against their use. The turbine, on account of its high speed, is little adapted to the paper machine service, and complicated speed-reduction gears are necessary when turbines are used.

The line shaft is fitted with cone pulleys and, from these, belts pass up through scuppers to cone pulleys, mounted on stands specially designed for paper machine service, which drive the lower couch roll, lower press rolls, dryers and bottom calender roll. These stands provide for belt

[1] This section covers the usual drive in use prior to introduction of electric drive systems, which will be dealt with separately. The Marshall drive is still in use in a majority of mills.

shifters and friction clutches, so that the belt can be advanced or retarded on the cones as needed and that particular part of the machine can be shut down independent of any other at any time.

There is also a *constant speed line* for driving the various pumps, screens, etc., or else these can be driven by individual motors.

In starting the machine the wire is first started, then the presses and finally the dryers, calenders and reels, the paper being led along from one part of the machine to the next by helpers. It is then necessary to adjust the tension of the paper between the various parts of the machine. If the paper sags too much between the couch roll and the first press it is obvious that the press is running too slow in relation to the wire, consequently we speed the press up a little and slow the wire down a little by means of the cone pulleys. If the paper apparently pulls in two between the couch roll and the first press, we would assume that the speed of the press was too high in relation to that of the wire and we would slow down the press a little and speed up the wire. In this way, without making any drastic alterations in speed of any part, the working of the entire machine can be tuned up, so there is no undue strain on the paper anywhere.

Starting the Paper Machine.

We will assume that the engine is running and that the constant and variable speed lines are both up to speed and ready to strike in the machine.

(1) The dryers must be started in advance of the other parts of the machine and steam must be admitted to the dryers so that they will be at the right temperature when the paper is put over. The dryer felt must be given a tension to see that it runs steadily and safely. Steam must not be admitted to the dryers before they are started since, as water will probably be lying in the bottom of the cylinders, they would be heated unevenly and strained on account of the unequal expansion. It is also desirable to open the drip line valve to its full extent when the steam is admitted so that the excess water will be blown out quickly, after which the drip valve should be closed to a point where the water will be extracted without wasting steam. A three- or four-inch drip line valve should be open not more than three or four turns. After the dryers have been started and water all exhausted the inlet valve should be set at a point adapted to the sheet of paper to be made.

(2) Each woolen felt, on the first, second and third presses, should be got into proper condition by starting it up carefully. If the presses have been left up prior to the starting of the machine, they should be carefully inspected to see that no lumps, foreign matter, tools, etc., are lying around, and then the presses should be let down, and the felt started. The shower pipes should then be opened, giving the felt a sprinkling. The presses should be run in this condition until the felts are thoroughly saturated. Then the water should be shut off and the presses run until the surplus water is all squeezed out and the felts running smoothly. Then,

the press weights are put on the levers. Be sure that the outlet of each save-all pan under each set of presses is clear, to prevent water from running down onto the felt. Treat each and every felt in this manner. Then shut them all down.

While this is being done, the dryers must not be forgotten and allowed to become overheated.

The preceding operations are usually attended to by the back-tender third hand and fourth hand. Simultaneously the machine tender is getting the Fourdrinier part and wire in readiness to start.

(3) First, the entire wire is given a thorough inspection, making sure that there is nothing lying around on the wire or near it that will injure it. The wire, deckle straps, apron couch roll, etc., are thoroughly washed with a hose. All showers are opened wide. The wire is started and run around for a few minutes to make sure that it is in perfect readiness for starting. All levers and weights on the couch rolls are inspected, to see that they are in proper place. When the machine tender is satisfied that his wire is in proper condition he stops it, and begins the "furnishing up" of the vats, screens, pump box, head box and save-alls.

(4) First, the fresh water supply is opened. All hands stand by while this operation is going on, keeping a sharp eye on anything that might need attention. The back-tender stands by the starting lever of the Fourdrinier wire. When the clear water furnish is at a sufficient height, the machine tender opens the stuff tap in the stuff box at the back side of the machine. The stuff mixes with the return water going through the pump and into the screens, head box and onto the apron. The machine tender watches the furnish, and when there are fibers enough in the water to make the sheet of paper he gives the signal to the back-tender to throw in the starting lever of the wire. The back-tender starts the wire and immediately takes up a hose and starts rinsing the jacket of the couch roll, as frequently the stuff runs up around against the guard-board. In case there is an old jacket, which has become threadbare, difficulty in keeping the stuff from running up around the roll is encountered, and the only way to get it down is by washing with a heavy stream of water. Care must be taken to have the guard-board properly adjusted and free from grit and particles of stuff under the lip. The wiper must be put in place, and the shower on the jacket run as wide open as may be without running down the jacket. During this operation, extreme care and attention must be given to the save-all under the couchers, that the stuff may not pile up against the wire. Also to see that the wash-roll shower and doctor on the roll is doing its work. In fact, the wire rolls must be watched all the way along during this process of starting, to make sure that no lumps collect on any of the carrying rolls, or breast roll.

(5) The first felt is then started, being careful that no lumps of stock have fallen onto the felt; if so, they must be carefully rinsed off before the felt is started. The third hand operates the squirt gun, which delivers a needle stream of water on the wire, which cuts a narrow tail-end. This tail-

end is lifted from the bottom couch by the back-tender and onto the first felt. This tail-end runs up onto the top press roll of the first felt. The back-tender steps along and pulls it down onto the second felt, and it is finally put up into the third press. The back-tender keeps a sharp eye on this operation, and at the proper time signals the third hand to slowly push in the squirt gun and gradually widen out the tail-end, until the entire sheet is passing through to the third press. By this time the back-tender has taken this narrow tail-end (or leader) across the dryers.

(6) The proper adjustment of the weights on the levers of all of the presses must be carefully taken care of. At the same time the proper temperature of the dryers cannot be forgotten, and the drying apparatus must be corrected according to conditions.

(7) Machines equipped with automatic temperature control may be set at the desired point for proper drying.

(8) During this process of starting up, the tension between the different sections must be carefully observed, as at this particular stage of the process the paper is extremely delicate and tender, and any unnecessary pulling strain between the sections will either cause the paper to break, or render it useless.

(9) The paper is thus taken across and put through the calenders at a point sufficient for the finish, and from the calenders to the reels. During this operation the machine tender stays up at the wet end and carefully scrutinizes everything connected with the Fourdrinier part making such corrections and adjustments as will ensure the safe running of the paper.

(10) If a dandy is used the dandy must be thoroughly rinsed and cleaned, and let down onto the wire before the paper has been carried through the presses. The suction boxes back of the dandy must be regulated to give the proper moisture to the sheet as it passes under it. If left too wet the dandy is likely to leave crush marks in the sheet. If left too dry, it is likely to lick up the web in places; and even if it does not do this, it does no good to the sheet to let the dandy walk on it. It will be apparent that there can be no impression left in the paper by the weight of the dandy if the sheet is too dry.

Weaving Devices.

There is a strong tendency for the Fourdrinier Machine, no matter how efficiently the shake may be arranged, to cause the sheet to have a grainy appearance. In other words, the fibers all point in one direction leading to excessive strength in the machine direction, and inferior strength in the cross direction.

To overcome this feature many devices have been made to cross these fibers in order that the strength of the paper may be equalized. It is very essential in nearly all grades of papers, especially bag and market that this stage of equilibrium exist or otherwise such a sheet in bag use splits when it is attempted to carry objects of any appreciable size or weight. Such a sheet must be avoided as far as possible, regardless of the difficulty.

A recent patent covering the above work consists of a revolving cylinder, made of parallel steel rings revolving at the same distance in the shallow depth of fibers and water, prior to reaching the suction boxes. As soon as this device has turned these fibers at an angle, or in other words crossed them, they come in contact with the suction box which in turn pulls these fibers down and holds them at that angle before they have an opportunity to straighten themselves out again.

This particular device has shown in many instances its vast importance. In using it, however, extreme precaution must be taken that no stock or particles of dirt cling to the parallel bars, otherwise more particles will accumulate, fall off, and make spots in the paper.

Another method that has become recognized is that of a cross channel device placed under the slices prior to the stock going onto the wire. This apparatus consists of an aluminum box the width of the machine, about one foot in depth and six inches in height. The box is divided into two compartments, an upper and lower. Each compartment is further subdivided into small channels about two inches in width. The small channels of the lower compartments are all directed in one direction at an angle of approximately 45 degrees with the slices. The channels of the upper compartments are directly opposite those of the lower section, thus forming two currents of stock.

With the use of this device the amount of water used determines the nature of the resulting sheet. If a large amount of water is being used at the slices the stock and water are forced out of the cross fiber device with great force and the stock tumbles around in all directions, even in a perpendicular direction to the wire. This boiling action results in a sheet of paper that is practically equal in strength in all directions which is no small feat when the original length of the fibers has been retained during the beating and refining operations.

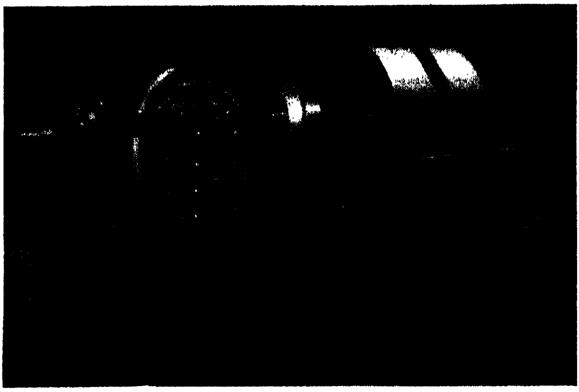
If on the other hand but little water is being used at the slices, the two compartments, the lower and upper, practically form the two webs of paper containing fibers directly opposite to each other. This sheet has all the appearance of a duplex sheet.

Modernization of Drives on Old Machines.

The increase of speed and width of paper machines demands increased power which the old Marshall train was ill equipped to supply within reasonable limits of size. Along with the conditions of competition created in the industry by the fast, wide machines came the realization by owners of older machines that they could only meet this competition by speeding up their machines. This brought strains on the driving trains which they were not designed to withstand, and the modern sectional drives involved investment which it was hard to justify.

Solution of the problems of the owner of the older machines, and an alternative to the installation of the sectional drive, even on the new, fast, wide machine, was provided by the development of the modern corner drive for use in the driving train of the paper machine. Combined with the development of belting suitable for the purpose, the hypoid drive, of the type shown in the cuts accompanying, has made possible the driving of a fast wide paper machine with a single prime mover and a line shaft.

Fig. 207 shows a complete hypoid corner drive unit, suitable for a section of a paper machine; and Fig. 207a shows the gear case itself. This



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

FIG. 207.—Heavy duty hypoid corner drive.

unit has been made possible by the development of highly efficient gears, modern lubricants and the use of roller bearings and other modern transmission units.

The complete corner drive includes a cone pulley, which runs in combination with another cone on the line shaft. The necessary changes of

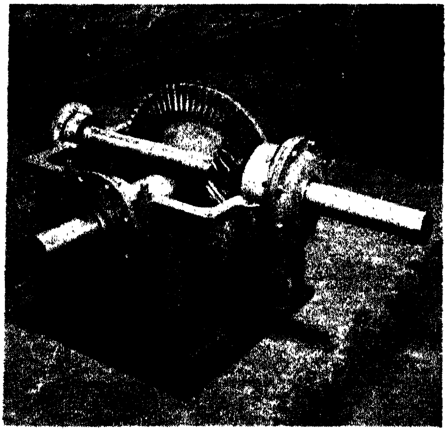


FIG. 207a.

Details of gear case for corner drive.

Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

speed of the section driven by a single unit are secured by a belt shifter, but this is usually operated by controls placed on the tending side of the machine. The unit shown in the cut has a cut-off coupling between the pulley and the gear case. For replacing older drives it is often found necessary to use a friction pulley and this can be arranged. A machine clutch may also be used if desired.

The gear case contains a gear and pinion of the hypoid type. These gears are generated on specially designed machines which give the teeth great accuracy and hence high efficiency of power transmission. The gears are of heat treated alloy steel. A feature of the hypoid gear is that both gear and pinion may be supported at two points by adequate bearings, firmly placed in the walls of the case.

These gears run constantly in oil. The cover of the gear case and the bottom section fit tightly together to form a leak-proof seal. Careful choice of oil has to be made, and lead base oil is to be avoided. However, under reasonable supervision the gears running in this case will last for years and practically eliminate the cost of maintenance of the machine driving train.

It will be noted in the open gear case that roller bearings are used in the gear case. Roller bearings are also used to support the cone pulley shown in the illustration. Where friction pulleys are used, interior roller bearings are used in the hub of the pulley.

A moderate sized unit of this kind will transmit enough power to operate a wide machine at the speeds demanded today. It also provides for the owner of an older machine, with an old fashioned wood-filled gear drive, an opportunity to increase his speed by an important percentage at a moderate investment.

Cause of Breaks on the Paper Machine.

Screens, Spouts and Pipes: All screens, spouts and pipes must be kept thoroughly cleaned to prevent the accumulation of slime. Slime spots are caused by the slime which has collected on spouts, pipes and screen vats breaking away and going through onto the wire, and making up with the web. If a slime spot gets by the couchers and presses to the reels, it makes dark spots, sometimes transparent, and more often leaves a hole in the paper the size of the slime spot.

Head Box: Dead corners in the head box cause lumps to accumulate and break away occasionally. The head box should be no larger than necessary and all square corners eliminated. Make these circular when possible by using fillets.

Apron: Wrinkles in the apron cause the stuff to roll and make lumps. Wrinkles should not be permitted. Holes in the apron cause stuff to roll into small hard lumps. Sometimes a patch can be temporarily used. A poorly folded apron causes stuff to work back under apron and deckle strap, causing bad edges or feather edges. The apron must always be folded with care and must be fastened to the angles in a way that will make square corners between the angles and the wire.

Breast Roll: Stuff carried back by the wire to the breast roll and under the apron will roll into little hard lumps and break the web. This can be eliminated by the use of a strong shower of water. The shower pipe must be so located as to force the streams of water up and between the apron and wire. This will prevent lumps from accumulating under the apron.

Tube Rolls: These must be in perfect alignment. A low tube roll allows the stuff to run under the deckle strap and make a poor edge which will break the web. Tube rolls that are sprung cause the rolls to wobble and run eccentric. This action makes bar marks, or thick and thin streaks across the web.

Tube rolls must not be allowed to stop and wear flat. Dragging over a dead tube roll wears the wire, and it also spoils the roll.

Tube rolls must always be handled very carefully. Tube rolls that are properly made are carefully balanced; if they are roughly handled, denting them or springing the journals the least bit, it throws the rolls out of balance and they will not run, but even if they do, they will not run true, but with an eccentric motion, the results of which have been already mentioned.

In changing a wire, workmen in their haste are apt to become careless and often inexperienced help may be called in from the Beater Room to assist, who not realizing the importance may do considerable damage.

For the changing of wires many mills, especially the larger concerns, have a well trained and well organized crew who do nothing else except repairs and changing wires, jackets and felts. This plan saves money and time, also accidents to the machinery.

Deckle Straps: Poor deckle straps with cracked edges, crooked places, worn edges and poor splices, uneven spots and projections should be avoided.

The deckle strap is nothing more or less than a dam against which the paper stuff forms, and a strap having any of the above mentioned defects will form an edge to the web of paper that will not safely run through the machine.

A cracked edge in a deckle strap will cause lumps and projections to form in the edge of the web and it will very likely break either on the couchers or presses.

Crooked places in the deckle strap are caused by hanging a spare strap up in a dry place and allowing it to stay in one position for so long that the rubber becomes slightly oxidized and becomes set. A strap with this defect will not fit the wire closely and allows stuff to run under it making a bad edge on the web which often causes breaks.

Worn edges on the strap to the extent that they become rounded will also make a poor edge on the web.

Poor splices refers to the strap coming apart in the splice. With reference to this particular defect, it sometimes happens that the splice in the strap is not well enough stuck together, so it will eventually come apart for a little distance at the beginning of the splice. The coming apart of the splice in the deckle strap is frequently avoided by being careful to put the deckle strap on so that the influence of the wire on the strap in pulling it around will pull *from* the splice instead of *against* it.

Uneven spots and projections on a deckle strap are caused by various things. Care should aways be taken with deckle straps when putting on wires, whether the deckle straps have to be taken off entirely and laid away, or whether they are lifted with the deckle frame. If taken up with the deckle frame, it is necessary to tie the strap up in places where it sags so that it will not be in the way. In doing this they should never be tied with a small hard string, as this dents the strap and sometimes these dents will not come out for a long time. A piece of woolen felt 3 inches or 4 inches wide should be used. This is soft and pliable and will never dent the edge of the strap.

It should also be borne in mind that hanging straps over sharp projections like the edge of the deckle frame should be avoided. This will also nick straps on the edge and if left too long will cause indentures which may not come out for some time.

All of these little defects in the edge of the strap will cause like imperfections in the edge of the web of paper, which may lead to breaks.

A spare deckle strap should never be hung up in a dry place, even if hung over the proper circles, because the rubber in these straps will become slightly oxidized and, where they go over the circles they will conform to that particular shape, which will not come out when the strap is put on to be run.

The old-fashioned way used to be to hang straps up on a prepared form of this sort with the idea that the strap would be turned around a few inches every day, but this method is so apt to be neglected that it is not wise to keep the strap in this way. The best way is to keep them in a box immersed in water, the box having sufficient room so that the strap will not have to be kinked or turned in short circles. If cared for this way the strap will always be fresh and good without becoming oxidized.

Suction Boxes: In making light sheets, sometimes the first box suction is closed. This box will fill with water and slop up through the sheet and cause breaks. It is better to lower the box down away from wire if not needed. Filings from a dead suction box dropping onto a wire are not desirable.

Couches: The tension or pull of the web from couches to first press must be carefully adjusted. If the web is pulled too hard, it will cause breaks on account of pulling fibers apart. If this condition does not cause breaks on felts, it may cause the sheet to snap off on the dryers and possibly not until the web reaches the calenders will it break. If pulled too slack at the couchers, it will cause wrinkling. Wet wrinkles will cut at the calenders. From one press to another the same thing applies.

Jackets dirty, worn, wrinkled, twisted, bagging or threadbare on edges will cause trouble. Doctor on top couch roll must be put down evenly on both sides. Must not run jacket too wet or too dry. If too wet it is likely to crush; if too dry, filings from the doctor are likely to drop onto the sheet and break it.

Wires: Holes, cracks, ravelings, pitch spots, wrinkles, poor seams, slack edges and filled meshes, grease and slime spots, etc. These have been discussed in connection with care of the wire.

Dandy Roll: Running the sheet too wet under the dandy roll will cause crush marks. The dandy roll wallows or wades in water, which causes a crushed or cloudy appearance in the sheet. It depends on the cause of too much water running across the suction boxes and under the dandy, how it can be corrected. If the suction boxes are wide open and at the same time there is more water than is necessary to properly close the sheet, some of the supply of water may be shut off, at the same time lowering the slices.

If the stuff is short and slow, it may be difficult to stop the crushing. Very slow stuff necessitates carrying the slices very low and the use of as little furnish water as possible, and yet the sheet may run so wet across the suction boxes and in under the dandy roll as to make it impossible to run a dandy roll without crushing.

It is never intended to prepare stuff that is so slow as to cause troubles of this nature, but sometimes things slip in the beater room. An accident on the paper machine may hold up the dumping of a beater of stuff for hours after it is ready to dump into the stuff chests. In such cases the stuff is likely to slop and slush around in the beaters an unreasonable length of time, which always makes the stuff slippery and slow. Some mills may not be equipped with beaters that can be stopped when the stuff is ready to go to the chests. Sometimes the beaters may be furnished with slow stock without the beaterman being aware of this fact. If the beaters are furnished with this stock, and there is no way provided for the stopping of the beaters when the stuff reaches the correct stage, there is no way to run it on the machine with any degree of success at a speed consistent with the weight of the sheet. Cutting out white water and substituting clear fresh water may help some. Heating the water or stuff may also help in these extreme cases, but it is wasteful and not good workmanship and should be avoided.

If the sheet is run too dry the dandy merely walks on it and many times does what is termed by papermakers as "licking up." It picks up the sheet from the wire in places, sometimes to the extent of making holes and causing breaks, but many times these spots are only lifted slightly by the dandy and they drop back into place, causing a blemish in the sheet which resembles a blister. The dandy when run on a dry sheet has no smoothing or pressing effect and does more harm than good, therefore the amount of water in the sheet under the dandy roll must be correct, constant and uniform. This is especially important in making water marks. The sheet must be plastic and yielding enough to take a deep and clear impression of the water mark.

The Hand of a Paper Machine.

When standing at the winder and looking towards the screens if the drive in on the *right-hand* side the machine is a *right-hand machine.*

Conversely, if when standing at the winder and looking towards the screens the drive is on the *left-hand* side, the machine is a *left-hand machine.*

Save-alls.

Save-alls for paper and pulp mills are precisely what the name implies. They are intended to save all of the fibers left in the white water, before it passes to the sewer and to waste.

There are many types of save-alls. The oldest type is very similar to a decker; a cylinder covered with fine wire is immersed in a vat of white water, suction is applied and the fibers in the water cleave to the surface of the cylinder and later in its revolution, a soft couch roll is brought in contact with the fibers adhering to the surface of the cylinder

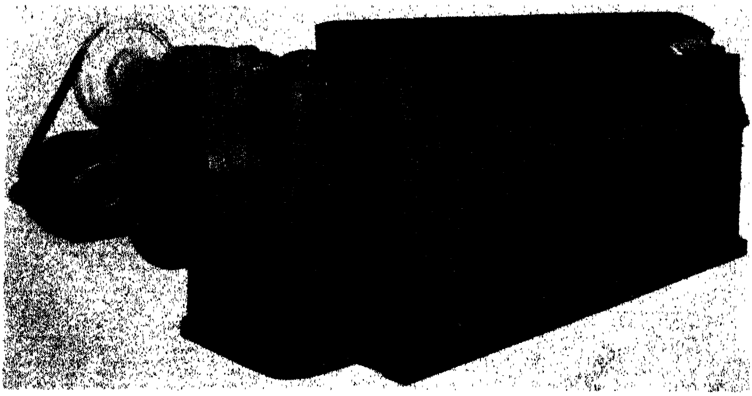
Courtesy: Bird Machine Co., South Walpole, Mass.

FIG. 208.—Bird save-all in mill making high grade rag bond paper.

which are picked up by the couch and at a certain part of its revolution scraped from the couch by a wooden doctor blade, which is in gentle contact with surface of the couch. The fibers of pulp through this process form a thick mush which falls from the doctor into a convenient mill box truck. The pulp thus collected can be shoveled or forked into the beater.

The above type of save-all has only a natural suction, i. e., a suction due to the difference in the head of water inside and outside of the cylinder. If a cylinder of the above type is put into a vat of clear water, there will be no suction, as the clear water will seek a common level through the meshes of the wire, but if put in a vat containing fibers of pulp, the water will be prevented from reaching a common level, due to the fibers partly sealing the meshes of the wire (a revolving dam) which backs up the water several inches higher on the outside of the cylinder than the water on the inside of the cylinder, therefore the so-called suction, which is *not* an induced suction.

Many mills today have a closed system for handling all of the water leaving the machine in such a way that none of the fiber or water goes to waste. In such a system all of the waste water together with stock from the wire trim and couch breaks goes to a save-all. The fiber and filler recovered by the save-all goes directly to the machine chest ready for immediate re-use on the paper machine. The filtered water is used for filling and dumping beaters and in the showers.



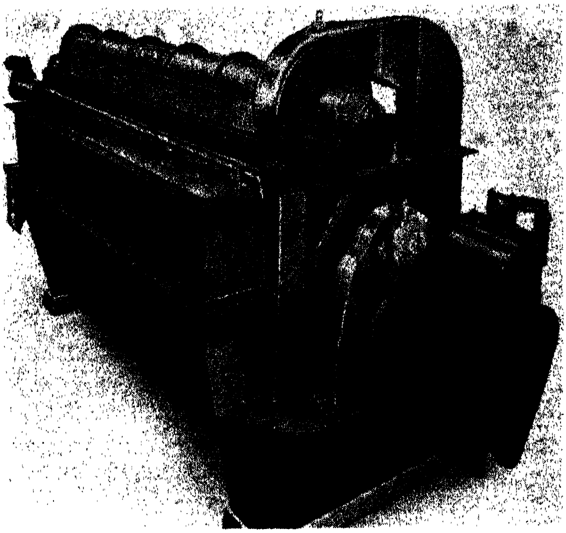
Courtesy: Improved Paper Machinery Corp., Nashua, N. H.

FIG. 209.—Pneumatic type of save-all with very fine mesh wire cloth on cylinder mold. A positive pressure blower is used to produce a suction on the machine and the discharge of this same blower is piped up to valve plates which introduce air to the vacuum channels of the mold just before the doctor blade. This blast of air shoots outwards through the wire and lifts off any foreign matter, and in addition to keeping the wire clean, makes it possible to use this very fine wire.

The save-all shown in Fig. 208 operates as follows: The white water entering the save-all deposits a mat of fiber on a large cylinder mold. This mat acts as an efficient filtering medium. It slows up the passage of the water through the cylinder, causing the head of water to rise, the cylinder remaining stationary. When the white water reaches the operating level, the float operated mercury switch starts the motor which drives the cylinder. As the cylinder turns, the recovered stock is removed by a couch roll. This presents a fresh surface to the white water which lowers the stock level and stops the save-all, and then the cycle is repeated.

Another type of save-all is the induced suction or pneumatic type. A cylinder is placed in a vat of water containing fibers of pulp and by means of a suction pump connected to air-tight chambers which communicate with the surface of the cylinder (at such times as the suction chambers are immersed in the water during its revolution) a suction is induced, which pulls the fibers onto the wire mesh. At a certain point in the revolution of the cylinder these suction chambers become pressure chambers, and by means of a blast of air the pulp is blown from the cylinder surface. This type of machine is also used for thickening pulp.

Unless the wire which covers the surface of the cylinder is of very fine mesh, very little of the very fine fibers or fillers such as clay, etc., is saved. Some manufacturers have thought it worth while to use save-alls of the settling tank type. These settling tanks must be of very large proportions to take care of all the white water from a pulp



Courtesy: Oliver United Filters, Inc., New York.

FIG. 210.—Continuous rotary vacuum type of save-all. Machine furnish or other suitable sweetener stock is added to the whitewater to form a mat which serves as a filter medium through which the water passes. Recovered whitewater solids are continuously returned to the paper machine. Capacity varies with the freeness of the mixture of whitewater and sweetener stock—usually from two to ten g.p.m. per square foot of filter area.

or paper mill. The capacity must be such that it permits of the water standing long enough to settle in the bottom of the tanks from which point the settled fibers and fillers are pumped. The white water is distributed by means of an annular trough, running around the entire circumference of the tank so that when it finally reaches the tank there is no velocity. This is to prevent agitation and allow the stuff to settle at the bottom, in the same way that a sample of it will settle in a bottle or glass jar.

This method permits the savings to be pumped back into the system without the extra labor required in the case of the first mentioned classes of save-all, where the savings are of such a consistency that they must be shoveled or forked into the beaters. The settling tank must be of ample capacity to effect a continuous operation, i.e., so that the white water may be running in at the top of the tanks at the same time the settlings are being pumped from the bottom; these tanks do not function until they become full of white water, for then the incoming supply flows lazily and comes to rest on top of this body of water and begins to settle immediately.

Still another type of save-all* extracts the fibers from the white water by means of centrifugal force. This method embraces many desirable advantages such as permitting of pumping the savings back to the system, instead of by manual labor, low first cost, ample capacity, low up-keep cost, self-cleaning and very low horsepower for operating.

A cone 19 inches diameter at small end flaring to 10 feet at large end, 7 feet high, is stepped in a bearing with the small end of the cone downward (like a spinning top) and two spiders are keyed to a shaft, which passes through the center of the cone. The spider at the apex is 19 inches inside diameter. The spider at the center is 4 feet in diameter. The rims of both these spiders are on an angle or flare that coincides with the slope of the cone. The shaft passing through the center of the cone, protrudes through the small end and is stepped in a box (similar to stepping a water wheel). This same shaft protrudes at the upper end of the cone for applying a gear or pulley for driving or spinning the cone. Hardwood staves are bolted to the spiders at intervals, complying with the distance needed for fastening suitable screen plates. Screen plate sections with very large perforations are screwed to the inside of the staves. They are cut on an angle so that the border of each plate makes a butt joint coming together on each stave. Thus the entire inner surface is lined with foundation plates in a way that permits of a smooth surface being presented to the white water and fiber material.

On top of the foundation plates is fastened a very fine mesh wire, the fineness of the wire being determined by the class of saving it must perform. The finer the wire the finer the savings. The cone also has a vertical annular rim 6 inches to 12 inches high which prevents the water from slopping over into the compartment between the outside shell or housing, which encircles the cone. Placed within this annular rim and clearing it two inches all around is a stationary solid head. On this head is also an annular rim. This head is adjusted to water level and the white water is spilled on this stationary head, which fills up and runs over the annular rim, which is about 4 inches high, causing the water to flow and distribute evenly all around the entire circle, falling against the sides of the revolving cone. The water is thrown through the wire mesh by centrifugal force, while the savings slip down the incline of the cone into a compartment directly under the small end, to which a centrifugal pump is connected; from this point the savings are pumped back into the system; surrounding the cone is a water tight shell usually made of tongue and grooved sealing, placed at a suitable distance from the

* Witham—McEwen save-all.

cone. This shell or housing may be square, octagonal or round. It may or may not follow the lines and shape of the cone.

Both the rejections and savings may be either pumped or run to waste as the case may require. In case this apparatus is used for water straining or filtering purposes, the clean water which is thrown through the meshes of the wire, may be pumped through the water system which serves the mill, while the savings which in this case will be dirt, slip down the incline of the cone and to waste. It will be seen that this save-all can be used for either saving pulp fibers or for filtering water, without making any change in its construction. The shape, speed and angle of the cone renders it self-cleaning. There is always enough water sliding down the incline of the cone to keep the filtering wire clean. A vertical shower pipe is placed adjacent to the cone and between the shell and the cone and following the slant of the cone, so that by opening a valve, the cone may be thoroughly showered, as it revolves, passing this fixed shower pipe. This is in case the meshes become filled up with sediment of any kind. In case of these save-alls being used as filters their capacity is nearly unlimited. One of these machines will filter 2,000,000 gallons in 24 hours and will free water from all solid impurities, supplying absolutely clean water for paper machine showers and the like; in case they are used as a save-all the capacity is nearly as great. Three horse power is ample for one save-all; they need no supervision.

CONTRACT SPECIFICATIONS

FOR

ONE (1) 184 INCH FOURDRINIER PAPER MACHINE SUITABLE FOR KRAFT BAG OR WRAPPING PAPER

MADE BY

(Name of Builder and Address)

FOR THE

(Name of Purchaser and Address)

(Address and Date.)

General Conditions.

The Design, material and labor embodied in this contract, unless otherwise specified, is to be the best of the several kinds, and is intended to cover the general detail and construction of one Paper Machine, as hereinafter specified and described, subject to the approval of ....Company, hereafter referred to as the Purchaser.

The ....Company (the Builder) shall allow inspection of the work at any time by the Purchaser, or his Agent.

In cases where a possible doubt exists as to the interpretation of these specifications, the Builder shall consult with the Purchaser before taking steps towards the performance of the work.

Extras.

These specifications are intended to embody a complete machine in all its parts, as called for by the contract; but any changes or additions, or extra parts, that may be called for, shall not be charged as "Extras" unless the same shall have been called to the attention of the Purchaser and done in pursuance of a written order from the Purchaser or his Agent.

Nothing that is necessary for a complete installation of the work herein called for shall be construed as "Extra."

Guarantee.

The Builder herewith guarantees that the material and workmanship shall be the best, and agrees to replace and make good to the Purchaser, at any time within one year from the date of first operation of the machinery, any portion that may have proved to be defective, under ordinary wear, during that time.

Any breakage or damage to the machine, caused by the negligence or incompetence of the employees of the Purchaser, shall not be included in the above clause.

Hand.

When standing at the Winder and looking toward the Fourdrinier, the driving arrangement will be on the right-hand side.

Widths.

Breast Roll will be	188 inches face
Table Rolls will be	192 inches face
Suction Couch Roll will be	186 inches face
Return Wire Rolls will be	188 inches face
Upper Press Rolls will be	185 inches face
Lower Press Rolls will be	186 inches face
Press Felt Rolls will be	192 inches face
Drying Cylinders will be	182 inches face
Dryer Felt Rolls will be	192 inches face
Calender Rolls will be	178 inches face
Reel Drum will be	178 inches face
Reel Cores will be	179 inches face
Winder Drums will be	178 inches face
Nominal Trim will be	164 inches

Flow Box and Apron.

Of two-way stream-lined design suitable for attachment to 60 inch high slice and with rear compartment for connection to the screens. Constructed entirely of selected cypress wood, having complete interior lined with No. 16 S. W. G. copper sheeting. Two adjustable baffles equipped with bronze screw adjustment at each end. Washout valves provided at the bottom of each main compartment and a large quick-acting dump-valve in the stock inlet compartment. The compartment next breast roll will be equipped with a 16 inch diameter perforated distributor roll mounted in anti-friction bearings suitably located and driven by chain from motor reducer.

FOURDRINIER PART

Wire.

The arrangement of the Fourdrinier part will be suitable for a wire 95′ 0″ long and 184″ wide.

Stock Inlet.

Of improved design comprising main slice 60 inches high located over center line of Breast Roll and equipped with hand operated worm geared screws permitting necessary vertical adjustment; also auxiliary outside slice 18 inches high provided with vertical and horizontal adjustment. Each slice fitted with adjustable lip for leveling the sheet.

A perforated distributor roll 10 inches diameter will be located ahead of the main slice, having journals mounted in anti-friction bearings and driven by a suitable gear motor.

Brass covered breast plate carried on heavy cross beams and necessary supporting frames.

There will be a wooden cambered footwalk across the front of the inlet with handrail for easy access to all adjustments.
Deckle width adjustment will not be provided.

Breast Roll.

The Breast Roll will be 26 inches diameter, 188 inches face, body made with a shell of centrifugally cast bronze, bored on inside and secured to hi-tensil cast iron heads, having brass end covers. The journals of high carbon steel forced in the heads by hydraulic pressure will run in extra heavy duty thrust type Timkin roller bearings enclosed in housings having improved seals, water flingers and deflectors, insuring the exclusion of water and retention of the lubricant.
Roll will be in perfect running balance at surface speeds up to 1400 feet per minute.
Breast Roll will be carried on spring supports from sill plates with independent connection to shaking mechanism.

Making Board.

Located next to the Breast Roll in place of the first two table rolls, of light-weight rigid construction with maple top, to meet the approval of Purchaser.

Table Rolls.

Twenty-eight (28) Table Rolls to fill space between Making Board and first suction box and two (2) Table Rolls under dandy, each 8½ inches diameter, 192 inches face, made of seamless drawn steel tubing, covered on the face and over ends with special grade of hard rubber ¼ inch thick, having special cast iron heads with high carbon steel journals and brass end head covers.
Rolls will be in perfect running balance at surface speeds up to 1400 feet per minute.
The roll journals will be brass cased where exposed and run in heavy duty Timken roller bearings enclosed in "Puseyjones" specially designed waterproof housings arranged to slide and clamp in position on top of the side rails, so as to permit of adjusting the spacing of the rolls to suit operating conditions.

Deflectors.

Suitable Splash Plates with reinforced curved blades and frames, all of Monel, having vertical and horizontal adjustment will be provided between the first fourteen (14) table rolls to deflect the water flung off the rolls from the under side of the wire; supported from the stationary side frames.

Return Wire Rolls.

The guide, stretch and all other Return Wire Rolls will be 14 inches diameter, 188 inches face, made of heavy turned lap welded steel pipe, covered on the face and over the ends with Monel jacket; fitted in ends with hi-tensil cast iron heads with high carbon steel journals. The journals will be Monel cased where exposed and run in extra heavy duty S. K. F. roller bearings enclosed in "Puseyjones" specially designed waterproof housings, removable from supporting brackets where required.
The rolls will be in perfect running balance at surface speeds up to 1400 feet per minute.

Wire Guides.

One automatic geared high speed type with single lever palm attachment to work in contact with front edge of wire; all working parts enclosed against water; located on the run of the wire between the last suction box and the suction couch, supported on suitable extension of the side frames.
One of the Return Wire Rolls will be arranged for hand adjustment.
The roll next to Couch Roll will be driven by belt from Couch Drive Shaft.

Wire Stretcher.

Of horizontal swinging arm automatic tension type, supported from the sill plates and geared so that both sides may be operated simultaneously when raising or lowering the roll by hand ratchet on front side; adjustable weights also provided to permit regulating the tension on the wire to suit operating conditions.

Ductors.

Ductor with rigid metal frame and Bakelite blade of proper design and weight to exert uniform pressure across entire face of roll, arranged on the Breast Roll and each Outside Return Wire Roll.

Suction Couch Roll.

One (1) Suction Couch Roll of latest Beloit design suitable for a wire 184 inches wide (186 inches drilled face) with centrifugally cast brass shell 36 inches diameter, having spiral drilling and fitted with an internal suction box 12 inches wide, of special design and construction for handling the water at high speed; also internal shower pipe and air device for blowing the paper leader on the first press felt.

The Suction Roll will run in S. K. F. roller bearings front and back, and the internal suction box supported on back in S.K.F. roller bearings, all enclosed in housings of manufacturer's latest design.

Roll arranged for direct drive without gearing, also cantilever device for supporting from the back side, in overhanging position, thus avoiding use of porter bar on front side when installing new wires.

Necessary supporting frames, with those on front side of hollow construction forming permanent built-in suction connection to header under machine room floor, eliminating use of removable hose connection and fittings.

All piping between roll and suction pump will be supplied by the Purchaser.

Air Roll.

To lead the sheet from couch to first press felt, 6 inches diameter, 188 inches face, made of seamless drawn aluminum tubing No. 8 S. W. G., fitted with aluminum heads and steel journals, equipped with S. K. F. ball bearings enclosed in water-tight mounts carried by a counterweighted hand-operated raising and lowering device; also provided with suitable belt drive for controlling the speed.

Presser Roll.

One top roll or lump breaker 17 inches diameter, 188 inches face, made of turned lap welded steel pipe fitted with hi-tensil cast iron heads high carbon steel journals and brass end head covers; the face covered with soft rubber 1½ inches thick of suitable grade and density of around 225 Plastometer.

The journals will be brass cased where exposed and equipped with Timken roller bearings enclosed in watertight mounts. Roll will be supported from top of Suction Roll frames by adjustable housings having pneumatic raising and lowering device.

Suction Boxes.

Eight (8) Suction Boxes of light yet rigid construction built up of brass plates and sections securely riveted together, of 7 inches suction width. Top of boxes will have machined dove-tail recess tapered from front to back to hold perforated covers of special selected end of grain maple 2 inches thick. Each box will have 4½ inch diameter suction outlet with improved quick releasing device and flexible hose connection on back side, a system of pipes for priming both ends and expanding rubber deckle heads with brass clamping plates and adjusting handles.

Attachments to the side frames will be furnished, also oscillating device of improved type, having crosswise movement, complete with all actuating mechanism including reduction gear and motor. The drive for the oscillating device will be completely housed on the back side Fourdrinier frames.

Piping arrangement and separating system between Suction Boxes and Pump will be supplied by Purchaser.

Dandy Roll.

Will be 20 inches diameter, 188 inches face, of latest open end, all bronze construction with end flanges supported on ball bearing trunnions: also a central combination hollow supporting shaft and shower pipe, fitted with spray nozzles spaced on 5-inch centers.

Suitable adjustable end stands with arrangement for raising and lowering Dandy Roll and regulating the weight on the wire to suit operating conditions. An extension from the stands will support the usual wiper bar and rail for remover trolley.

Dandy Roll will be located between the third and fourth Suction Boxes and directly over two Table Rolls.

Deckle Arrangement.

Edge ruler of latest design with adjustable side frames and rubber edge ruler extending approximately 21 feet from slice toward Suction Boxes.

Save-alls.

Extending from the Breast Roll to the last Suction Box, made in several sections of built-up sheet Monel and angles, all arranged and proportioned to readily carry off the white water and discharge into suitable receiver on the back side supplied by Purchaser.

A Ductor as previously specified will be arranged at the Breast Roll to empty into the Save-all Box.

One 2½ inch cleaner shower arranged at Suction Box end of Save-alls.

Fourdrinier Arrangement.

Will be of improved, adjustable and high speed duplex shaking design, combined with the latest "Puseyjones" wire handling device, arranged for installing the wire from tending aisle without necessity of removing the Fourdrinier proper from fixed operating position.

There will be a pair of welded steel box section side frames covered by a protective coating of sprayed zinc, rigidly connected together by brass cased tubular cross beams for supporting Shake Rails and Table Rolls, Deflectors, Dandy Roll, Suction Boxes, Inside Return Wire Rolls and Save-all arrangement; all supported on two roller bearing equipped under-carriages, each connected to a motor-operated geared device permitting the mechanical rolling in and out of the under-carriages on suitable tracks for convenience when installing new wires. The two tracks across the pit under the Fourdrinier, also the corresponding tracks in the tending aisle floor will be permanently located. Each under-carriage will be fitted with a hinged track support to facilitate the handling of new wires.

There will be furnished suitable removable end brackets and intermediate stands attached to the under-carriages for supporting the poles on which the new wire is draped in the tending aisle; also a portable carriage designed for use with the crane, complete with special aluminum poles for transporting and assisting with the installation of new wires.

After fully draped, the wire is transported over the Fourdrinier when the under-carriages are mechanically run back into normal operating position under the Fourdrinier, after which the wire poles, brackets and stands are removed, and the Breast Roll and Stretch Roll adjusted to take up slack.

The side frames will be equipped with a motor-operated raising and lowering device, having one set of intermediate and one set of end screw jacks next to Couch Roll so that it will be possible to adjust the pitch of the wire to run uphill from the Breast Roll 3 inches toward the Guide Roll or downhill from the Breast Roll to 8 inches below top of the Breast Roll.

The Breast Roll will be carried on independent horizontal and vertical spring supports from the sill plates. There will also be provided a quick-releasing motor-operated mechanical arrangement for moving the Breast Roll from its operating position to a hanging position on the end of the Fourdrinier frames when changing wires.

The Return Wire Roll next to Breast Roll will be carried from the side frames by hanging vertical springs, so as to shake in motion with the Breast and Table Rolls.

The Table Rolls will be carried on bronze slide bars on top of welded steel shake rails covered by sheet brass and supported from the non-shaking side frames by a series of vertical spring tempered bronze leaf springs having adjustable patent rubber seated holding brackets.

The Shake Rails on each side will be divided in two sections, the section next to Breast Roll about 8 feet and the other section about 17 feet long hinged to the first section and pivoted at ends next the Suction Boxes.

The Breast Roll, first Return Wire Roll, both ends of the short section and the hinged end of the long section of Shake Rails will be separately attached by special Bakelite fitted connections to the shaking mechanism on the back side.

The shaking mechanism will comprise two (2) extra heavy duty Bertram patent shake units, each with enclosed adjustable stroke device, providing a true horizontal motion of from 0 to 1" amplitude. The units will be connected together by means of shaft and flexible couplings. A Texrope drive will connect the shaft with a variable speed motor suitable for range of 100 to 500 shakes per minute, depending upon the length of stroke. Length and speed of stroke adjustable while running. The first Return Wire Roll shake device will be driven direct from the connecting shaft with hand adjusted eccentric.

One shake unit will transmit the shake motion to the Breast Roll and adjacent end of the short section of Shake Rail, and the other shake unit to the opposite end of the short Shake Rails and adjacent end of the long Shake Rails, thus providing quick adjustment of the shake motion at either or both points as desired by operator.

All bolts and nuts of stainless steel; all other parts inside the wire, where not already specifically referred to, will be of non-corroding material, or adequately protected with non-corroding material.

Footboards.

One Footboard extending across the Fourdrinier, and located ahead of the Dandy Roll, also one Footboard at stock inlet as hereinbefore specified; made of improved camber self-draining construction of wood reinforced with angle irons, eliminating use of underneath truss rods.

A slatted wooden Footboard removable in sections, supported from the side frames will extend the full length of the Fourdrinier on the tending side, equipped with two flights of portable steps.

Fourdrinier Electrical Equipment.

Necessary motors with starters and controls for the perforated rolls at the flow box and inlet, suction box oscillator, shake motion, raising and lowering device, and removable under-carriage mechanism will be furnished, but all wiring will be supplied by the Purchaser.

Water Pipes and Showers.

A complete system of water piping, comprising a header on tending side starting with inlet at the Breast Roll and extending to the press part supplying the Fill Pail, Suction Boxes, Hose, Water Jets, Fourdrinier and Press Showers.

All the branch connections from the headers will be provided with straight shut-off valves and unions located beyond the shut-off valves.

All piping will be of copper or brass and all valves and fittings of brass.

There will be six (6) 2½ inch Millspaugh deflector spray type shower pipes for the returning wire, one (1) at Save-alls, one (1) stationary spray shower at the stock inlet, and one (1) shower for each press felt. All shower pipes of brass provided with valves and piston cleaners.

Located following the last Suction Box will be a Water Jet of latest hand-operated trolley design for cutting the paper on the wire, also two adjustable Water Jets for trimming the deckle edge of the sheet.

PRESS PART

Main Press Rolls.

First Press, Upper Roll, 28 inches diameter, 185 inches face, rubber covered.

First Press, Lower Roll, 32 inches diameter, 18 inches face, suction type, rubber covered.

Second Press, Upper Roll, 28 inches diameter, 185 inches face, Stonite covered.

Second Press, Lower Roll, 32½ inches diameter, 186 inches face, suction type, rubber covered.

The First and Second Press Lower Rolls will each be of Beloit latest design suction type with centrifugally cast bronze shell, 186 inches drilled face, the First Press 30 inches diameter and Second Press 30½ inches diameter, both covered with rubber of suitable grade and density 1 inch thick, having spiral drilling as per latest practice. The Internal Suction Box will be 4 inches wide of special design and construction for handling the water at high speed.

Each roll will run in S. K. F. roller bearings front and back, and the Internal Suction Box supported on back in S. K. F. roller bearing, all enclosed in housings of manufacturer's latest design. Journal extension on back side fitted with approved flexible coupling for direct connection to driving shaft without gearing. The housings on front side, also supporting frames, will be of hollow construction forming permanent built-in suction connection, eliminating use of removable hose connections and fittings.

All piping between pumps and press frames will be supplied by Purchaser.

Each Upper Press Roll will be made with semi-steel body of medium weight design, having forged steel journals forced in ends by hydraulic pressure. Journals prepared for antifriction bearings. Rolls will be of the proper weight in accordance with latest practice, the First Press covered with rubber $\frac{7}{8}$ inch thick of suitable grade and density, and the Second Press covered with Stonite $\frac{1}{2}$ inch thick.

All the Upper Press Rolls will be provided with a straight shoulder between neck and bearing sufficient to permit grinding without necessity of removing bearings from journals.

Main Press Housings and Bearings.

The Journals of the Upper Rolls will be carried in S. K. F. self-aligning roller bearings enclosed in mounts of latest design having concealed revolving water flingers preventing the entrance of water and improved pressure seals for retaining the lubricant. The mounts will be supported in cast steel swinging arms, so arranged that the Upper Rolls may be properly couched, and connected to a system of compound levers and weights so as to properly distribute additional weight on Bottom Rolls as desired.

Each set of Housings carrying the swinging arms will be of cast iron equipped with gear motor for raising and lowering the Upper Roll to give clearance between Upper and Lower Rolls for convenience in putting on press felts.

A removable lightweight blocking piece will be provided under each Lower Press Roll, on front side for convenience when putting on press felts.

Ductors.

One vibrating Ductor for each Upper Press Roll, constructed with wrought steel balanced frame, fitted with Lodding flexible holder and Bakelite blade. Oscillating arrangement complete, including roller supports, worm gearing and chain drive from extension of Upper Roll Journal on driving side.

Crumb catcher provided for each press with adjustable bracket supports.

Broke Conveyor.

In connection with First Press Ductor to assist in removal of Broke, comprising a rubber canvas endless belt extending across the machine with suitable end pulleys and supporting framework. Belt will be driven by gear motor and operated from push button on front side of machine.

Save-alls.

A built-up Monel Save-all of proper form and dimensions will be arranged under each Lower Press Roll, carried on suitable brackets as required for convenience when changing felts.

Footboards.

There will be two main Footboards at each press, one located on the Housings directly before, and the other on the Upper Roll Arms directly after. The former will have steps and brass handrails from the floor on front and back sides and the latter handrails only.

Each Footboard will be of latest camber self-draining construction of wood reinforced with angle-irons, eliminating use of truss rods.

Main Press Frames.

Complete extending under the entire press part of low design supporting the Upper Press Roll Housings, Lower Press Rolls, Footboard Supports, Small Stands, Save-all Brackets and Felt Roll Bearings.

Frames will be extended suitable for the later installation of a Third Press with felt running straight through. The Second Press Felt will be arranged to carry the sheet across the space provided for the Third Press and convenient to the Smoothing Press. Suitable passageway in front of Smoothing Press.

Frames will also provide for the later installation if desired of a water marking device between the First and Second Presses.

General Arrangement of Felts.

The First and Second Felts, also future Third Press Felt will pass in a forward direction through their respective presses, arranged to suit lengths of exactly 56 feet, with shortest possible press centers and paper leads for high speed operation.

Felt Rolls.

All the necessary Felt Rolls will be 13¼ inches diameter, 192 inches face, made of heavy turned lap welded steel pipe, covered with hard rubber $\frac{5}{16}$ inch thick, having hi-tensil cast iron heads with high carbon steel journals and brass and head covers. The journals will be brass cased where exposed and run in heavy duty S. K. F. roller bearings mounted in latest design waterproof housings, removable from supporting brackets where required, and with extensions for use of porter bar when installing new felts.

Each roll will be placed in perfect running balance at surface speeds up to 1400 feet per minute.

One of the rolls for each press felt will be "wormed" on the face with hard rubber strips to act as felt spreader.

Blow Rolls.

One (1) paper carrying roll directly following the nip of the First Press and one (1) after the Second Press to prevent blowing will be 6½ inches diameter, 188 inches face, made of seamless drawn tubing No. 8 S. W. G., having hi-tensil cast iron heads and high carbon steel journals, carried in S. K. F. ball bearings mounted in adjustable housings of latest design. Each roll will be provided with a suitable belt drive for controlling the speed.

Rolls will be placed in perfect running balance at surface speeds up to 1400 feet per minute.

Felt Stretchers.

One Felt Stretcher of heavy design for each felt. fitted with brass gearing and screws connected to operating motor by chain drive. Both sides of Stretcher may be operated simultaneously or the back side independently through means of handwheel on tending side when squaring the felt. The Stretcher for First Press Felt will be vertically located in the basement, to permit of close spacing and short draws between the presses. The Stretcher for Second Press Felt will be horizontally located on top of main press frame extension, until such time as the Third Press is installed when it will be vertically located in basement. The Stretcher for the future Third Press Felt will be vertically located in basement.

Automatic Guides.

One Nash Automatic low-down geared high speed type for each felt, with single lever palm attachment to work in contact with front edge of felt. All working parts anti-friction mounted and enclosed against water.

Shower Pipes.

One Shower Pipe for each press felt, as before mentioned.

Vickery Felt Conditioners.

One for the First Press Felt and one for the Second Press Felt of latest construction, supported directly on the sill plates.

Piping between Pump and Conditioner, also the steam and water supply will be furnished by Purchaser.

Small Stands.

All necessary Small Stands and Frames for the general arrangement of the press part.

Electrical Equipment.

Necessary motors with starters and controls for the Broke Conveyor, Press Housings and Felt Stretchers will be furnished, but the Purchaser will supply all wiring connections.

SMOOTHING PRESS

On the end of the Dryer Frames next to the Third Press will be mounted a pair of press rolls for removing the wire and felt marks before they are indelibly dried into the paper, comprising:

Rolls.

Upper Roll 28 inches diameter, 185 inches face, rubber covered.

Lower Roll 28 inches diameter, 186 inches face, bronze cased.

The Upper Roll except for grade and density of rubber cover will be duplicate of the First Press Upper Roll and interchangeable with both the Upper Main Press Rolls as hereinbefore specified.

The Lower Roll will be made with hollow semi-steel body having forged steel journals forced in ends by hydraulic pressure. It will be encased with a centrifugally cast bronze cover ½ inch thick, turned and ground on the face. The back side journal will be extended and fitted with approved coupling for connection to drive shaft.

Rolls will be fitted with necessary sheaves on tending side to facilitate use of rope carrier for leading the sheet through the smoothing press.

Bearings and Housings.

Rolls will be carried in S. K. F. roller bearings duplicate of those on Upper Press Rolls, supported in housings connected to suitable levers and weights for applying pressure to the Upper Roll, also approved ratchet lifting device for raising Upper Roll.

Ductor.

A Ductor with balanced steel frame, Lodding holder and Bakelite blade, also crumb tray will be provided in connection with the Lower Roll.

Paper Roll.

To lead the sheet from the press felt into Smoothing Press, 10 inches diameter, 188 inches face, made of No. 8 S. W. G. brass tubing, with cast iron heads and steel journals running in S. K. F. ball bearings, enclosed in mounts having vertical adjustment.

Dryers.

Forty-five (45) Main Dryers, each 60 inches diameter.

Six (6) Felt Dryers, each 48 inches diameter.

Each Dryer 182 inches overall face, 177 inches between inside flanges of shell, designed and constructed for 35 pounds working steam pressure, and tested at 70 pounds hydrostatic pressure.

Each Dryer will have shell of close-grained cast iron, bored on the inside, turned and accurately ground straight face on the outside concentric with the journals. The heads will be of semi-steel secured to the shells by special hi-tensil steel bolts. The tending side journals will be cast with the heads, but the driving side journals will be forged steel forced in the heads by hydraulic pressure and pinned with screw dowels. All journals adapted for anti-friction bearings and those on driving side extended and fitted to receive driving gears.

All the Dryers will have tending side head fitted with manhole and driving side head with handhole; also carefully and properly balanced.

The tending side journal of one 60 inch Dryer will be drilled and fitted suitable for installation of a temperature control device as supplied by the Purchaser.

Two (2) Felt Dryers will be used on the return of each wet end felt on the first section and one (1) on the return of each felt on the second section; arranged so that the side of the felt which comes next to the paper will be next the surface of the Dryer.

Vents.

A standard pet cock will be placed in the head of each Dryer on the tending side for drainage; also in each steam joint on the driving side for venting air from the Dryers.

Steam Joints and Siphons.

Connected to the journal extension of each Dryer on the driving side and supported from the gear casing will be an improved oilless pressure sealing type Steam Joint with graphite composition steam-tight packing discs, arranged to admit steam to the Dryer and remove water of condensation therefrom by means of a ¾ inch brass adjustable Siphon Pipe.

Each Siphon Pipe will be rigidly supported inside the Dryer by means of an oilless bearing attached to the dryer head; so arranged that it may be adjusted and held in any determined position when evacuating condensate or to the top of the Dryer when venting air through the Steam Joint. A special scoop device will be fitted to the end of each Siphon to assist in the removal of the condensate.

A special nozzle device will distribute the steam uniformly to the interior of the Dryer.

Cooling Dryer.

The last upper and lower Dryer will be arranged with dual piping to permit the use of either water for sweating the sheet before entering the calenders or steam for drying.

Vertical and Horizontal Piping.

The Vertical Steam Inlet and Water Outlet Pipes for all the Dryers will be 2½ inches and 1 inch respectively, connected at the upper ends to the Steam Joints above mentioned and at the lower ends to the Horizontal Steam and Water Headers by welded connections. The Horizontal Steam Header and the Horizontal Water Header will each extend the full length of the dry part. The steam header will be fitted with a special inlet tee, and each header divided into sections as required for connection to Drainage System.

Each Vertical Steam and Water Pipe will be fitted with a standard iron body brass fitted globe valve, and also a brass mounted union placed just above the valve. The piping between the steam joint and union will be flexible metallic hose, but all other piping of steel. Each Vertical Water Pipe will also be fitted with an improved type flow sight.

Dryer Drainage System.

Not included in this specification.

Dryer Bearings.

The Dryer journals will run in S. K. F. extra heavy duty self-aligning roller Bearings on the tending side and on driving side, all having proper freeness to allow for expansion due to temperature changes; enclosed in housings of latest design with improved seals against entrance of dust and oil leakage.

The driving side Bearings will be stabilized in the housings to take end thrust of the Dryers; also located outside the gearing to facilitate dismantling and renewal. The tending side bearing housings will be of special "Puseyjones"—S. K. F. floating design to compensate for end movement of Dryers due to expansion and contraction.

Each bearing housing fitted for connection to Bowser Oil Circulating System with sight feed gauge, overflow and drain plug.

Each tending side bearing housing will have closed end fitted with a polished ornamental brass cover plate.

Dryer Frames.

Cast iron dryer side Frames of substantial open two-tier design will be arranged to carry the Dryers in three (3) main sections, comprising twenty-one (21) dryers in the first section, twelve (12) dryers in the second section, and twelve (12) dryers in the third section. There will be a marking press suitably located in the upper tier in place of one dryer between the first and second sections and a size press between the second and third sections. Neat guard rails provided across the open spaces between the frames on front side also forming supports for the lower tier Ductors. Space of 10 inches will be provided between edge of Dryer and inside of Frame.

The Bearings of the Dryers in the lower tier on the tending side will be carried directly on the sill plates, which also carry the upper Dryer Frames; the Bearings on the driving side will be carried in the continuous framing forming the gear enclosure.

Frames for carrying the Upper Felt Dryers and felt equipment will be furnished complete, as well as necessary steel H-beams to carry the lower felt equipment on the return in the basement. Necessary beams for supporting the Felt Dryers in basement will be supplied by Purchaser.

General Arrangement of Felts.

Will be for one (1) upper and one (1) lower felt on each dryer section.

The first section will be driven at two points; the second and third sections each at one point.

Dryer Driving Gears.

The Driving Train will be of the latest improved high speed enclosed arrangement comprising a spur gear approximately 36 inches diameter mounted next to the neck and on the journal extension of each 60 inch diameter dryer. All the dryers in the lower tier of each section will be horizontally connected together in train by intermediate idler gears, which in turn drive the upper tier dryers by means of small idler pinions. The Felt Dryers will not be geared, but provision will be made for the later installation if desired by the Purchaser.

There will be four (4) main driving pinions in the bottom tier gearing; two for the first section and one each for the second and third sections.

All the Dryer Gears and idler pinions will be made of hi-tensil molybdenum cast iron. The main driving pinions will be made of cast steel heat treated to 275-300 Brinell. All gears will have special cut stub teeth and properly balanced.

The whole system of gearing will be neatly enclosed in cast iron oil-tight casing attached to an integral with the Dryer Frames, arranged for lubrication from the Bowser circulating system, also supplying the Bearings. The casing will be in sections, each with cover plates for observation and access to interior, all easily removable for convenience in changing gears or dryer bearings. The arrangement will be open and accessible for observation and the handling of Broke by air or pole from the back side. Each intermediate idler gear and driving pinion will be mounted on a forged steel shaft running in S. K. F. heavy duty roller bearings, all enclosed in improved housings with oil and dust seals, supported in the casing and lubricated from the Bowser System. Each main driving pinion shaft connected to the intake shaft by flexible coupling. Provision will be made for removing driving pinion without disturbing motor or cone drive unit.

Bowser Oiling System.

Of the latest design and construction equipped with receiving tank and filter in connection with a pressure tank to supply oil direct to the bearings of the Dryers, Idler Gears, Driving Pinions and Calender Rolls; also directly to the gears. Necessary duplex motor driven oil pump unit with automatic control, also cooling device. A sight feed valve will be fitted in the feed lines to each bearing and the gears.

The supply and drain headers will be of galvanized pipe and all branches to bearings of special copper tubing, but Purchaser will supply all piping between headers, tanks and pumps, necessary to complete the installation.

The gearing will be lubricated by means of a direct oil spray at each lower intermediate gear and driving pinion, also by overflow from the roller bearings, thereby transmitting the lubricant to the remaining gears by contact. The surplus lubricant will be collected in the bottom of the gear enclosure and disposed of through connecting piping to the return oil header.

Ductors.

Vickery type Ductor with rigid frame, flexible holder and removable bronze blade will be placed on the first six lower dryers of first section, the last three lower dryers of the second section, and the last upper dryer of each section. Each Ductor will be fitted with hand-operated cam device for throwing on and off.

Footboards.

An open grill iron Footboard, supported by cast iron brackets will extend the whole length of the Dryers on both the tending and driving sides with the necessary flights of steps and hand rails for access to and from as approved by Purchaser.

Paper Carrier.

Complete equipment of Sheehan patent rope feed for threading the sheet through the dry part with necessary ball bearing aluminum sheaves, take-ups, supports and adjustable brackets for carrying the return ropes from the return felt supports in the basement. Proper rope grooves will be turned in the tending side head of the dryers. Necessary ropes will be supplied by the Purchaser.

The arrangement will provide for one set of ropes carrying the paper leader from ahead of the smoothing press, through the first dryer section to the marking press; transferring to a second set of ropes carrying the leader thru the marking press and second dryer section to the size press; transferring to a third set of ropes carrying the leader through the size press and third section of dryers.

Felt Rolls.

All the necessary Dryer Felt Rolls will be 12 and 14 inches diameter, 192 inches face, made of heavy turned lap welded steel pipe having hi-tensil cast iron heads with high carbon steel journals, running in heavy duty S. K. F. roller bearings enclosed in suitable design mounts and supporting brackets. The larger size Rolls will be used in the places where the felt strains are greatest.

Rolls will be placed in perfect running balance at surface speeds up to 1400 feet per minute.

Guides.

One Nash automatic geared high speed type for each felt, with single lever palm attachment to work in contact with front edge of felt. All working parts anti-friction mounted.

Also one hand Guide for each felt of improved design, operated from machine room floor tending side, through handwheels and sprocket chain extensions.

Automatic Tightener.

One "Puseyjones" improved felt Tightener, having horizontal guides and hand adjusted weight loaded tension arrangement complete for each felt.

Paper Spring Rolls.

Located at the end of second and third section of dryers to lead the sheet to the size press and calenders respectively, will be a Spring Roll 12 inches diameter, made of turned steel pipe, covered on face and over heads with Monel jacket, fitted with hi-tensil cast iron heads and high carbon steel journals running in double S. K. F. heavy duty ball bearings No. 6216 enclosed in housings with circles of spring to allow for uneven tension of the draw of paper.

Rolls will be in perfect running balance at surface speeds up to 1400 feet per minute.

The Spring Roll at end of second dryer section will be supported by vertical Guides having hand-operated geared adjustment up and down.

MARKING PRESS

Suitably located between First and Second Dryer sections in place of one Upper Dryer, comprising:

Rolls.

Upper Roll. 14 inches diameter, 184 inches face, plain.

Lower Roll, 20 inches diameter, 185 inches face, rubber covered.

The Upper Roll or shaft for supporting the removable Marking Plates will be made of double extra heavy steel pipe accurately turned on the face, fitted with cast iron heads and steel journals. Balanced at surface speeds up to 1400 feet per minute. Marking Plates supplied by Purchaser.

The Lower Roll will be made with hollow semi-steel body turned in balance with forged steel journals forced in ends. Covered on face with rubber ¾ inch thick of suitable grade and density. Back side journal extended and fitted with coupling for connection to drive shaft.

Bearings and Housings.

Upper Roll carried on S. K. F. roller bearings and Lower Roll on S. K. F. bearings all enclosed in improved mounts. The Upper Roll mounts supported in sliding Housings having suitable spring pressure loading device as approved by Purchaser.

The Lower Roll supported on substantial side frames from the sill plates, with provision for later installation of a Paper Carrying Roll before and after the Marking Rolls.

Drive.

Lower Roll will be driven by belt on cone pulleys direct from second intake shaft of the first dryer section.

SIZE PRESS

Located between the second and third sections of dryers, comprising:

Rolls.

Upper Roll, 28 inches diameter, 185 inches face, Rollstone covered.

Bottom Roll, 28 inches diameter, 184 inches face, rubber covered.

Rolls will be similar to and interchangeable with those in smoothing press except for grade and density of covering. Each roll equipped with splash rings on front end to protect carrier ropes.

The paper will pass in a forward direction through the size press.

Housings and Pedestals.

The Upper Roll will be carried in S. K. F. roller bearings with mounts duplicate of those on the upper main press rolls, attached to swinging arms. The arms will be connected to levers and weights to properly distribute the weight over the entire surface of the Lower Roll, and to give additional pressure if desired. Ratchet lifting device will be connected to the arms on each side for lifting the Upper Roll from contact with the Lower Roll.

The Housings carrying the swinging arms, also the S. K. F. bearings and mounts on the Lower Roll will be supported on cast iron frames resting on the foundation plates.

Ductor.

The Upper Roll Ductor will be of the oscillating type with steel frame, Lodding holder and Bakelite blade, similar to those on main presses.

Vat.

Semi-circular pan beneath the Bottom Roll will be made of Monel properly reinforced to give the required strength and stiffness, provided with drain and supported by cast iron brackets attached to the housing frame so as to pitch toward drain.

Shower Pipes.

Two brass pipes for applying size to the top and bottom of the sheet before it passes between the rolls.

Paper Roll.

Located directly after the size press nip and ahead of the Receiving Roll, will be 10 inches diameter, 184 inches face, made of No. 8 S. W. G. brass tubing, fitted with cast iron heads and steel journals, running in S. K. F. ball bearings No. 2313 mounted in suitable supporting brackets.

Roll will be in perfect running balance at speeds up to 1400 feet per minute.

Front end fitted with sheave for rope carrier.

Receiving Roll.

Will be 23½ inches diameter, 184 inches face, located following the size press to receive the sheet therefrom, and deliver to the first bottom dryer of the second section.

Roll will be made with steel tube body covered on the face with rubber ¾ inch thick of suitable grade and density, having hi-tensil cast iron heads and high carbon steel journals carried in S. K. F. roller bearings. Front end fitted with sheave for rope carrier. The driving side journal will be extended to receive a cast iron cone pulley for driving purposes and a similar cone pulley will be attached to the intake shaft of the size press lower roll. Necessary belt shifter will be furnished.

Roll will be in perfect running balance at speeds up to 1400 feet per minute.

Frames.

Necessary cast iron Frames will be furnished between the size press and the first lower dryer of the third section of dryers for supporting the Receiving Roll and miscellaneous equipment.

Spread Roll.

Between the first lower and upper dryer of the third dryer section, which will run without felt, there will be a properly crowned rubber covered Spreader Roll about 9¾ inches diameter, 184 inches face, carried in anti-friction bearings. Roll will be made with steel pipe body fitted with cast iron heads and steel journals, covered on face with hard rubber of suitable grade and density.

Paper Carrier.

Complete equipment of "Sheehan" patent paper feed as before specified. Rope sheave will be attached to the tending side head of the Paper Roll, Receiving Roll and separate loose sheave on the Spring Roll and the upper size Press Roll.

The third dryer section will be arranged so that the Felts will by-pass the first lower and upper dryers if desired.

FINISHING PART

Calenders.

Two (2) stacks of chilled iron Calender Rolls, each containing eight (8) rolls as follows:

One (1) 20-inch upper.
Five (5) 14-inch intermediates.
One (1) 20-inch next bottom.
One (1) 30-inch bottom.
Rolls all 178 inches face.

Housings will be of heavy box pattern arranged to permit all rolls to be taken out endwise.

Two (2) of the 14-inch rolls in each stack will be bored and fitted with steam or water connections of improved type.

All roll bearings except for Bottom Roll will be of the latest S. K. F. roller type with provision for taking thrust load as follows:—

20-inch top—(2 per journal)
14-inch intermediate—(___per journal)
20-inch next bottom—(___per journal)

The bottom bearings will be of self-aligning, babbitt lined, water cooled type with provision for the introduction of high pressure oil by means of hand pumps to facilitate starting. All bearings lubricated by pressure feed oiling supplied from Bowser System in connection with the dryer bearings. All bearings will have closed ends except those on the bored rolls and driving side for Bottom Rolls.

There will also be furnished three (3) additional 14 inch diameter rolls, one bored, all complete with bearings and mounts.

Necessary ladders, steps and hand bars on each stack.

Levers and weights for applying pressure to the journals of the top roll. The roll bearing housings except for the Bottom Roll will have lugs cast integral with each housing through which the lifting rods will pass with adjustable nuts on the lifting rods, operated by gearing from direct connected motor supplied by the Builder.

Complete equipment of Vickery flexible Ductors, each mounted on right frame with improved supporting brackets, pressure adjusting and throw-off mechanism.

One (1) Spreader Roll attached to each stack, about 11¾ inches diameter, 178 inches face, made of steel pipe covered on face with rubber of suitable grade and density, having cast iron heads and steel journals running in S. K. F. roller bearings with proper supporting mounts and brackets having 8 inches horizontal adjustment. Face will be crowned as approved by Purchaser.

Reel.

One (1) Pope patent type uniform speed Reel with enclosed gearing and complete with five (5) reeling drums.

The main driving drum will be 42 inches diameter, 178 inches face, of similar construction to the receiving dryer, with journals running in S. K. F. roller bearings enclosed in mounts supported on heavy cast iron side Frames. An extension from the Frames will carry a Ductor having a Bakelite blade and suitable tension arrangement.

The reeling drums will each be 12⅝ inches diameter, 179 inches face, made of heavy lap welded steel pipe, turned on the face and fitted with hi-tensil cast iron heads and high carbon steel journals, square on the end to accommodate connection to the friction brake and turning device of the unwinder.

The reeling drums will run in Timken bearings enclosed in self-aligning mounts in such a manner that when one drum is partly loaded it may be released to a set of supporting arms where the reeling is completed; a new drum in the meantime being installed in the starting supporting arms ready for reeling when the other drum becomes filled. The supporting arms will be connected with a series of gearing to easily and conveniently adjust to position as required for high speed operation; also with special oil dash pot snubbing device to prevent reels from bouncing when reeling unfinished paper.

An adjustable spreader bar of latest type will be provided for eliminating wrinkles in the paper going into the reel.

A special counterweighting device will be furnished as approved by Purchaser for relieving the reeling pressure on roll of paper.

The maximum diameter roll of paper that can be wound on this reel will be equivalent to 60 inches diameter on the winder.

Unwinder.

Comprising a pair of stands and supporting housings, to receive the drums filled with paper taken from the reel, equipped with quick-acting clamps to accommodate the anti-friction bearings on the reel drums. Tending side stand mounted on base provided with sidewise and endwise adjustment.

A hand operated sliding coupling will be furnished to connect braking arrangement with end of reel drum.

Complete regenerative braking unit for mounting tension on the sheet will be located on the driving side and supplied by Purchaser.

For emergency use in place of the regenerative braking unit, Builder will furnish a mechanical friction braking arrangement comprising a large drum arranged for water cooling and fitted with "Raybestos" lined brake strap with pneumatic control for applying pressure, controlled from front side convenient to the winder.

Slitter and Winder.

One (1) two drum uniform speed Winder of "Puseyjones" latest high speed design suitable for winding rolls up to 60 inches diameter, equipped with anti-friction bearings throughout, improved Slitting attachment and ejecting and unloading device for mechanically removing the paper rolls without use of crane or hoists.

The winding drums will each be 21 inches diameter, 178 inches face, made with semi-steel body bored on the inside and fitted with cast steel heads and journals. The journals on the driving side extended to receive couplings. Both drums grooved on the face as per latest practice.

The top pressure roll will be 12 inches diameter, 178 inches face, made with body of extra heavy turned steel tubing, fitted with hi-tensil cast iron heads and high carbon steel journals; equipped with hand-operated, countergeared lifting and adjustable counterweight mechanism to assist in winding tight rolls.

The three (3) paper lead rolls will each be 12 inches diameter, 178 inches face, made with body of turned steel tubing, fitted with hi-tensil cast iron heads and high carbon steel journals. The rolls immediately following the Slitters will be arranged to run free in the bearings or spiked to provide for drag on the sheet in contact. The roll next to the Unwinder will be arranged as a dance roll with adjustable spring device to compensate for uneven tension on the sheet. The winder drums, top pressure roll and paper lead rolls will run in S. K. F. heavy duty roller bearings, enclosed in mounts of suitable design.

One (1) turned steel plain winding shaft equipped with collars and nuts suitable for pipe cores will be carried in babbitt lined, quick-opening boxes connected to a hand-operated countergeared raising and lowering mechanism.

The Slitting Attachment having a maximum trim allowance of 164 inches, will be located directly ahead of the winding drums for convenience when handling the paper and to eliminate long draws. There will be ten (10) pairs of shear cut Slitters, the upper 5⅝ inches diameter of patent ball bearing type and the lower 10 inches diameter of double edge, individual unit stepped-up gear type.

Each lower Slitter Unit will have gears of 3 to 1 reduction running in ball bearings, enclosed in oil and dust-tight mountings, fitted with clamping and adjusting geared device. A motor driven small diameter through splined shaft will drive all the lower Slitters in common. The stepped-up gear type permits changing Slitter Blades without disturbing driving shaft or bearings.

The upper Slitters will be attached by means of clamp hubs to a rigidly braced supporting bar extending the full width of the Winder and supported from the side Frames. Each upper Slitter except edge trimmers will be fitted with air cylinder attachment for throwing blades on and off by remote control on front side.

The lower Slitter units will be supported on a rigid cross beam with two center supports and having a machined steel rack on the top full length used for adjusting the Slitter Units quickly and conveniently to desired working position.

Adjustable Slitter Boards of cast iron and steel plate accurately machined and rigidly braced will be located directly ahead of and following the Slitters. One (1) Spreader Bar of adjustable bow type on the lead of paper following the Slitters.

The latest design ejecting and unloading device will be provided complete with all motor operated mechanism for the quick handling and removing of the filled paper rolls from the Winder to the floor, skids or other means of transportation. The device will be built-in and supported from the main side Frames.

There will also be a special device for supporting the empty winder shafts and automatically depositing them in the bearings.

The main side Frames will be of extra heavy pattern with rigid cross bracing as required for operation of the Slitter and Winder without excessive vibration at the maximum speed.

The Winder Drums, Paper Lead Rolls and Slitters will be accurately balanced for speeds up to a maximum of 3000 feet per minute.

The winder drums and slitter shaft will be arranged for direct connection to motors supplied by Purchaser.

DRIVING ARRANGEMENT

The Fourdrinier, the Two Press, the Smoothing Press, the Four Dryer, the Size Press, the Two Calender and the reel sections of the machine requiring variable speed; also the Slitter and Winder, will be driven by a sectionalized individual motor drive, supplied by the Purchaser. The Marking Press will be driven by belt from dryer intake as hereinbefore specified.

The Builder will furnish the proper and necessary extension shafts complete with supporting bearings and stands, solid and flexible couplings as required for connecting each machine section to the extension shaft of its respective motor drive reduction gear unit.

FOUNDATION PLATES AND BOLTS

A complete set of cast iron foundation plates from standard patterns, extending from stock inlet to winder inclusive. All joint bolts to be furnished by the Builder and all foundation bolts and washers by the Purchaser.

The holding down tap bolts for fastening the feet of the machine frames to the foundation plates will be furnished by the Builder.

MISCELLANEOUS

Speed.

The paper speed of the machine, except the Slitter and Winder, will be from 200 to 1200 feet per minute. The maximum paper speed of the Slitter and Winder will be 3000 feet per minute.

Balance.

The Breast Roll, Wire Rolls, Felt Rolls, Spring Rolls, Reeling Drums and miscellaneous small diameter rolls will be in perfect running balance for surface speeds up to 1400 feet per minute. The Couch Roll, Press Rolls, Dryers and Reel Driving Drum will be in perfect static balance.

In General.

The object of these specifications is to set forth and describe all parts of the machine and equipment that are to be furnished by the Builder; further, it is the intent of the Builder that the design and construction throughout will embody all the latest improvements that will permit of efficient mechanical operation for the production of brown kraft, semi-bleached and fully bleached kraft specialties of weights from 30 to 200 pounds, $24 \times 36 - 480$ basis.

The Purchaser will be given the privilege of approving all details entering into the design and construction, and at all times permitted to inspect any or all parts during fabrication in the shop of the Builder; also to specify the manufacturer to cover the rubber roles.

Any defects in material or workmanship occurring within a period of one year after the starting of the machine will be remedied or replaced by the Builder.

Spare Parts.

The following parts will be furnished, all duplicate and interchangeable with those hereinbefore specified in connection with the paper machine:

2—table roll bearings
2—table roll bearing mounts
1—breast roll bearing
1—ratchet and pawls for wire, press and dryer auto guides
6—suction box rubber heads
1—perforated maple suction box cover
1—20" dia. dandy roll for use with trunnions and stands
1—28" dia. Stonite upper press roll assembled with bearings and mounts
1—13½" dia. R. C. press felt roll assembled with bearings and mounts
1—roller bearing for front or back of suction couch or press rolls
1—roller bearing for internal suction box of press roll
6—end deckle springs for suction rolls
1—tending side roller bearing for dryers
1—driving side roller bearing for dryers
1—lower 60" dryer gear
1—main dryer driving pinion with shaft, bearings, mounts and half coupling
1—lower idler gear with shaft, bearings and mounts
1—upper idler gear with shaft, bearings and mounts
1—12" dryer felt roll assembled with bearings and mounts
2—dryer felt roll bearings
1—steam joint without siphon
1—roller bearing and mount for upper calender roll
1—bottom calender roll sleeve bearing
2—calender ductor blades
1—plain winder shaft
1—winder drum bearing

Wrenches and Tools.

As required, of special type, for adjusting, assembling and dismantling any part of the machine.

Drawings.

There will be furnished without charge by the Builder, the necessary plan drawing of the machine and the foundations hereinbefore specified, as required to assist with the installation in the mill of the Purchaser; also two sets of drawings showing the several sections of the machine for the convenience of the Purchaser when ordering repairs.

Painting.

The machine will be painted the Purchaser's standard color, applied in shop during erection. Sufficient material for a finishing coat will be furnished to be applied by the Purchaser after the machine has been erected in the mill.

Exceptions.

White water, suction and stuff pumps, also screens are not included in these specifications.

The Fourdrinier Wire, Deckle Straps, Press and Dryer Felts comprising the clothing for the machine; the steam, water and stuff piping to and from the machine, and items not otherwise specified, are not included in these specifications.

Delivery.

The machine will be properly prepared for railroad shipment. Delivery on the Suction Rolls, Calenders, and other items purchased by the Builder as complete units not required at Wilmington for shop erection will be f.o.b. point of manufacture; for the remaining equipment, f.o.b. cars, Wilmington, Delaware.

Erection.

The Builder agrees to furnish the services of a skillful erecting engineer whose duty it shall be to superintend and further assist in the erection of the machine upon arrival of same in the mill of the Purchaser.

The board, lodging and traveling expenses of the said erecting engineer shall devolve upon the Purchaser, but his wages shall be paid by the Builder for a period not to exceed fourteen (14) weeks of forty hours each.

If the erecting engineer's services are required for a longer period, the Purchaser shall pay the Builder for such services at the usual rate.

If the Purchaser, in order to expedite the erection of the machine, requires the services of additional erectors, the Builder will supply same, but the total number of erector weeks shall not exceed the fourteen (14) weeks of forty hours hereinbefore mentioned.

The Purchaser is to furnish all necessary laboring help and millwright help to expedite the erection.

PROPOSAL SPECIFICATION

FOR

ONE 234-INCH FOURDRINIER NEWSPAPER MACHINE

Hand.

When standing at the Fourdrinier and looking toward the Winder, the driving arrangement will be on the right hand side, or left hand side, as determined at a later date.

Widths.

Breast Roll will be about	236 inches face
Table Rolls will be about	243 inches face
Suction Couch Roll will be suitable for a wire	234 inches wide
Lower Suction Press Rolls of suitable width	
Rubber Covered Smooth Press Roll will be	234 inches face
Drying Cylinders will be	232 inches face
Calenders Rolls will be	230 inches face
Reel Drum will be	234 inches face
Winder Drums will be	230 inches face

Screens.

Not included in this specification.

REMOVABLE TYPE FOURDRINIER PART WITH McDONNELL SHAKE ROLL

Flow Box and Apron.

The Builder is to submit to the Purchaser a design of Flow Box embodying the features of economy of space and proper distribution of the pulp upon the Apron. The purchaser is then, within a reasonable time, to approve the design or to offer such modification of it as will make it suit his ideas. The Flow Box is to be made of cast iron, copper lined, and will be put together in a substantial and workmanlike manner.

Apron arranged for Van-de-Carr slice.

Wire.

The arrangement of the Fourdrinier part will be suitable for a Wire 90 feet long and 234 inches wide.

Breast Roll.

The Breast Roll will be 26 inches diameter, about 236 inches face, body made of a shell of cast gun metal, secured to heads, and with journals of the roll to be of steel. Heads to have brass covers. Body to be bored and roll to be in running balance, this design making a roll of minimum weight, yet of maximum strength and stiffness. Journals carried in antifriction bearings with water-tight housings. Roll balanced for 1500 feet per minute.

Table Rolls.

Table Rolls, each 11¼ inches diameter, about 243 inches face, made of steel body and covered with rubber ¼ inch thick, having cast iron heads with steel journals.

All Table Rolls to be in balance for 1500 feet per minute.

Table Rolls carried in antifriction bearings with adjustment lengthwise of machine to enable center to center of rolls being changed.

Water Deflectors.

Suitable Deflectors to be furnished between first fourteen Table Rolls.

Automatic Guide Roll.

The Automatic Guide Roll will be 16 inches diameter, made of steel pipe, covered with rubber ½ inch thick, and having cast iron heads with steel journals and carried in patented automatic wire guide with antifriction bearings and with special attachment coming in contact with one side of the wire. Roll to be in balance for 1500 feet per minute. Wire guide located between last Suction Box and Suction Couch Roll.

Return Wire Rolls.

Stretch Roll 15⅝ inches diameter. All other Return Wire Rolls 15⅝ inches diameter. These rolls to be made of steel pipe, covered with rubber 5/16 inch thick, and having cast iron heads with steel journals and carried in antifriction bearings. Rolls to be in balance for 1500 feet per minute.

The Wire Roll nearest the Suction Couch to be driven from the Suction Couch Intake Shaft through pulleys and belt.

Doctor backs with Micarta blades on all outside Return Wire Rolls.

Wire Stretcher.

The Wire Stretch Roll housing will be carried on swinging arms so that the weight of the roll rests on the wire to act as a Stretcher.

Suction Couch Roll.

One (1) Suction Couch Roll, 40 inches diameter, and suitable for wire 234 inches wide. Antifriction type of bearings.

Roll designed for direct drive, thus eliminating gear, and also designed so roll may be held from shaft on driving side when changing a wire.

Aluminum paper roll, carried in antifriction bearings and arranged so it can be raised quickly from its tending side bearings. Roll equipped with air wheel for revolving roll.

Top Couch Roll.

One (1) Feather-weight rubber covered Couch Roll to be used over the Suction Roll. Roll to be covered with rubber of 210 density.

Supporting brackets and hydraulic lift all arranged so roll may be lifted quickly from the Suction Roll. Housings arranged so roll may be moved to change the amount of couch.

Dandy Roll.

One (1) Dandy Roll 30 inches diameter, 236 inches face, No. 50 mesh wire cover. Roll complete with trunnion type bearings.

Suction Boxes.

Eight (8) metal Suction Boxes of material approved by Purchaser with special treated maple wood covers 1¾ inches thick. A system of pipes for priming both ends of each box to the same water level, so that the machine tender need observe the tending side of machine only.

The suction pipes will connect to the Boxes by an improved device, by means of which the pipes are attached to or released from the boxes quickly.

Brass suction header.

The Boxes to be equipped with Rice-Barton oscillating device, crosswise motion, including the driving equipment and motor.

The Dandy Roll will be placed so that three Suction Boxes will be between it and the Breast Roll, and five Suction Boxes between it and the Suction Couch Roll.

Deckle Arrangement (Shakeless).

One (1) Van-de-Carr slice 84 inches high with sheet brass adjustable tip and apron board with sheet brass cover to be furnished by the Builder. A deckle edge ruler will be used in the place of deckle straps.

Fourdrinier Rails.

The forward rails will carry the Table Rolls, and secondary rails the Dandy Roll and Suction Boxes.

Save-all Boxes.

Save-all Boxes and trays will be made of material as approved by Purchaser, and arranged and proportioned to readily carry off the white water from the Table Rolls.

The Breast Roll Doctor will have a Micarta blade and will be arranged to empty into the save-all tray nearest to the Breast Roll.

Water Pipes and Showers.

A complete system of brass pipes comprising a pipe commencing at a point under the Breast Roll, provided with an inlet tee and with branch connections to the shower pipes, fill pail, hose and water jet.

There will be four (4) Rainstorm patented brass shower pipes for the returning wire, one brass nozzle spray shower over the flow box, one brass nozzle spray Shower at the slice, and one brass shower for each press felt.

Located between the last Suction Box and Guide Roll will be a water jet for cutting the paper on the wire; also deckle edge squirts.

Fourdrinier Frames, etc.

The Fourdrinier part will be adjustable and removable, and will shake. Fourdrinier designed to be removed as a unit when changing the wire, with suitable motor furnished by the Builder for removing.

Heavy cast iron beams on each side of the machine, these supporting the Save-alls and Fourdrinier Rails. These beams are to be hinged at the Breast Roll end.

Fourdrinier to be adjustable as to pitch, the amount to be determined at a later date. The adjusting mechanism to be so arranged that the operators can change the pitch to any position within agreed limits by means of power supplied by motor. Motor to be furnished by the Builder.

Suitable beams, wire poles, overhead shafting, pulleys and motor to be furnished by the Builder to facilitate placing wires on the machines.

McDonnell Shake Roll.

This Roll to be located at a suitable place between the Breast Roll and the First Suction Box.

Roll to be made of steel pipe, with heads and steel journals, and covered with hard rubber. Roll to be equipped wiith antifriction bearings and housings, and suitable supports.

Suitable tracks and truck, to be furnished by Builder, for taking Roll out when wire is on.

Shake Drive.

One new straight line Shake to be furnished driven by an AC motor through a Texrope drive. Motor to be totally enclosed and to be furnished by Builder; starting equipment to be furnished by Purchaser.

Fan Pump.

Not included in this specification.

Stuff Pumps.

Not included in this specification.

Suction Pumps.

Not included in this specification.

PRESS PART

Press Rolls.

First Press Upper Roll 28 inches diameter, stone.
First Press, Lower Suction Roll, 36 inches diameter, rubber covered.
Second Press Upper Roll, 28 inches diameter, stone.
Second Press Lower Suction Roll, 36½ inches diameter, rubber covered.

The First and Second Press Upper Rolls to be stone, made from our patented designs. Roll center shaft to be hollow and fitted with water joints.

The Lower Suction Press Rolls for the First and second presses will have bodies of gun metal shells covered with rubber one inch thick, and will have antifriction bearings. Rolls to have direct drive, thus eliminating gears.

Press Housings and Pedestals.

The journals of the Upper Rolls will be carried in antifriction bearings and swinging arms connected to a system of levers and weights so as to properly distribute the weight over the entire surface of the journals, thus giving additional pressure to the weight of the roll on the paper, if so desired, or by changing the position of the fulcrum pin, the pressure can be decreased.

Cam levers will be provided for the tending side to raise the compound levers and weights while the paper is being carried over.

Housings carrying the swinging arms to be of box pattern type and designed to eliminate the use of inside rolls; no operating mechanism for lifting each end of the Upper Press Rolls to be furnished, but a locking device will be provided for holding the Upper Roll away from the Lower Roll.

Swinging Arms and Upper Roll Bearings to be arranged so Upper Roll may be couched.

Doctors.

One Doctor, type as selected by Purchaser for each Upper Press Roll with light weight frames and flexible Doctor Blades. The Doctors are not to oscillate. A pipe lever will be provided for the driving side for raising the Doctor.

Save-alls.

A Save-all, material as approved by Purchaser, and of proper form and dimension, will be arranged under First and Second Lower Press Roll, carried on supports on inside of press bearings.

Footboards.

Wooden Footboards with handrail and the necessary steps with special treads and supporting frames will be arranged at each pair of Press Rolls.

Press Frames.

Complete, extending under the entire press part. These Main Frames will support the Upper Press Roll Housings, Lower Press Roll Pedestals, Footboard Supports, Small Stands, Save-all Brackets and Felt Roll Brackets.

General Arrangement for Felts.

The First and Second Felts will pass in a forward direction through their respective presses and arranged to suit press felts not less than 50 feet long. Stretchers to be located in basement.

Felt Rolls.

All the necessary Press Felt Rolls will be $15\frac{5}{8}$ inches diameter, made of steel pipe and covered with rubber $\frac{5}{16}$ inch thick and having cast iron heads with steel journals and carried in antifriction bearings with split caps. One Felt Roll for each felt will be fitted with worming strips.

Blow Rolls.

One aluminum Blow Roll carried in antifriction bearings will be provided for each felt.

Felt Stretchers.

One Press Felt Stretcher for each felt, located in basement and to be motor operated.

Motor and equipment to be furnished by Builder.

Automatic Guide.

One Automatic Guide for each felt.

Shower Pipes.

One brass Shower pipe for each press felt, as before mentioned.

Felt Suction Boxes.

One metal Suction box, with maple cover for each press felt.

Felt Conditioners.

None included in this specification.

SMOOTHING PRESS

Note.

Smoothing Press to be located at wet end of dry part, just before the receiving dryer.

Rolls.

One (1) rubber covered Top Smooth Press Roll 34 inches diameter, made with a hollow cast iron body, fitted wtih hammered steel journals and covered with rubber one inch thick.

One (1) gun metal Lower Smooth Press Roll 34 inches diameter made with a hollow cast iron body, fitted with hammered steel journals and covered with a centrifugally spun gun metal shell $\frac{3}{4}$ inch thick.

Housings and Pedestals

The Journals of the Upper Roll will be carried in antifriction bearings and swinging arms connected to a system of levers and weights so as to properly distribute the weight over the entire surface of the journals, thus giving additional pressure to the weight of the roll on the paper, if so desired.

In combination with the connecting rods of the lever and weight system will be fitted a ratchet lifting device to lift the Upper roll from contact with the Lower roll.

Housings carrying the swinging arms will be supported on extension to the main lower dryer frames.

The journals of the Lower roll will be carried in antifriction bearings resting on suitable Frames.

Paper Feed Arrangement.

Loose sheaves will be mounted on the Upper and Lower Rolls for the Dryer Carrier Rope.

Doctor.

One (1) Doctor with flexible blade will be furnished for the Lower Roll. Doctor to oscillate. No crumb catcher to be furnished.

DRYER PART

Dryers.

Forty-eight (48) cast iron Paper Dryers, each 60 inches diameter, 232 inches face.

One (1) cast iron Paper Receiving Dryer, 42 inches diameter, 232 inches face.

The inside of the shell of all the Paper Dryers to be bored and the outside face to be turned and polished, the tending side to have a manhole fitted with specially designed manhole cover. There will be no extension of the journal outside of bearing housing on the tending side. On the driving side the journal will extend outside the bearing and will be keyseated to receive driving spur gear. Dryers to be balanced.

Dryer heads and journals to be semi-steel and to be ground both at bearing and gear fits.

There will be separate bolted-on rope sheaves for the frontside heads for Sheehan carrier ropes, on all Paper Dryers.

Felt Dryers.

Six (6) cast iron Felt Dryers, each 48 inches in diameter, 236 inches face. There will be two of these Felt Dryers located on the top and two on the bottom First Dryer Felts, and one Felt Dryer located on the top and one on the bottom Second Dryer Felts.

The inside of the shell of each Dryer to be bored and the outside face to be turned and polished. The tending side of each Dryer to have a manhole fitted with specially designed manhole cover. There will be no extension to the journal outside of the bearing housing on the tending side. No gears to be used on these Felt Dryers, but the driving side journal will extend outside the bearing and will be keyseated so driving spur gear may be added at later date if desired. Dryers to be balanced.

Dryer Siphons.

Arranged in each Dryer at the driving side will be a brass Siphon pipe to remove the water of condensation from the Dryer. One patented siphon installator to be furnished.

Air Valves.

Hand operated brass air valves for each dryer.

Steam Joints.

To the extension of each Dryer journal on the driving side will be fitted a Steam Joint, with antifriction bearing between collar and sleeve.

Vertical and Horizontal Piping.

The Vertical Steam Inlet Pipes and the Vertical Water Outlet Pipes will connect at the upper ends to the Steam Joints above mentioned and the Horizontal Steam and Water Pipes by nipples and union. The Horizontal Steam and Drain Pipes will be located under the machine room floor, and will extend full length of the dry part.

A brass mounted union and a valve on each Vertical Steam and Water Pipe, the union to be placed just above the valve for convenience in cutting out the steam supply and drain, if so desired.

Dryer Pedestals.

All Dryers to be carried in antifriction bearings with suitable housings. Design to be approved by Purchaser.

Dryer Frames.

Cast iron Dryer Side Frames will be arranged to carry the Dryers in two tiers; twenty-four (24) Dryers in the lower tier and twenty-four (24) Dryers in the upper tier. Frames for carrying the upper felt equipment will be furnished complete.

To carry the lower felt equipment on the return in the basement, the Purchaser is to furnish necessary steel channel beams.

Dryer Gears and Pinions.

The driving and intermediate spur Gears for all the Paper Dryers will be made of semi-steel and have machine cut teeth.

The Dryer Gear arrangement is specially designed for high speed machines and contemplates the use of smaller Gears on the end of each Dryer than is standard practice, and with an intermediate Gear between each Lower Dryer and intermediate Gear under each Top Dryer meshing with the intermediate Gear on the lower tier. All the Dryer Gears and lower intermediate Gears will be of the same size. The spacing between all the Top and Bottom Dryers to be the same except for the break between the two felts. The Dryer part will be arranged for four (4) intake drives.

Gear Casings.

The Main Dryer and the intermediate Gears to be totally enclosed with oil tight, cast iron casings. Casings designed using minimum amount of space allowing for spearing and handling of Broke from driving side of machine, and will be bolted to the dryer frame.

Doctors.

The six Lower and last four Upper and Lower Dryers to be fitted with Doctors having suitable blades and so balanced to give the proper pressure of the blade on the Dryer. Type of Doctor to be selected by purchaser.

Footboards.

Two sliding offset ladders will be provided for the frontside, also a Footboard with handrail and ladders for the driving side.

General Arrangement for Felts.

Will be for two Upper and two Lower Felts. The first Lower Felt will not pass around the first three Lower Dryers.

Paper Carrier.

Paper Carrier complete to be furnished including intermediate sheave, ropes and rope tighteners. Intermediate sheaves fitted with antifriction bearings. Carrier designed for $\frac{5}{8}$-inch diameter rope.

Felt Rolls.

All necessary Dryer Felt Rolls will be 16 inches and 14 inches diameter, made of turned steel pipe having cast iron heads with steel journals and carried in antifriction bearings.

Guides.

One Automatic Guide for each felt.
One Hand Guide for each felt.

Automatic Tightener.

Two (2) antifriction Automatic Tighteners having horizontal guides and double weight tension arrangement complete for each felt.

Paper Spring Roll.

Located at the end of the nest of dryers to lead the sheet of paper to the calenders will be a Spring Roll 16 inches diameter, made of gun metal, having cast iron heads with steel journals and carried in antifriction bearings, mounted in brackets by circles of springs to allow for uneven tension of the draw of the paper.

Roll to be arranged for water-cooling and suitable water joints to be provided.

Lubricating System.

Bowser oiling system for all main dryer bearings designed so continuous oiling system can be used. Piping, filters, etc. for oiling system to be furnished by the Builder.

CALENDERS POPE REEL WINDER

Calenders.

One stack of chilled iron Calender Rolls, containing eight (8) rolls as follows:
One (1) 16 inch top roll
Five (5) 16 inch intermediate rolls
One (1) 22 inch next-to-bottom roll
One (1) 34 inch bottom roll
All Rolls to be 230 inches face, with heavy box pattern housings. Housings wide enough to permit the intermediate rolls to be taken out endwise, and high enough for two more rolls.

Rolls equipped with antifriction bearings, design as approved by Purchaser.

The oiling system to be connected with the system for the dryer bearings.

Levers and weights to be furnished. Lift rods on outside of housings.

The strong backs from rod to rod under the roll boxes all will be of steel and will be carried by adjustable nuts on the lifting rods which will be operated by electric motor.

Complete equipment of Doctors, of design as selected by Purchaser.

Two of the intermediate rolls to be bored and fitted with joints.

A cross walk with handrail and two ladders, at each front and back side housing, to be furnished.

Reel.

One (1) Pope Uniform speed reel and unwinder with five (5) reel bars fitted with antifriction bearings.

One standard unwinder located between reel and winder, designed for water-cooled brake.

Slitter and Winder.

One Rice-Barton two-drum, heavy type high speed Winder. Winder drums to be carefully balanced for high speeds and carried by antifriction bearings.

Suitable riding roll and equipment of a design to be approved by Purchaser.

Heavy type Slitter designed as low as possible. Paper rolls to be balanced and carried by Timken bearings. Suitable cast iron Slitter Board.

Six top Slitters with shaft and mountings. No bottom Slitter Shaft to be used, but each of the six bottom Slitters to be mounted on end of a motor. These motors mounted on a heavy beam resting on floor. Motors will be furnished and will be adjustable crosswise of machine and provided with suitable means for holding them in position when slitting.

Winder designed to deliver rolls of paper to floor without the use of slings or hoists.

DRIVING ARRANGEMENT

Hypoid Gear Units.

There will be six single Hypoid Gear Units, one for the couch, one for the First Press, one for the Second Press, one for the Smoothing Press, one for the Calender, and one for the Reel; also two double units for the dryers.

Each Unit will be mounted on a self-contained bedplate, and the gears and bearings to be totally enclosed to insure against oil leakage. All shafts carried in antifriction bearings.

The floor cone will be keyed to a jack shaft which will drive the pinion shaft through a Rice-Barton cut-off coupling type of friction clutch.

Intake shafts for all units with flexible couplings where required, and removable sections for dryer intakes.

Quill Drives.

Steel Quill and Yoke Shaft complete to be furnished for the two dryer drives. The Quill and Yoke Shafts to be carried in antifriction bearings with a self-contained bedstand at the Quill and single stands for the other bearings. Couplings to be furnished as required.

Belt Guides.

Belt Guides for all units, operated from front side of machine, through shafts and universal joints.

Clutch Shifters.

Clutch Shifters for all units operated from front side of machine.

Line Shaft.

Complete Line Shaft of turned and polished steel with antifriction bearings and couplings as required.

Line Cones.

Necessary split Line Cones for each of the above units.

Dryer Helper Drives.

Two Dryer Helper Drives to be furnished; one for each of the double units, including Motor, Reduction Unit, Over Running Clutches, Governors, Chain Drives and Oil Casings.

GENERAL

Foundation Plates.

A complete set of cast-iron Foundation Plates from standard patterns extending from Flow Box to Winder inclusive.

All Foundation Bolts and Washers are not included in this specification.

In addition to these Foundation Bolts and Washers just mentioned, the Foundation Bolts and Washers for holding the drive stands and bedplates are not included in this specification. The holding down tap bolts for fastening the feet of the machine frames to the Foundation Plates will be furnished by the Builder.

Drawings.

There will be furnished without charge by the Builder the necessary Drawings for erecting, including a drawing showing a plan view of the machine and its driving arrangement, as hereinbefore specified.

Speed.

Machine designed for maximum speed of 1500 feet per minute.

In General.

The object of this specification is to set forth and describe as clearly and definitely as possible all the parts of the machine and its equipment that are to be furnished by the Builder, and it is his intention that in workmanship, materials and finish, this machine will be fully equal to others of its class which he has built.

Exceptions.

The Fourdrinier Wire, Apron, Deckle Straps, Felts, Belts, etc. comprising the clothing for this machine, also the steam, water and stuff piping to and from the machine, not otherwise specified, are not included in this specification.

Painting.

The machine is to be painted Builder's standard color unless otherwise specified.

Delivery.

The machine to be painted and crated suitable for railroad shipment and delivered f.o.b. cars shipping point.

Erection.

The Builder further agrees to furnish the services of a skillful erecting engineer, whose duty it shall be to superintend and further assist in the erection of the before-mentioned machine upon arrival of same at destination. The board, traveling expenses and wages of said erecting engineer shall be paid by the Builder. In this connection, however, it is further understood that should the erection be delayed beyond the term of, say fifteen (15) weeks, if found necessary, then Purchaser shall pay for such additional services of said erector.

The Purchaser is to furnish all necessary laboring help and millwright help, also the use of crane and other handling apparatus to expedite the erection.

Respectfully submitted,

(Builder's Signature)

14. The Finishing Room

The work of the finishing room divides itself into two general classifications, which are themselves much further subdivided. The two classifications are (1) making rolls. of paper (2) making bundles of paper.

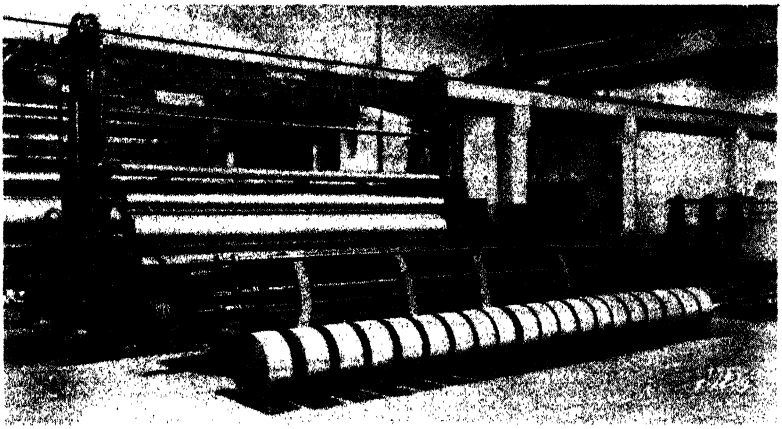
Whether bundles or rolls are to be made depends entirely on the purpose for which the paper is to be used.

The extent of the operations of the finishing room will vary all the way from the very simple state of affairs in a newsprint mill where the rolls are shipped practically as they come from the machine, to that in a mill making a wide line of book or writing papers, or specialties of some kind, in which case the finishing room may well be one of the most extensive and important parts of the whole plant.

Today these operations are frequently integrated with the work of the Fourdrinier machine, so before going into detail on each operation we will summarize the various operations that come under the head of finishing and explain why each is necessary.

Reels: Paper runs continuously except when the web breaks. Winders are intermittent. Reels are used in order to take care of a continuous web and yet allow the winders to stop and start. In order to take care of the increasing diameters of reels, the reels are driven by an endless link slip belt and clutches are provided to stop full reels and start empty ones. Reels are described in detail and illustrated in Chap. 13.

Winders: Winders are used to wind the paper from the reels into rolls of any given weight or diameters. Slitters are used to cut the wide sheet into definite widths. Winders constructed to give the best results are usually of the two-drum type, the drums being placed parallel, level and far enough apart to permit the web of paper to pass between them with a safe clearance. Each drum is independently driven with shift belt and cone pulleys on the drum nearest to the reels. It is necessary to have such apparently unnecessary adjustments on a winder. To illustrate this necessity, first the winder shaft is placed in a position between the drums and resting its weight equally on each drum. The web of paper is threaded down under the first drum and brought up between the two drums and around the winder shaft. When the winder is started, the winder shaft also starts winding the paper, being turned by its own frictional contact against the drums. The winder shaft is usually heavy enough to produce the necessary friction for driving itself, also for tight winding. As the diameter of the roll of paper increases, the weight increases in direct proportion, so that when the roll of paper is completed, it may weigh 2000 lbs instead of 150 lbs when it is started. The heavier the roll gets, the tighter it winds the paper and the center of the roll will be much softer than the outside, which will cause the rolls to start. This condition must be avoided, and one way to do this is to run the first winder drum a little faster than the second drum. This is done by shifting the cone belt slightly in favor of faster speed, which will feed the web to the winding roll with slightly less pulling. This also helps keep wrinkles out of the paper. Further adjustments are used to help offset the increasing weight of the roll of paper. Counterbalancing weights are used. Levers are screwed to the upper shaft of the winder at an angle which will give increased lifting force to the winding roll proportionately as it increases in diameter and weight. A spiral lift is better than straight levers, as it can be designed to counterbalance accurately the increasing weight of the rolls, for the reason that a straight lever reaches its maximum lifting force long before



Courtesy: Cameron Machine Co., Brooklyn, N. Y.

FIG. 211.—Modern winder 222 in. wide in southern wrapping paper mill.

the roll of paper is completed. The spiral lift is constructed with a groove in which a rope may run and weights added to the lower end of the rope. It is understood that the friction applied to the roll is important, but perfect rolls cannot be made by friction alone. Newsprint rolls must be perfect. The spiral lift above mentioned is so constructed that each coil of the spiral recedes from the center carrying the counterbalancing weight by means of the rope in the groove farther away from the center and in direct proportion to the lifting force required for the increasing diameter and weight of the roll of paper.

Paper Cutters: A sheet cutter is a machine designed to convert large sheets into smaller ones, consisting of carrying rolls, pinch rolls, a stationary bed knife and a revolving knife. Several rolls of paper wound on a reel or shaft are placed in the loading frames back of the cutter. The sheets are threaded through the cutter over a drum roll and down past the bed knife. On top of the drum roll is a punch roll. When the cutter is started the drum and pinch roll pull the sheet forward at a given speed. The revolving knife is set to shear against the bed knife and cuts the sheets off at every revolution. The lengths of the sheets are calculated from the speed of the drum and revolving knife. The widths of the sheets are determined by slitters placed on a revolving shaft to slit the sheets into correct widths, for instance, if the sheets are 96 inches wide and are to be cut into sheets 24 inches by 36 inches the slitters are set 24 inches apart and the revolving knife is set for a sheet 36 inches long.

Roll finishing requires no special training or intelligence beyond the ordinary. Sheet finishing requires expert knowledge and training. The boss finisher in a mill making writing, book, bond, envelope or specialties, must be very highly experienced in all branches of this department. In mills making high grade specialties the finishing room is one of the most important units. It is in this department that the paper is given its final inspection, undergoing a hand sorting process, eliminating all visible blemishes or mechanical defects, such as wet wrinkles, calender cuts, slime spots, crush marks, pin holes, thin streaks, wire spots, dry wrinkles or off finish.

Trade customs are general rules and regulations governing the sale of different grades of paper. Shipping 25 per cent more paper than a customer orders is not customary; shipping 10 per cent over or short an order for special colors or grades is customary and considered a good delivery, as it imposes no unreasonable hardship on either the manufacturer or the purchaser. Trade customs are established for the benefit of both buyer and seller and are understood to be a compromise based on reasonable limits of tolerance. Trade customs cover every grade and color of paper made, specifying limitations such as weight per ream. In making wrapping paper 24 x 36-35 lb to 480 sheets to the ream, 2½ per cent over or under the given weight is within the limitation of trade custom.

Roll Finishing.

Rolls of Paper: The first classification is the simplest. In most cases the paper, as it is rewound from the jumbo roll formed on the reels in the machine room, passes through a rewinder. This machine usually consists of a rewinder and slitter combined so that, by means of various cutting devices, the operators are able to obtain whatever sized rolls their orders may call for.

This rewinding and cutting operation requires the severest attention. A dull knife will often result in spoiling many rolls of paper. The knives must be placed at exactly the right points for cutting the paper; otherwise oversized or undersized rolls will result. Actually the slitting process and the rewinding process are not distinct and separate operations, but must be considered one in relation to the other.

The rolls must be wound absolutely straight to insure a uniform advancement of the web of paper from the jumbo roll. The sheet of paper must be held rigidly, and must have been properly calendered to insure presenting a good uniform surface from the jumbo roll to the finished rolls, otherwise causing rolls to be formed that have hard and soft spots. A roll of this sort would not be particularly objectionable if it were to be used as a counter roll, but if it were going to be further cut up or used in a bag machine or any other automatic machine for making paper products, serious difficulties would follow. For instance, the roll could not be properly fed to the machine. The slackness of one side would cause wrinkles, followed by breaks. This would mean an immediate rejection of such a roll of paper.

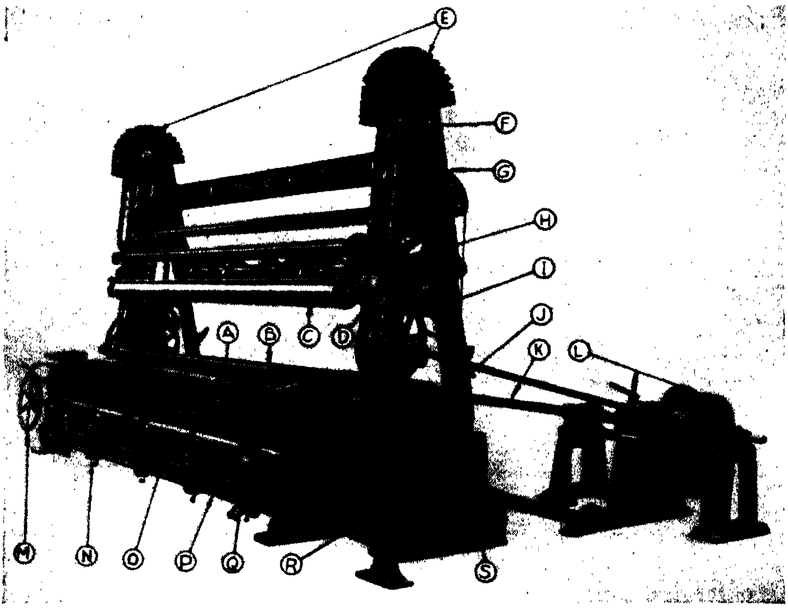
Courtesy: Cameron Machine Co., Brooklyn, N. Y.

FIG. 212.—Winder 310 in. wide connected to largest newsprint machine in the world at mills of Edward Lloyd, Ltd., Sittingbourne, Kent, England.

There are hundreds of little things at this particular stage of paper-making—the finishing room—that can completely offset the value of a good sheet of paper. Paper that has had all the attention and care that paper possibly could have, before being sent to the finishing room, may be completely ruined. Consequently extreme precaution must be exercised.

The machinery should be of the best and most improved makes and care should be exercised to keep it in the best order. The knives of the slitters must be kept properly sharpened and not allowed to sheer, otherwise feathery edges will result, or an overlapping will take place between the consecutive rolls. This works a hardship on the operators who are taking away the paper from the rewinder, and often results in the spoiling of a roll due to the inability of the help to separate it from another roll. Spreaders of various types are used to prevent this, the most usual type of spreader being a steel strip pressing on the paper which is bowed out at the point where the spreading is required.

A great many different varieties of winding and slitting machines are in use in paper mills and in converting establishments. Very often a single plant will have a number of different styles and kinds of winders and slitters. Often older types that are admittedly superseded have to be kept in service. Also there are great differences of opinion among experienced men. No one make or style of machine is generally admitted to be the answer to all slitting and winding problems. Some of the toughest problems in the paper industry, and those that are very directly reflected in money loss and in forfeiting customer good will are encountered in the finishing department.



Courtesy: Cameron Machine Co., Brooklyn, N. Y.

FIG. 213.—Typical modern rewinder.

A FRONT REWIND DRUM—This drum is grooved spirally to assure separation of the rewound rolls and longitudinally to remove wrinkles in the web.
B REWIND SHAFT—At the beginning of the run this shaft lies on top of the paper in the valley between the front and rear winding drums. The slit paper is pulled forward over the rewind shaft. The riding roller is lowered onto the paper and the rewind shaft. The slit paper is tucked tightly around the rewind shaft and the unslit end is torn off. The winder is then off to a good firm start.
C RIDING ROLLER—This is a driven roller and it is counterweighted so that maximum pressure is applied at the start of the run when it is needed.
D BEVEL GEAR—This gear drives the riding roller from the riding roller drive shaft, "F".
E AUTOMATIC COUNTERWEIGHTS—These weights permit the full pressure of the riding roller to be applied on the rewind shaft at the beginning of the run. As the roll grows in size, the riding roller rides up on top of the roll, which permits the weights to spill over the back of the machine and these weights pulling on the suspender chains counter-balance the weight of the riding roller as the roll of paper grows in diameter. Uniform density of the rewound roll from core to circumference is thus assured.
F RIDING ROLLER DRIVE SHAFT—This shaft is driven from the main drive shaft "S", through bevel gears.
G WINDING SHAFT COUNTERWEIGHT CAM—Weights, suspended from this cam counterbalance the weight of the rewind shaft evenly from the start to the finish of the run.
H WINDING SHAFT CARRIAGE CHAIN—The hand wheel on the opposite side of the machine operates this chain through sprockets to raise or lower the rewind shaft as required.
I HAND WHEEL—This hand wheel enables the operator to shift the mill roll from side to side as required.
J BRAKE DRUM AND BAND—As the illustration shows, the brake is applied by means of the brake control hand lever "R".
K MILL ROLL SHAFT
L MILL ROLL BRAKE DRUM AND BAND—Controlled by foot treadle or hand lever as required. Control may be located at either side of the machine.
M SLITTER SUPPORT BEAM HAND WHEEL CONTROL—A turn or two of the hand wheel throws all slitters in or out of action simultaneously.
N MILL TYPE SLITTER WHEEL—This is an improved unit in which the slitter wheel is mounted on an axle with a ball bearing at each end. A wing nut provides for regulating the pressure through springs on each individual slitter wheel as required.
O SLITTER PLATEN ROLL—This consists of highly polished hardened steel sleeves butted together on a core shaft. The paper passes over this roll and the cutters press through the paper against the roll.
P SLITTER SUPPORT BEAM
Q TRIM GUIDES—The trim guides are placed alongside the end cutters and deflect the trim onto the floor.
R BRAKE CONTROL HAND LEVER
S MAIN DRIVE SHAFT—Provision can be made to drive by belt through special Cameron clutch; by slip belt; direct motor drive or any other method approved by Cameron engineers.

Rewinding.

There are various methods of performing this operation of cutting and rewinding. One of these is the *surface rewind method.* By this method all the rolls are formed side by side on a single shaft by surface contact with a pair of revolving support rolls, on which the rolls of paper rest. No power is applied directly to the rewind shaft. This method, when the equipment is properly designed, and when accompanied by the proper method of slitting, is decidedly superior to the old center rewind method. The *center rewind method* is not practical when narrow rolls are required, as they will not stand alone after they have been built up to any considerable diameter. Further trouble with this method is due to variation in the thickness of the paper across the width of the sheet, causing the rolls to build up largest where the web is thickest, thereby pulling the paper faster on the thicker portions, thus causing the web to feed unevenly and preventing first class work.

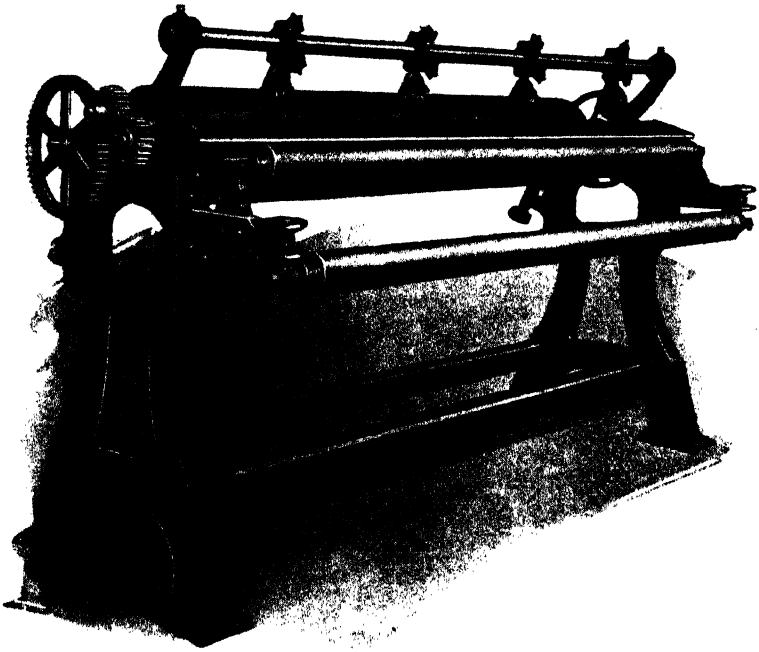
As has already been stated it is generally conceded that the surface rewind method is the better one, and the next point to be considered is what is the best method of slitting so that the two operations, quite distinct from each other, will work in perfect unison with each other.

Slitting.

The rotary shear, or rotary slitter, method is one that in the past has been widely used and was, at one time, considered to be the last word on the subject of slitting. The writer today prefers the more modern *score cutter* to be described later, but much good work is still turned out with machines equipped with rotary shears. To work properly the rotary shears must have a keen edge, and yet this edge is bound to become dulled slightly, even after only moderate use, thereby causing a ragged or frayed edge on the strips, which then become interlaced or meshed together in the rewinding process. As before stated, when this interlacing takes place it is often impossible to separate the rolls from each other. The slitter shaft should be heavy enough not to vibrate or chatter and should be well braced and the knives should be large enough in diameter that they do not have to rotate excessively fast.

On account of serious difficulties in maintaining production and high class finishing with the rotary slitters, some of which have been touched on above, the *score cutter* has come to be much used in modern finishing rooms. This device consists of a single cutting disc with a "V" edge, so mounted as to revolve under spring pressure against the surface of a glass-hard steel cylinder. This surface is very smooth and highly polished. The steel cutter wheel is mounted on ball-bearing centers, revolves practically without friction and has an actual cleaving action through the paper at the point of contact with the cylinder against which it is pressed. This appliance invariably yields a clean cut, even, perfect sheet or roll of paper. The edge of the paper is not stretched, owing to the cleanness of the cut. Further, there is not the same difficulty in keeping these steel cutter wheels sharp as there is with the rotary slitters, since they do not have a regular knife edge but rather a very hard permanent edge, something like a cold chisel. The variety of materials that can be handled with such equipment is very great—all the way from the most delicate tissues to coarse boards, also fabrics, textiles, etc. Great difficulty was experienced with rotary slitters at very high speeds, but the score cutter apparently knows no limit as to speed.

No matter what principle has been embodied in reducing the jumbo roll to the sizes specified in the orders, whether to 9-inch rolls or 40-inch rolls or what not, one can hardly place too much emphasis on the necessity of taking every precaution to prevent bad edges, slitter breaks, slack edges and to insure exact and proper width of roll.



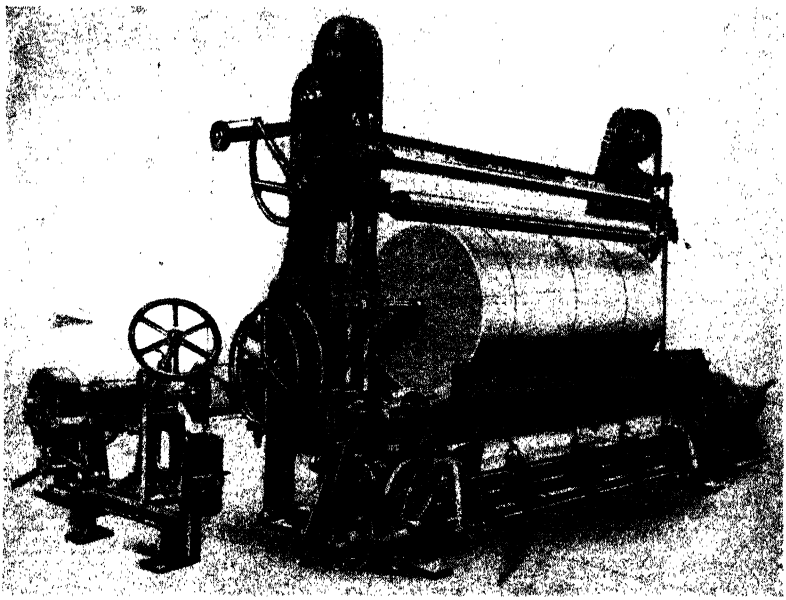
Courtesy: Pusey and Jones Corp., Wilmington, Del.

FIG. 214.—Winder and rotary slitter.

Another precaution that must be taken is the prompt insertion of plugs in the rolls, so that when these are later piled up in transportation or storage they will not be pressed inward and flattened and loose their symmetrical cylindrical shape.

After the rolls have been cut to the proper size, plugs inserted, etc., they are ready for the final stages of finishing. This consists in putting on the wrapper, which may be done either by hand or mechanically. In large, modern finishing plants mechanical methods are usual on account of the high cost and uncertainty of labor. The roll is wrapped with either one, two or three plies of good durable paper. A strong sheet of 60-pound kraft is suitable for this purpose. This is to insure against rough usage and tumbling during transportation.

The width of the wrapper is, of course, determined by the width of the roll; sufficient allowance being made to have the ends of the wrapper almost meet when folded over on the ends of the roll. An inside header should be placed under this folded portion to prevent any paste reaching the outer edges of the roll. The outside header is then pasted over the ends of the roll, serving not only as a means of securing the end, but adding to the neatness of the roll when properly applied. The work is now completed with the exception of stenciling and labeling. Care should be taken that this work is done neatly and not in haphazard fashion, otherwise when a



Courtesy: Cameron Machine Co., Brooklyn, N. Y.

Fig. 215.—Typical modern rewinder showing automatic system of counterweights attached to chains for control of riding roll pressure.

number of rolls are stored in a jobber's warehouse the appearance of good workmanship is lost. With a material like paper, appearance, even in minor details, counts for a great deal.

For the detailed illustrations of progress in the development of winding and slitting practice incorporated in the following passages I am indebted to the late Mr. James A. Cameron of the Cameron Machine Company, Brooklyn, N. Y., whose firm has specialized for more than 30 years in slitting and winding, and who was himself probably the foremost expert in the world on this subject, and to whom the entire paper industry is vastly indebted.

The old method of winding a roll on a shaft mounted on two bearings and driven by a slip belt or friction clutch is considered by many paper-makers to be good enough for rough work. This system has, of course, the advantage of simplicity and cheapness in the initial cost; but what is saved on machinery is taken out of the coal pile and also added to the pay roll and to the "broke" pile. The production of firmly wound rolls in this way, especially those of large diameter, requires an excessive amount of power because the roll is made compact and firm only by the pull on the web. Starting with too slow a speed and too much pull on the web when the roll is small, one is apt to end up with a racing speed and too little pull on the web when the roll becomes large. The slippage of the belt or other friction drive eats up power; and when all is said and done, the roll produced is not what it ought to be.

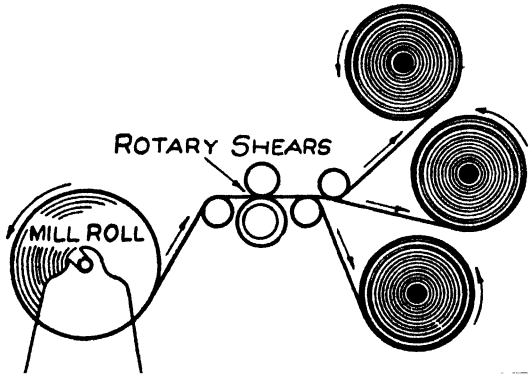


FIG. 216.—Multiple shaft "center wind" system slip belt drive to each shaft.

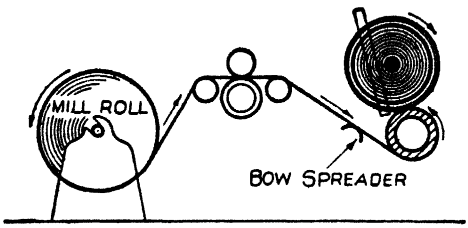
*Courtesy: Cameron Machine Co., Brooklyn, N. Y.**

* For the drawings for Figs. 216 to 227, inclusive, we are indebted to Cameron Machine Co., Brooklyn, N. Y.

It is often necessary to have a separate shaft for each separate roll, as shown in Figure 216, which further complicates things; and it is almost impossible in such cases to adjust the friction drive for each of the several shafts so that each shaft will exert a proper amount of pull on the web, and not distort the web by one shaft pulling stronger or faster than another. It still has some advantages in board mills, as each of the several rolls can be of different diameter, if desired; and where it is necessary to tear out a portion of the web for a defect, only that immediate portion is lost, and not a portion clear across the full width of the web—as would be the case where all the rolls are wound on a single shaft. Aside from these points in its favor, there is nothing further to be said, and the disadvantages far outweigh the advantages as compared to more efficient methods of winding to be described later. The winding method illustrated roughly as Figure 216 is employed in various forms in winders both large and small, the principle being substantially the same in all cases, and the machines differ more in size than in principle. When this system is used in producing many small rolls of narrow width at one operation, the delays and difficulties are too well known to require comment.

Another system of slitting and roll-winding may be termed the one-drum surface wind system, as indicated in Fig. 217. This is another relic of the past which deserves an honorable and well-earned rest. In this case, the rolls are wound up on a single shaft in contact with the surface of the drum, revolved by friction contact with its surface. The center of the

FIG. 217.—
One drum "surface wind" system.



roll moves upwards or outwards from the drum in either a vertical line or at an angle, as it builds up in diameter. This system is in some respects better than the multiple shaft system shown in Fig. 216; but it is far from reliable or desirable where even passably good rolls are required. Yet there are cases where this system has been successfully employed in connection with a tissue paper machine where jumbo or log rolls only are required, but ordinarily it is impossible to secure sufficient traction at the start of the winding to guarantee beginning with a firmly wound basis on which to build up the roll as it increases in diameter. This defect defeats any hope of really good work on the average requirement.

In some examples of the one-drum winding principle, a pressure roller is rigged to ride on the top of the rewound rolls, shown in Fig. 218. In this case the rolls are wound on top of the drum with the pressure roller directly above them. This gives increased traction on the web at the start and helps some, but even then the traction is not sufficient for a good start except on light weight paper such as tissue, where it is passably satis-

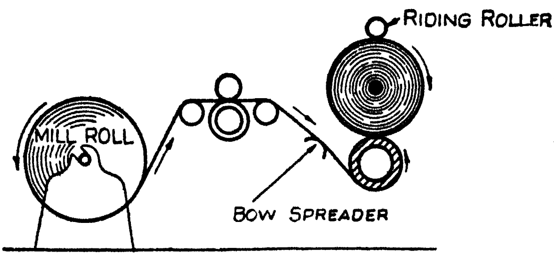


FIG. 218.—
One drum and riding roller "surface wind" system.

factory in producing jumbo rolls of the original trim width of the web for subsequent slitting and rewinding.

Figure 219 shows a system of winding in which the web after being slit passes upward between two drums to the winding shaft which rests, at the start, in the valley between these drums. One of the drums—usually the one nearest the operator—revolves at a speed slightly faster than the other. This system is an improvement over the systems referred to in Figs. 216, 217 and 218. It has been worked out in various types and models of machines and constitutes a commendable effort toward improving the process of roll-winding.

Here, however, we find the same defects, but in less degree, as are found in the one-drum system of winding, Figs. 217 and 218, arising from the fact that the traction on the web at the start of the winding is not sufficient to permit enough tension or drawback on the web to insure a firm hard roll at the start. In fact, the web must be quite slack at the start, as there is nothing to pull it forward through the machine at the start except the friction due to the weight of the rewind shaft as it rests on the drums. As the roll builds up, however, a gradual increase of tension is possible, and the roll is gradually brought to a fair degree of firmness, and grows progressively harder.

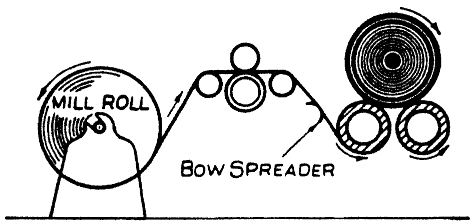


FIG. 219.—Two drum "surface wind" system.

Although the rolls produced by the system shown in Fig. 219 are for the greater part acceptable, they are sometimes liable to "star" or collapse at the center when they are wound without cores, or to have occasional loose cores when cores are used, or to get out of round in subsequent handling or shipping. This may happen in spite of the skill and care the operator uses in producing the rolls by this system.

Where this system is applied to small machines for comparatively small diameter rolls from a narrow web, a loosely wound start may be prevented by means of pressure applied to the ends of the rewind shaft; but this is not always practicable on wide machines, as the shaft is not stiff enough to transmit this pressure evenly clear across the width of the machine. The pressure, therefore, is effective on the ends only and tends to bow up the shaft in the center, which gives poor results.

Another point must be considered here, and that is the tendency of the roll to wind progressively harder and harder as it builds up, and to become actually too hard towards the finish. The downward pull of the sheet between the drums resulting from the tension or drawback on the web, together with the accumulated weight of the roll as it builds up, also the increasing traction power of the overspeeded front drum as the weight of the roll builds up (which, by the way, tends to swedge the roll down into the valley between the drums and jam the paper on the roll more and more firmly)—all combined together, tend to produce a roll which is harder and harder as the diameter increases. This brings on a train of evils with which all practical producers and consumers of rolls are familiar, and this condition must be combated in one way or another.

To counteract the condition where the two-drum system of winding produces rolls of large diameter which are too hard as to the outside portions, mechanism has been provided by builders of some of the machines of this class whereby the ends of the shaft on which the rolls are wound are lifted bodily by counterweights, thereby easing the weight of the roll on the drums with a view to preventing too tight winding as the roll increases to large diameter. This preventive is of doubtful benefit in the average case, as the shaft will bend slightly under the weight of the roll of paper rather than actually hold up the roll, and thus the ends of the rolls only are apt to be eased off the drums. This fact, in turn, tends to interfere with good winding by creating an uneven traction on the web.

In the two-drum method of winding, no means are provided to insure that the rolls will be perfectly round and of uniform diameter clear across the width of the web. A web of only slightly varying thickness across its

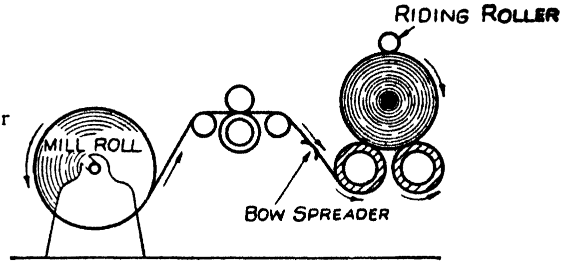


FIG. 220.—Two drum and riding roller "surface wind" system.

width will tend to build up a roll of larger diameter at the thicker portion. This, in turn, may produce an uneven draw on the sheet and a tendency toward wrinkling. But in spite of these defects, this two-drum method of winding is, nevertheless, a practical one—if not the most desirable.

Builders of this class of machine deliver honest value in service proportionate to the low price charged for these machines. They are usually simple in structure and proportionately low in price. To avoid the shortcomings of this method of winding, it is necessary to employ additional mechanism at a correspondingly higher cost.

An effort to improve some of the features of the two-drum system of slitting and roll-winding is shown in Fig. 220. In order to overcome the difficulty of starting the winding operation with sufficient tension on the web to insure a reasonably firm start, a pressure or riding roller was rigged so as to bear on top of the roll of paper, and by its weight increase the traction power exerted by the drums, and also help to keep the rolls round and of uniform diameter.

This pressure roller corrected the difficulty at the starting of the winding, but unless it was removed prior to finishing the run, it had a tendency to increase the liability of too hard a roll at the finish when applied to a winding method where the web is threaded between the drums, as already referred to in connection with Fig. 219. This system, therefore, did not accomplish any substantial gain in the search for real improvement—although a step in the right direction.

In this method of winding, as in all other methods where rolls are wound side by side on a single shaft, there is a natural tendency for the adjoining edges of the paper to overlap or interweave unless proper means are provided to prevent it. This tendency is the more pronounced where the rotary shear method of slitting is employed, as will be commented on later. This condition will render the separation of finished rolls difficult or in some cases impossible.

An adjustable bow spreader is usually employed to prevent this overlapping of the edges of the paper prior to rewinding.

The bow spreader is in itself apt to be a source of vexation. The spreader requires a rather nice and skillful adjustment. If unsuccessfully handled, it will throw up wrinkles in the paper and, under all conditions, the spreader will tend to stretch one edge of the paper in pushing the slit sections of the paper out of their normal path in order to spread the edges one from the other to prevent interweaving in the winding. More or less harm is done to the paper by this spreading operation. It is desirable that the paper shall be wound so that in unwinding same for utilizing it for the purposes for which it is intended, the web will run true and flat and be absolutely free from wrinkles. It is unnecessary to comment further on the effect of stretching a web on the edges or distorting it or wrinkling it, other than to point out that the bow spreader in effecting the spreading or separating operation is apt to do harm to the surface of the paper—more or less, in proportion to the skill and good judgment of the operator.

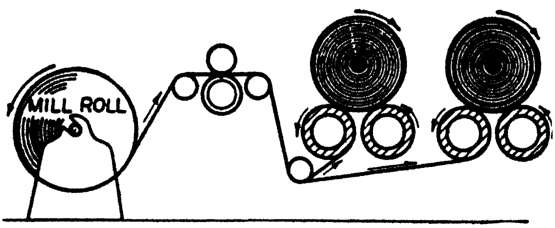


FIG. 221.—Four drum, multiple shaft, "surface wind" system; separate shaft for each roll.

In the four-drum system shown in Fig. 221, two pairs of drums are used; in other words, two two-drum winders are united in a single machine. The slit sections of the web are staggered alternately from one pair of drums to the other, each section being wound up into a distinctly separate roll, each roll having its own separate shaft.

The same comment as to the necessity of starting with a comparatively soft roll, as in the case of the system shown in Fig. 219 and finishing with a roll which may be excessively hard, as in both that system and the one immediately following, applies also in the case of the four-drum method.

Here, however, it is more practicable than in the case of the two systems just mentioned to provide apparatus for easing up the weight of the rolls of paper as they increase to large diameter. The separate rewinding shafts are proportionately short, being only a little longer than the length of each separate roll. Care must be taken, however, not to counterweight one roll more than its neighbor or the traction on the web will be uneven with a tendency towards wrinkles. This is aside from the liability of one section to snap off if it is placed under proportionately greater strain than the next one.

It is to be said in favor of the four-drum system that it has eliminated entirely the danger of the rolls interweaving in the winding. The troublesome bow spreader is consequently eliminated. Machines employing this system are at their best when winding two, three or possibly four rolls to a set. When it is attempted to wind more than four rolls to a set, the complications are proportionately increased and become prohibitive if narrow rolls are required. But this situation can be met in part by winding the rolls side by side on a continuous shaft, using the front pair of drums for this purpose and resorting to the bow spreader for separation between the rolls, as the system shown in Fig. 219. This practice will permit the winding of moderately narrow rolls such as bag rolls, envelope rolls, etc., but is seldom resorted to as it is not in line with the normal purpose for which the machine was designed.

Rolls of several different diameters can be wound at the one time, but this practice is seldom advisable or necessary.

For winding small diameter rolls such as 9-inch diameter counter rolls, this system is too slow and cumbersome in the matter of starting up each individual roll on a separate winding shaft, also in the matter of removing the finished rolls.

What is gained by winding on separate shafts to insure complete separation of the rolls, is apt to be sacrificed by false starts due to unbalanced traction, also breaks in the individual sheets due to unbalanced tension, as well as difficulty in splicing breaks properly and conveniently.

The search for a system of slitting and roll-winding which has the greatest number of good points, with the least number of bad ones, must go further.

The system shown in Fig. 222 reverts to the use of the pressure roller riding on top of the roll of paper, but provides for threading the web under both drums and up over the front drum, with the idea of improving the traction of the web at the start and avoiding the tendency towards producing too hard a roll at the finish.

The slitting method employed in this system is the same as in the previous systems discussed—the rotary shears—but here, the shears are placed below the front drum with a view to bringing the slitting operation nearer to the winding operation. This position of the slitters is an important step in the right direction. It would seem at first thought that real progress had been made, but practical difficulties arise which are hard to combat.

It must be borne in mind that the revolving shears, unless their edge is absolutely true and perfect and unless they are set with care and skill, will tend to produce a rough or slightly frayed edge on the paper; and it requires constant attention to keep the shears sufficiently sharp to avoid this. There is a further tendency of the rotary shears to stretch or distort or crack the edges of the paper by pushing one edge down and away from its normal path of travel by as much as the shear blades overlap each other.

Effective spreading mechanism is of vital importance where shears are used, especially in a position so near the winding. In cases where the shears are mounted at the rear of the machine, the bow spreader will, with all its faults, actually spread the slit sections, when it is properly adjusted, provided the sections are not too narrow and too many. In Fig. 222, however, where the shears are mounted just below the front drum, there is not sufficient length of draw to utilize the bow spreader and it becomes necessary to use individual spreaders, one for each slit section. This makes a complicated arrangement requiring constant skill and care on the part of the operator. What is gained in the proper placing of the slitter with respect to the winding drums is lost by employing a defective method of slitting, the revolving shear.

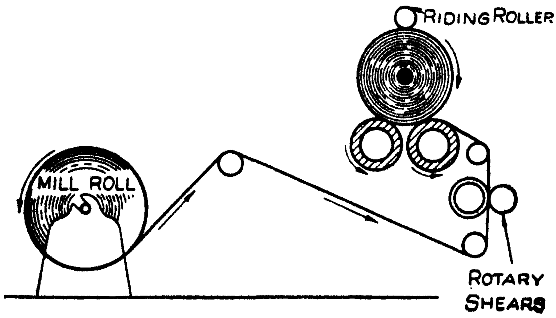
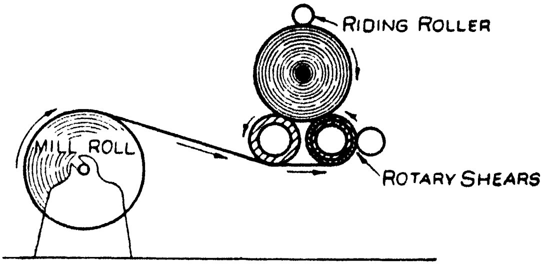


FIG. 222.—Two drum and riding roller "surface wind" system with "rotary shears" below front drum.

In addition, a complicated arrangement of guide rollers for leading the web past the slitters is required, and the space available is limited. This brings on two conditions; one is that the threading of the paper is inconvenient, and the other that in case one of the slit sections breaks, the flap end of this section of paper is apt to foul around one or another of these guide rollers or around the shaft on which the cutters are mounted. The method illustrated in Fig. 222 has been followed by several machine builders, but it has never gained favor to any considerable extent.

In the system shown in Fig. 223, a winding method similar to that already illustrated in Fig. 222 was employed, but with the rotary shear in direct contact with the front winding drum. In this case the front winding drum had an outside surface built up by a succession of rings having a sharp cutting edge alternated with spacing sleeves or collars, the outside diameter of the rings being the same as the outside diameter of the sleeves. This made a continuous surface except that adjoining the edge of each of the rings mentioned there was a slight depression in the surface of the adjoining sleeve to permit of the overlap of the rotary shear blades. These blades were mounted on a shaft just in front of the drum. The rings on the drum were spaceable by using various lengths of sleeves between them, and the rotary shear blades were, of course, spaceable sideways to match up with the rings for any change of width of strip required. This practice was effective in a limited number of cases on narrow width machines.

Fig. 223.—Two drum and riding roller "surface wind" system with "rotary shears" on front drum.



With this method of slitting it is difficult to introduce any form of spreader; and this is one of the serious defects in the system, as the shears distort the edge of the paper and make interweaving a serious objection.

In the system shown in Fig. 224 we see a further application of the winding method shown in Fig. 222 and Fig. 223, but here the slitting means—the rotary shear—is placed above the winding mechanism and so arranged as to rise along with the pressure or riding roller as the roll of paper builds up in diameter. In this case, the slitting is at a point, with respect to the rewinding, quite as near as in Fig. 222 and almost as near as in Fig. 223. Here again the difficulties as to the separation of the rewound rolls, where the rotary shear system of slitting is employed so near the rewinding, are substantially the same as already pointed out in Fig. 222 and Fig. 223. This method of slitting and roll-winding has been utilized more particularly by foreign builders of machines.

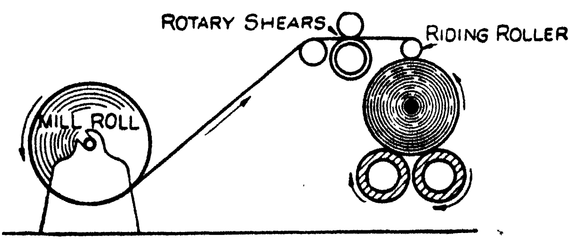


Fig. 224.—Two drum and riding roller "surface wind" system with "rotary shears" on riding roller frame.

Further effort toward improvement is creditable to builders of a type of machine using what is known as the top-slitter method, as illustrated in Fig. 225. By this method of slitting, the danger of the rolls interweaving or failing to separate readily is avoided without the use of any spreading mechanism or any complicated construction in winding mechanism—such, for instance, as the four-drum type of winder. Here, we find, furthermore, an effort to get away from the use of rotary shears.

The top-slitter consists of a thin steel disc with a serrated or saw-toothed edge mounted on a collar and supported on a shaft directly above

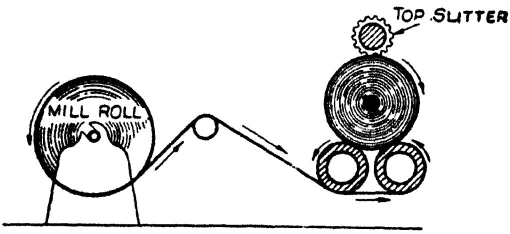


FIG. 225.—
Two drum "surface wind" system with "top slitter."

the rolls of paper. The shaft rises vertically as the rolls increase in diameter. By this method, the slitting is done *after* the paper is actually on the rewound roll; and by penetrating between the edges of each adjoining roll, the separating of same is assured. The slitter itself is simple and it is to be regretted that this system has not proved an effective substitute for the revolving shears. Its advantages are offset by the fact that it is liable to produce a still more ragged and dusty edge than dull shears; and in some cases it is not at all practicable, because where a soft spot is encountered in the roll of paper this method of slitting fails to operate—especially on medium to heavyweight paper. Furthermore, a reasonably narrow selvage trim cannot be made in this way.

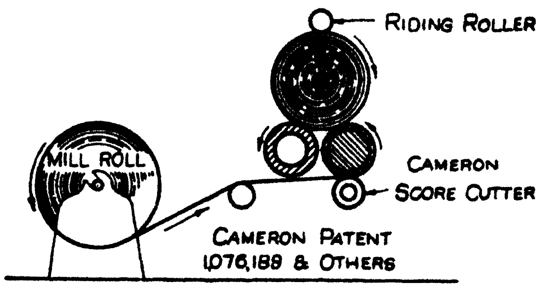


FIG. 226.—
Two drum and riding roller "surface wind" system with "score cutters" direct on front drum.

When we pass to the system shown in Fig. 226, we leave behind many of the aggravations and bedevilments which have put a hard strain on the piety and patience of the operator of less efficient slitting and roll-winding machines, also his boss. The roll-winding method here used consists of two drums supplemented by a riding or pressure roller which rides on the top surface of the rolls of paper, moving upward as the diameter of the rolls increases—the same principle as already referred to in connection with Figs. 222, 223 and 224.

This method of winding has been combined with a different method of slitting than any used in the types of machines previously referred to. The method is known to the trade as the "Score Cutter," to distinguish it from the shear cutter or rotary shears. In this method, the slitting is done directly on the front drum as the paper passes to the winding operation. The success achieved here was no doubt sought when the designers of the system placed the rotary shear in contact with the front drum, as already described. The score cutter, however, in this position does what the shear cutter failed to do. Whereas, the shear cut method distorted the edges of the paper and stretched them slightly, aside from a tendency towards a ragged cut, the score cutter method leaves the sections of paper lying smoothly and evenly in a side by side relation as they go forward to the rewinding; and when reasonable care is given the edge of the score cutter wheels, the separation of rewound rolls is, with reasonable precautions, assured.

The drum against which the slitting is done, although it is an essential part of the cutting apparatus, is from another point of view, more often regarded by the operator of the machine as part of the winding mechanism. The operator does not have to concern himself with this drum in any way whatever. The surface of the drum is flint hard and highly polished, and consists of several long tubular sections or sleeves fitting closely end to end on a core shaft. These sleeves are made of forgings of a special steel, heat treated in a way to be excessively hard and tough. This construction of the drum insures a surface more perfect and at less expense than would be possible in case the drum were made of a single mass. Furthermore, these tubular sections are removable and replaceable in case of accident to the surface of the drum or necessity for regrinding through long service. Experience extending over many years has shown that the surface described is practically indestructible and seldom shows signs of wear to an extent interfering with the operation of the machine.

The slitting is done on the surface of the drum above described, as the paper advances toward the winding. A steel disc or wheel with a "V" edge (one disc for each slit required) revolves on ball bearings in a bracket provided with spring pressure sufficient to cause the "V" edge of the wheel to press clean through the paper on the face of the drum. The cutter wheel and the paper and the drum all travel at the same surface speed, the rate of speed being fast or slow, as desired. There is, accordingly, no friction or undue wear between the surface of the drum and the edge of the cutter. As the cutter edge rolls through the paper, it has a rolling contact with the flint hard face of the drum, and the pressure required to force the cutter edge through the paper is not sufficient to mar the surface of the drum or batter down the edge of the cutter by this rolling action, except that the cutter edge will show a tendency to flatten, in continuous service, and must be honed up to a semi-sharp rounding from time to time. The surface of the drum can be disregarded, as it seldom requires regrinding or renewal even after years of continuous service.

In spacing the score cutters for the width of paper required, it is necessary to respace only a single element for each cut (not a pair of elements as in the case of the revolving shears). The diameter of the score cutter wheels need not be uniform for all of the wheels, as the individual spring adjustment on each cutter provides for variation in diameter. All the cutters are brought in or out of work by a single lever, which also controls the amount of pressure needed for light or heavy weight paper.

Aside from the individual merits of the score cutter as compared to other methods of slitting, the vital factor in its favor is that it contributes towards good roll-winding, in that the sections of paper as they are slit remain in a smooth and undisturbed side by side relation on the surface of the drum as the paper goes forward to the winding operation. Too much emphasis cannot be placed on this distinguishing feature of the score cutter method of slitting, as its use in connection with the method of roll-winding employed in the system shown in Fig. 226 does away with a train of difficulties liable to arise from the use of the rotary shear as a slitting method.

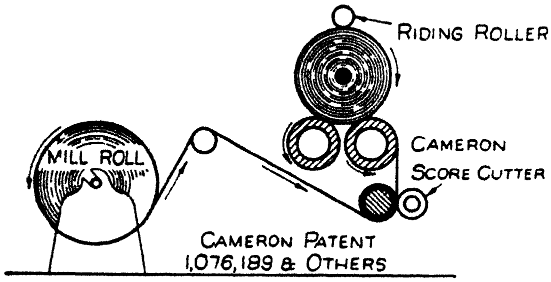


Fig. 227.—Two drum and riding roller "surface wind" system with "score cutters" on separate roller below front drum.

In the system shown in Fig. 227 we find the same winding method as in the system just described, and the same slitting method—the score cutter. In this instance, however, the slitting is done on a separate roller placed below the front drum. This practice is advisable on large machines for high speed work on wide webs or for producing rolls of extreme diameter, for the reason that the drums in such machines must be of proportionately large diameter, and it is not economical to produce a drum with the specially constructed surface described in diameters as great as required on large mill type machines. It is, therefore, less expensive to incorporate a separate roller just below the front drum. The two systems just described differ from each other in this one structural feature only, but in the operating results they are the same; the first system being used for machines for handling webs of comparatively narrow width, say from 80″ to 90″ down, and the second system for handling webs say from 80″ or 90″ up.

The systems shown in the diagrams from Fig. 216 to Fig. 227 are, in the main, representative of the basic ideas in each case, without attempting to give the details of construction of an actual machine employing any one of these systems. Machines have been built and used representing each of them. In some cases, several builders have adopted one and the same system and have worked out its details in various ways. All of the above mentioned systems have some merit, some naturally more than others as applied to a specific requirement—all are in use. There are types of machines which would not fall under any one of the above mentioned systems, being an offshoot of one or another; but space does not permit the discussion of each of the subdivisions of the above systems, as, in the main, those mentioned represent in a broad way the progress to date.

When it comes to the consideration of winding methods, it must be said that there is no one single type of winding mechanism that will cover all possible requirements in the whole range and scope of uses for slitting and roll-winding machines. It is not to be inferred that the methods are the only practicable winding methods nor the only ones with which the patented score cutter has been coupled. Special machines for special purposes have been evolved where one or another of the winding methods described, or modifications of them, are used in connection with the score cut method of slitting for solving a specific problem.

Bundle Finishing.

Returning to the other phase of finishing—*bundle finishing*—it is well to note at the outset that, although this operation is not so difficult as roll finishing, it is more tedious and requires more operators.

Large jumbo rolls averaging 29 inches in diameter are brought from the machine room and placed on an unwinder, from which they are fed to the cutters, where they are cut into the desired widths and also cut off transversely at regular intervals, thus making rectangular sheets of regular and exact size. The sheets are gathered up, counted and placed in piles. In some mills this is still done by hand, but the majority of finishing rooms now use machines called "lay boys" for this purpose.

The smaller sizes of sheets are shipped flat. These are wrapped and tied, the nature of the wrapper varying with the size of the bundle. The bundles are, as far as possible, arranged at a weight of 100 pounds. The wrapper in such a case should be of three sheets of paper of 60-pound basis. This operation naturally varies with the nature of the paper and the degree of caution taken by the maker. Also there is a difference according to whether the paper is for domestic or export trade. Bundles for export trade are sometimes enclosed in heavy cases of wood or fiber board.

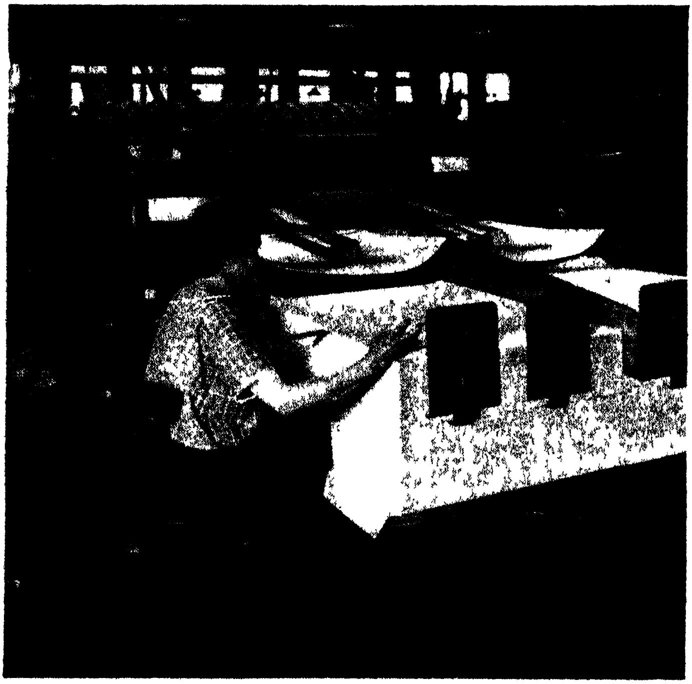
Frequently orders are taken calling for large size sheets which cannot conveniently be shipped flat. These are folded. The folding is done in two ways, depending on the customer's preference. One way is simply to fold the sheet, permitting the pressure of the bundle to crease it rather sharply. The other method of folding is the interlapping method in which the sheets are interlapped by the ream so as to prevent creasing when compressed by the weight of the bundle. Of the latter method there are again two subdivisions, the loose and the hard, depending on the customer's preference.

Efficient handling of cut paper is necessary in order to maintain production and orders should be so arranged that there will not be too much waste as a result of the trim.

Sheet Cutters and Cutter Tables or Lay Boys There are many various types of sheet cutters. It is necessary to select a make best suited to the needs of the particular kind of paper to be cut.

The function of sheet cutters is to cut paper from jumbo rolls into sheets of specified lengths and widths. Some of these cutters are equipped with two fly knives making it possible to cut two different lengths of sheet at one operation.

The widths of the sheets are determined by the slitters. The paper is first slit into desired widths before passing to the fly knives. Slitters are mounted on revolving shafts located on the cutter frame, but back of the revolving or fly knives, so that when the sheets pass through the slitters they are already cut to the desired widths. If a roll of paper 96 inches wide is to be cut into sheets 24×36 inches, the cutter is adjusted first by



Courtesy · S D. Warren Co, Boston, Mass.

FIG 228—Sheet cutter or lay boy.

spacing the slitters 24 inches apart (four times 24 inches equals 96 inches), second by adjusting the speed of the revolving knife to cut the sheet 36 inches long. This is accomplished by running the paper through the cutter 120 feet per minute and setting the revolving knife to 40 cuts per minute. Example:—120 feet equals 1440 inches, divided by 36 inches equals 40 cuts of the fly knife per minute. The speed of the fly knife is controlled by shifting the belt on the cone pulleys which drive the knife. The principal things to look out for in order to get perfect length, width and a perfectly square sheet are:—See that the paper does not slip on the drum; use the pinch roll; do not run the frictions on the roll of paper too tight, just enough to keep the paper from wrinkling. See that the slitters do not slip from the correct width of paper. Measure the sheet frequently. Fold the sheets to be sure that they are cut square. If the sheet is not cutting square, it can be corrected by slightly adjusting both the fly knife and bed knife by means of set screws provided for this purpose. The shear on the fly knife causes sheets to cut out of square, also, rolls of paper with soft ends or an increased circumference of one end of the drum, which thus will feed one edge of the paper slightly faster than the other edge. Paper is counted into quires and reams on a cutter by cutter girls or boys who lay the sheets on the cutter table. If cutting from four rolls, 6 cuts make 24 sheets, 1 quire; if cutting from 8 rolls, 3 cuts make a quire of 24 sheets; if from 12 rolls, 2 cuts, etc.

In cutting fine papers it makes no difference as to the number of rolls cut at the same time, as this grade of paper cannot be counted as cut on account of the very careful sorting required; in the case of market papers, etc., the paper can usually be counted and sorted satisfactorily in one operation. The above applies only to the ordinary cutting table and cutter girls for laying, sorting, counting and jogging into reams or quires.

The lay boy is an automatic machine which is attached to the front side of the cutter, which receives the sheets as they are delivered from the fly knives and places them on the jogging table automatically. The capacity of these lay boys is far greater than the hand operation, especially on fine papers as the paper is heavy and lies flat without curling. However, it does not *inspect* the paper for imperfect sheets.

Seybold Electric Automatic Spacer Paper Cutting Machine.

This machine is an accurate, rapid production paper cutter developed for the paper industry and allied trades. An important feature of the machine is the automatic spacing mechanism which consists of a travelling electric control connected with the back gauge, and a four-sided spacer bar on which the operator arranges a series of movable stop contacts. In operation, immediately after a cut, the back gauge moves forward until a contact is made with the next spacer bar stop bringing the lift of paper to the exact, predetermined cutting position. A red light flashes to signal the operator that the machine is ready to make another cut. Immediately after the cut is completed, the back gauge again starts forward toward the next cutting position.

The four sides of the spacer bar permit the arrangement of four separate series of stop combinations. Double contacts allow for the removal of inside trims or cutouts.

An illuminated magnifying glass assures easier, quicker and more accurate reading of the tape rule thereby minimizing operator's eye strain. Push button controls eliminate the slow laborious handwheel turning for both forward and backward movement of the back gauge. By a touch on a switch, the automatic spacing mechanism is disengaged and the machine is converted into a standard cutter. The spacer bar set-up is not disturbed. Another touch on the switch converts the machine back to an automatic spacer cutter.

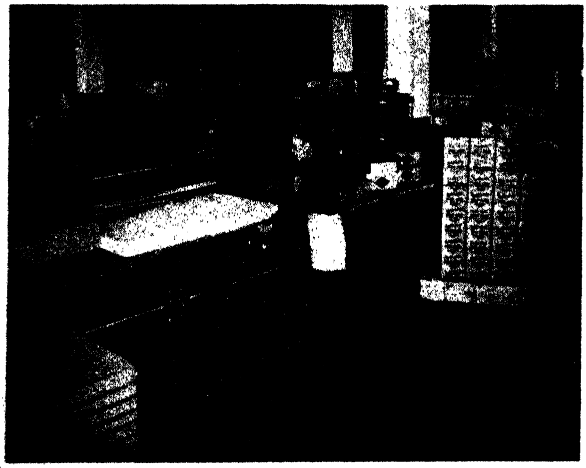


FIG. 229.—Seybold electric automatic spacer paper cutting machine installed in Canadian mill.

Courtesy: Harris-Seybold-Potter Co., Dayton, Ohio.

Super-Calendering.

Super-Calenders: The Super-Calenders are machines used for giving a smooth surface or glazing to papers requiring more finish than can be given on the calenders at the end of the paper machine.

A stack of these super-calenders usually contains either nine or eleven rolls. One roll is of chilled polished steel and the next roll of cotton or paper. These rolls are placed alternately in the stack beginning at the bottom with a steel roll—first steel and then cotton or paper. The reason that these stacks of calenders contain an odd number of rolls, such as 7, 9 or 11 rolls, is so that the paper may go over the top of the first roll and pass down through each nip of the calenders, and come through the last or bottom nip on the working side of the stack.

The cotton or paper rolls are made by pressing discs of the material onto an iron or steel core by hydraulic pressure and then they are turned, ground and polished on the surface.

These paper or cotton rolls thus prepared and finished make a beautiful surface when placed alternately in the stack. The steel rolls having a hard polished surface and the cotton or paper rolls also being polished, but of a more yielding nature, have an effect on the surface of the sheet of paper resembling the ironing of a shirt bosom. To add to this ironing effect the stack of calenders must be run for a time without the sheet on them and until they became quite hot, due to friction. This finishing effect is also augmented by applying steam showers to the surface of the paper just as it enters the top of the stack in the first nip. In some cases, steam showers are applied to both sides of the sheet, but the most common procedure is to apply to one side at a time and turning the sheet over every time it is run through the stack. This is done to insure an even finish on both sides of the paper and also to prevent the sheet from curling; all papers treated in this manner are called super-calendered. These super-calenders are run at a speed of approximately 1,000 feet per minute.

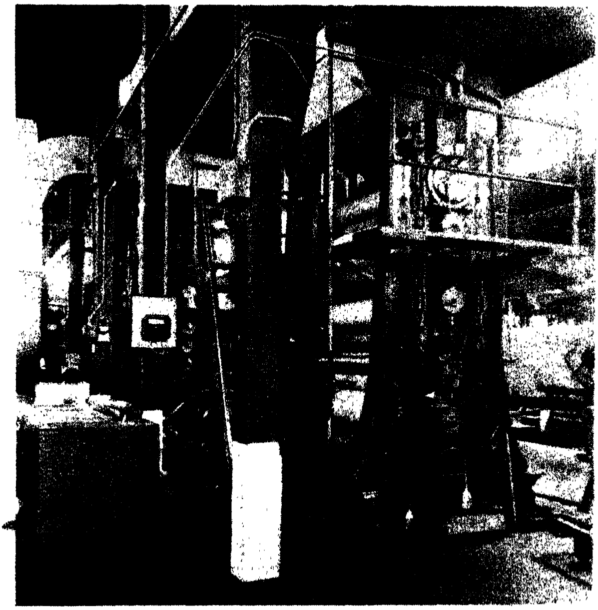


FIG. 230.—
Super-calender stack showing alternating steel and fabric rolls and equipment for automatic control of pressure.

Courtesy: Taylor Instrument Companies, Rochester, N. Y.

Super-calenders are best driven by a 2-motor drive, as they operate at least 30 per cent of the time at threading speed and the power goes down in proportion to the speed, which is not much more than 10 per cent of the normal calendering speed. To use one motor for this would obviously be very inefficient. With two suitably selected motors both are operating at all times at full load. Also no clutches are required, as in the case of a single motor drive. Westinghouse engineers have recently brought out a single motor drive operating on two electrical frequencies which would seem to combine the advantages of both systems. It calls for but one simple set of reducing gears or else a chain drive.

An immense variety of finishing room machinery has been developed, all of which it would be impossbile to describe in such a work as this. However, all of these machines follow the main types we have described and vary only in the introduction of special devices intended to increase production, improve quality and facilitate and lighten the work of the operators.

Storage and Shipment.

The efficiency of a modern finishing room depends largely on the equipment installed for handling the rolls and bundles of paper. Of recent years

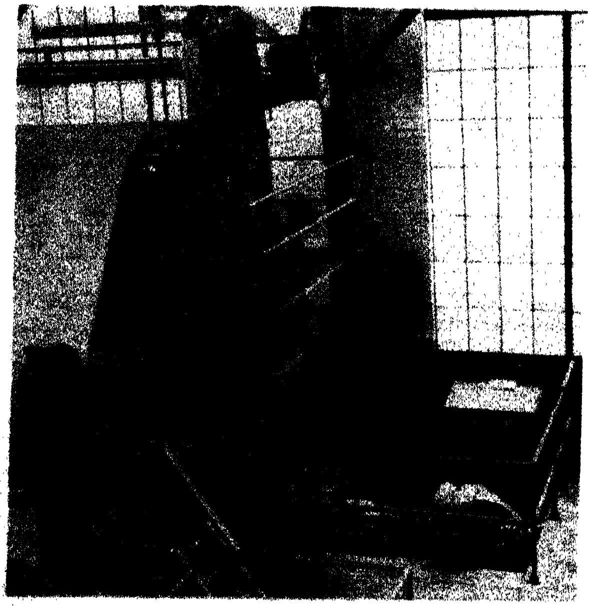


FIG. 231.—High speed supercalender for rotogravure paper showing adjustable voltage d.c. motor drive.

Courtesy: Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

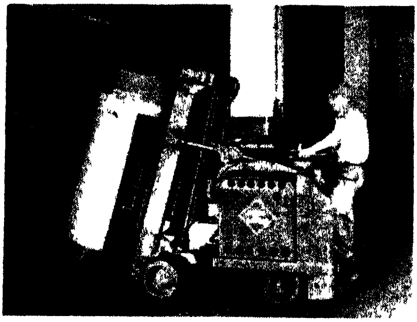
much has been done in this connection by introducing traveling cranes and overhead conveying systems for bringing the jumbo rolls into the finishing rooms from the machine room and for storing the finished rolls and bundles.

Courtesy: Toledo Scale Co., Toledo, Ohio.

FIG. 232.—Typical modern shipping room showing special scale installations for rapidly and efficiently weighing rolls without removal from platform.

Tiering machines have also proved exceedingly useful. These are small trucks with an elevator device. The roll of paper is rolled onto the truck when the platform is at ground level, then the platform is elevated and the roll pushed off into its place in the warehouse or car. These devices will handle considerable weights, lift to any reasonable height and can be operated with facility by one man.

The less the paper is handled by manual labor the better, because while a roll of paper is not exactly fragile, it is comparatively easy to damage. If a corner of a roll of paper is damaged the roll must be unwrapped and stripped until the entire damaged portion is removed.



(*a*)

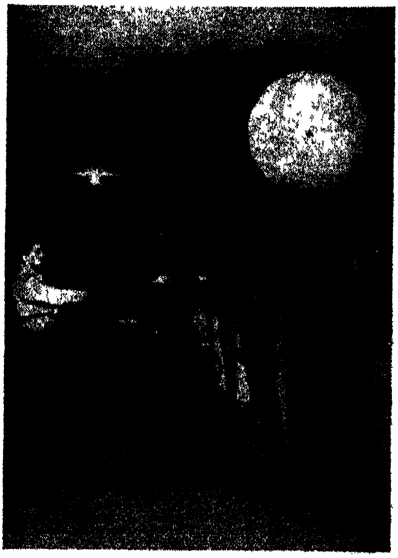
(*b*)

Courtesy Elwell Parker Electric Co., Cleveland Ohio

(a). Electric truck specially designed for handling rolls of paper.

(b) Packages of cut paper being handled on electric platform truck. At left note wooden skids frequently used for sidewalk and warehouse delivery of book and ledger paper.

(c). Type of electric truck commonly used for lifting or tiering rolls of paper.



(*c*)

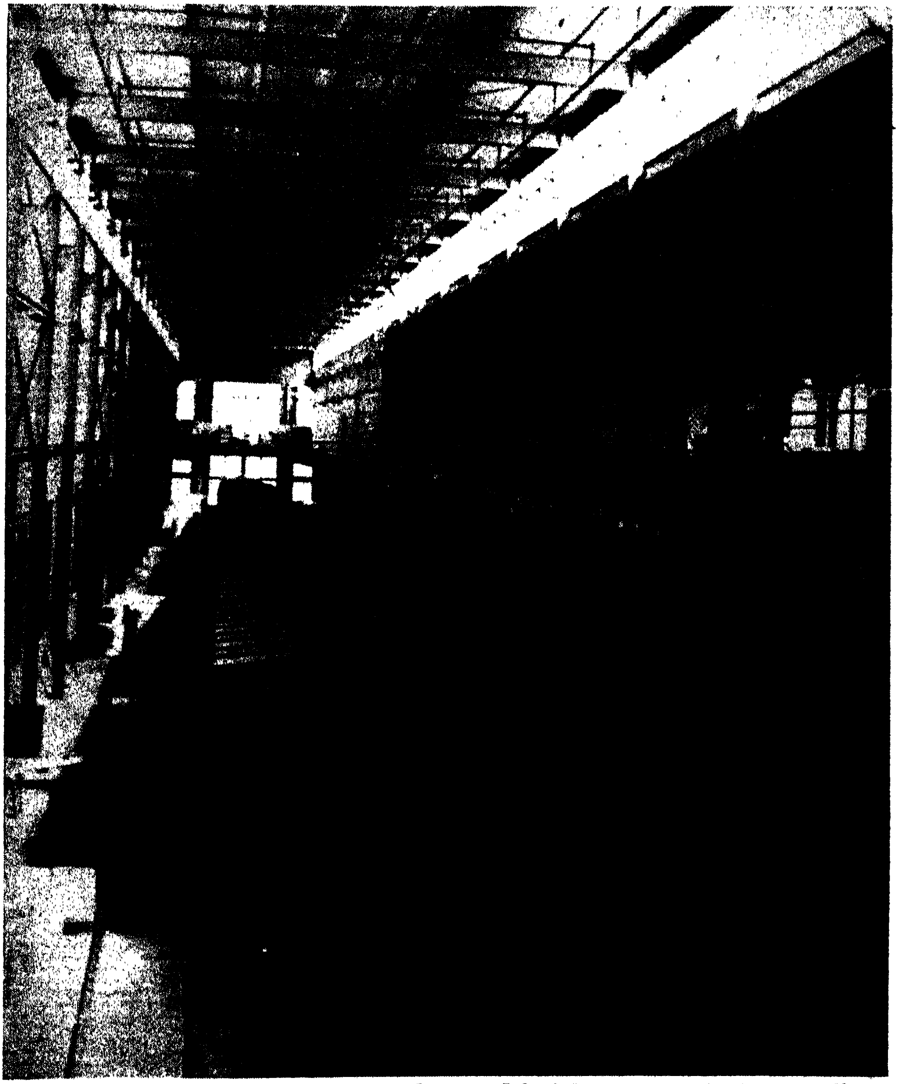
FIG. 233.

It is always preferable to store roll paper standing on end because this preserves the cylindrical shape of the roll. Also in the majority of cases it utilizes the storage space to the best advantage. Even a short period in storage or transportation lying on its side will subject a roll to enough pressure that it will not remain perfectly cylindrical. This gives rise to a great deal of trouble on modern printing presses as the paper unrolls in an irregular manner, and even the most imperceptible alterations in tension give much trouble on these delicate high speed machines.

Special trucks, such as the one illustrated in Fig. 233 (a), have been devised for handling paper, the nose of which is flat and thin, consisting of a single piece of steel. This is easily inserted under the edge of the roll, as it stands on end on the floor, and when the roll is tipped back it reclines in a cylindrical steel plate depression, in which position it cannot possibly be injured.

Care should be taken not to leave rolls standing where they will be in the way of trucks, etc. Much good paper is needlessly damaged by attempting to utilize passages in warehouse, etc., for storage.

Cars in which paper is to be shipped should be carefully examined for nails, bolts, etc. The floor of the car should be covered with strong paper before any rolls are loaded. It is a good plan to nail a strip of clean wood around the car about four feet from the floor. If the car is only partly loaded the rolls should be specially well braced with strong timbers and care should be taken that the ends of these timbers do not come in direct contact with any of the rolls. Although under present circumstances cars are frequently loaded double-deck it is better as a general rule only to have one tier. It is a good rule to assume that whatever the rated capacity of the car may be, if the entire floor is tightly packed with rolls of paper, it is carrying a sufficient load. However, at present, two tiers are frequently necessary, and that being the case, even more care should be exercised with the top tier than the bottom one, as it will be more affected by the motion of the train. Before closing the car heavy timbers should be placed across the doors.

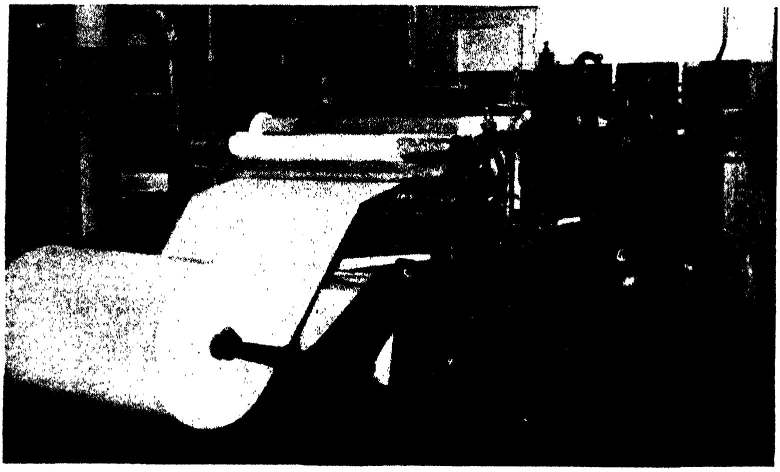


Courtesy: Inland Empire Paper Co., Millwood, Wash.

Typical car loading department in modern paper mill.

15. Coating and Converting

There are numerous processes to which paper is subjected which do not strictly fall within the province of this book. Carbon paper, fly paper, sand paper, towels, cups, napkins, electrical insulation are a few of the things we might mention which are basically paper, and which are made in huge mass production operations, but which are not considered part of the paper industry itself.



Courtesy: Oxford Paper Co., Rumford, Maine.

Fig. 234.—Paper coating machine.

Coating is in a somewhat different category, as this operation is usually carried on by paper concerns themselves and often in the same plant where paper is made. In fact in certain modern developments, coating is performed right on the paper machine as the paper is made. In this chapter we will necessarily restrict ourselves to a few observations on converting in general and to a brief description of the coating process.

Paper Converting.

There is an unlimited field for converting paper into something different from what it is when finished into a plain sheet of paper direct from the paper machine. Anything that is done to it that changes its original shape, color or use moves it into a different classification, viz, converting. The comparatively small converting operations that may be accomplished under paper mill supervision are confined to imprinting, striping, surface staining, waxing, saturating, super-calendering, etc. The making of paper bags is a converting operation and is an entirely different industry from making bag paper. Paper mills make thousands of tons of wall paper but they know scarcely anything about the decorating and printing by which this is made into finished wall paper.

Waxing Paper.

Waxing paper is essentially a converting process which can not be profitably done on a paper machine; nevertheless, it is frequently done in a paper mill under the supervision of papermakers. Commercial waxing machines may be purchased and erected in the paper mill finishing room or other available space. It is not difficult for a man who is used to handling paper to learn readily to operate the waxing machine. The advantages of waxing paper under the supervision of the man that makes it are numerous and should not be overlooked. The application of wax to a sheet of paper specified to weigh 30 lb., 24 × 36—500 sheets to the ream after waxing requires considerable experimenting to get the correct weight of the paper before and after waxing.

Surface waxing requiring 5 per cent wax requires a sheet of paper heavily sized and with a high machine finish. The size and finish prevent penetration of the wax into the body of the sheet which needlessly increases the amount of wax used. The amount of wax applied to a sheet of paper may be controlled to a limited extent on the waxing machine by applying the wax at a lower temperature and running the machine faster. If the foregoing suggestions are not observed both in the making and calendering of the paper, it will be found difficult to comply with the specified percentage of wax and finished weight of the paper. The cost of the paper may be 4 cents per pound. The wax applied will cost approximately 10 or 11 cents per pound plus the labor, power and heat. The result is obvious. The more wax applied to the paper, the higher the cost of the finished paper.

The melting point of hard wax is approximately 125 degrees F. The evaporation point is from 150 to 160 degrees F. The temperature of the wax is kept within the range between these two points by means of automatic temperature control devices. The speed of the waxing machine is also variable. It therefore is obvious that a limited control of the amount of wax applied to the paper is within the scope of the waxing operations. Concerns operating converting plants must often purchase paper from paper mills miles away. If a carload of paper is received from the mill and found to be lacking in any of the above mentioned requirements thus making it impossible for the converter to transform it into waxed paper, as per specifications of the purchaser, some one has a carload of paper on his hands.

The reason that it appears advantageous for a paper mill making specialties to have a waxing machine under the supervision of the paper maker is that if the paper lacks size or finish or is defective for any other reason such as formation, weight or texture, it can be remedied at once by the papermaker. The installation of a complete waxing outfit includes a metal melting tank (apart from the waxing machine) elevated above the waxing vat, to permit the flow of melted wax to the machine vat through a pipe with a hand-operated regulating valve. The incline of the pipe from the tank to the vat must be enough to drain the pipe quickly, especially if the supply tank is located a few feet away from the wax machine. Liquid wax will get hard over night and plug the pipe. Coils are placed in the bottom of the tank through which steam is circulated for melting the cakes of hard wax. The steam pipes in the bottom of the melting tank should be covered with water to a depth of 3 or 4 inches above the top of the pipes to prevent burning the wax and causing evaporation. The heat applied to the wax is controlled by an automatic temperature regulator so that the melted wax may be delivered to the waxing machine in a regulated supply and at the constant correct temperature.

Striping.

To stripe paper with color while it is being made on a paper machine, one bottom dryer is removed to give space for the striping rolls and the vat which contains the color. The location of this apparatus must be near the calender end of the dryers at a point where the paper is dry as color will creep and smear damp paper. The arrangement for striping consists of a color vat in which color runs constantly in a supply large enough to keep the striping rolls inked. An overflow pipe is located at the top of the vat which takes care of any surplus color. This pipe discharges into a small tank from which the color overflow is pumped directly back into the makeup or supply tank overhead. In this way there is no color wasted when the paper breaks or when there are other interruptions. If such a reclaiming arrangement for color were not provided a waste of time and color would result.

Surface Staining.

The surface staining of paper as it is being made on a paper machine is usually done on the machine calenders by means of water boxes in which liquid color is used, one water box for staining one side of the paper and two boxes if both sides of the paper are to be stained or colored. The same overflow system is used to prevent wasting color as is used for striping.

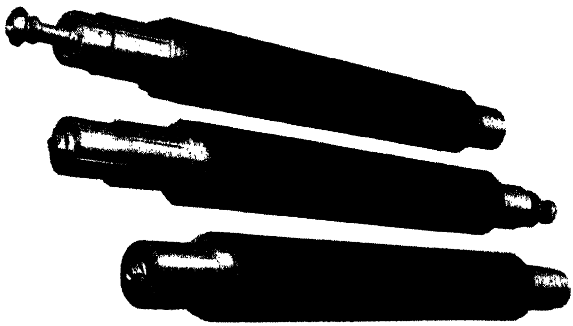
Saturating.

Saturating paper as it is being made on a paper machine may be accomplished by means similar to striping paper which provides for a vat of liquid into which the sheet of paper is immersed. The liquid solution may be animal sizing, starch, dextrine, etc. These mixtures are used for surface conditioning the paper to improve the finish when it is calendered. Saturating mixtures are also used to render the paper waterproof or greaseproof. In every case, the vat for supplying these mixtures must be located at a point along the dryers where the paper is dry enough before immersing and where there will still be dryers enough left before the paper reaches the calenders to again dry the paper suitably for calendering. The immersion vat is equipped with a small roll placed within about two inches from the bottom of the vat. This roll must turn easily in fixed journal boxes placed at each end of the vat. The vat and roll must be about two or three inches longer than the paper is wide. Two small rolls are placed on each edge of the vat so that the sheet of paper is put over the first dry roll and down under the wet roll at the bottom of the vat and up over the next dry roll and over the dryers to the calenders in the usual way. These vats are usually made with flaring sides so that the paper may pass over the dry rolls at an angle of about forty-five degrees.

By means of a hand wheel at the front side of the paper machine the wet roll may be lifted out of the solution with a rack and pinion, the lower ends of which are attached to the journal boxes of the wet roll. When the wet roll is raised out of the vat high enough to allow the paper to pass beneath, it is held in this elevated position by means of a ratchet and pawl located on the front side of the paper machine. When the paper breaks the wet roll may be quickly raised, the paper put through, and the roll quickly lowered to its original position in the solution. This must be done before the slack of the paper is taken up. This prevents the necessity of operators having to pass the paper under the wet roll, when it is immersed in the solution. This may also be done by using two pinch rolls with the bottom roll running about one-half its diameter in the solution, thus serving as a pick-up roll supplying solution to the bottom side of the sheet. The top side of the sheet is supplied with solution from a small vat placed over the top of the sheet. The supply of solution from the top vat is regulated with an adjustable outlet for serving the top side of sheet. In most cases the paper is strong enough to turn the solution rolls without a special drive, as the foregoing apparatus is mostly used on slow running paper machines making paper ranging from $24 \times 36 = 35$ lb. to 60 and 70 lb. If a more elaborate apparatus suitable for saturating all weights of paper at higher speeds is required, it will be necessary to remove at least two dryers to give room for operators to pass through. All rolls will have to be power driven, with speed changing adjustments, and it will be necessary to run two dryer felts instead of one. In such a case it would probably be better to purchase machines designed for the work, place them in the finishing room and run them as a separate operation. A small mill making a line of specialties with machines running at a moderate speed can easily build a saturating vat equipped with rolls, mixing tank (an oil barrel will do) elevated for gravity supply to the vat, and overflow connected to a small centrifugal pump piped back to the elevated mixing tank. All this may be done by the mill mechanics without shutting down the paper machine. The one bottom dryer may be removed on a week-end shut down. Dryer-felt rolls may be placed to carry the dryer-felt across the bottom of the space left by the removal of the bottom dryer. The ready-made vat can then be placed in position, the piping connected for a supply of solution to the vat, and also to the pump for the return to the mixing tank. All of this work may be done and the machine be ready to make saturated paper Monday morning.

Imprinting.

The imprinting of paper can be done on a paper machine by inserting imprint rolls between the dryers at a point where the paper has the correct amount of moisture, which is usually found at a point about one-half the drying distance of the dryers. At this point one bottom dryer is removed to give space for the imprint rolls. These rolls must have an independent drive with a variable speed changing device so that the paper may have the correct tension when passing between the imprint rolls in order to avoid wrinkles and cutting. The imprint rolls must also permit of adjustment so that the design or lettering may be pressed against the paper at



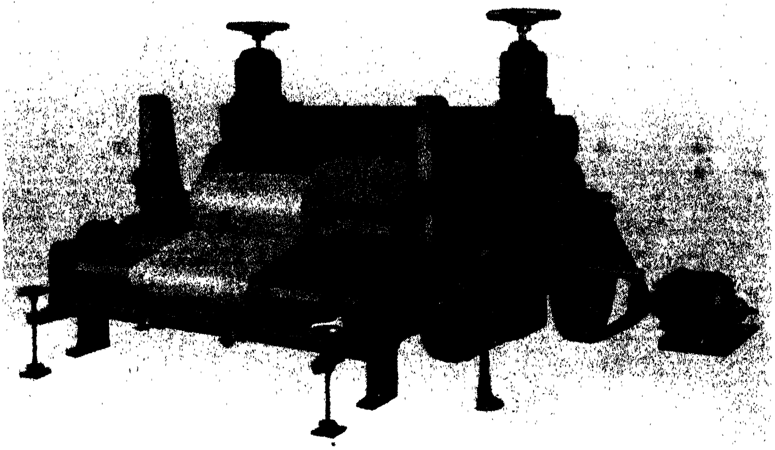
Courtesy: Dodge Mfg. Corp., Toronto, Canada.

FIG. 235.—Cast nickel-steel corrugated steam heated paper rolls.

a pressure that will produce the best and plainest impression on the paper. After the paper passes the imprint rolls it continues over the remaining dryers to the calenders and on to the reels. If the imprinted paper is cut into sheets, the cutting and the imprinting must synchronize so that the imprint will appear in the center of each sheet of paper that is cut. If the paper is shipped to customers in rolls nine inches in diameter for wrapping articles, the imprints must be spaced at equal distances apart both lengthwise and crosswise of the sheet. Trade-marks are very frequently used by large commercial stores so that the paper in which commodities are wrapped signifies where the purchase was made. The Woolworth stores, for instance, have a trade-mark in the wrapping paper they use which consists of a large imprint of the letter W placed in the center of a diamond.

Embossing.

Embossing is done on a separate machine, set up in the finishing room. Such a machine has a backstand to hold the roll of paper to be embossed, a steel engraved roll carrying the design to be embossed, and a two-time paper-filled roll. The embossing rolls run in roller bearings. This equipment can be tied in with other converting equipment so that as soon as the web of paper is embossed it can go direct into the next converting operation. In other installations the web of paper can be slit and cut into sheets directly after embossing. Such a machine will handle anything



Courtesy: Paper Converting Machine Co., Green Bay, Wis.

FIG. 236.—Paper embossing machine.

from 10-lb. tissue up to heavy boards. Such machines make paper napkins, towels, embossed fillers for confectionery boxes and many similar products.

Coating.

Coated paper is extensively used for books, magazines and advertising matter containing fine half-tone engravings; for printed labels; for playing cards; and in an extremely glossy type known as "Friction" or "Flint" (from the machines on which they are finished) in box coverings, and for toy games, kindergarten supplies, etc. Then there are also fancy coated papers containing mica and powdered metals which are extensively used for cover stock (for trade catalogs, etc.) and for box coverings, calendars and fancy announcements.

The great use of coated paper, however, is in high-grade printing, and much research has been applied to improvement in its quality.

The coating mixture is a cream made from clay, satin white, titanium oxide and other pigments, suspended in a solution of casein. To render casein insoluble one must use an alkali, or a mixture of alkalis.

A typical formula for the solvent mixture is: Borax 4.5 lb., Trisodium phosphate 29.6 lb., Soda ash 5.5 lb., Aqua ammonia, 26°, 0.4 gal. Usually all the ingredients but the ammonia are mixed, the casein added, heat applied, the mixture cooled, and finally the ammonia added.

The preparation of casein paper-coating mixtures [1] is a most complex branch of applied chemistry. The leading concerns in the industry devote lengthy and expensive research to this subject, and very great improvements have been accomplished of recent years.

The common method for coating papers is to flow the creamy coating mixture onto the web of body stock, whereupon a series of brushes distribute the coating more or less equally over the surface. The wet web

Courtesy: S. D. Warren Co., Boston, Mass.

FIG. 237.—The "feed" end of a brush coating machine showing arrangement for distributing coating mixture onto the web of paper.

is then carried on air blasts through a drying alley with progressively higher temperatures which cause drying. This method of coating has served for many years but it suffers disadvantages because of brushing inequalities and because of lack of control of the speed and time of drying.

Recently S. D. Warren Co., Cumberland Mills, Maine, invented a new coating device known as the "air-blade coater." This device might be likened to a printer's cutting knife laid horizontally across the full width of a coating machine. The sharp edge is slit across the full width and a thin blade of air is forced through the slit by pressure. The web of paper carrying a layer of coating passes under this blade of air which cuts away all surplus coating and leaves a smooth surface.

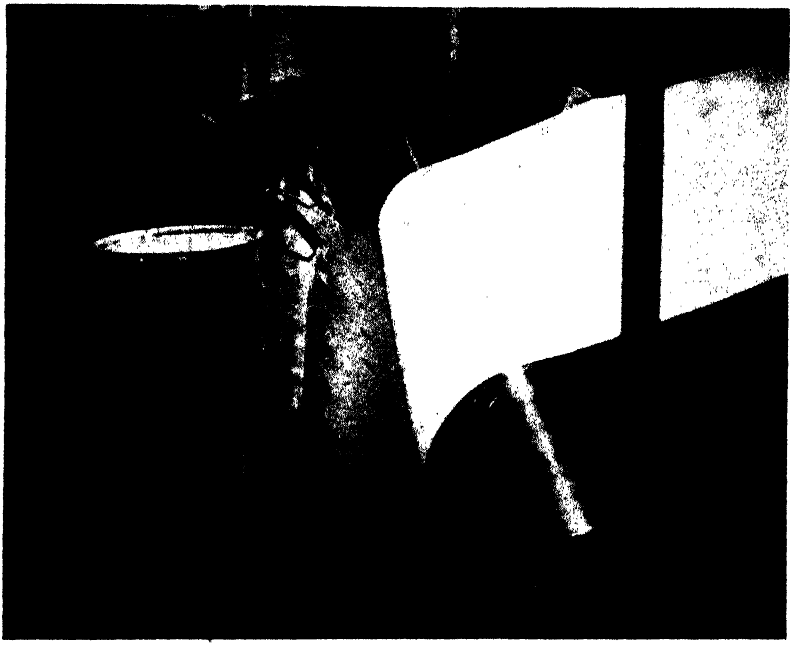
More recently still, the Warren Company developed a coating machine

[1] Sutermeister and Browne, "Casein and its Industrial Applications," New York, Reinhold Publishing Corp., 1939, especially chapter by Sutermeister on paper-coating.

which uses the air blade device in conjunction with an enclosed vertical drying tower in which the drying of the coating is uniformly controlled and timed.

After the coating has been applied to the web of body stock and dried this web is rewound onto a roll which is run through the calenders so that the coating may be properly smoothed and polished.

A good sheet of coated paper should meet the following requirements: it should be uniformly smooth and firm so as to contact *all* the dots in a

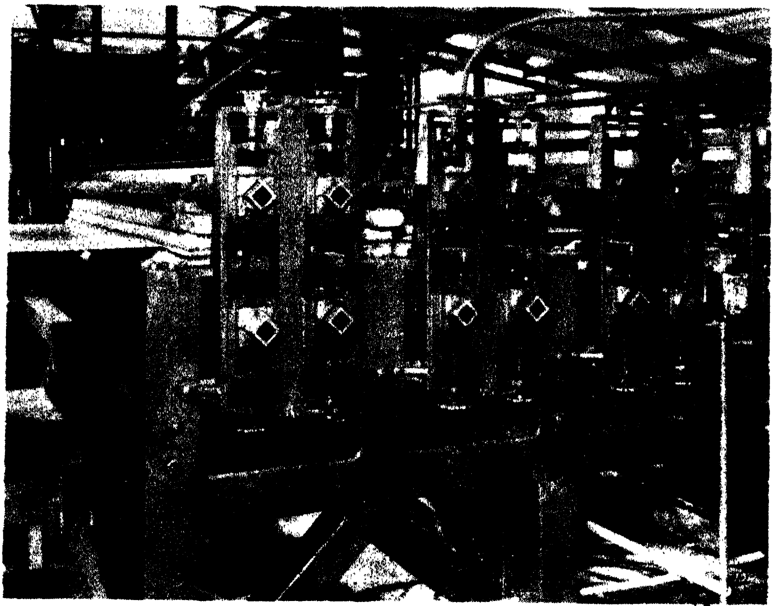


Courtesy: S. D. Warren Co., Boston, Mass.

FIG. 238.—Air-blade coater.

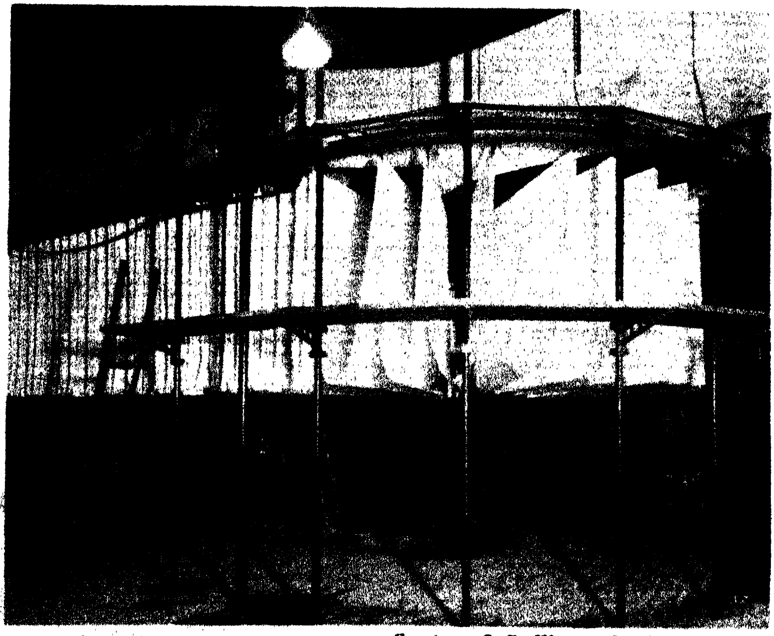
half-tone; it should readily absorb the ink—have an affinity for it; it should hold the ink pigment while the vehicle penetrates and dries; it should fold well; it should be of an attractive color.

The quality of the paper to be coated is of very great importance. It should be properly sized. If it is deficient in sizing an excessive amount of the coating mixture will be absorbed. Paper for coating must be absolutely clean. Dirt specks, even if very small, will show through. This will even be accentuated by the high super-calendering to which the coated paper is subjected. Uniformity of thickness throughout the sheet is very important. Paper that has a tendency to curl will cause untold trouble throughout the coating operation. It will dry unevenly on the drying lines after coating and will cause trouble at the super-calenders and reels and in the finishing room.



Courtesy: S. D. Warren Co., Boston, Mass.

Fig. 239.—Doublecoater showing brushes for distributing coating mixture.



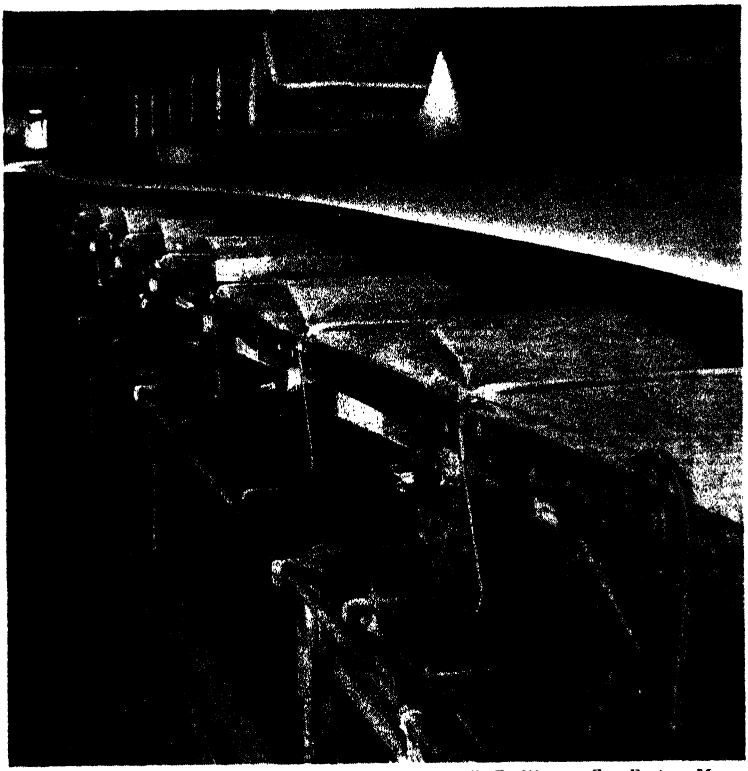
Courtesy: S. D. Warren Co., Boston, Mass.

Fig. 240.—Festoon type of dryer for coated paper.

There are four varieties of paper coating machine:

(1) *Brush coaters* that coat only one side of the paper as it passes between a series of rolls and over a large cylinder, on which it is held tight by a rubber suction. The brushes have a reciprocating motion and distribute the mixture which is flowed on from a spray pipe.

The degree of stiffness of the bristles in the brushes varies as the paper moves forward. The first brushes encountered by the paper are called "scrubbers" and consist of gray Russian bristle. The next set are called



Courtesy: S. D. Warren Co., Boston, Mass.

FIG. 241.—"Floater" type of dryer for double coated paper. A blast of hot air from below suspends the weight of paper in mid-air as it traverses the long heated drying chamber.

"blenders" and they are black China bristles. The last set, of badger hair, are called "finishers" and are much less durable than the others, often having to be replaced several times a year. The gray Russian and black China bristles in the first two sets are much more durable. They often last as long as 18 months. The quality and condition of the brushes is one of the most important factors in the entire coating process. Not only can defective brushes cause great trouble by shedding bristles, but on the efficiency of the brushes depends the entire satisfactory spreading of the coating.

(2) *Roll coaters* that use no brushes, but which coat one side only. The bottom roll dips in a vat of the coating mixture and transfers this to the upper roll over which the paper passes while under tension. These machines are little used in America, the brush type being much more popular.

(3) *Doublecoaters* in which the paper dips into a vat of the mixture and then between rubber "squeeze" rolls and two sets of brushes and on to the drying system. Many modifications of this machine have been devised to get around the difficulty of applying the mixture evenly and without lumps or foam.

(4) The *Warren "air-blade coater"* which does away with brushes altogether and permits much finer control of the entire operation. Also the brushes always gave trouble through the shedding of bristles, causing cuts in the paper in the super-calenders with great consequent loss.

Dryers.

The "festoon" system shown on p. 544 is still in general use. It has the disadvantage of taking up a great deal of room—from 200 to 400 ft. For that reason the line often is doubled, forming a return line system. This also gives the coating machine operator constant supervision of the finished paper. Modern mills have substituted completely automatically controlled air-conditioned drying tunnels or continuous chambers. Double coated paper is dried on a "floater" where a blast of air holds up the paper until it is so dry it can be handled without sticking. In the Warren system a vertical air-conditioned tower or a horizontal air-conditioned tunnel is used for drying the paper after it emerges from the coating machine.

16. Paper Defects; their Cause and Cure

Like all commercial products paper is liable to possess certain defects which cause trouble for the printers and other users of paper. It is incumbent upon a mill which wishes to hold the good will of the consumer to do everything possible to reduce the percentage of defective product to a minimum.

Fortunately, most of these defects fall into well defined classifications and the cause of them is well known in most cases and can be prevented by greater care on the part of the help and by the improvement of mechanical and chemical processes.

Mechanical Defects.

Some of the principal mechanical defects in paper which are preventable are soft wound rolls, rolls soft in spots due to uneven calendering, dirty paper, poor finish, too light, too heavy, too narrow, too wide, one-sided finish, curling, paper too soft, too hard, slack sized, faulty formation, punch test, tearing strength, porosity, lack of endurance, wet wrinkles, calender cuts, slime spots, crush marks, pin holes, wet spots, thin streaks and dry wrinkles.

Soft wound rolls are due to faulty winding, such as the lack of friction on the sheet. Rolls soft in spots are often caused by uneven expansion of the calender rolls. This may be remedied by the use of cold air blast on the over-expanded places. Dirty paper may be due to enlarged slots in screen plates, bent bars, the lack of screen capacity; slimy and dirty screen vats, pumps, pipes and head box. Dirty pulp is often the cause, in which event the remedy is apparent. Many conditions may be responsible for poor finish, lack of proper beating, pressing, coarse felts, over drying, dirty dryer surface, lack of calendering and poor quality of pulp. Too light or too heavy paper is traceable to thick and thin stuff, uneven speeds, slipping of pump belts and the lack of consistency regulation. Too wide or too narrow paper is sometimes caused by the slitters slipping, mistakes in setting, and not infrequently by carelessness. One-sided finish may be corrected by adding more moisture to the dull side of the sheet before it passes through the calenders. Curling is frequently caused by one-sided finish. Paper that is too soft is due largely to the nature of the pulp used; the harder paper is pressed, the more compact the sheet. Cutting the stuff a little shorter and closing it a little tighter on the wire helps. Slow stuff usually makes harder paper than free stuff. Chemicals are sometimes used in the beaters to harden the paper but this is an expensive makeshift. Paper that is too hard is usually traceable to the nature of the pulp used. A quantity of soft pulp mixed with the hard helps to soften. Also the more liberal use of clay and care to avoid too heavy pressing helps. The correct way is to select a pulp suitable for a paper requiring a special character. The lack of size in paper may be the result of overheated stuff. The friction heat must be considered, also the use of re-water for charging beaters and for make-up water on the machine. Sometimes lack of alum and forgetfulness on the part of the beaterman are to blame. Faulty formation is traceable to the nature of pulp used. The formula being fixed beating, jordaning, the speed of the machine, the flow of the stuff on the wire, the amount of water used, the regulation of slices and shake, the even flotation of stuff on the wire, are all dependent on the skill of the machine tender. The punch test, tear, porosity, endurance and general character of the paper depend entirely on all the above mentioned conditions. Wet wrinkles, calender cuts, slime spots, crush marks, dry wrinkles, thin streaks and wire spots are all mechanical blemishes and are all preventable. Pin holes in paper are often caused by sulphite pulp having excess lime, precipitated in the form of gypsum particles, the result of too high combined SO_2 in the cooking acid. Kraft, soda, rag, jute and groundwood pulp are usually free from this trouble.

Slime Spots.

These appear in paper as hard, shiny, discolored patches. They are caused by accumulations of slime forming somewhere in the preparation of the stock and getting onto the wire. Dirty screens, beaters, dirty piping, dirty chests, headboxes, etc., are sure to produce this evil. It can be corrected by having all such equipment so designed that there is little opportunity for slime to accumulate, and then having it inspected at sufficiently frequent intervals that it will be thoroughly washed out when necessary. When a beater or chest is flushed out to remove slime the wash water should not be sent to the save-all system, but should go direct to the main sewer, otherwise the slime will just remain in the system and build up in total volume. The screens used with the paper machines are the worst offenders as to slime in the whole mill. The causes leading to the accumulation of slime in these screens and the steps to be taken to prevent it have been discussed already in connection with the section on screens in the chapter on the machine room, so it is not necessary to do more than refer the reader to that place. The discharge pipe leading from the screens is another bad place, which should be watched for slime.

In general slime can largely be prevented by taking certain precautions when the equipment is installed. Care should be taken to avoid all sharp corners in equipment and piping in which stock is to be handled. Such corners, when unavoidably present, should be filled in with fillets. Chests should be so designed that the currents created by the agitators reach every part of the chest, leaving no dead pockets in which the stock can stagnate and slime collect. All surfaces in contact with stock should be well finished and smooth. Roughness and irregularities afford lodging places for small particles which eventually grow into blobs of slime, fall off and pass into the stock furnished to the machine. The first step in preventing slime is to build all equipment in accordance with the above precautions. The second is to have frequent and regular wash-ups of all such equipment to get rid of what slime will inevitably form.

Hair Cuts.

When a fiber of wool or sisal or a human hair or some other harsh material gets into the sheet it will cut the paper as it goes through the calender stack. This causes a great deal of trouble if the paper is being used for printing, and in fact for any use.

The sisal fibers are much the worst. They get into stock on account of sisal twine or rope being used for bundling in the finishing room. Pieces of this material get swept up with the broke and as the treatment of broke in the beater is of short duration the fiber goes into the stock in almost its original condition. Sometimes sisal gets into stock from bundles of pulp. One way to prevent this is not to allow the use of sisal twine. The second precaution is to see that no sweepings from the finishing room floor are put into the bin with the broke.

The wool fibers come chiefly from the washing of new felts, or from felts which have been newly napped. All wash water from this source should be run directly to the main sewer and under no circumstances allowed to go to the save-alls, which would lead to wool fibers in the white water and thus getting back into the stock.

There are certain other fibers which get into the stock from sweepings and miscellaneous causes, but according to an investigation of the matter made by a large printing company, more than three-quarters of all fibers causing hair-cuts in paper are either sisal or wool fibers. This investigation was made by examining all the offending fibers with a microscope and comparing them with standard slides showing known fibers.

Human hair is another source of trouble. Employee's shower baths should be arranged so there is no possibility of the drainage getting into the mill water.

Calender Cuts.

Calender cuts are slits extending horizontally across the sheet, the paper along the line of the slit being glazed and discolored. These cuts will invariably cause the paper to break when used in a press or in any automatic machine. They are the result of careless supervision of the calenders. For instance, if anything makes the sheet go over from the dryers to the calender slack, there will be sure to be calender cuts. The sheet should go over just as tight as possible without straining it. Improper lubrication of the calenders may cause cuts. Another cause would be slipping of the belt driving the calender. If the calender rolls are crowding it is sure to produce calender cuts. Also if the sheet is a little thicker on one edge than on the other it will wallow as it goes down through the calender and this again will cause these cuts. The remedy in the case of each of the above causes of calender cuts is obvious and it only requires watchfulness and suitable regulation to eliminate these defects.

Calender Spots.

These are due to little specks of paper that get on the sheet as it goes through the calender stack. They bruise the paper, glazing it slightly at the same time. These little scabs are largely due to wet ends, etc., going through the calender stack, after which the scabs of paper adhere to the rolls and go around again and again. Good calender doctors, well looked after, will do much to prevent this trouble, but it is bound to happen at times in spite of all precautions. However, in the case of an occurrence of this kind taking place, the stack ought to be well cleaned before the paper is put through again.

Crush Marks.

Crush marks are distinguished by a curdled appearance in the paper. These marks are quite distinctive in appearance and cannot well be mistaken for any other form of defect once they are recognized. The cause of these marks is that the felt fills up with clay and other filler as well as with fine fiber. The water cannot get through the felt at this point and consequently is squeezed out as the felt and the paper pass through the press, spoiling the surrounding portions of the sheet. The cure for this is simply to keep the felts clean. Detailed instructions on the care of felts will be found in the chapter on the machine room.

Dandy Crush Marks.

These marks also have a curdled appearance, but differ from the ordinary felt crush in not being localized but rather spreading over the whole surface of the sheet. These marks are caused by the too liberal use of water with the dandy roll, the roll wading in water which cannot get through the sheet in the usual manner. The best remedy is to use less water and more suction back of the dandy.

Coucher Crush Marks.

Coucher crush marks are coarser than dandy crush marks and there are wide separations between the lumps of stock. These are caused by the suction boxes failing to take sufficient water out of the sheet, which may be due to too liberal use of water, to too slow stock or to imperfect operation of the suction boxes themselves, such as inadequate suction. It may also be due to the machine running too fast for the weight of paper being made. To prevent these marks it is advisable to find out which of the above causes is responsible and then adjust the operation of the machine so as to correct the fault.

Dandy Blisters.

These blemishes look like a blister that has been raised up on the surface of the paper and then pressed down, causing a number of concentric wrinkles. The chief cause of these marks is a dandy roll that is filled up in places. This is especially so if the sheet is pretty dry under the dandy. A dandy roll that will run without trouble if supplied with a liberal amount of water will start to pick up if the water supply is decreased. The real cure for this trouble is to take the dandy off and clean it as described in the chapter on the machine room. However, some temporary relief may be secured by giving a little more water and this trouble can be lessened by keeping the showers used in connection with the dandy working evenly and perfectly. A perforated steam pipe directly in front of the dandy roll is a help to keep the roll clean and open especially on high speed specialty machines.

Bubble Marks.

When stock shows a tendency to foam, bubbles will frequently form on the wire which will break when they come over the suction boxes. The spot where the bubble was, will be deficient in actual fibers and consequently there will be a thin spot on the paper. These marks are usually quite perfectly circular, in which respect they differ from other marks which are usually irregular, and they are not noticeably curdled or wrinkled. With light tinted papers the bubbles will leave a distinct ring of concentrated color when they break. A steam shower or compressed air shower running across the sheet some distance back of the dandy will usually break these bubbles up. This shower should be sufficiently far back of the suction boxes that the shake will have a chance to fill up the places left thin by the breaking of the bubbles before the sheet passes over the suction boxes.

Froth Marks.

These marks are due to large patches of froth or foam forming as the stock flows onto the wire. Sometimes a paper machine will be used at a much lower speed than the average of which such a machine is capable, owing to a variation in the weight of the paper being produced. The pump, however, is driven by a constant speed line and in comparison with the machine is racing at a very high speed, churning the stock up and causing it to foam. As the distance from the pump to the wire is small, the stock will go on the wire foaming, and this condition will be accentuated if there is anything in the stock peculiarly conducive to the cause of the foam. This can largely be avoided by introducing a drive for the pump, on a machine which is to be used at a variety of speeds, which will permit of the speed of the pump being varied.

A good shower right over the apron and slices, and proper lowering of the slices, will usually break down all the foam, but if foam persists in spite of this a little kerosene may be added to the stock in the beaters, or dropped into the pump box—4 or 5 drops a minute. This tends to keep foam down by forming a thin film on the surface of the stock. The shower should have $\frac{1}{16}$-inch openings and a good pressure so as to create a fine needle stream. Alum will also tend to decrease the foam in most cases, although there are some cases where alum will positively increase foam, for instance, when certain pigments are used which react with alum so as to produce a gas.

Some very good froth inhibitors containing sulphonated oils are on the market today and have the advantage they cannot cause oil spots on the paper as they are water soluble.

Blemishes Caused by Drops of Water.

Steam will condense on the roof of the machine room and drops of water will drip onto the wire. These marks are easily distinguished from bubble marks as they are irregular in outline although roughly circular. Sometimes the drop falls with sufficient force to make not only a mark but a hole. The cure for this evil is to have a ventilation system that will prevent condensation taking place.. This is dealt with at length in the section on ventilation in the chapter on general design of pulp and paper mills.

Pitch Spots on Wire.

These cause small holes in the paper. The pitch fills up the meshes of the wire and no stock occupies this space and consequently no paper is formed. The cause of pitch goes right back to the nature of the wood used for pulp. Some woods naturally produce more pitch than others. It also depends on cooking conditions. The presence of gypsum or calcium sulphate in the cooking acid will tend to increase pitch, as the small granules of this material form nuclei around which pitch collects. This gypsum or calcium sulphate in the acid is due to improper burning of the sulphur to a large extent. This case is illustrative of the manner in which the various parts of a pulp and paper mill depend on each other. Troublesome holes in the paper may in this case be traced directly back to inefficiency in the sulphur burners. This subject is also touched in the chapters on the sulphite mill and acid plant.

The immediate cure for this evil is to clean the wire thoroughly. Sometimes a steam jet will soften the pitch and enable it to be washed out. Great care should be taken when removing pitch not to injure the wire. However, this is merely a temporary remedy. If pitch spots occur once they will occur again. The real cure is to thoroughly investigate the fundamental cause and attempt to cure that.

Lumps.

Lumps or "slugs" are caused by little hard accretions of stock forming on the deckle strap or elsewhere and falling onto the surface of the sheet. Similar lumps are sometimes caused by fibers forming into knots on the under side of the screen plates and when they become heavy enough dropping off into the stock. This has been discussed in describing the construction and operation of screens in the chapter on the machine room. Almost anywhere that stock has a chance to churn around for any length of time not too violently such lumps will form.

These lumps will be pressed out forming blotches which interrupt the continuous strength of the paper and afford an opportunity for breaks, especially if near the edge.

A hole in the apron is another cause of such breaks. The tendency of the stock to run down through the hole will draw fibers into it which will be packed hard against the wire into a little knot. As soon as this is dislodged another will start to form and this hole will thus provide a constant source of these lumps, and the source may not be discovered until the holes wear large enough to be readily perceptible.

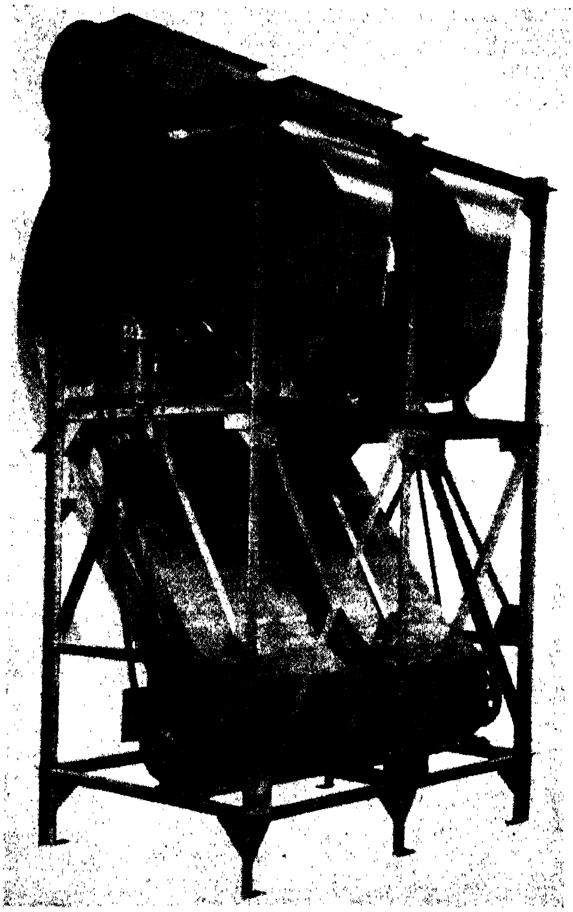
The cure for this class of troubles depends on the particular source. If it is the screens, the trouble probably is that the stock is standing too high in the vat. If the lumps are found to come from the deckle strap, the showers and poppets (or troughs through which the deckle straps pass) should be examined to see that they are exerting their proper cleansing functions. If a hole in the apron, the apron must be mended or replaced. A good sharp, clean shower back of the breast roll, under the apron, spraying water on the apron and the wire will help dispose of all such lumps if any are forming.

Wet Spots.

Any bruise or depression in one of the press rolls will cause the paper which that spot comes in contact with to be somewhat wetter than the average. This wetness will not be removed by passing through the other presses, even by passing over the dryers in some instances, because it will always be a little wetter than the remainder of the sheet. If wet enough when it reaches the calenders such a wet spot will give rise to a blemish looking much like a slime spot, all the fibers being crushed and moulded together into a glazed blotch without strength and marring the look of the sheet. Obviously the cure is to repair the offending roll.

Sawdust Spots.

Groundwood pulp, unless very carefully screened, will contain some sawdust. Moreover, in making sulphite pulp, sawdust frequently does not cook in the digesters, remaining hard and woody. By rights there should be no sawdust in the chips, if they are properly screened, but sometimes through carelessness or the use of poor equipment some sawdust gets into the digesters, and probably with the best practice there is always a little which has adhered to the chips in spite of all precautions. Special chip cleaning systems are in use in some modern mills and for many grades are well worth the investment.



Courtesy: Sumner Iron Works, Everett, Wash.

FIG. 242.—Double chip duster.

These particles of sawdust will go right through with the stock into the beaters and into the paper machine. There they may form a blemish out of all proportion to their size, these marks sometimes being as large as a silver quarter. This is because the sawdust holds the sheet up off the dryers, letting it remain wet in a small circular area surrounding the piece of sawdust. When the sheet reaches the calenders this wet spot will be crushed in the manner described under the heading Wet Spots above.

However, this sort of blemish can usually be distinguished from an ordinary wet spot as the sawdust or the trace it has left can usually be recognized in the center of the blemish.

The cure for this condition is more careful sawing, screening and chipping. However, if the screens on the paper machine are in good condition they should catch such particles, so that if sawdust spots are appearing it would be a good idea to look and see if the screen plates have not been bent by someone stepping on them or dropping a tool on them or pounding them too hard with a slapper.

One of the best ways of making sure that chips are not contaminated with sawdust is to pass them through a suitable chip duster. There are several of these machines on the market. The principal feature of them is an arrangement whereby a blast of air removes the sawdust, but is so adjusted that it does not blow away the chips themselves. The machine illustrated in Fig. 242 is a good example of this type of equipment. Another machine consists of a tower with a number of staggered baffles which spread out the chips as they tumble down, exposing them to a powerful blast of air. In operating equipment of this kind, care should be exercised that the air intake is not contaminated with dust or other undesirable particles.

Pin Holes.

Sometimes a sheet of paper will display small glistening particles which fall out, leaving little pin holes when the sheet is crumpled. The glistening material is gypsum or calcium sulphate formed in the cooking acid on account of SO_3 being present in the sulphur gas. Therefore, the cure for this trouble goes right back to the sulphur burners, and for the details of this the reader should consult the chapter on the acid plant. Naturally this defect can only occur in papers containing sulphite stock.

Thin Streaks Due to Ridged Wire.

If, for any reason, such as a lump of stock adhering to a carrying roll or the breast roll, the wire acquires a ridge, the stock will not form on this ridge, or at least will not form as thoroughly as on other portions and this will yield a thin strip reaching lengthwise of the sheet. There is no real permanent and sure cure for a ridged wire. In the hands of a careful operator a wire will not become ridged.

Thin Streaks Due to Seam of Wire.

Sometimes the seam of the wire will fill up and make a thin streak. This sort of thin streak runs across the sheet. It is the result of a bungled job at seaming and there is really no cure for it. It is a case where the papermaker can learn from experience.

Blow Marks.

Air will sometimes get under the paper as it passes into the pinch of the press rolls. This air will raise up the sheet in a sort of bubble, which will be ironed out as the sheet goes through the press. The air will make two paths or trails, one on each side of the bubble, just as will happen if you run a roller along a rubber tube full of air. These trails will leave marks on the paper which are easily recognized by their occurring in pairs.

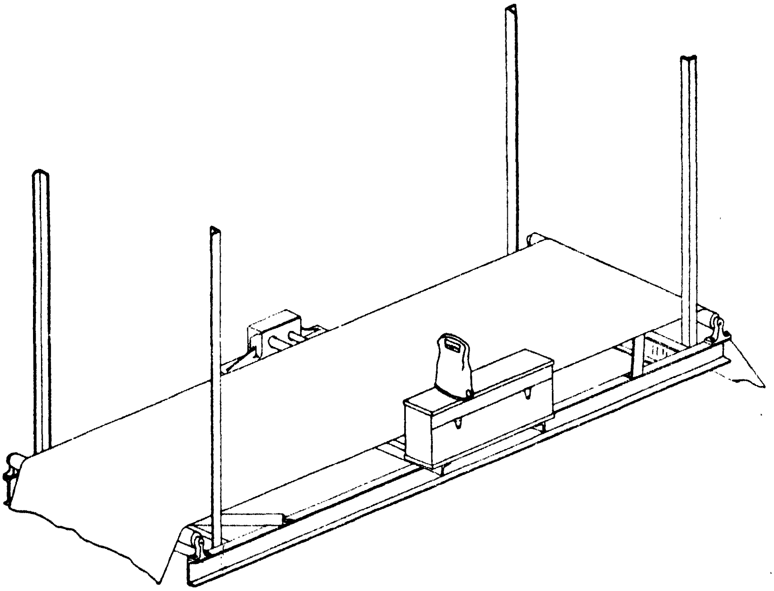
When the bubble is pressed down it will overlap the remainder of the sheet at each side. The mark will thus finally appear as two thick, irregular blotches, running the length of the sheet, separated by a thin patch between them. One cure for this is to place a small very light felt covered roll on the paper after it has been carried across from the couchers to the first press. This roll will ride on the paper and insure it entering the pinch of the press level and free from air. This trouble cannot well occur on machines equipped with suction press rolls as the air is thoroughly drawn from under the sheet by suction. On the usual machine, however, there is no place for the air to escape to. This trouble is most likely to occur when the felt has just been washed and is so wet that air cannot pass through it. It is not a constantly occurring trouble and one may make a lot of paper without experiencing this difficulty, but we mention it so it will be recognized when it does take place.

Lack of Uniformity.

One of the most annoying defects in paper is lack of uniformity in the weight. By that we mean variation in the weight in proportion to the area. In the first place this could cause needless expense in the operation of the mill itself. Breaks at the wet end of the machine are usually due to the lightness of the sheet. Such breaks may well represent a loss of upwards of $100 per hour. Overweight wastes material. From the customer's point of view variation in weight is annoying and will frequently result in rejections. This is particularly true where the paper is sold to a converter or manufacturer of paper products. Efficient devices have been developed to indicate continuously the weight of the sheet at any stage, wet or dry, in the manufacturing operation, and to give instant warning of variation from standard weight. Such devices afford continuous control as compared to intermittent tests with calipers or weighed samples. They also obviate the necessity of cutting stock for samples. The most usual place for the installation of such devices is at the wet end just before the sheet enters the dryers. In the case of heavy papers produced at low speed, these devices are also successfully used at the dry end. One of the best known of these devices is the Toledo Auto-Check, the principle of operation of which is as follows:

As shown in Fig. 243, the sheet of paper passes over three rollers all in the same horizontal plane. The weight of the material between the two outside rollers will be divided among the three rollers as follows: one-quarter of the total weight will be supported by each of the outside rollers and one-half on the middle roller. Thus it will be seen that if there are four yards of material between the two outside rollers, the weight of two yards will be supported by the middle roller. The middle roller is mounted on the Auto-Check mechanism and becomes the weighing or load element of the device and the reading of the device is the weight of the middle two yards of the material. This is true whether the material is moving over the rollers or at rest.

The load, represented by the desired weight of the material being made, applied to the roller (as the two yards mentioned above) is counterbalanced by an appropriate beam and poise. Then a pendulum equipped with a pointer travelling over a chart indicates any variation from the predetermined correct weight. In the use of this scale it is desired to know only whether the material being manufactured is lighter or heavier than the established weight. Therefore, the Auto-Check is equipped with a pre-



Courtesy: Toledo Scale Co., Toledo, Ohio.

Fig. 243.—Diagram showing principle of Toledo continuous Auto-Check. The weigh roller in the middle is supported in a lever arm at each end. These arms are held in place by a pipe shown to the right of the weigh roller. Above this is mounted the scale mechanism and indicator.

determined weight chart having a zero line, and over and under graduations on either side. The beam is graduated so that the poise may be set to the weight desired for the material being manufactured. Then the indicator will point to zero only when material of the desired weight is passing over the weigh roller.

The Toledo continuous Auto-Check is placed in the line of the moving material as it passes from the manufacturing machines, and as close to the machine as conditions will permit. This gives immediate notice to the operator of any variation in weight of the material being produced, permitting the necessary adjustments to be made.

The movement of the indicator on the chart is great enough to permit ease of reading at a distance of 20 or 30 ft., at no sacrifice in accuracy. For example, in use on a paper machine, the indicator will easily show a variation of 1 lb per ream of 24″ × 36″ size, where the weigh span is 10′ 0″, and the sheet 5′ 0″ in width. Thus it is not necessary that the chart indication be close to the point of control.

Specks in Paper.[1]

The appearance of a sheet may show imperfections caused by foreign materials or malformation on the wire. These are the most common causes of poor-looking paper.

Generally, specks need microscopic examination. A binocular microscope and a set of dissecting needles are useful. For chemical tests on small particles small test tubes made by sealing up one end of small glass tubing are convenient if the reaction is to be watched under the microscope.

Rubber: This is very objectionable. It finds its way into the stock along with rag stock, sometimes as rubber paste in tire fabrics and the like, and sometimes in paper stock as rubber bands from office waste.

Under the magnifying glass rubber specks can be stretched by pinning down one end with a dissecting needle and pulling out the speck with another needle point.

Rubber specks will give a characteristic rubber odor if burned by sticking into a flame on the end of a needle. They are soluble in carbon tetrachloride.

Rosin Specks: There are translucent amber-colored specks so resembling rosin that they are easily recognized. Proof of their identity can be had by dissolving the separated stock in ether in a small tube so that the action can be watched under the microscope. Qualitative rosin tests can be applied to the speck as given under qualitative tests for rosin.

Other specks resembling small bark particles may come from size which was made from impure rosin without proper filtration. Although not as translucent as the ordinary rosin speck they usually carry enough rosin to respond to the qualitative test.

Wood Specks: Chips or wood fibers which might result from the accidental grinding off of a beater paddle or similar cause can be quickly identified by applying phloroglucinol; they give a characteristic red coloration as in the groundwood test.

Iron Specks: Washer or beater bars, Jordans, scaly pipes, corroded overhead ironwork, and iron buttons from rags contribute iron in metallic or oxidized form at times. The metallic particles will be attracted by a magnet after being freed from the sheet. The scale or oxidized iron can be dissolved in concentrated hydrochloric acid and a drop of potassium sulphocyanate added. Iron gives a characteristic wine-red color. This test can be applied to the separated particle in a small tube, or the sheet suspected to contain iron may be placed on a glass plate, wetted with concentrated hydrochloric acid for five minutes, and then with 10 per cent potassium sulphocyanate solution. Each iron speck shows red when the sheet

[1] Abstracted from report of the Committee on Paper Testing, T.A.P.P.I., 1920.

is held up to the light. The glass plate forms a convenient holder for the sheet. The red color fades in a few minutes and count should be taken immediately.

Another method is to immerse the paper in 2 per cent potassium ferrocyanide, then in 2 per cent acetic acid, then wash well in water. Hang the sheets vertically until dry. There will be a blue coloration wherever there was an iron speck in the sheet. This method makes a more permanent record than the sulphocyanate treatment.

Oil Spots: Oil spots are translucent and can be spread or thinned with ether or chloroform. Extraction with either of these solvents removes the oil, unless it is of a peculiar pasty formation caused by use of oily rags in the stock. Mineral oil in rags is prone to form a dirty congealed mass in the washers, which specks the halfstuff with black specks in which mineral oil is the binder. Such specks in the finished sheet are not entirely removed by ether or chloroform. They are slightly translucent, and unaffected by solution in concentrated sulphuric acid.

Color Spots: Poorly ground colors such as poor ultramarine give a fine specky appearance usually identified by color only.

Alum spots: These are usually pulverized by the pressure of the calender rolls. They are soluble in water and give a slight acid reaction with indicators. This reaction is best watched by dissolving the speck in a very small test tube and adding the indicator while the tube is under the microscope and against a white background.

Coal Particles: Coal dust is insoluble and gives no color reactions with any reagent. In appearance iron scale can be mistaken for it, and in doubtful cases an iron test should be made on the sheet and the unaffected black particles examined for coal.

Under the microscope it can be seen that coal particles in a calendered sheet have been so pulverized by the pressure of the rolls that they shatter very easily when picked with a dissecting needle. Large particles give a characteristic black smear when crushed and rubbed across the sheet.

Button Specks: Bone buttons ground by beaters or Jordans into small pieces come through into the finished sheet as a light colored powdered spot due to crushing in the calenders. A hole is often made at a button speck due to the crushed button piercing the sheet and then partly crumbling out after calendering. Such specks can be differentiated from alum as they are insoluble in water and give no acid reaction with the indicators.

Paper Specks: In stock made from old papers small undefibered pieces may slide through the screens and form a speck on the sheet. Such specks are fibrous and when lifted out of the sheet they can be defibered under the microscope with dissecting needles, showing their identity by this characteristic.

Foam Spots: Because of the depression left after each foam bubble there is a circular spot more translucent than the rest of the sheet formed wherever foam bursts on the partly formed sheet. The result is characteristic, circular, and translucent as a small round watermark would look.

Drag Spots: Stock adhering to the slices on the wire forms small uneven lumps when it drags off upon the sheet. These spots are not very common but can be recognized as an irregular formation having no foreign material present.

Knots: Fabrics in rag stock with knotted threads very often show the knots in the finished sheet. The knotted thread is easily recognized under the microscope.

The above, of course, are not all the possible defects that can occur in making paper. On such a complicated machine as a Fourdrinier paper machine new sets of circumstances are always happening which will lead to unexpected results. The thing to do is to get at the source of the trouble by a process of elimination, examining and dismissing the more to be expected sources of trouble first, one by one, before the more unlikely reasons are looked into. This is just as in finding out why an automobile refuses to go. One does not take the ignition system to pieces until one has ascertained if there is any gasoline in the tank. Defects may be very persistent and mysterious, but continued careful investigation will reveal the cause of all of them and when the cause is arrived at the defect can be remedied.

17. General Design of Pulp and Paper Plants

It is, of course, not possible to give in a single chapter, or even a single book, such information as would enable a previously inexperienced person to undertake the complete design of a plant for making any kind of pulp or paper.

If that were possible, there would be small need for the services of engineers who have made the design of plants for this purpose a life study. The final efficiency (or inefficiency) of a big pulp and paper mill will depend on how a multitude of minor problems have been settled, and the highest qualities of engineering experience and good judgment alone suffice to meet these requirements.

Anyone contemplating investing money in a plant for manufacturing any kind of pulp or paper should retain the services of a competent engineer, preferably one known to have had previous experience in such matters, and then his decisions should be abided by.

However, there are a considerable number of items that anyone taking an active part in the manufacture of pulp and paper should know something about, that do not exactly fit into any of the other chapters of this book, and so are being considered under the present heading.

Such are problems of location, water supply, railroad facilities, fire protection, illumination, ventilation, piping, power transmission, etc. Each of these subjects might well be the subject of a separate treatise. Excellent works have been written on many of them. Consequently, they will only be discussed briefly in the present connection, with special reference to the actual manufacture of pulp and paper and subject to the limitations of the writer's own experience.

Location.

Three chief factors influence the location of a pulp and paper plant: supply of raw material, power and disposal of finished product. If a plant could be located at a point favorable both to the obtaining of raw material and the market for the finished paper it would be ideal. This is now rarely possible. The modern tendency is to locate the plant where the raw material is. Immense pulp and paper mills are being operated in the most remote parts of Canada, far from any market for their products. During the past ten years many large plants have been erected in the South, to utilize the abundant wood resources of that region, but their products are mainly consumed elsewhere. In common with all other manufacturing processes, if anything has to be shipped a long distance, it is better to ship a comparatively small bulk of material which has been enhanced in value by manufacture than a larger bulk of material yet to be enhanced in value.

The latter proposition involves paying freight on a lot of substance that is subsequently got rid of in manufacture.

Many paper mills, especially those making the finer grades of paper and specialties, are located far from any source of raw material. This is largely due to circumstances connected with power and labor. Years ago groups of mills grew up at certain points because at that time they were advantageously situated with regard to power and raw material. The communities that have grown up around these mills are largely populated with men familiar with the industry. It is easier to get the highest class of labor in such a location. Moreover, the power is frequently still there and consequently the mills remain there.

Other factors that influence the location problem are nearness to supplies of equipment and chemicals, climate, water, taxation, personal preferences of important officials, sentimental considerations, etc.

The above remarks deal merely with the general location, *i. e.*, why mills are numerous in some parts of the country and scarce in others. We will now consider the details regarding a suitable pulp or paper mill site.

Selection of a Site.

If we consider first a development consisting of a sulphite mill, groundwood mill and paper mill, where the wood is received by rail, it is obvious that such an industry should preferably be situated on the banks of some large body of water. When we come to discuss water supply later in this chapter we will deal with the reasons for this, but assuming that several million gallons of water are required per day, the advantages of such a location are immediately apparent. Failing this, artesian wells must be sunk at great expense. Some of the paper mills in the Kalamazoo district have had to do this, owing to the gradually increasing inadequacy of the water supply, which was originally quite sufficient.

Now, the banks of rivers are very various in formation, and putting the plant near the river will sometimes increase the engineering work necessary to provide suitable foundations and room for buildings. It is ideal when a level location can be secured right beside a good sized river or lake. However, in many cases, on account of the desire to utilize water power, pulp and paper mills are located at points where the site has literally to be carved out of the banks of the river.

The most natural arrangement of the parts of such a plant is to have the sawmill, wood room, digester house, sulphite mill, beater room, machine room and finishing room follow right one after the other in the order named, material thus progressing through the plant in a straight line. Frequently, however, to secure economy of space and to surmount natural obstacles, some parts of the plant have to be in basements below others. The less of this that is done, the simpler will be the conveyor and elevator systems required, the less will be the power used up in elevating materials and the arrangement of the piping for steam, water, stock, etc., will be just that much easier. Provided the conditions (*viz.*, coal storage, ash handling, etc., will permit) it is always preferable to place the boiler house centrally, or so that steam lines supplying paper mill and sulphite mill will be reduced to a minimum.

Room must be provided for storage of wood. This subject has already been discussed at some length in the chapter on the wood room. Due precaution should be exercised that the area chosen for wood storage is not liable to be flooded and is not a fire menace to the plant or to other adjoining properties.

Railroad Facilities.

Today truck transportation has developed to such a point that railroad facilities are by no means the dominating factor that once was the case, some quite large mills making little or no use of railroads any more. However, in laying out most plants regard should be given to the location of sidings, which should be of adequate capacity. Also, if there are several railroads touching the point, the sidings should be arranged so as to have the most convenient connections with all of them. Sometimes the plant is located on a slope with one railroad on the high level back of the plant and another along the water-front. In such a case it is very convenient to arrange to receive raw materials over the road on the high level and to ship finished products out on the low level. Frequently it will pay the mill well to own a locomotive for switching purposes, thus being more or less independent of the service rendered by the railway company. Apart from steam locomotives, small gasoline and diesel locomotives are used for this purpose, which are specially useful as all fire risk is removed. Excellent electric locomotives are also obtainable, operating either from a trolley, a third rail or with storage batteries. Car-hauls, which are hoists arranged for pulling cars short distances around a plant, will be found very useful when a locomotive is not at the disposal of the plant. If a crane is at hand for loading or unloading coal or wood it can be used as a car shifter. In laying out sidings ordinary good judgment must be exercised so that cars which are being loaded or unloaded will not be in the way of other operations.

Piping.

For water supply and fire protection, cast-iron pipe is usually used. This variety of pipe lasts very well when buried in the ground, and is generally satisfactory when used in 12-foot lengths, with caulked joints of the bell and spigot type. Wrought iron or steel pipe can be, and often is, used for this service, but its use is not desirable as it cannot be depended on as can cast-iron pipe. Not only will it seldom last so long, but it may corrode and give out unexpectedly soon. This is a drawback inseparable from the nature of the material. Galvanizing has some preservative effect, but not much in actual practice. Wrought iron, however, is much superior to steel pipe.

Cast-iron pipe can also be used for many other purposes around the pulp and paper mill. This material can now be obtained in almost any diameter from 2 inches up, and in any length required. Flange joints can be had, as well as bell and spigot joints, and all kinds of fittings. Such small cast-iron pipe is excellent for handling bleach liquor.[1] Cast-iron pipe is also used for handling stock from the blow-pit to the screens in the sulphite mill, etc.

For ordinary connections for water and stock in the beater room and machine room where kraft and groundwood (neutral or alkaline) stock predominates, wrought iron pipe is satisfactory. If sulphite predominates galvanized, flanged cast-iron pipe is preferable because most satisfactory in the long run, although first cost is higher. Wrought iron pipe has higher tensile strength than cast-iron pipe of the same size and is less liable to be damaged by strain, blows, etc.

Spiral welded steel pipe is increasingly used in the paper industry. It has the advantage of unusual flexibility to take care of changes in temperature, pressure and alignment. It is especially useful for temporary construction. It is cheap compared to other kinds of pipe, relatively light in weight, and can today be furnished in any size from 4 in. diameter to 30 in. or larger, and in all standard and special lengths.

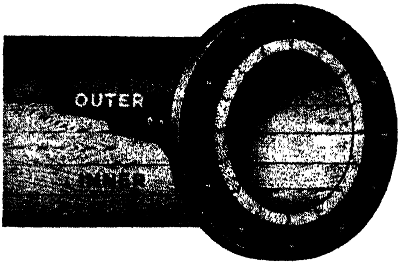


FIG. 244.—Sectional view of wood-lined steel pipe.

Courtesy: Michigan Pipe Co., Bay City, Mich.

In the acid plant, and for acid lines in the digester house, hard lead pipe or lead-lined iron pipe is used. Hard lead is lead which contains a small percentage of antimony. It resists almost all acids. Unless made with special skill, lead lined pipe will give trouble due to the lead lining separating from the pipe. There is at least one line of lead-lined pipe on the market which has been developed to such a point that no trouble of this kind is experienced. All kinds of fittings and valves can also be secured in this material.

Bronze piping is used for some of the smaller connections where acid containing liquids are being handled. It has not the resistance to acid of the lead, but it is easier handled in small sizes and has greater mechanical strength.

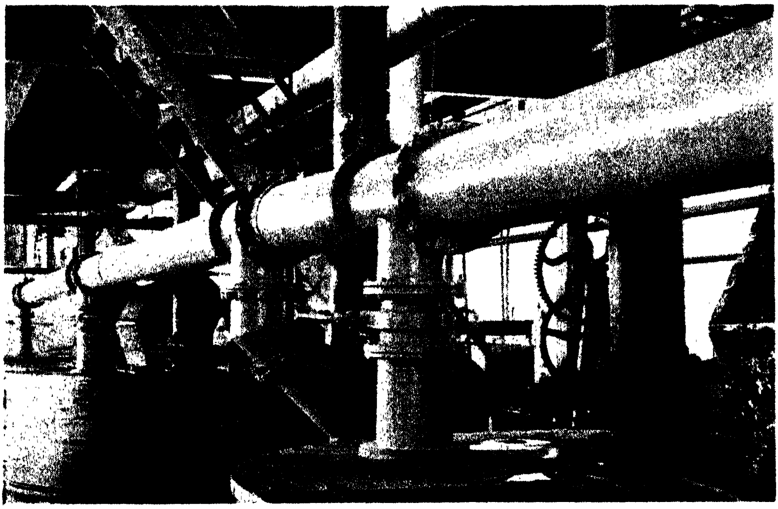
Wood lined steel pipe which consists of an alloy steel cover lined with redwood is very useful in many types of pulp and paper mill construction. It eliminates one of the worst hazards in clean paper making, the formation of scale in the pipes, which subsequently peels off and drops into the stock. It also cuts down slime formation and accumulation. All standard sizes

[1] See "How We Solved Bleach Pipe Problem," W. H. Scott. Paper Industry, Nov., 1919, p. 623.

and fittings are available, and cutting and flanging is a relatively simple operation. The table on page 566 gives an idea of the great versatility of this useful product.

All pipe lines carrying steam or hot liquids should be well insulated with magnesia or some other good insulating material. The manufacturers of these materials have compiled tables (which can be obtained from any of them) which will enable exactly the right thickness of insulation to be estimated.

Steam piping should be wrought iron or steel. Manufacturers of this material make three grades: "Standard," "Extra Heavy," and "Double Extra." For pressures up to 160 pounds all pipe over 14 inches should



Courtesy: Michigan Pipe Co., Bay City, Mich.

FIG. 245.—Typical installation of wood-lined steel pipe in beater room.

be $\frac{3}{8}$-inch O. D. pipe. All other pipe should be standard full weight, except high-pressure feed and blowoff lines, which should be extra heavy. For pressures from 160 to 200 pounds, and with superheated steam, all high pressure feed and blow-off lines, high pressure steam lines with threaded flanges, etc., should be extra heavy. Pipe 14 inches and over should be $\frac{3}{8}$-inch O. D. pipe. Full weight pipe should be used for all steam lines other than those mentioned above on which pressures between 150 and 200 pounds are maintained. Flanges should be cast iron, threaded, except for superheated steam, when solid rolled steel flanges should be used. Welded flanges are used on many lines with satisfactory results. Of recent years there have been great advances in pipe fabrication for high pressures using cast steel, special alloys, etc.

Steam piping is best carried out by a reliable piping contractor, whose experience will tell him just what weight and variety of pipe, flange, fitting and methods of support to use in any given case. Moreover, such people

SURVEY OF WOOD LINED PIPE SERVICES[1]

Type of Mill	Quantity and Sizes in Each Mill	Service Period	Liquid or Stock Satisfactorily Conveyed	Pressure lb.	Temperature
Fine writing papers and rayon pulp	1800′ of 6″, 8″, 10″, 12″, 14″ and 20″	1 mo. to 7 yrs.	Coagulated water. White water. Bleached and unbleached stock.	80 60 60	
Ground-wood pulp sulphite pulp, paper	3300′ of 4″, 6″, 8″, 10″ and 12″	5 mo. to 5 yrs.	Filtered water. Untreated water. White water. Stock.	60 35 5 to 40 10 to 30	80° F. 80° F. 80° F. 80° F.
Sulphite pulp and paper	3600′ of 6″ and 10″	1 to 3 yrs.	Sulphite stock and white water from pulp mill to paper mill. Sulphite stock from machine chest to paper machines. White water from paper machines to stock washers. Fresh water from deep well to paper machines.	 20 80	 75° F. 50° F.
Soda and Sulphite wood pulp	2735′ of 4″, 6″, 8″, 10″, 12″, 14″, 16″ and 18″	3 mo. to 4 yrs.	Cold filtered water. Warm water. Thin pulp suspension.		110° F.
Book, Bond and writing	900′ of 8″ and 12″	2 to 6 yrs.	White water. Old paper half stuff. Beater furnished.		
Sulphite Bond	1730′ of 6″, 8″, 10″, and 12″	6 to 7 yrs.	White water paper stock, bleached and unbleached sulphite.		
Sulphite Pulp	1000′ of 10″ and 12″	2 to 3 yrs.	White water. fresh water. unbleached and bleached stock.	50	Room
Glassine and grease-proof, sulphite	3970′ of 4″, 6″, 8″, 10″ and 12″	1 to 5 yrs.	Unbleached and bleached stock lines. Fresh white water lines.	 40	42° to 150° F.
Paper	4910′ of 6″, 8″, 10″, 12″ and 14″	1 to 3 yrs.	Bleached sulphite. Stock storage. De-Aerating installation.		
Catalog and specialty paper mill	1200′ of 8″ and 12″	5 yrs.	Reclaimed paper stock. White water.	35 30	70° F. 80° F.
Paper	190′ of 10″ and 12″	6 yrs.	Bleached stock containing chlorine		
Sulphite Stock	2200′ of 6″, 8″ and 10″	1 to 6 mos.	Bleached and washed stock. Screened brown stock. Unwashed direct chlorination stock neutralized with lime. Unwashed bleached stock. White water from bleached stock washers.	46 to 125 50 37 6 to 10 Vac.	40° to 50° F. 40° F. 40° F. 40° F. 40° F.

[1] Courtesy of Michigan Pipe Co., Bay City, Mich.

Survey of Wood Lined Pipe Services—(*Continued*)

Type of Mill	Quantity and Sizes in Each Mill	Service Period	Liquid or Stock Satisfactorily Conveyed	Pressure lb.	Temperature
Book and Bond Papers	1000′ of 8″, 10″ and 14″	1 mo. to 1 yr.	Pulp stock. Bleached sulphite stock.	100 60	
Sulphite pulp and paper	950′ of 8″	2 yrs.	Unbleached sulphite. Bleached sulphite. Clear water. White water.		50 to 80° 75 to 130° 50° F. 60° F.
Sulphate pulp mill	650′ of 4″, 10″ and 16″	3 yrs.	Sulphate stock.		
Kraft paper	655′ of 6″ and 10″	1 to 2 yrs.	Fresh water lines. Bleached kraft stock lines.	60 60	
Tissue	1000′ of 10″ and 12″	Up to 5 mo.	Bleach plantwhitewater. Unbleached sulphite white-water. Screened unbleached sulphite stock 1½% Unbleached sulphite stock 5%.	70 40 40	
Paper mill	300′ of 6″ and 10″	2 yrs.	Paper wood pulp stock.		80 to 90° F.
Sulphite pulp and paper	250′ of 10″, 12″ and 14″	1½ to 2 yrs.	Water supply 3 to 6%.	40	
Ground-wood pulp and paper	345′ of 6″, 8″ and 10″	1 mo. to 3 mos.	Sulphite and mixed stock furnish to paper machines.	40	85° F.
Sulphite pulp	35′ of 6″, 8″, 10″, 12″, 14″ and 18″	4 mo.	Sulphite brown stock. Sulphite bleach stock. White water.		
Paper mill	185′ of 14″, 16″ and 18″	4 mo.	Groundwood stock from fine screens to deckers by gravity flow 4%. Beater dump line 3%. Mixing pump to Bird screens on paper machines. White water from wire pit to mixing pump. 1%.	30 Gravity	40 to 70° F. 40 to 70° F. 40 to 70° F. 40 to 70° F.
Book, bond and writing paper	450′ of 8″ and 12″	2 to 3 yrs.	White water old paper, Half stuff, and beater furnished.		
Book	110′ of 6″, 10″ and 12″	3 to 5 yrs.	White water return line to paper machine. Beater room and washing system.		
Catalog	100′ of 10″ and 20″	3 yrs.	Groundwood stock line to knotters. Stock lines from chlorinator to bleacher tanks in bleach plant.	40 to 50	
White waxing tissue	195′ of 4″, 5″, 8″, 10″ and 12″	1 to 5 yrs.	Paper stock, sulphate and sulphite pulp stock.	5 to 40	35 to 130° F.

have devised many special joints and fittings. However, the above brief notes may be considered good practice as far as they go.

In designing systems of steam piping, when the proper size and weight of pipe has been determined, the next item to consider is the removal of the water of condensation that is always present, but which can be much reduced by efficient heat insulation. The effect of water moving through a pipe at a high velocity is much the same as that of a solid body when it comes in contact with elbows, valves, etc. Even if there is no actual destruction of pipe or fittings from this hammer effect, there will be a constant hammering and abnormal vibration which will in time loosen the joints and cause leaks.

The system should be so arranged that there are no places where water will be pocketed and carried along by the steam in slugs. This is particularly important with lines leading to coils used for heating tanks, digesters, etc., and engines. The cold liquid surrounding the coil may condense the steam so perfectly as to cause the formation of a vacuum. The water will then be shot through the pipe at a very high velocity, causing tremendous hammering and vibration. This effect, on a smaller scale, is probably familiar to all of our readers who have steam heating systems in their homes.

To avoid condensation, all pipe should pitch in the direction of the flow of the steam, and if there is any doubt about this, a trap or drain should be installed. Efficient steam traps of ample capacity are the chief weapon against condensation troubles and losses: the leading makers have compiled excellent manuals on the use of steam traps. All main headers and manifolds should end in a drain pocket connected to the drainage system. Branch lines should be taken from the top of headers, when possible, never from the bottom. Separators should be placed in the line leading to each engine or evaporator or other steam consuming unit, as near the unit as possible, and all such separators should be connected to the drainage system. Care should be exercised that valves and other fittings do not form water pockets. Globe valves should always be set with the stem horizontal; gate valves may be set with the spindle vertical or at an angle. All meters, etc., should be provided with by-passes.

Piping should always be arranged so that there are no unusual strains due to expansion and contraction. In supporting the piping certain points may be fastened firm, or anchored, and the expansion and contraction between these fixed points taken care of with expansion joints, bends and sliding supports. Systems have been devised where all the supports are of the sliding variety. All supports should be from the building and not from equipment.

It is a good plan to have a distinctive color of paint for all the different lines carrying water, steam, acid, stock, bleach, vacuum, etc. Thus any part of any line can be immediately distinguished wherever it is met with in the mill. The same system of colors can be adhered to in the drafting room. No piece of steam heated equipment should ever be set up without some provision for taking care of excess pressure, such as a good safety valve. Check valves should be on the line leading from soda and sulphate digesters to prevent stock being blown back when another digester is being discharged.

Pumps.

A complete description of all the various types of pumps used in pulp and paper plants would require a book in itself. Moreover, excellent works

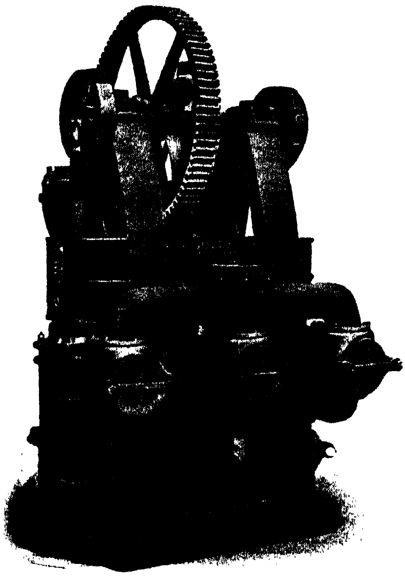


FIG. 246.—Vertical triplex plunger pump for paper stock.

Courtesy: *Goulds Pumps, Inc., Seneca Falls, N. Y.*

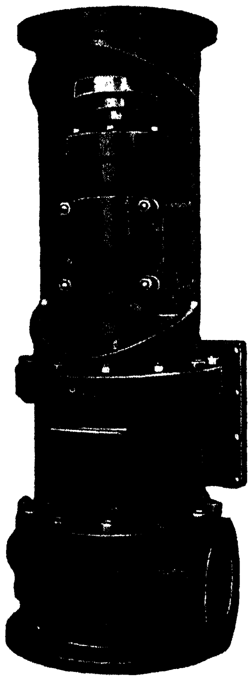


FIG. 247.—Vertical centrifugal paper stock pump.

Courtesy: *Goulds Pumps, Inc., Seneca Falls, N. Y.*

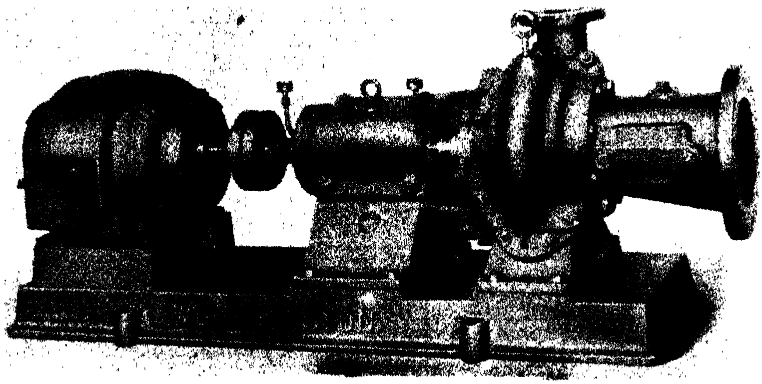
now exist on the theory and practice of both plunger and centrifugal pumping equipment, as well as on the general subject of hydraulics and hydrodynamics.[1] Consequently, we will only touch on the matter very briefly

[1] Among other works we might suggest: W. M. Barr—"Pumping Machinery." Edward Butler—"Modern Pumping and Hydraulic Machinery." R. L. Daugherty—"Centrifugal Pumps." C. G. DeLaval—"Centrifugal Pumping Machinery." A. M. Greene—"Pumping Machinery. E. W. Sargeant—"Centrifugal Pumps." G. E. Russell—"Textbook on Hydraulics." All obtainable from the publishers of this book.

here. The pumping equipment required in the boiler house is dealt with in the special chapter on that subject.

Pumps are to the paper mill what the heart is to the human system. Hence it is very poor policy to install a cheap pump. In fact, there is hardly any place in the design of a mill where it is more necessary to be liberal and to play safe. The failure of some comparatively insignificant pump may close down a whole system for hours, or even days.

Also, it is well to remember that a pump may be a very fine piece of machinery and it will be totally unsuited for pulp and paper mill work. Some of the pump manufacturers have sales engineers who have given special attention to the problems of paper mill work. In any case the buyer should examine all claims advanced by the pump manufacturer, who (while meaning well) may perhaps not fully understand the nature of the service that will be expected from the pump. It is well to stick to makers who have made somewhat of a specialty of pulp and paper mill work, even if others offer slightly more attractive prices or deliveries.



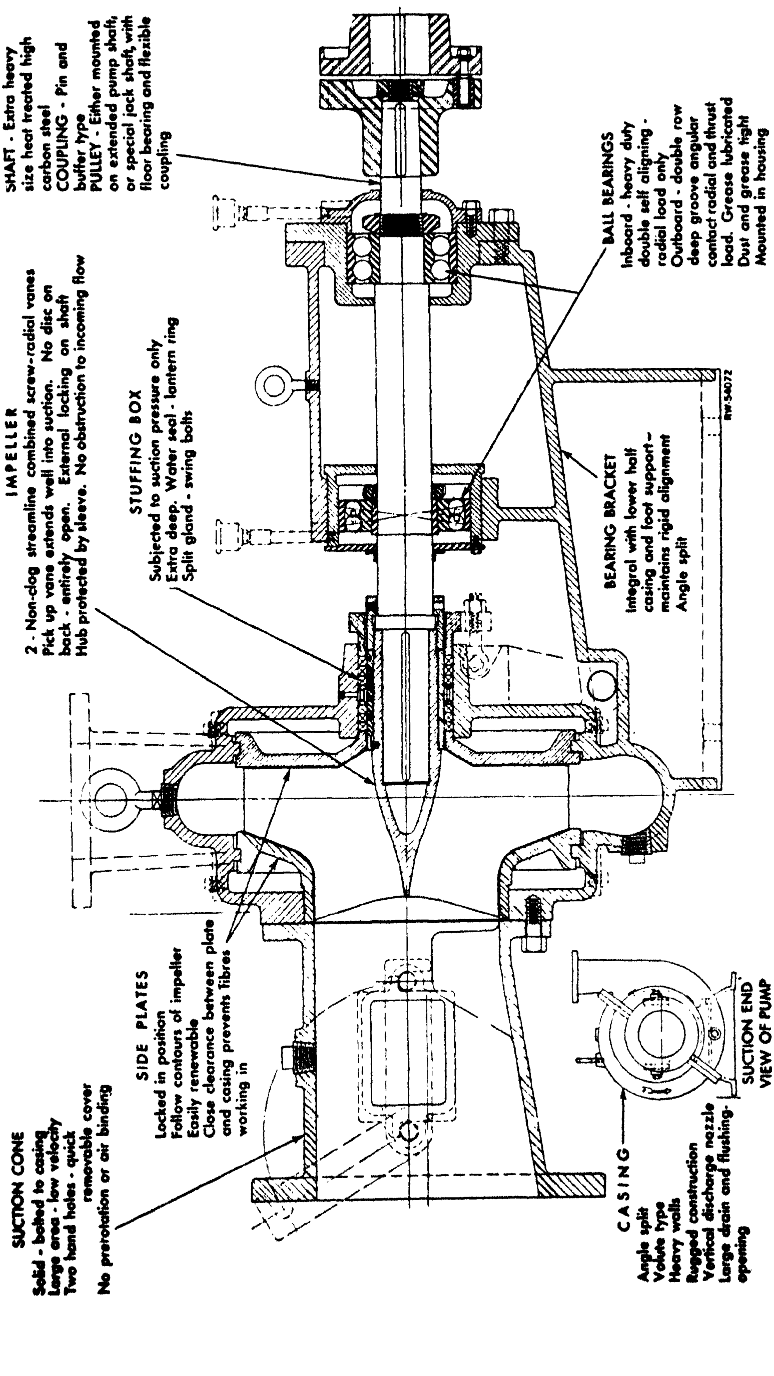
Courtesy: Worthington Pump & Machinery Corp., Harrison, N. J.

FIG. 248.—Typical centrifugal paper stock pump.

Some of the points to look out for in a pump are: Strength, simplicity, non-clogging characteristics, nature of material (*i. e.,* if it will resist the chemical action of the fluid to be pumped), mechanical efficiency (i. e., economy of power), durability and ease with which repairs can be made.

Pumps Used in Pulp and Paper Mills.

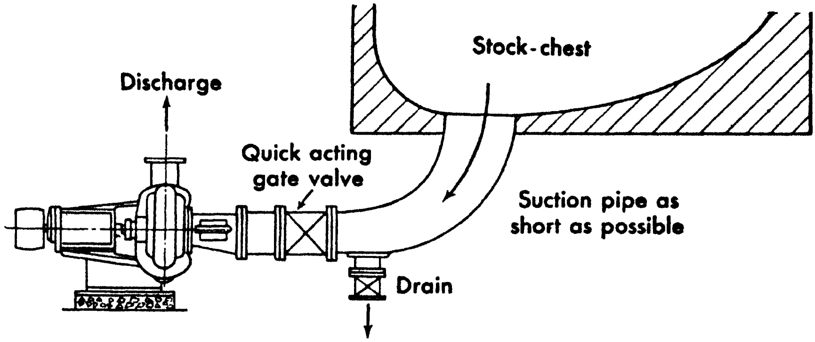
No general rules as to capacity, head, speed, etc., can be given that will apply to all mills. Each mill is an individual job. The pumps are installed to serve the machinery for producing paper, and are auxiliaries only. They must adapt themselves to the different requirements of the mill. A description of the pumps as used in the various departments of a paper mill will be given below.



Courtesy: Worthington Pump & Machinery Corp., Harrison, N. J.

FIG. 249.—Diagram showing construction of typical centrifugal paper stock pump.

1. Pumps for general water supply.
2. Pumps for Power House.
3. Pumps for groundwood mill.
4. Pumps for Sulphite Mill.
5. Pumps for Soda Mill.
6. Pumps for Paper Machines.



Courtesy: Worthington Pump & Machinery Corp., Harrison, N. J.

FIG. 250.—Diagram showing proper connection of centrifugal pump to stock chest.

Pumps for General Water Supply.

Usually two pumps used. One pump takes water from river and delivers it to the filters. The second pump pumps from the filters into standpipe, elevated tank or direct into pipe system of mill. For this service the centrifugal type of pump is recommended. Or, if water supply comes from wells, triplex or other reciprocating pumps may be used. Some mills are fortunate enough to take their mill water from the penstock of their water turbines and dispense with supply pumps altogether.

Service	Type of Pump	Material Handled	Construction
River water	Centrifugal, Single Stage, Double Suction	Unfiltered water	Bronze fitted
Filtered water	Centrifugal, Single Stage, Double Suction	Filtered water	Bronze fitted

Pumps for Power House.

In mills having their own power house for producing steam and power usually the following pumps are used:

Service	Type of Pump	Material Handled	Construction
Boiler feeding	Centrifugal, Multi-Stage	Hot Water	Bronze fitted
Condenser circulating (surface condenser)	Centrifugal, Single Stage, Double Suction	Cold water	Bronze or iron fitted
Hot well pump for condenser	Centrifugal, Single Stage, fitted for Vacuum service	Hot water	Bronze fitted
Hot well pump for miscellaneous returns	Centrifugal or Triplex	Hot water	Bronze fitted
Condenser vacuum pump	Steam Ejector or Dry Vacuum Pump	Air and vapors	Bronze fitted

Pumps for Groundwood Mill.

Service	Type of Pump	Material Handled	Construction
Grinder pump	Centrifugal D. S. Enclosed Impeller or Triplex	Clear cold water	Regular or bronze fitted
White water pump	Centrifugal D. S. Enclosed Impeller	Pulp water containing less than one-tenth of one per cent pulp	Regular or bronze fitted
Groundwood pump ½%	For well-screened stock, Enclosed Impeller, Double Suction. For poorly screened stock, Fan Pump, Open Impeller	Pulp water ½-1% consistency	Regular or bronze fitted
Groundwood pump 3%	Open Impeller Fan Pump or Triplex Ball Valve	Pulp water 3-4% consistency	Regular or bronze fitted

Pumps for Sulphite Mill.

Service	Type of Pump	Material Handled	Construction
Acid pump	Centrifugal, Double Suction, Enclosed Impeller	Sulphurous acid, also called B-sulphite liquor	All bronze pump, solid bronze shaft, lead packing for stuffing box. Liquid attacks steel
Lime water pump	Centrifugal, Double Suction, Enclosed Impeller	Clear water which is sprayed over limestone in tower	Regular
Blowpit pump	Special Side Suction, Open Impeller Fan Pump	Sulphite stock from blowpit. Contains foreign matter, as stones, knots, etc., consistency 1-3%	Regular or bronze fitted, extra large clearances, generally belt driven—easy to clean construction
Pulp pump, screens to deckers	Centrifugal, either Side or Double Suction, Enclosed Impeller	Stock diluted ½% consistency	Regular or bronze fitted
Pulp pump, deckers to beater chest	Open Impeller Fan Pump or Triplex Ball Valve	Stock of 3-3½% consistency	Regular or bronze fitted

Pumps for Soda Mill.

Service	Type of Pump	Material Handled	Construction
Fresh liquor pump	Centrifugal, Single Suction, Enclosed Impeller	Caustic soda liquor about 10° Be. or 1.05 sp. gr.	All iron fitted, long stuffing-box gland
Liquor circulating pump	Centrifugal, Single Suction, special pump	Hot caustic liquor 100 lbs. suction pressure about 10° B. or 1.05 sp. gr.	All iron fitted, extra heavy casing
Black or used liquor pump	Centrifugal, Single Suction, Enclosed Impeller	Used liquor or black liquor, 10° Be. or 1.05 sp. gr.	All iron, long stuffing-box gland
Thick or evaporated liquor pump	Triplex Ball Valve or Centrifugal Hot Well Type	Thick liquor, about 40° Be. or 1.2 sp. gr. under 20-25″ vacuum	All iron fitted centrifugal pump to have large vents on suction
Leaching liquor pump	Centrifugal, Single Suction, Enclosed Impeller	Reclaimed soda liquor	All iron fitted, long stuffing-box gland.
Blowpit pump	Special Side Suction, Open Impeller Centrifugal	Soda stock from blowpits, contains foreign matter as knots, etc., consistency 1-3%	Regular or bronze fitted, extra large clearances. Generally belt driven. Easy to clean construction
Pulp pump, screens to deckers	Centrifugal, either Side or Double Suction, Enclosed Impeller	Soda stock diluted to ½% consistency	Regular or bronze fitted
Pulp pump, deckers to beater chest	Open Impeller Fan Pump or Ball Valve Triplex	Soda stock of 3-3½% consistency	Regular or bronze fitted

Pumps for Paper Machines.[1]

Service	Type of Pump	Material Handled	Construction
Stock pump, Jordan chest to Jordans	Triplex Ball Valve or Centrifugal Open Impeller Fan Pump, Single Suction	Groundwood and sulphite pulp from beaters 3% consistency	Regular or bronze fitted
Stock pump, machine chest to mixing box	Ditto	Ditto from Jordan 3% consistency	Ditto
White water pump	Centrifugal, Side or Double Suction. Enclosed Impeller	White water draining through wire of machine and from other sources. About 1-10% consistency	Ditto
Mixing box to screens of paper machine	Centrifugal, Side or Double Suction. Enclosed Impeller	Pulp from Jordan plus white water diluted to consistency of 0.4%	Ditto
Shower pump	Centrifugal, Side or Double Suction. Enclosed Impeller	Clear water for showers	Ditto
Suction roll vacuum pump	D. A. Single or Duplex Vacuum Pump, or Centrifugal	Drains from wire or felt	Bronze fitted
Suction box vacuum pump	Ditto	Ditto	Ditto
Drying rolls condensation pump	Simplex or Duplex Steam Pump	Removes condensation from drying rolls of paper machine	Regular fitted

Belting.

Belting is still the most ordinary means of transmitting power in pulp and paper mills, although direct drive by individual motors is constantly increasing in application. In order to be of maximum efficiency the belting will need to fill definite requirements of pliability, strength, durability, freedom from stretch and a surface that will reduce slipping to a minimum. Chain drives are useful in many types of installation but must be used with caution as they lack flexibility.

Belting is made from a number of materials such as leather, rubber (or more correctly, canvas impregnated with rubber), canvas, camel hair, etc. The selection of the right variety of belting for a given set of conditions is a matter of much importance. Leather belting is more durable than any other, and is the most generally useful, but there are some places where it cannot be used. Tests carried out by E. D. Wilson[2] at the Mellon Institute, Pittsburgh, support the following conclusions: (1) Leather possesses a considerably greater power-transmitting capacity than any other belting material. (2) This advantage persists at all speeds up to 5,000 feet per minute. (3) The relative capacities of the various belts remain the same no matter what kind of pulley is used. (4) Leather belting possesses a higher overload capacity than other belting. (5) Leather belting is the only type of belting that improves with age, all other kinds being best when new. (6) Leather belting does not need to be as wide as other belting to produce the same effect. These conclusions are based on tests of the most exacting and scientific nature, and may be accepted as correct.

[1] With reference to high-speed news machine: other types of machine would require slightly different pump equipment.
[2] Paper Industry, Sept., 1919, pg. 443.

Rubber belting is chiefly used in very wet or steamy places. Around screens, and any place else where frequent "washing up" has to be done, rubber belting is generally desirable. Rubber belting is quickly destroyed by oil or grease. Paper mills ordinarily being considered wet, sloppy places, rubber belt is very generally used for all purposes, but in many instances it would be better to use leather belting and remove the cause of the wetness or slop. In general it is always better to remove destructive conditions, if possible, than to a allow them to persist and get a belt that will stand them. For instance, if a rubber belt seems desirable and cannot be used on account of oil dripping on it, it is the most logical thing to protect the belt against the oil, not to seek for a belt that will stand up against oil. Many times when the wrong kind of belting is in use it is because when the belt had to be replaced none of the right kind was on hand, but the wrong kind was. Errors of this kind when once made are often persisted in. It is good economy to have a good stock of all kinds of belting used in the mill.

Camel hair belting is excellent where a belt is required that will resist acid and alkali. It does this better than any other kind of belting. It also resists high temperatures that would destroy leather, canvas or rubber belting.

The following practical hints regarding the use of belting may be found useful:

1st. It is better to select a wide thin belt and a pulley with a wide face, rather than a narrow thick belt of the same strength. The belt can then be run looser without slipping as it has more contact surface. For example—A 12-in. 4-ply belt of the same strength as a 6 in. 2-ply would be much better to use, since it has twice as much surface of contact with a pulley and does not have to be run so tight to prevent it from slipping. A thin 4-ply belt is also much less liable to buckle when going around a small pulley whereas a thick 8-ply is stretched on the outside and buckled on the inside, thereby considerably shortening its life.

2nd. It is better to have a belt run loose than tight. If a belt has to be drawn "fiddle string" to make it transmit power properly without slipping or if a sticky dressing has to be applied to prevent it from slipping when run only moderately tight it is a positive indication that the belt is too narrow and a wider one substituted even if broader faced pulleys have to be put on. In certain cases where it is necessary to shift a belt as in the case of elevators and cone pulleys, the edges of the belt are subjected to much wear. In such cases a thick, hard belt will last longer than a broad thin one. Sometimes a very firm, hard, stiff belt is better to use than a soft, pliable one; judgment in such cases is necessary to decide what to use.

With belting of the proper size and pulleys of the proper width of face to transmit the power required of them the belt ought to run moderately slack without slipping. The use of "dressing" should be resorted to only as a temporary remedy for a slipping belt and should not be indulged in as a general practice.

Rosin should never be put on a belt to prevent slipping as it is very injurious and its action is only temporary. For this reason a small supply of dressing should always be kept on hand to use in case of emergency to prevent the necessity of having the rosin. The surface of belts and faces of pulleys should be kept clean and smooth. All accumulations or lumps on pulleys should be removed and the surface of belts be kept smooth not by "scraping" unless absolutely necessary but by wiping or washing.

A running belt can be very nicely wiped by holding on it a rag wet with gasoline.

A leather belt running under the proper conditions seldom requires any treatment. If it is running in a very dry place and seems inclined to get hard, an occasional application of castor oil both inside and outside will keep it soft and pliable. Wool fat or degras is also excellent for this purpose, but such treatment should not be repeated too frequently so as to make the leather too soft and greasy as it then becomes "stretchy" and loses to some extent its firmness and strength. All that should be done is to use an occasional dose of castor oil or wool fat just sufficient to keep the leather from getting harder than it was when new and to keep the surface "velvety" when it appears to be getting a trifle too hard and glassy.

Rubber belting is more sensitive to the use of dressing than leather and it requires considerable care and attention to keep a rubber belt in good condition.

The natural rubber with which a rubber belt is covered is the best contact surface that can be had so long as it is kept in good condition. When the white powder with which a new rubber belt is coated is rubbed off, exposing the soft velvety surface of the rubber, this presents almost an ideal contact surface for a pulley. All that is necessary, therefore, is to keep this rubber surface in its natural condition for as long a time as possible.

When the inside surface of a rubber belt appears to be somewhat too hard or glassy it is best to clean it with a rag and gasoline, then apply a very small amount of linseed oil. The best way is to moisten a rag with the oil. By passing the rag lightly across the belt while it is running, only a film of oil gets onto the belt. The rag should not be soaked to such an extent that too much would get on the belt at one time. The object is only to get a trace of oil on the surface of the belt, so as to take off the "glassy" surface and have the rubber surface velvety or in its natural condition. If too much is applied the belt will slip until the oil soaks into the pores, and by soaking in too much oil the life of the rubber coating is injured and it becomes more or less rotten. The object is, therefore, to take off only the "glase" and form only a film of soft rubber in its place. It should not penetrate the rubber and soften it as castor oil or wool fat does to a leather belt.

Stretched cotton belts stuffed with grease require only to be kept clean and free from accumulations of dirt the same as any belt, and to be kept in a soft greasy condition, by the application of oil. As before stated, they are the best variety of belt to use in places exposed to oil, which would soon ruin a leather or rubber belt, but is beneficial to this kind of belt.

The ideal belt drive is horizontal. However, such a drive is exceptional, and the best has to be made of other conditions. In driving beaters and other such equipment it is advisable to have the belt wrap around the driven pulley as far as possible. With a horizontal drive, this is partially accomplished by allowing the upper strand of the belt to run slack. This arrangement is not desirable in driving beaters, as space and economy of belting do not permit of such drives. The same effect can be secured, and improved on, by an idler pulley, as shown in the illustration. The best known of these devices is the "Lenix."

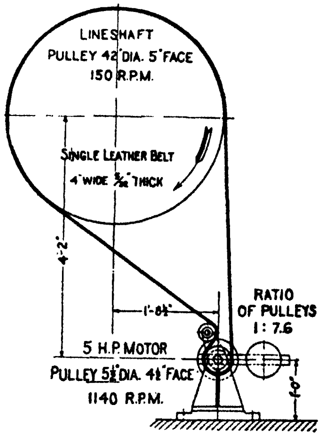


FIG. 251.—Diagram showing belt drive for beater or other similar equipment, illustrating use of idler pulley.

Courtesy: "The Paper Industry and Paper World," Chicago, Ill.

In driving beaters the Lenix device is frequently used in the following manner: The lineshaft is arranged vertically below the shaft of the beater pulleys. The Lenix device is operated by means of a hoisting rig from the beater floor in such a way that when it is desired to stop the beater the resilient idler pulley, or Lenix, is thrown back. When it is desired to start up the beater, the Lenix is thrown forward so as to engage the full width of the belt with the driving pulley. This accomplishes the same effect as the ordinary tight and loose pulley arrangement, but is much better for the belt. With the tight and loose pulley arrangement the full starting load is carried by one edge of the belt and the other edge tends to become bruised by the belt shifting fork.

Unless a great deal of money is to be wasted, belting must be figured very carefully. Speeds of driving and driven pulleys should be taken with a speed counter and over a long period of time. The old formulas, such as the one that "the horsepower to be transmitted, multiplied by 800 and divided by speed of the belt in feet per minute would give the width of the belt in inches" are not to be trusted in these days of high priced belting. They are all figured so as to give a generous factor of safety and will frequently result in much wider belts being selected than there is any need for.

Rope Drives.

Rope drive is quite extensively used in pulp and paper mills, especially for machine drive. For general purposes this method of drive is much commoner in England than in America. However, recently several large paper machines have been equipped with rope drive in this country and it is also used for driving beaters, electric generators, etc.

There are two systems of rope drive, the Continuous and the Multiple. The continuous system has been most used in America and the multiple in England and on the continent of Europe. In the continuous system a single rope is passed as many times around both driving and driven pulleys as there are grooves to be filled, and is then carried across the whole width by means of tension pulleys. This system is very useful where drives have to be carried around corners or angles. In the multiple system there are as many rope belts as there are grooves on the pulley. This system has the advantage that if one strand breaks the rest will carry on the work until a suitable opportunity arrives to remedy the defect.

Courtesy: Allis-Chalmers Mfg. Co., Milwaukee, Wis.

(a). Texrope drive on beaters. (b). Texrope drive on chipper.

FIG. 252.

Users of rope drive claim that it is much more efficient than belt drive. Belts depend entirely on friction for their grip on the pulley. Moreover, a film of air is always caught between the belt and the pulley, which tends to cause slipping. The rope runs in a groove so cut that the rope takes a firm hold on the groove, but does not fill it entirely, the air passing freely out through the open space under the rope. Finally, the best cotton rope is cheaper than an equivalent amount of leather belting. Cotton rope is preferable for rope drives, although manila has been used.

In driving paper machines by rope drive a large grooved fly wheel is placed in the basement under the dryer part of the machine. From this wheel ropes lead up and down the basement, conveying power to short counter-shafts situated in the basement under the several roll shafts of the paper machine. Upon these counter-shafts below and roll shafts above are the cones, between which power is transmitted by a loose belt with a tightener pulley. The advantages claimed for this method of drive are the doing away with bevel gearing and the long main line shaft, avoiding the loss of power usually occasioned by the numerous bearings of this shaft.

Texrope Drives.

This is a patented multiple V-belt drive that has come to be extensively used for driving chippers, beaters, Jordans and other such equipment. It is more efficient than ordinary belting, and more flexible and shock-absorbing than chain drives or direct-connected units. It uses no lubrication and is unaffected by dirt or moisture, and is adaptable to either fixed or variable speed.

Ventilation.

When we consider that paper leaves the paper machine containing approximately 5 per cent moisture, whereas the stock from which the paper is made is nearly 100 per cent water, and when we recollect further that 55 or 60 per cent of the water is removed as vapor in the dryer part of the machine, we are in a position to attribute some importance to ventilation in the paper mill.

Moreover, at the wet end of the machine there is a certain amount of moisture from the stock flowing over the wire, the various showers, etc. Also, the air of the beater room and other parts of the mill is moist. If a pond is used in the wood room it gives off vapor, especially in winter when the temperature of the water is raised to remove ice from the wood. Finally, in the digester house there are sulphur fumes and moisture, and in the bleaching room there is chlorine.

There are two main effects to be considered in discussing the ventilation (or lack of it) of a paper mill. One is the effect on the product and the other the effect on the workmen.

Moisture, if not carried off, will condense on roofs, girders, piping, etc., and drip back on the paper or into the stock. This can be avoided entirely by a proper system of fans and heaters for blowing hot air along the upper part of the machine room. The amount of moisture that air will hold increases with the temperature and a comparatively slight increase in temperature will prevent all condensation.

In one of the best systems for accomplishing this fresh air from outside is drawn into a compartment filled with steam coils which raise the temperature of the air to about 71° F. By means of a blower and a system of flues this air is distributed all along the roof of the machine room. The slope of the roof, the design of the hood placed over the dryers and many other factors (for instance, if one end of the machine room is more exposed to cold winds than the other) affect this problem, and a careful study should be made of conditions and the combined heating and ventilating system designed to meet them. This is far from an unimportant matter since several tons of moisture are given off daily in a mill of any size.

Many well-meant attempts at ventilation are almost useless, because the details of the design have not had the attention of anyone competent to deal with such problems. Frequently the fans for removing moist air will be of much greater capacity than the system for supplying fresh, warm, dry air. This will result in cold air being drawn into the building in winter through window frames, doors, cracks, etc. In other cases an unnecessarily large volume of warm, dry air is furnished in the effort to do the thing thoroughly which is simply wasting electricity and steam to no good purpose. Hoods over dryers are sometimes not properly placed so that every unusual draft through the room causes steam to be carried out into the room. Mills roofs are frequently designed so that moisture pockets form which are full of stagnant, humid air, not reached at all by the currents created by the fans. This is an argument against very steep roofs. If a steep roof is necessary on account of the snowfall, a ceiling or false roof should be provided, nearly flat, so as to prevent pockets of moist air. However, it is better to avoid such ceilings, as the space between is hard to ventilate and usually affords an opportunity for rot and decay to attack the whole roof.

The lack of a good ventilating system in the machine room will result in much paper being damaged and the loss from this source in a year or so would pay for suitable ventilating equipment.

Some mills use steam pipes arranged in rows along the roof but this system is inferior to blowing hot air into the building since the moisture tends to collect and condense on the walls and elsewhere and it will gradually rot the window frames and other wood work and corrode the machinery.

A good ventilating system is a great help in keeping the product uniform, regardless of what the weather conditions may be. Firms designing "air conditioning equipment" will guarantee exactly the same conditions of humidity and temperature the year round regardless of what the external weather conditions may be.

Modern mills frequently deliver heated air between the drying cylinders of the machine to carry off moisture as it is evaporated. The volume of this air must necessarily be very large—from 25,000 to 100,000 cubic feet of air per minute. The air must be hot enough to carry off the moisture at maximum efficiency, but not hot enough to reduce the strength of the paper being made. About 140° to 150° F. is right. The air is usually distributed through 6-inch pipes placed between the dryers, one pipe for each roll. The pipes are slotted to discharge the air, the slots running the length of the pipe and being about 6 inches long by $\frac{1}{4}$ to $\frac{1}{2}$ inch wide.

The above remarks are all related to the influence of ventilation on the product. There is also the effect on the help to consider. Workmen today are not satisfied to work in a humid, steamy, uncomfortable and unhealthy atmosphere because they know that such conditions are preventable and unnecessary. Moreover, even if they will remain on the job in such a mill; they cannot do as good work as if the working conditions were more agreeable.

Adequate provision for ventilation is especially necessary, for obvious reasons, in rooms where waste paper and rags are being sorted, dusted, cut and otherwise prepared for use. In old-fashioned establishments this work was frequently carried out in dark, unventilated, evil smelling holes, unfit for any person to work in. The rag sorting rooms of the modern paper mills using rags are clean and sanitary enough to eat a meal in. Not only has this change made the work much better from a sanitary and humane point of view, but it results in increased efficiency on the part of the workers.

Portions of the mill where bleach is being handled should be provided with good ventilating systems and the fans and air passages should be protected against the action of chlorine vapors, which rapidly corrode metal work. There are a number of paints and lacquers which are more or less resistant to chlorine, but for fans the most satisfactory material is steel, covered with a rubber coating by the same process whereby rolls are given their coverings. Lead coating or galvanizing will not stand up against chlorine and its compounds. Some form of gas mask or respirator ought to be at hand for use in case of a break down of the ventilating system and for making repairs. In fact, such equipment will come in useful in many parts of the paper mill—in the digester house, blow pits, acid plants, around sulphur burners, in case of fire in any part of the mill, etc. Gas masks of high efficiency originally designed for military purposes are now offered for sale by several firms. These are much better than ordinary respirators which withhold dust and similar material but not chemical vapors or smoke.

Another place where proper ventilation is very needful is in the grinder room of ground wood mills. It is almost as necessary to have hoods over the grinders, or some other adequate means of ventilation, as in a machine room, and grinder room roofs will frequently be found in a very bad state of repair through ignoring this fact.

In the design of a ventilating system the first thing to receive attention is the amount of moisture which will leave the dryers. For a machine room this figure may be determined by finding the difference between the moisture of the sheet as it goes onto and leaves the dryers along with the output of the mill for any stated interval. It is also necessary to know the amount of moisture in the air as taken into the mill. Knowing the temperature of the air as it enters and leaves the room, one can find with the help of Psychrometric Tables what amount of moisture may possibly be carried by any volume of air. A safe margin should be held so that one does not figure upon the air leaving the mill saturated with moisture. An idea of the amounts of moisture which may be held by air at various temperatures and various degrees of saturation is given in the following table.[1]

AMOUNTS OF MOISTURE HELD BY AIR AT DIFFERENT RELATIVE HUMIDITIES

Grains of water in suspension per cubic feet of air.

	Percentage of Saturation				
Temperature °F.	10%	40%	70%	95%	100%
−20	0.017	0.066	0.116	0.157	0.166
−10	0.028	0.114	0.200	0.270	0.285
0	0.048	0.192	0.337	0.457	0.481
10	0.078	0.310	0.543	0.736	0.776
20	0.124	0.494	0.864	1.173	1.235
30	0.194	0.774	1.354	1.836	1.935
40	0.285	1.140	1.994	2.703	2.849
50	0.408	1.630	2.853	3.870	4.076
60	0.574	2.298	4.022	5.459	5.745
70	0.798	3.192	5.586	7.578	7.980
80	1.093	4.374	7.654	10.378	10.934
90	1.479	5.916	10.353	14.045	14.790
100	1.977	7.906	13.836	18.765	19.766
110	2.611	10.445	18.278	24.806	26.112

As soon as one has determined how much moisture will be carried by any definite amount of moving air, and knowing the amount of moisture in it at the start, he can find what volume of air should pass through the system at any given time. The simplest way of finding if the ventilating system is sufficient may be noted by the presence or absence of condensation in any part of the mill after the system has been running for some time with all doors and windows closed. The presence of any condensation would show one of two things; either that more air should be moving through the ventilating pipes, or else that the air should be heated to a higher temperature. Any of these systems should be built so that the capacity may easily be changed to correspond with varying degrees of weather so that much more dry, warm air may be sent into the mill on a very cold or a very moist day than on a day when the weather is moderate.

A system designed in this way should be satisfactory as regards condensation on the ceiling of the room, but it would not be sufficient to prevent condensation in concealed places between roof planks and the roofing paper. In all probability it would not be economical to attempt such a result with ventilation alone, but by following a scheme of roof construction especially designed to take care of these difficulties, the dangerous condition may be avoided. Such construction consists in some proper use of insulating material in connection with the roof.

Problem. How much air should be used to ventilate a machine room in a paper mill where seventy-two tons of water are evaporated by the dryers in twenty-four hours? The weather is −20°, the relative humidity is 75%, and the air used in ventilation leaves the mill at 110°.

[1] Data selected or estimated from the complete tables contained in "Psychrometric Tables" by C. F. Marvin, of the Weather Bureau, U. S. Department of Agriculture, Government Printing Office, Washington, 1915.

Solution. Moisture sent into the room by the dryers: 72 tons per 24 hrs. = 3 tons per hr.; *i.e.,* 100 lbs. per minute = 700,000 grains per minute.

The fresh air at 70% relative humidity and at $-20°$ taken in for heating and ventilating the mill contains 0.116 grains of water per cubic foot (see tables); suppose this air leaves the mill at a relative humidity of 95% when heated to 110°. It is then carrying 24.806 grains of water per cubic foot. In passing through the mill it has taken up $24.806-0.116 = 24.690$ grains of moisture per cubic foot. Then it will require $\frac{700,000}{24.69} = 28,351$ cubic feet of air per minute to ventilate this machine room.

The question of the distribution of steam to the heating and ventilation system is further dealt with in the chapter on the power plant.

Savings due to introduction of properly planned hoods, economizers, etc., may well run as high as $100 per day in a 100-ton mill.

Lighting.

Of recent years mill lighting has advanced to such an extent that there now is a new class of technical men known as illuminating engineers. The need for good light in a paper mill is almost too obvious to mention, but the most economical method of securing good lighting is far from simple. Moreover, frequently the wish to provide good lighting is not coupled with the knowledge of how to do it and illuminating units are placed in unsuitable places where they are detrimental rather than useful. *Powerful illumination is not necessarily good illumination.* Good lighting implies exactly the right amount of light of the right quality at the right place. The chief effects of good lighting are:

1. Reduction of accidents.
2. Greater accuracy in workmanship.
3. Decreased spoilage of product.
4. Increased production for the same labor cost.
5. Less eye strain.
6. Better working and living conditions.
7. Greater contentment of workmen.
8. Better order, cleanliness and neatness in the plant.
9. Easier supervision of the men.

In this list it will be noted that items 5, 6, 7, 8 and 9 have a bearing on accident prevention. R. E. Simpson of the Travelers Insurance Company states: "A survey of 91,000 accidents from the records of the company for a single year showed that 23.8 per cent were due to improper or inadequate illumination." The same authority explains that it is hardly possible that this percentage prevails at the present time, due to progress in illumination, but he goes on to say: "There is some foundation, however, for assuming that 18 per cent of our industrial accidents are due to defects in the lighting installation."

As a result of the investigation of lighting by insurance companies, engineers and others, several states have adopted lighting regulations and the state of Wisconsin maintains an Industrial Lighting Commission to see that factory lighting in that state is in conformity with modern ideas. Under the auspices of the electric lighting industry much valuable work has been done on this subject at the laboratories at Nela Park, Cleveland. The insurance companies, the manufacturers of lighting equipment and various government agencies will all be found willing to help those who wish to have the best lighting at the lowest cost.

There are many points that seem of minor importance at first sight, which, if remedied, will do much to improve the lighting system. Lights are frequently hung too high or too low to properly illuminate the work without glare. In many cases some system of indirect, or semi-indirect lighting will avoid shadows, which are especially annoying around complicated machines. In some cases the glare from a brightly polished portion of a piece of machinery is a constant source of annoyance. This can often be remedied by painting the portion offending, or if this is not possible, by changing the position of the light. Steady reflection of light from a moderately polished surface, such as the surface of a sheet of highly finished paper, is very exhausting to the eyes in time. This can be improved by having a more diffused source of light. Where color is of importance lamps should be chosen which modify the natural quality of the electric light so as to make it more nearly resemble daylight. These lamps are readily obtainable today and not only permit of close matching of colors, but also are more restful and agreeable to the eyes.

Where matching of colors has to be carried out with great exactness, special color matching outfits can be obtained which exactly simulate daylight. Around paper machines and other equipment, portable lights, protected with wire screens, should be available for making adjustments and repairs in parts of the equipment not reached by the ordinary illumination.

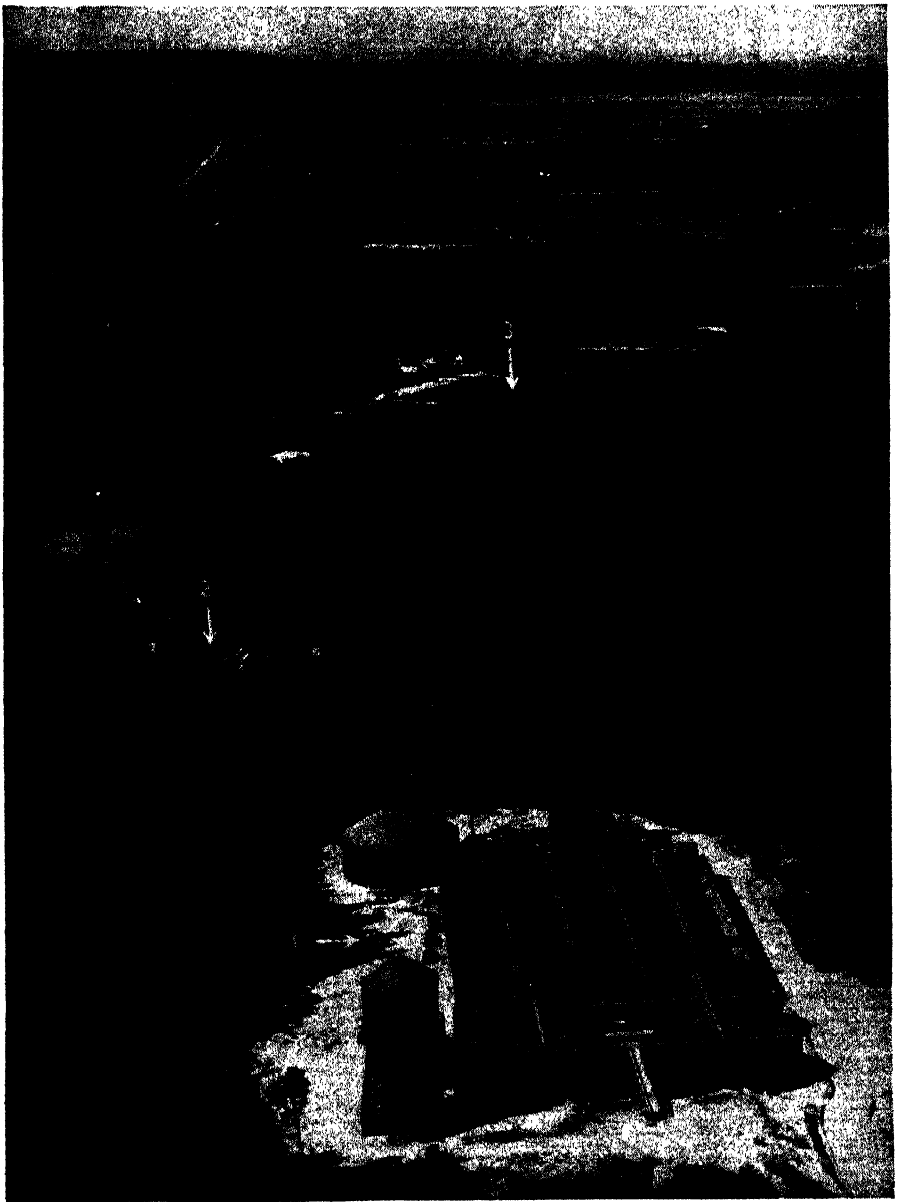
In addition to satisfactory artificial light, every effort should be exerted to admit as much sunlight as possible. A maximum amount of steel sash and glass in the walls with overhead skylights of large extent is typical of modern factory construction and makes for increased efficiency.

Flood-lighting of yards, wood piles, railroad sidings, docks, etc. has advanced to a stage of efficiency and economy where there is no longer any excuse for dangerous darkness. Chlorine cars should always have a spotlight directed on them to protect them from accidental or mischievous interference, and to facilitate emergency repairs or adjustments. A profusely lighted plant at night is an excellent advertisement.

The liberal use of a good white paint especially made for factory use so as to stand moisture, chemical fumes, etc., will do wonders in increasing the effectiveness of either day light or artificial illumination.

Water Supply.

In consequence of the very large volumes of water required in pulp and paper manufacture an adequate supply of water of a suitable degree of purity is a matter of prime importance.



Courtesy: Pulp Div., Weyerhaeuser Timber Co.

FIG. 253.—Aerial photograph of water supply of a large paper industry on the Pacific Coast. Water is purified at the filter plant (1) shown in the foreground. A mile-long pipe line follows a ravine (2) and carries purified water to the pulp mill (3) located at tidewater.

The quantity of water used will vary greatly with the kind of paper being made. In a mill making fine papers from rags, where the stock is washed for a long time with a great deal of water, volumes of water will be required that are enormous in comparison with the output of the mill. In mills making news-print, wrappings, etc., the washing is not so elaborate, but the greater volume of material handled makes the volume of water very large.

For the average paper mill making ordinary grades of paper, other than rag paper, on the Fourdrinier or cylinder machine, from 30,000 to 50,000 gallons per ton finished paper is probably a safe estimate. Rag paper mills have been known to use as high as 200,000 gallons per ton. Efficient re-use of white water may reduce the consumption to as low as 15,000 gallons per ton in a book paper mill.

In pulp mills, a groundwood mill will use from 20,000 to 35,000 gallons per ton of pulp produced; a sulphite mill from 50,000 for unbleached to 100,000 for bleached pulp; for soda pulp (bleached for book paper) about 120,000; and for kraft about 100,000 gallons per ton. The above figures are taken from the writer's personal records of actual mill operations. Probably more trustworthy as averages are the figures in the following table compiled by H. J. Skinner.

GALLONS OF WATER PER TON OF PULP

Part of Process	Ground-wood	Unbleached Sulphite	Bleached Sulphite	Bleached Soda	Kraft
Wood preparation	5,000	10,000	10,000	5,000	10,000
Liquor making		30,000	30,000	35,000	35,000
Fiber preparation		15,000	15,000	15,000	15,000
Bleaching			30,000	30,000	
Machine operation	10,000	10,000	10,000	10,000	10,000
Fresh-water showers	25,000	30,000	35,000	35,000	25,000
Steam and power	Hydraulic	15,000	15,000	15,000	15,000
Miscellaneous	10,000	5,000	5,000	5,000	5,000
Totals	50,000	115,000	150,000	150,000	115,000

It is not the writer's intention to attempt to deal with the subject of the mechanical and chemical treatment of water, which would require a big book in itself,[1] but merely to comment on a few points which practical papermakers should constantly have in mind. A good water supply is of the utmost importance. In fact many of the early paper mills chose their location mainly because of the quality of the water supply.

If there is any impurity in the water it will get into the paper since the fibers in the forming web of paper on the wire form a regular filter that will catch and retain any sediment or coloring matter.

There are two kinds of coloration in water. Coloration due to sediment, which can usually be removed by settling or by coagulation with alum or sulphate of iron in settling tanks or ponds, and dissolved color, usually

[1] See chapter on water by H. J. Skinner in "The Manufacture of Pulp and Paper," Vol. 4, New York, 1928; also A. M. Buswell, "Chemistry of Water and Sewage Treatment," A. C. S. Monograph, Reinhold Publishing Corp., New York; also numerous publications of the U. S. Government.

resulting from decaying vegetable matter, such as peat bogs, which is very hard to get rid of.

Hard water is water containing mineral salts in solution which are chiefly lime salts, of these the carbonate being the most common. Rain water is almost perfectly soft, but as it falls through the atmosphere it dissolves carbon dioxide and this enables it to dissolve lime and other minerals out of the soil and rocks over which, or through which, it runs. Thus, almost all water taken from streams, lakes, wells, etc., requires to be softened before using.

In pulp and paper mills objection is made to hard water on two general grounds. First, it should not be used in the boilers. Second, it is unsuitable for use in the actual manufacture of pulp and paper.

Considering the second point first, if hard water is used in the beaters, an excessive amount of alum will have to be added, in order to get rid of the hardness, because no size will be precipitated by the alum until all hardness is removed from the water. Not only does this use up alum, but it also imparts an element of uncertainty to the whole sizing operation, since the hardness of the natural water will vary from day to day and the beaterman will never know exactly how much alum should be added. Frequently beatermen will attribute this trouble to variations in the chemical strength of the alum, but usually the water is actually at fault.

Hard water is undesirable for washing any kind of pulp, either after manufacture, or after bleaching. In fact, it is much better if the mill has a uniform supply of soft water so that no hard water need be used at all at any stage of the process. Since a water softening system ought to be installed anyhow for the use of the boiler house, it is the best practice to make it at the same time of sufficient capacity to serve the whole mill.

Treatment of Boiler Feed Water: It is not possible within the scope of this work to enter into detail on the treatment of boiler feed water. It is necessary, however, to touch on the great importance of this matter as a problem in practical pulp and paper mill operation. Preparation of water for boiler feed purposes falls naturally into two main classifications. One is the removal of sediment and mechanically suspended material of all kinds. The other is the softening of the water, or the removal of dissolved salts of lime, magnesium, etc., which tend to incrust or corrode the boilers.

Hardness in boiler feed water is the direct cause of scale, leaky flues, muddy burning and many of the other troubles incident to large scale steam production. It shortens the life and reduces the efficiency of the boiler; increases the repair expense and frequently causes inopportune and costly delays and shutdowns. Most harmful of all, the scale, acting as a thick and effective insulation of the flues, causes an enormous increase in the consumption of fuel. The fuel wastage due to the use of hard water may be anywhere from 10 per cent to 30 per cent.

The cost of boiler cleaning, boiler repairs, boiler compounds, etc., all due to the use of hard water is also a big item in the operation of a large plant. Boiler compounds should be viewed with suspicion. They are only temporary make-shifts at best. A steam boiler is not designed as a vessel in which to carry out chemical reactions, and the constant adding of materials to the water in the boiler cannot help but corrode and weaken the boiler itself. The aim should be to supply as nearly as possible pure water to the boiler, the purification having been effected in a purification and softening plant outside the boiler system.

If the reader will turn to the advertising pages of any technical periodical, especially those dealing with power plant engineering, or with the pulp and paper industry, he will note the advertisements of numerous companies offering systems for purifying and softening water. The fact that all of these concerns have systems installed at one plant or another, the owners of which find satisfactory for their purpose, seems to indicate that there must be more than one method of purifying and softening water that is satisfactory. It is not within the scope of this book to describe these systems, but all concerns exploiting such equipment are ready to supply excellent literature covering not only their particular system, but water purification and softening in general. Which system to install must be decided largely on a basis of cost and prestige of the manufacturer, unless the reader is enough of a chemist and water purification engineer to decide on the relative merits of the different systems from the data supplied by the manufacturers.

However, these systems mostly fall into three classes. These are (1) The Lime Process (2) The Soda Process (3) The Lime and Soda Process.

Lime Process: The carbonates of lime and magnesia, to which the hardness of the water is due, are precipitated with slaked lime in solution (lime water) in some suitable form of apparatus, either with or without heat.

Soda Process: Soda ash (sodium carbonate) and caustic soda (sodium hydroxide) are added either alone or together to the water to be softened. Caustic soda is more efficient in this process than soda ash. This treatment is used with water containing *sulphates* of lime and magnesia. Barium hydrate is sometimes used instead of caustic soda or soda ash, or in certain proportions with them.

Lime and Soda Process: When both sulphates and carbonates of lime and magnesia are contained in the water to be softened, this process is used. The soda is added first, enough being used to consume all the sulphates present, and then lime added.

Simple boiling will soften water if it is merely afflicted with "temporary hardness," i. e., contains *carbonates* of lime and magnesia. If the water possesses "permanent hardness," i. e., contains *sulphates* of lime and magnesia, mere boiling is of no avail.

Zeolite Process: There is one other excellent method of softening water —the zeolite system. This system avails itself of the properties of an interesting material known as a zeolite, which automatically removes calcium salts from the water, yielding perfectly soft water from any ordinary source. In time the zeolite becomes exhausted, but can easily be renewed by a simple treatment. This system is in successful use in many industrial plants. It is a rather expensive system for use simply on boiler-feed water, but is ideal where *perfectly* soft water is needed as in textile manufacturing and certain branches of paper manufacture.

Phosphate Processes: Methods of treating water to remove all hardness have recently been developed using patented phosphatic compounds sold under the names of "Buromin" and "Calgon" which are highly efficient although the required reagents are very expensive.

There are some other troubles with water, which are important from the power plant point of view, besides hardness.

Acidity: This may be due to industrial waste dumped into streams by chemical plants, tanneries, textile plants, smelters, other pulp mills, etc. In sulphite mills there is always a possibility, if check valves do not work properly, or in the event of indirect heating equipment for digesters becoming leaky, of acid getting into boiler feed water. This causes acid corrosion which creates more havoc even than scale. If there is any possibility of acid getting into the boiler feed water, very frequent tests should be made with litmus, or an electric device may be rigged up which will ring a gong as soon as there is enough acid content in the boiler feed water for a current of fixed intensity to pass through the water, the conductivity of which is increased by the acid. Such devices are valuable where indirect cook is used in the digester house.

Foam: Microscopic organisms, sewage, industrial wastes, etc., are the chief substances present in water which cause this trouble. Filtration, sometimes preceded by the addition of a coagulating agent such as alum or sulphate of iron, is the usual cure for this evil.

Priming: This is the giving off of steam in spurts and belches, caused by excessive amounts of salts in solution in the boiler feed water. Too much soda, added to get rid of scale-forming impurities, is a frequent cause of this evil. Frequent blowing down of the boiler is the usual remedy for this evil. If this has to be resorted to at too frequent intervals it is advisable to look about for some new source of water supply.

Any and all of the systems of water softening may be preceded by a system for clarifying or removing suspended matter and sediment. This usually consists of filter beds or tanks, the use of a coagulating substance, such as alum or ferrous sulphate (sulphate of iron) being now quite general. Alum, in addition to removing sediment, will frequently remove dissolved colorations.

None of the above systems should be confused with water treatment for sanitary purposes. Water may be perfectly crystal clear, and also perfectly soft by chemical test, and, therefore, entirely suitable for boiler feed or for making paper, and yet contain large numbers of bacteria of the most virulent nature. To purify water in the sanitary sense, as is done by towns and cities, extensive filtration, accompanied by treatment with chlorine or bleaching powder, is needful.

So far we have said much about the quality of water and little about the quantity. The water supply of a pulp and paper mill should be adequate to take care, not only of the normal needs, but also of requirements in case of fire. There should be a storage tank of adequate capacity mounted on a tower sufficiently high to give a satisfactory nozzle pressure at the top of the highest building or wood pile in the plant. The water supply should be connected with the supply of the town, city or village (assuming that the plant is situated near one) or of some other nearby large manufacturing plant, so that assistance can be rendered in case of fire or explosion putting the power plant out of commission. Conversely, this enables the pulp and paper mill to be of mutual service in case of emergencies.

Assuming that a pulp and paper industry consists of a ground wood mill, a sulphite mill and a paper mill; should each of these have its own main water supply, or should there be a single pumping installation? This will depend entirely on local conditions, the distance separating the various parts of the plant, etc. This is typical of the engineering questions concerning paper mills about which no general directions can be given.

Neither can anything definite be stated with regard to the kind of pump to be used for general water supply. Both centrifugal and plunger pumps are used, multi-stage turbine pumps being very generally satisfactory.

18. Personnel and Records[1]

Now that the mechanical operations and the chemical and physical changes involved in the manufacture of pulp and paper have been thoroughly discussed it is necessary to consider another vital factor in papermaking. There is nothing more essential in the conduct of a successful paper industry than an efficient operating force. A mill may have been designed by the most experienced and ingenious engineers, it may be equipped with all the latest and most efficient machinery regardless of expense, the raw materials may be of the best and highly trained chemists may be at hand to supervise each operation in accordance with the best scientific practice, and yet such a plant may barely struggle along on account of neglect of the human factors entering into paper production.

Cooperation in the Organization.

The personnel of a pulp and paper manufacturing concern means the entire assemblage of people from the president down to the most insignificant laborer who are in any way concerned with the necessary activities of the organization. The personnel of all pulp and paper concerns is much the same. First there are the general executives whose duty it is to supervise financing, manufacturing operations and future development, the purchase of raw materials, the general sales policies, etc. The vast number of those employed in such an industry never come in direct contact with these activities, but it should be remembered that if these large affairs are not attended to in a faithful and judicious manner all work further down the line would be of no avail. Next there come those in charge of various special departments, and between such executives there must be actual and intelligent cooperation if maximum efficiency is to be obtained in the concern as a whole. Such men are the sales manager, the advertising manager, the general purchasing agent, the chief engineer, the chief chemist and finally—most important of all—the superintendent or mill manager or whatever it may be decided to call the man who is actually in charge of the manufacturing plant.

To illustrate the need of cooperation between these men, if the sales manager has no conception of the difficulties and intricacies of manufacture, it is obvious that he cannot market the concern's product in a very intelligent manner. He is hardly in a position to answer complaints, to accept or reject important orders which require immediate decision, or to direct the work of his subordinate salesmen.

Similarly, the advertising manager is the man through whom the concern speaks to the public, or that section of the public where its customers

[1] All names of mills, grades of paper, etc., used in text or illustrations of this chapter are entirely fictitious.

and potential customers are found. It is self-evident that such a man cannot talk convincingly about something he knows nothing about. He must know the company's product from the wood pile to the finishing room.

If necessary cooperation between the purchasing department and the manufacturing department is lacking much needed supplies and equipment will not be on hand when needed, many unnecessary or unwise purchases will be made and much money and time will be wasted.

The necessity for the closest of relations between the chemical laboratory and the manufacturing department is too obvious to even comment upon. If the chemist is to be any good at all to the concern he must be familiar with every stage of the process of manufacture and also must be well informed on general trade conditions, the available raw materials, the market in which the company's product is sold, what the competition is, etc.

Requisite Qualifications of a Superintendent.

The superintendent must display a nice balance of abilities. The principal qualities to be looked for in the ideal superintendent are:

(1) Practical experience.
(2) Scientific and technical knowledge.
(3) Business sense.
(4) Ability to handle and get on with men.

Practical experience: This has no necessary relation to length of time spent in the industry. There are many men who have spent a lifetime in an industry and who know little more than when they began. It is the result of learning day by day and keeping one's mind open and not making the same mistake twice. However, other things being equal, a man's experience generally will increase as years pass and there are many tricks of the trade which only time can teach.

Scientific and technical knowledge: This does not necessarily imply training in a technical school or the scientific department of a university. It is the result of an alert, inquiring mind. In the course of years spent in an industry a man with the scientific trend of mind will find out *why* things are done. He will not be satisfied with the answer that they have always been done that way. A college training is an excellent thing for the man who knows how to use it after it is obtained. It opens the way to many short cuts to knowledge. However, it is no guarantee of technical ability and many of the most scientific men in the industry started without it. The truly scientific technical man is never through with learning. He is always ready to consider new developments. In this he can be helped by the technical periodicals of which there are several excellent ones in the pulp and paper industry, by meetings of technical associations, etc. The dangerous stage is when a man thinks he knows enough about the industry. Just then someone is sure to get ahead of him. There is always more to learn about any industry, but especially about an industry involving such a variety of sciences as does paper manufacture.

Business sense: Cases where men who are scientific geniuses, and who have had a long experience in practical work, have failed absolutely in running the business end of an industry are too numerous to mention. An ideal superintendent must know something about ordinary business economics. He must realize that the final crucial test of any manufacturing operation is "Does it pay?" A wonderful product is of little practical value if it costs more to make than its sales department can possibly get for it. No one expects a mill superintendent to be a financier or a commercial genius, but he must have a grasp of the ordinary principles of business.

Ability to handle and get on with men: We will have so much to say on this subject later that we will dismiss it here with the comment that it is the most important requirement of all, because if a superintendent's men cannot or will not work with him he is automatically prevented from displaying his other abilities.

Cooperation Among the Employees.

One of the most common causes of imperfect efficiency in pulp and paper manufacturing industries is lack of cooperation between the various departments of the concern. The most frequent cause for this lack of united effort is a too intensified rivalry between the different departments. Rivalry is an impulse that can be utilized to advantage if it can be kept under control. However, this is hard to do. Many superintendents make the mistake of over-encouraging rivalry in order to increase production and lower costs. In the end it does neither. The rivalry grows and in the end is replaced many times by an actual hatred.

Rivalry between departments is detrimental to the success of the mill in many ways. In attempting to cut down costs below those of a rival a foreman may dispense with one or more of his men. His actual output of work may continue up to standard for a short period, but only on account of extra effort forced from the remaining men who soon become dissatisfied either through overwork or sympathy with their former fellow workmen. However, they realize that they are being driven to enable the boss to make a good showing. Dissatisfaction leads either to strikes or to indifferent work.

Foremen often refuse to help each other by lending help or tools in time of trouble. The rivalry between foremen will become so intense that one will delight to see the work of another suffer even if the whole plant is inconvenienced.

Rather than encouraging men to outdo each other it is better to teach that if the whole plant benefits, each man in it benefits and that therefore it is not only right, but good policy, to refrain from doing anything that will cut down general productiveness.

The relationship between men and their bosses plays a large part in the success of the paper mill. Every boss must have the good will of his men. This is true not only of department foremen, but also of the plant superintendent as well. The superintendent is the most important single individual in the personnel of the paper mill. He must keep the mill running as a paying proposition. He must ever be on the watch to reduce unnecessary expenses. He must adjust labor troubles and settle disputes among the men. He represents the owners' interest in the concern. To be successful in all this he must have the hearty cooperation of all the men. This can only be secured in one way. This is by and through the sincere personal regard of his men.

Personal Relations between Superintendent and Men.

No superintendent can direct the operation of a mill with any hope of success if he is disliked by his men. Men will work under a superintendent whom they dislike, if they have to, but they will not give him all of which they are capable. They are bound to relax as soon as they are out of his direct observation. Some superintendents seek to govern the men through fear. Through fear a man may be made to work, but he cannot be made to work efficiently. The very dread which some superintendents inspire in their men causes the men to become nervous and incapable of doing good work. No man knows where the reprimand or sarcasm is going to strike next and suspicion and irritability soon prevails throughout the whole plant.

The superintendent should never misrepresent things. If he makes a promise he should do everything in reason to make good. If he cannot make good he should frankly tell the reason why.

Needless to say, the superintendent who wants the cooperation and respect of his men will have to be sociable and agreeable. This can be done in such a manner by a man of good judgment as not to lose the respect that he also must retain. It is a matter requiring some tact to retain proper respect and yet not to be cold and distant. Men should always be spoken to when they are met during working hours, or on the street, or anywhere else. The writer considers any man who works for him and is honest as a friend and to be treated as such both in and out of the mill. Some superintendents have more capacity than others for remembering names and little things about men, but it is a great help if a superintendent can remember something about each man so it will be evident when he speaks to him that he knows the man as an individual. One man likes to be questioned about his family and another about his garden or some other hobby, and if a man's relatives are ill he likes to have them inquired about. These things are little, but they have a powerful influence on the general atmosphere of a plant. However, unless the superintendent can maintain such relations naturally it is better not to attempt it at all. Insincerity is very apparent to workmen.

A superintendent should always believe what is told him by his men unless he is absolutely sure a man has prevaricated. In other words, a man gets the benefit of the doubt. If it is found that a man cannot be treated in this manner he may be considered a hopeless case and should be dropped out of the organization.

In this day and age men will not stand for bullying. The writer recollects having worked for men whom he constantly feared and could not trust. He never felt sure when he went home at night that he would not return the next day to find his place filled with some other man. It is impossible to do good work for an erratic and overbearing man of this type.

It is also bad policy ever to interfere with foremen. There is nothing a capable man so much resents as to be placed in charge of an operation and then to have the superintendent or manager issue instructions to some man under him. If the superintendent notices something obviously wrong he should go to the foreman, not to one of the workmen. This secures the confidence of both the foreman and the workmen.

The method used by some managers of going to workmen to get posted as to the details of operations is very disorganizing. The men feel that when they have a grievance they must go far up the line, even to the president of the company. They feel that they are getting more credit and it ends in making a mere figure-head of the foreman or superintendent.

A superintendent should discourage the carrying of tales to him by workmen. Men should be given to understand that they must settle all differences calling for adjustment with their immediate superiors.

It is bad to spy over men. It is not only objectionable, but futile. No system of spying could possibly be effective unless it involved much waste of time. Mills have to work nights as well as days and men have to be trusted to do their own work properly.

The writer has known superintendents who have made a practice of spying on their workmen at night, sometimes as late as one or two o'clock in the morning. When anything like that becomes known, the men lose all confidence in their superior and feel that they are branded as dishonest. It is well for a superintendent not to go near the mills at night unless in case of a breakdown or some other exceptional circumstance. If it is necessary to go into the mills at night the workmen should be let know of it in some manner so that they will not think that it is spying.

Bullying, spying and overbearing conduct will make men secretive and much harm may be done in this manner. The writer has seen cases where the men were absolutely afraid to say anything about any accident that happened during the night and would even lie about them because they knew full well beforehand that without regard for the circumstances the superintendent would accuse them of sleeping or loafing on the job. In this way small accidents will stand unreported and may grow into serious matters. If a man feels that he is sure to be discharged or bullied for making a mistake (perhaps a very pardonable and natural one) he will invent some plausible story about it. If, however, conditions were otherwise and he was not afraid to explain about the mistake, the whole matter could be discussed and there would be small chance of that man making the same mistake again.

Development and Training of a Papermaker.

Progress is not quite so difficult nowadays as it was when the writer began his trade. At that time the paper and pulp industries were carefully guarded as more or less secret processes, which was a great handicap to anybody undertaking to learn the business. For instance, the position of machine tender seemed to compare very favorably with the position of locomotive engineer. I mean by this that we had to wait until somebody died or grew too old to run his machine before we ever had an opportunity to be advanced to that position.

From the very beginning, or the bottom round of the ladder, up to the point of being a machine tender, there were all sorts of obstacles in my way. I was obliged to start in the machine room and do all of the dirty work. I lugged the drinking water, did the scrubbing, passed along the monkey wrenches, ran errands, hustled broke, and was not allowed to become too much interested in the skilled part of the work. For instance, if the paper broke on the machine and I asked the machine tender what broke it, he might tell me that the break came from the stuff chest, or it might be the fault of the pump in the basement or some other way of misleading me as to the real cause.

Perhaps this would be a good place right here to say that a young man who starts in to learn the paper business has not necessarily got to commence in the machine room, but without influence it naturally follows that a young man must take a position wherever he can get it, whether he begins at the wood pile and works forward or at the finishing room and works back, or again in the machine room and works both ways. In any event he must cover the ground thoroughly in order to be proficient.

At this time also there were no unions to protect a man from unfair treatment or from ugly and overbearing superintendents. If I were asked to work even 48 hours consecutively without sleep, I did not dare to refuse because it would cost me my job. Today this condition is far different. It is even against the law to compel a man or even to urge him to work beyond the specified hours fixed by legislation. Men nowadays must be treated like human beings.

I worked for at least two years as roustabout, cutter man, third hand, winderman and finally back tender before I could get an opportunity to try my skill at operating a machine, and I would not have had a chance even then, had it not been for the fact that the machine tender wanted to go away on a vacation and there was no one else whom he would trust to take his place while he was gone, except myself. This merely broke the ice for me, but did not put me in more of a hopeful position for getting a machine, because there was still the obstacle of waiting for a dead man's shoes.

There is another phase to the question which has occurred to me repeatedly since I have been in charge of mills, which is that owing to my own experience I have been able to decide with some degree of accuracy as to whether an applicant is fitted for the position which he seeks.

Since pulp and paper manufacturing plants run day and night, it is necessary for one to become accustomed to night work, which is very unnatural. It does not require a stretch of imagination to know that this way of working one week nights and the next week days will upset anybody's system. One cannot sleep in the daytime, nor can he eat rationally at night. It causes an upsetting of one's whole makeup, brings on dyspepsia, insomnia, and various unnatural tired and wornout feelings.

I have frequently had application from college men, young, robust, snappy fellows, who wished to learn the pulp and paper business. They were willing, so they said. to start in at the bottom, in fact they wanted to cover the ground thoroughly, and would take their turn with the rest, but there have been only one or two out of the many men whom I have started who have not fallen by the wayside.

First of all, we get intelligent young men right after their school course, unprepared to stand any of the hard knocks and after having to sacrifice their health in many cases, go without sleep, and perhaps be knocked around, and having their intelligence insulted (so they think) by the rough characters they may come in contact with, they often give up. I mean *rough,* not in the sense that the papermakers themselves are particularly rough but on account of the nature of the work which has to be covered during the man's advancement. There are various other reasons why a young man will drop out during the journey from the bottom round of the ladder to the top.

Very frequently a young married man makes application. He starts in and finally makes the excuse that his wife does not want him to work nights. Then we frequently get young men who have absolutely no mechanical ingenuity or ideas. This condition is really hopeless. It is a well defined fact that it is useless to try to make a farmer out of a mechanic or to put a mechanic behind a plough.

The paper and pulp industry calls for so many branches of work other than the mere matter of making paper that a case of this kind simply wastes the time of the employee and the employer; putting a man in charge of expensive machinery who has no idea of the care of such, is a very costly experiment. The man's judgment never is anywhere near correct and he makes very costly blunders and usually does not succeed after wasting possibly eight or ten years of his life.

Qualifications for Success as a Papermaker.

The young men who start in the business who are most apt to succeed are those who are accustomed to rough and tumble work; have the determination to forge ahead; are not too sensitive as to their associates and are usually the boys who have had even a worse and a harder lot before they started in with the business, together with a natural trend for mechanics. You can imagine a bright, young man, with a college education, who makes a start in the paper business, how humiliated and insignificant he must feel to be ordered around, since he has been accustomed up to that time to polite treatment.

Then there is the intemperate young man. I would rather have a good, willing fellow that is reliable and temperate than to have one of the opposite type who might know very much more about the business. A willingness to obey orders and apply oneself to the learning of the business is a good asset. There is just as much call for good, reliable conscientious and steady men today as there ever was. They have always been at a premium and always will be.

Then there is the disturber, whom we sometimes get into the organization. Their activities in an organization of men are as harmful as a rotten apple in the center of a barrel of good ones. They will do more towards disorganizing a crew of men in one month than can be put right in a year, and then it cannot be made right except when the cause is removed. It is sometimes very hard to single out the person who is spreading unrest and discontent in your organization. These men have a faculty of covering their tracks to a great extent and have caused a great many bad disturbances.

Now some of these causes for disqualification of an employee can be charged directly to the individual himself while others are inborn and cannot be remedied.

Finally the qualifications a man should have who desires to make paper and pulp manufacturing his life profession are:

First—Physical health.

Second—He must be absolutely honest and trustworthy.

Third—Willingness to undergo and put up with the various ordeals he must pass through, as he goes up the line towards promotion.

Fourth—He must have a natural trend toward the business, and be naturally interested in technical and scientific things.

Sixth—He must be a man who has a respect and deep interest for the success of his employer.

Seventh—He must be cooperative.

Eighth—He must be able to stand all of the disappointments and obstacles which he is bound to encounter and be willing to help and assist in any way that he can to further the interest of the company for which he works.

Ninth—He must have stick-to-it-ive-ness and the great desire to learn the business.

Adjustments in Organization.

I call to mind an instance which happened in my own experience where I was eligible to the next position as machine tender, as I was the oldest employee in that department. I had been promised by the superintendent that I could be assured of the next place. After some time a vacancy occurred on one of the machines. I was perfectly sure that I would be given this position, but to my chagrin and disappointment the superintendent put his own son over my head, into the position that I thought rightfully belonged to me, as I had the superintendent's word of honor that I would get this position. I, of course, immediately quit, and by doing so, I lost ground. This display of temper and haste, without taking second thought, cost me at least one whole year of experience. This was one of the number of disappointments which a young man must put up with, as I saw later. If I had stayed I would not have lost my year's experience and would have been installed as machine tender before the year was out. I speak of this fact because I run across these conditions every day.

There is always an easy way to smooth out misunderstandings and difficulties, and there is a hard and rough way. I am satisfied that one cannot unravel and smooth out a misunderstanding with men by bullying or insulting methods.

After organization is formed and things are running smoothly there may occur a vacancy. It may be the foreman for the yard operations; it may be foreman for the sawmill department, or some place where a man must have charge of a number of men. It will readily be seen that it is a difficult job which requires a great deal of careful study and observation to go into a crew of workmen and select a foreman to take a position as just described. A man may be perfectly competent to handle the job; he may say that he can get along with men; I may give him a position. The first thing I know some of his help come into the office with a story concerning his unjust treatment.

Some men, as soon as they are advanced a few steps, get so overbearing and feel that they are so much better than the men who work under them, that it is quite impossible to get along peaceably; they become arrogant, and overbearing and actually spoil their prospects for any position of trust or responsibility.

Every man must be capable of his job, from the superintendent to the broke hustler. The superintendent who does not know how to handle men cannot hope for success. Besides a thorough knowledge of papermaking, he must have tact and foresight, prudence and judgment. This is true of the foreman also. Every man in the plant must have a thorough knowledge of his job and he must be physically able to perform its duties. If through deficient knowledge or physical incapacity a man depends upon others to help him perform his duties, somebody's work is bound to suffer and the efficiency of the mill is consequently lowered. No man should be called upon to do work of which he is incapable. He may attempt it, he may almost succeed, but in the end his attempt will prove a decrease in the mill efficiency.

The working conditions of the mill must be favorable in order to keep the personnel up to standard. The truly efficient workman will not work in a mill which does not meet the conditions to which he has been accustomed in other mills. The men all appreciate the little consideration which their employers grant them and more than repay the small cost by their greater efficiency in the work. To sum up—each man in the paper mill's personnel must be a man capable of his job, a man satisfied with his job, a man loyal to his job.

Machine Tender.

The machine tender is responsible for the operation of his machine and the quality of the paper turned out by it. He directs the work of the back tender, third hand and other machine help, although the more detailed supervision of these men is largely in charge of his assistant, the back tender.

The machine tender should encourage the back tender to observe his manner of tending the machine so that he—the back tender—can assume those duties whenever occasion may so demand.

The machine tender is responsible for starting the machine. His immediate concern is the wire, which must be free from slime and otherwise ready for the stock to flow onto it. When the machine tender is perfectly sure that the wire is in proper condition he begins furnishing up the vats, screens, pump box, head box, save-alls, etc. He checks the consistency of the stock and is in close touch with the men in charge of the Jordans and with the beater room.

It is his function to decide when the stock is to be allowed to flow onto the wire. From that point on the back tender carries the paper through the presses and over the dryers. While this is being done the machine tender inspects the screens, suction boxes, deckle straps, couch roll and presses and other parts of the wet end and takes particular notice whether his sheet is level or not, which can be especially well noted at the couch roll, and makes whatever minor adjustments may be necessary. He is guided in this by the weigh sheet which the back tender tears off, weighs and brings to him as soon as the dry paper is going through the calenders. When this is all done, and everything at the wet end is running smoothly he should take a general look over the dry end to see everything is all right.

The Back Tender.

The back tender is to the machine tender what the first mate is to the captain of a vessel. He is largely responsible for the third hand and other help around the machine. By devoting proper time and attention to the training of these men so that he can rely on them to accomplish their work in a quiet, efficient manner without constant directions being shouted to them, he can leave just that much time and attention free for acquiring the further knowledge that will be necessary before he can aspire to the position of machine tender.

Similarly, the more the back tender can devote his time to routine matters and the supervision of the other help, the more time the machine tender can give to inspecting the machine and seeing that everything is in the best working condition, determining the cause of irregularities, etc.

The chief responsibility devolves on the back tender in connection with breaks. He must see that the other help are in their proper places to take the paper after he personally has passed it over the dryers, etc. During wash-ups the back tender should be responsible for the washing of the felt, being assisted by the other help, and the machine tender being free to look after the wire, etc.

When starting the machine, after the machine tender has let the stock flow onto the wire the back tender takes the sheet through the presses and over the dryers, watching to see that the dryers are hot enough to thoroughly dry the sheet before it is led through the calender stack. The third hand should be allowed to perform this work from time to time under the direct supervision of the back tender, who should take care to see that he does not do it in such a manner that his hand is in danger of getting caught in the presses or dryers.

If the dryers are working properly, the back tender next runs the sheet through the calender stack or stacks making sure that the doctors are clean so as to prevent calender spots, and seeing that the calender is properly lubricated so that there is no slacking back, which is the chief cause of calender cuts, one of the most objectionable defects in paper.

It is also his duty to see that the paper is going over from the calenders to the reel properly so as not to cause rolls with hard and soft spots on the reel. We have already spoken of the harm this does in the chapter on the finishing room. In this he is largely dependent on the efficiency of his third hand.

The back tender should see that the floor around the machine is kept in an orderly manner and not encumbered with broke, spears, tools or rubbish or sloppy with stocks, etc. An untidy floor has been the cause of many an accident.

All the time the back tender should be learning as much as possible of the machine tender's art and should be teaching his own to the third hand. In this way he is preparing himself for advancement and training a man to take his own place.

The back tender needs to be a man of resourcefulness and able to think quickly in an emergency. It is a responsible position, but one full of opportunity for usefulness and for future advancement.

Third Hand.

Just as the back tender is an understudy for the machine tender, so is the third hand an understudy for the back tender, that is, he should be if he is ambitious and capable. The third hand should assist the back tender and machine tender generally in washing up and in renewing felts, wires and jackets. By so doing he will learn much about the duties of the men immediately above him.

Making splices at places indicated by the back tender is a job usually relegated to the third hand, and it is a very important job from the point of view of the company's customers. Crushes, calender spots, slime spots, etc., have to be cut out and a neat splice made and a flag inserted in the roll to mark the location of the splice.

The third hand is usually charged with responsibility for the reels, winders and slitters, and in the absence of other duties that is his normal position to be ready to take over the paper from the calenders.

The third hand's prospects for advancement are largely dependent on his avidity for work. It depends on the man himself whether he will be looking for opportunity and always finding some way of being useful to the machine tender and back tender, or whether he will merely do what is absolutely demanded of him.

Beaterman.

The position of beaterman is a very responsible one in all mills, and one where a great deal of science can be applied if the man will take the trouble to learn from observation. He should see that color, size, and alum are added in the proper order, and at sufficient intervals of time for the best results to be obtained, not all dumped in so as to get the work done as soon as possible. He should supervise the furnishing of lap stock, seeing that the beater help open out the laps properly and that the roll does not jump as the laps go under. He is responsible for the condition of the roll and bed-plate, the keeping of the beater in a clean condition (free from slime, etc.) and the entire conduct of the operation. Therefore he must watch the appearance and feel of the stock most carefully, regulating the roll as may be necessary to secure the proper result, in accordance with the general instructions of the superintendent, and his own judgment.

Industrial Bureau.

The past few years have brought forth the need of maintaining within the pulp and paper manufacturing concern a department to look after the welfare of the employees and to serve as a medium between the management heads and the employees themselves. The problem, however, is to decide just how far to go with this sort of work. For instance it is reasonable to suppose that a company employing from 300 to 500 or possibly 1,000 men on the payroll can not afford to go into this as deeply as concerns employing 20,000 or more and incidently using men speaking several languages. Such a department is usually termed an Industrial or Employment Bureau.

Regardless of how large the personnel of the Bureau may be the following two main divisions of activity must be kept in mind:

1. Getting Workers; 2. Keeping Workers.

Getting workers necessarily includes the following:

1. Getting applicants from among whom to select the workers. 2. Interviewing, selecting, examining and investigating the applicants. 3. Developing labor sources from within the plants.

The above, of course, furnishes but a very much simplified sketch of what the work of this first division might consist of.

Keeping workers might include some of the following ideas:

1. Accurate enrollment details; 2. Intelligent introduction of workers to the conditions of employment to their supervisors; 3. Analyses of enrollment of details—age, sex, nationality, intelligence and experience; special qualifications, kind of work at which started; supervision, rate, hours, physical conditions peculiar to the individual; 4. Quiet and tactful follow-up of every new employee to determine the accuracy of placement, satisfaction with work, attitude of co-workers; 5. Familiarity with progress of every employee through watching records of attendance, production, wages, transfers and suggestions offered; 6. Investigation of reports of dissatisfaction.

In order to carry out the above work the Chief of this Industrial Bureau, that he may carry his work out both for the benefit of the organization that he represents and the employees themselves, must be acquainted with the following details:

1. General policies and supervising personnel of the industry and physical working conditions; 2. Conditions, hours and rates of neighboring and competing industries; 3. The number and kind of workers needed

by the industry; 4. Kind of work to be done; 5. Conditions of work; 6. Hours, regularity and permanency of work; 7. Kind, amount and frequency of reward.

In the present stage of agitation it has become quite necessary to employ such a medium for watching the hiring of men. In large corporations where the hiring lies entirely in the hands of numerous foremen, graft, favoritism and autocratic power often result and men discharged in

Form 690-B

APPLICATION FOR EMPLOYMENT No. ....

WITH

Note—Application for employment must be made out and signed personally by applicant in ink. Each question must be answered in full.

Name in full (no initials) .... Married or single? .... White or colored? ....

Address: Street and Number .... City or Town .... State ....

Position desired .... Wages expected per Hr. / Wk. .... Could report for work .... days after engagement

Date of Birth .... Year .... Height .... Weight .... Lbs.

Birthplace: City or Town .... State or Country .... Have you been naturalized? .... Date ....

What languages do you speak? .... Have lived in United States .... years

Grammar School attended .... No. of years .... Year of graduation ....

High School attended .... No. of years .... Year of graduation ....

Technical School attended .... No. of years .... Year of graduation .... Degree ....

Give below four employers to whom we can refer. (Read note at bottom of this blank.)

Time Employed (Give Month & Year)	Name and address of Employer	Name of Foreman	Kind of Work Done	Wages Received	Reason for Leaving
From	Name			$	
To present date	Address			Per	
From	Name			$	
To	Address			Per	
From	Name			$	
To	Address			Per	
From	Name			$	
To	Address			Per	

Were you ever employed by this Company? .... If so, where and when? ....

Give names of your relatives in this Company's employ ....

State condition of your health .... Have you any chronic ailment? ....

Are you ruptured? .... Have you ever had tuberculosis? .... Fits or epilepsy? .... Rheumatism? ....

Explain fully your defects in sight, speech, hearing or limb ....

Give below: Full Names of living Relatives and their Home Addresses

Wife or Husband ....

Children ....

Father ....

Mother ....

Grandparents ....

Brothers ....

Sisters ....

In case of my illness, etc., notify ....

I certify that my answers to the above questions are true, and I also agree that said questions and answers shall form the basis of my employment.

Date .... 192 Telephone No. .... Sign here ☞ ....

FIG. 254.

one department for being agitators may be promptly picked up by another foreman who may at the time be short of help. Few manufacturers have a really efficient Employment Department. The old system of letting the foreman hire men regardless of experience and qualifications is, and always will be, a big expense as well as the least efficient way of securing productive labor. The management that permits the old system to continue either through ignorance or fear gives no attention to working conditions of the employees, the very backbone of the industry, and the employees continue to growl and agitate trouble at the smallest disturbance. Before installing a system of this nature the writer encountered these difficulties daily. Oftentimes men fired in one department for being radical agitators have in a short time returned to be hired by another foreman, unknowingly, of course, as he had no adequate means for investigating the past of this particular workman. Frequently problems dealing with the welfare and betterment work and industrial education are handled by the same bureau.

SMITH & JONES PAPER CO.

....
(Place & Date)

....

....

Dear Sir:

... .of..............................

applicant for a position with us as...... ....
has given your name as a reference, and claims to have been employed by you

As.................... FROM.................... TO ....

RATE .... CHECK NO..........................

....DEPT. FOREMAN....................

USING REVERSE SIDE, kindly advise if information given above is correct and whether you can recommend the applicant as to ability, character and disposition. Any further information will be appreciated and treated as confidential.

Very truly yours,

....

....

I authorize you to furnish the information requested.

....
Signature of Applicant

....
Witness

FIG. 255.

As previously stated it is often a hard question to decide just what the powers of this department are to be—whether the employment manager will have the sole right to select, hire or fire workers; whether the foremen can have the right to decline to accept workers selected by the employment department; whether the rights of transfer should lie in the hands of the foremen or the employment bureau.

The powers of such a department are, therefore, largely dependent upon the nature of the plant—in specialized work with a tightly woven working organization these powers might lie entirely in the hands of the Industrial Bureau with advantage to all parties concerned. In organizations, however, where operations are widely diffused and varied, as is the case in most pulp and paper mills, it is best to adopt an intermediate plan. One organization employing 1,500 men has an Industrial Bureau consisting of a Chief and two alert assistants. The forms adopted and the powers of this department will be briefly touched upon.

SUPERINTENDENT'S NOTICE OF REGISTRATION

______________ 192

Mr. ______________ Sup't ______________ Mill

Mr. ______________ No. ______________

has registered with the Industrial Bureau.

Signed ______________
Industrial Bureau

FIG. 256.

Figure 254 shows a usual form of employment blank. All men seeking positions, no matter to whom they apply, are directed to the Industrial Bureau where they are interviewed by the Chief of the Bureau. The applicants are then requested to fill out this application form which is by no means elaborate and cumbersome and contains all the data essential for the purpose. In conjunction with this form is used a follow-up slip on each applicant to verify the statements made by the applicant by writing to his former employers. This form is illustrated by Figure 255.

SUPERINTENDENT'S ENGAGEMENT CARD

To Paymaster ______________

Name ______________ Card No. ______________

Local Address ______________

Date Engaged ______________ As ______________

For DEP'T ______________

Rate ______________ Week Per Hour ______________

Old No. ______ Signature of Employee ______________

Reason ______________

Approved Reported for Week

______________ Sup't ______ M. ______________ 192

Approved by General Superintendent ______________

FIG. 257.

Each morning all Superintendents demanding help, call the Industrial Bureau stating the type of man wanted and nature of jobs. The Chief of the Bureau then looks over his files containing the waiting lists and selects the men suitable for the jobs in question. This man then reports to the Bureau and is given a slip illustrated in Figure 256. Also, if the Mill Superintendent has the right to pick out a man, he is furnished with the form shown by Figure 257. The man with this form must report to the Industrial Bureau, where he will properly enroll and then report to his Superintendent.

The man then reports to the Superintendent who generally accepts him. If he has any reasons for not accepting the man he has the right to reject him but must first state his reasons for so doing.

DEPARTMENT TRANSFER

To Paymaster: 192

Name .... No. ......

Local Address .... Place of Birth .... Age ......

Was transferred this day from .... Department

to .... Department to be Employed

as .... at rate of ...... per ......

Present Rate .... Present Occupation ....

Approved

.... General Superintendent .... Industrial Bureau

Reported for work this day at ...... M. New No. ......

Date .... 192 .... Foreman

FIG. 258.

We now have the man installed on the payroll. It is the duty of the Chief of the Industrial Bureau to see that the man is content with his job. Special provisions are made to educate the foreigners in elementary English. The application of efficiency on record system has a gratifying effect on the workers when properly applied. It minimizes the opportunities for display of favoritism, a practice that is often abused by foremen

INDUSTRIAL BUREAU

.... 192

Name .... No. ......

ReRated .... 192 ......

New Rate .... Per Hour ......

Old Rate .... Per Hour ......

Explanation ....

.... Mill, Factory—Department ....

.... Superintendent

Approved: .... General Superintendent

FIG. 259.

in positions where they can recommend wage increases. It places all the employees on an equal basis, as far as opportunities for increase are concerned, and it puts the wage increase problem squarely up to the workers. By this means and others for keeping in close touch with the workmen, the highest type of efficiency can be obtained; for it is only when working under such favorable conditions that the ordinary worker can put heart and soul into his work. The neglected worker usually becomes indifferent, drifts or stays in a rut. Welfare work with the intention of improving the home life of the worker will often bring an improved state of affairs. One of the most practical ways to supplant an employee's indifference with inter-

REMOVAL FROM PAYROLL

TO PAYMASTER: 192

Please Pay .... No. ....

Occupation .... In full to and including 192

(To be filled out by Paymaster)	AMOUNT		
Week ending........			Has all Co. property been surrended? ....
Week ending			Foreman must fill out Green copy of this blank and send same promptly to Industrial Service Department.
Paid on Acc't			
Net Am't Due........			

Checked by ....

Approved: Signed

....

FIG. 260.

est and enthusiasm is to permit him to buy stock of the company. There are various ways of selling the stock, such as the installment plan, or by organizing saving funds which will be used to buy stock as soon as they have reached a high enough mark.

By following out such methods the man takes an interest and works for the benefit of the company, and under most conditions will soon be ready for a transfer or promotion. In such an event the mill superin-

REMOVAL RECORD—[Confidential]

To Industrial Service Department: 192

Name .... No. ....

Occupation .... In full to and including 192

Discharged-Dropped-Suspended-Left .... 192. .... Dep't
(Cross out words not used)

Nationality .... Age ....

Reason [In full] ....

....

[1] Do you expect to reinstate? .... [2] Ability ....

[3] Character? .... [4] Deportment? ....

[5] Would you re-employ in your Dep't? .... [6] Do you think it advisable to re-employ elsewhere? .... [7] Industrious? ....

[8] Satisfied with shop conditions and pay? ....

Approved: Signed

.... Sup't

FIG. 261.

tendent (in conjunction with the Industrial Bureau) arranges a transfer for this man to a better job, in which case the form represented by Figure 258 is made out and filed, copies going to both the paymaster and the Industrial Bureau. If it is purely a matter of re-rating, a card such as Figure 259 is filed in the two departments.

ABSENTEE REPORT

Mr.____________________ Dep't______________ Date______________192

Please report the following Absences and return to the Industrial Bureau at once

Employee Number	NAME	Excused	Not Excused	Absence Satisfactory	Absence Not Satisfactory	REMARKS

FIG. 262.

INDUSTRIAL BUREAU

—Week Ending____________________

	Penimore Sulphite	Penimore Paper	Allen Paper	Allen Pulp	Allen Finishing	Paper Handlers	Stock Handlers	Bag Factory	Cartage Barn	Power House	R. & E.	No. 5 Paper	No. 1 Pulp	Store	G. Expense		TOTAL
1—Average No. on Roll																	
2—Total Exits																	
3—Total Entrances																	
4—Transfers																	
5—Change Rate (Increase)																	
6—Change Rate (Decrease)																	
7—Applications																	
8—Absences Investigated																	
9—Absences Without Notice																	
10—Laid Off, No Work																	
11—Released																	
12—Accidents																	
13—Hours Lost, Account Accidents																	

Notes:

____

Industrial Bureau

____

FIG. 263.

If under these conditions of good protection by the Industrial Bureau, a man fails to qualify for his position, shows a tendency to be an agitator, then he is discharged. He is given Figure 260, properly filled out, and submits same to the paymaster, who then pays the man in full. At the same time Figure 261, properly filled out, is filed by the Industrial Bureau for further reference on the adaptability of the worker. This form, as indicated, is of a confidential nature.

In the event of a man wishing to leave for good reasons—not dissatisfaction—the above forms are also made out as in any other instance.

In order that the Industrial Bureau may be able to obtain further statistics for compiling charts, the form shown in Figure 262 is made out daily by the clerks of each respective mill.

EMPLOYMENT BUREAU

Name:

Began	Clock No.	Rate	Dept.	Work	Date			Reason
					Transfer'd	Rate Changed	Released	

FIG. 264.

At the end of each week the Industrial Bureau hands to the management the form shown in Figure 263 containing a generalized summary of the data obtained by them during the week. This form enables one to trace the labor conditions throughout the plant, and any radical changes can be immediately spotted and taken care of. From this data the Industrial Bureau graphically shows the labor maintenance and turnover figures for various periods.

All of these various forms are kept in a neatly arranged folder so that all statistics relative to one man are always available and easily found when properly filed. The face of this folder is represented by Figure 264.

Labor Turnover.

Labor turnover is the result of many causes, dissatisfaction of the employee, inefficiency of the employee, activities of agitators, etc.

This turnover measured in dollars is generally estimated from $25 to $150 per employee measured by the following:

1. Placing of employees in departments where they are not adapted to the nature of the work.

2. Decreased production while learning.
3. Cost of time involved while teaching the new operator.
4. Breakage and spillage of material and machines as a result of inexperience on the part of the operator.

In studying this proportion of labor turnover, we find several important factors. These have developed much discussion among those who have studied this problem. The students of the question may be divided into four principal groups:

1. Those who use terminations as a basis for figuring labor.
2. Those who use replacements as a basis.
3. Those who use payroll figures.
4. Those who use attendance figures.

From the above the only conclusion apparent is that no definite formula has yet been established by any standard committee for computing this labor turnover. Moreover all the various applications have their merits and demerits.

Talbot has devised a method which he terms Labor Maintenance. Briefly stated we record:

Annual growth.
Periodic growth.
Specific growth.

Annual growth requires additions to the working force to be retained indefinitely. Periodic growth needs added workers at the beginning of the busy season to be laid off later at its close. Specific growth also requires temporary help.

The accompanying chart, Figure 265, shows such conditions as related above. In the background are sketched the numbers of persons at work week by week. At the base above the zero line, are sketched in solid lines the number of men taken on, and below the zero line, also in solid lines, are sketched the number of men let out. To gain a fairly accurate conception of change of personnel throughout other divisions of the same organization, similar charts should be for each. Charts of this nature made in a continuous sequence prove almost invaluable in tracing the growth or decline of each main department, in that they present the annual growth, seasonal fluctuations, and also demonstrate clearly the unnecessary changes taking place during the height of production.

This form is made out weekly and filed in the Industrial Bureau and serves as a guide or check to the form which we will now describe, which is placed monthly on the desk of the chief executive of the company. Unlike the chart mentioned this form, Figure 266, is a summarized account for all departments for a period of one month. In this form several main features are brought out:

1. Average number on payroll.
2. Fluctuation factor.
3. Per cent turnover.

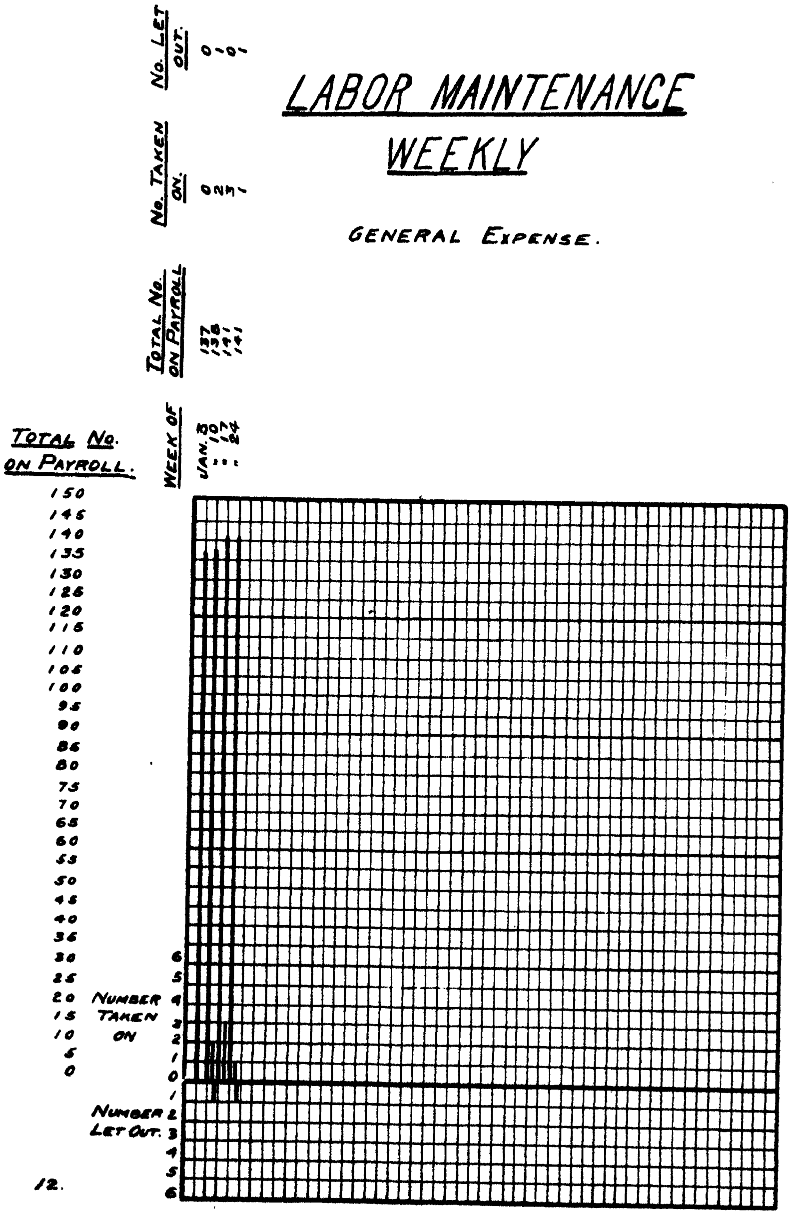

LABOR MAINTENANCE
WEEKLY
GENERAL EXPENSE.
No. LET OUT.
No. TAKEN ON.
TOTAL No. ON PAYROLL
WEEK OF
JAN. 3
10
17
24
137
138
141
141
TOTAL No. ON PAYROLL.
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
NUMBER TAKEN ON
NUMBER LET OUT.
12.

Fig. 265.

Item one, the average number of men on the payroll is self-explanatory.

Item two, the fluctuation factor, shows the rise or decrease in the personnel of each department. For example: referring to form 228, using the first notation "total of all mills," we have the following statistics obtained from the Industrial Bureau:

Average Number on Payroll, 1,234.

Total taken in, 78.

Total let out, 55.

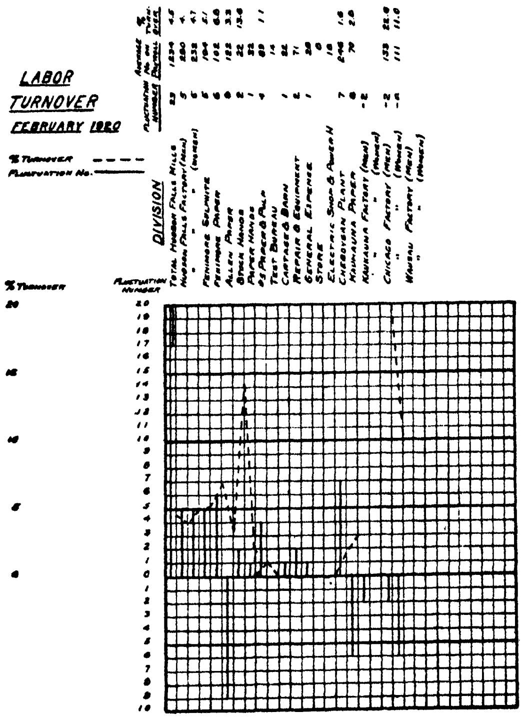


FIG. 266.

In this particular instance we have 78 men taken on and 55 men let out, showing 55 complete cycles. It is this factor, and the average number on the payroll, that we use as a basis for figuring the percentage turnover. The difference between numbers taken on and number let out we designate as the "Fluctuation Factor," in the case it is positive—23 men. These facts are then plotted on Form 266—the heavy black line indicating the Fluctuation Factor, and the dotted line the percentage Labor Turnover. By means of such a form the executive at a glance can trace the labor conditions throughout the plant. In the event that the turnover is relatively high, he looks up the report form shown in Figure 265, in order to find out just what trend affairs have taken.

The above forms are open to criticism, like all other forms that are in use, but for this particular line of work they have shown themselves to be useful and valuable to the executive.

Graphic Reports.[1]

The present managers of corporations, mostly men who have risen through the ranks and have become thoroughly familiar to the relationships that one department bears to another, have an enormous task that daily confronts them. Important decisions must oftentimes be made at a moment's notice, without opportunity or time, for a voluminous amount of correspondence and calculation. As a result, graphic records have become generally adopted as a proper medium for the quick presentation of facts in nearly all large industries. There are many forms and appliances for the presentation of these facts, almost all of which are applicable to any industry, according to what the management may desire.

To the trained mind, the analytical mind, these graphic charts, when properly and honestly compiled, furnish a medium whereby he develops himself at the same time that his job is growing bigger. He need not spend or waste time looking over a group of figures but he has presented to him a picture of what he wishes to see. It may be only a line, it may be a group of lines, or it may be a series of images, but in all instances there is some one feature made a pronounced factor, enabling him to grasp the trend of affairs in the space of a few minutes of time. This visual picture becomes a fixed factor in the mind of that executive, whereas the group of figures would soon fade into oblivion.

If from the above it is seen that charts help to visualize the trend of affairs, that they tend to fix facts in the mind of the individual, and moreover do not necessitate the expenditure of a large amount of money, then it certainly seems logical that charts are worth while. Even if the executive is not of the analytical mind, then it is to his advantage that he adopt this comparatively easy method for the presentation of facts. These charts may be made flexible, covering many operations over an unlimited period. Direct and indirect labor costs can be traced with production and estimated sales; costs of running various departments from year to year showing seasonal fluctuations; comparative quality of various articles; departmental facts; sales, etc. All of these facts regardless of the nature of the business can be made in a presentable form.

This work should be in charge of a conscientious and reliable man (not necessarily a technical man), for once the system has been put in operation the work is quite elementary. The facts, however, must be honestly presented or otherwise the work is detrimental to the executive. It is the function of this man to collect for the business all the data and facts which would be of any assistance to the executive, the officers and department heads. A concern doing a business of $1,000,000 per year or over should

[1] For more detailed information on this subject consult: Riggleman and Rorty, "Graphic Methods for Presenting Business Statistics." McGraw-Hill, New York, 1926.

have a large room for the doing of such work. It should be called the Record Room, and be an adjunct to the Manager, giving him all the data

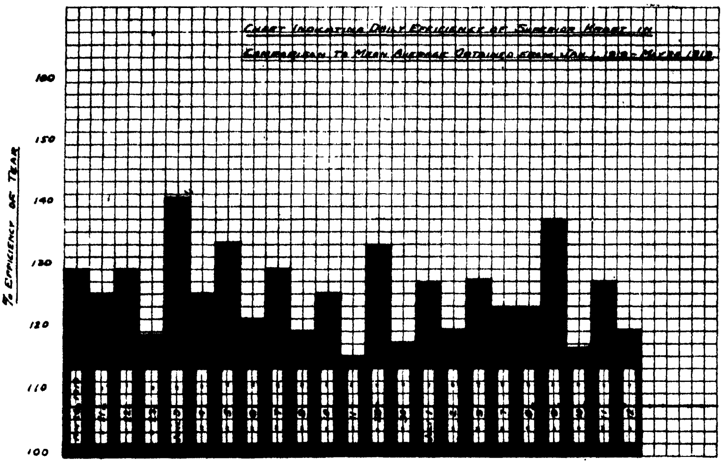


FIG. 267.

portraying the running conditions for which he is responsible. Definite rules should be made that originals should not be taken from the record room, but duplicates or blue prints should be obtainable. Only by follow-

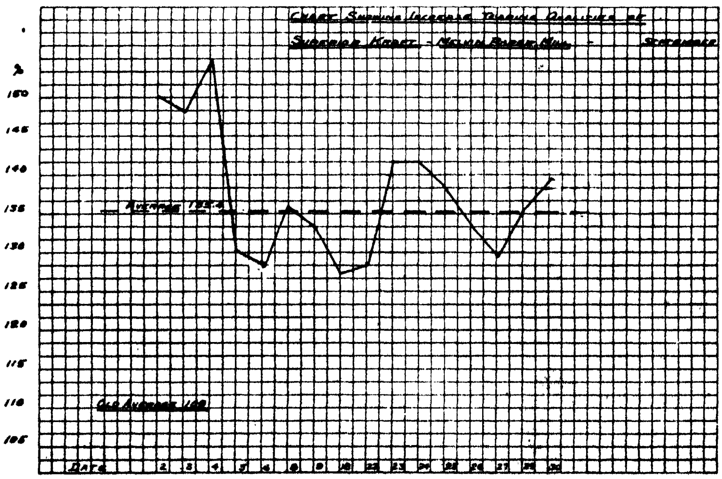


FIG. 268.

ing that rule will the system prove its worth. Of course, it is needless to say that adequate facilities must be given for filing of the completed charts. This room should be accessible to all department heads and those immediately connected with the various operations, in order that they may keep in touch with affairs and thereby realize the advantages of such a system.

The nature of the data that can be compiled in this chart form is of course dependent upon the industry, its size, and the financial backing of the Manager or President. In operations covering the manufacture of paper we have adopted several forms, some of which illustrate but one fact, others covering a period of one week, others monthly, etc.

First of all let us consider charts illustrating tests on quality of paper between various grades in some instances, and also variations from day to day on the same grade.

Figure 267 illustrates the fluctuation in quality of a standard grade of paper. This chart is made out on a bar principle, and the various heights of column readily visualize for the observer just how that particular grade of paper has been running from time to time.

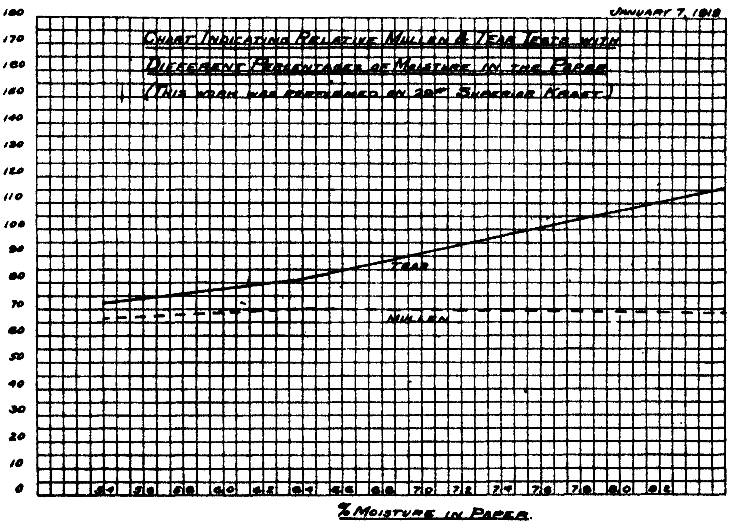


FIG. 269.

Figure 268 is a chart illustrating the same facts, but by the use of a single line, instead of a series of bars. This, of course, consumes less time in the making but it is generally conceded by those who make use of such charts that the bar principle is better, where but one factor is being indicated.

Figure 269 involves two factors illustrating the influence of moisture in a sheet of paper, where the tearing resistance of the paper is emphasized. In this chart we have two lines, one for tear, and the other for the Mullen test plotted by means of two factors, one the moisture contained in the sheet of paper, and the other, the values of the two tests, Tear and Mullen, each taken individually. At a glance an operator can ascertain the relative importance of moisture in a sheet of paper by noting the rise of the tear line, with increased moisture content contained in the sheet.

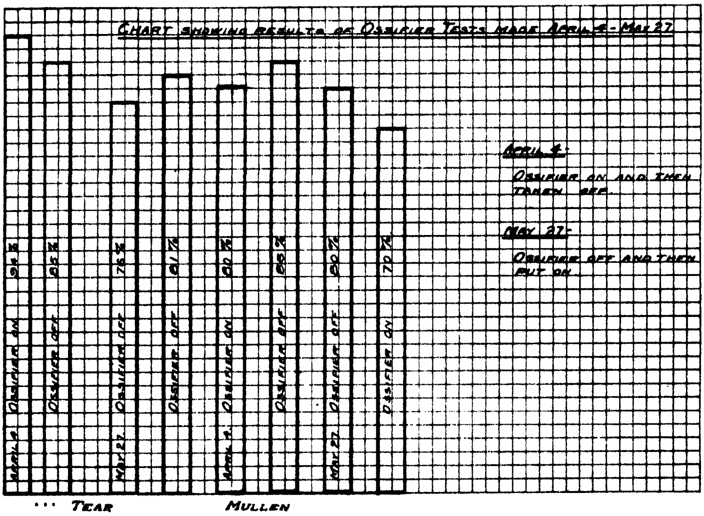


Fig. 270.

Figure 270, like Figure 269, illustrates two varying factors but presented in the form of bars. The choice between these two different forms must be left to the preference of the executive.

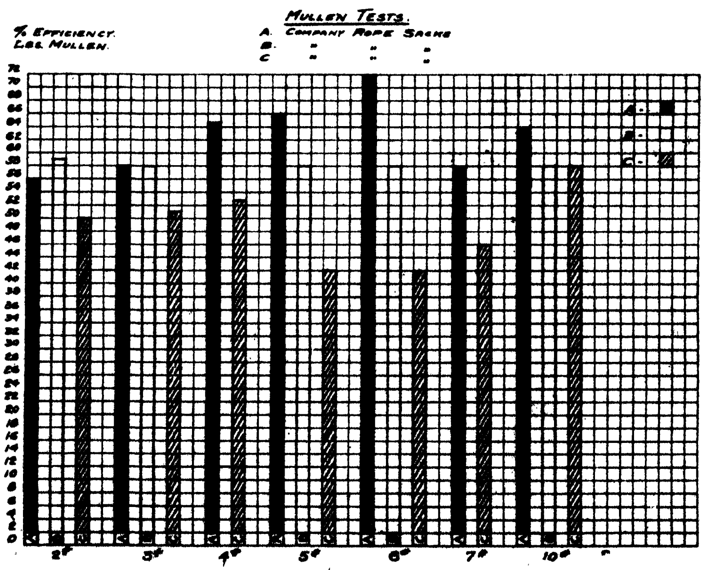


Fig. 271.

Figure 271 shows the comparative rating of different sizes for three different manufacturers. The bar principle here is undoubtedly the best

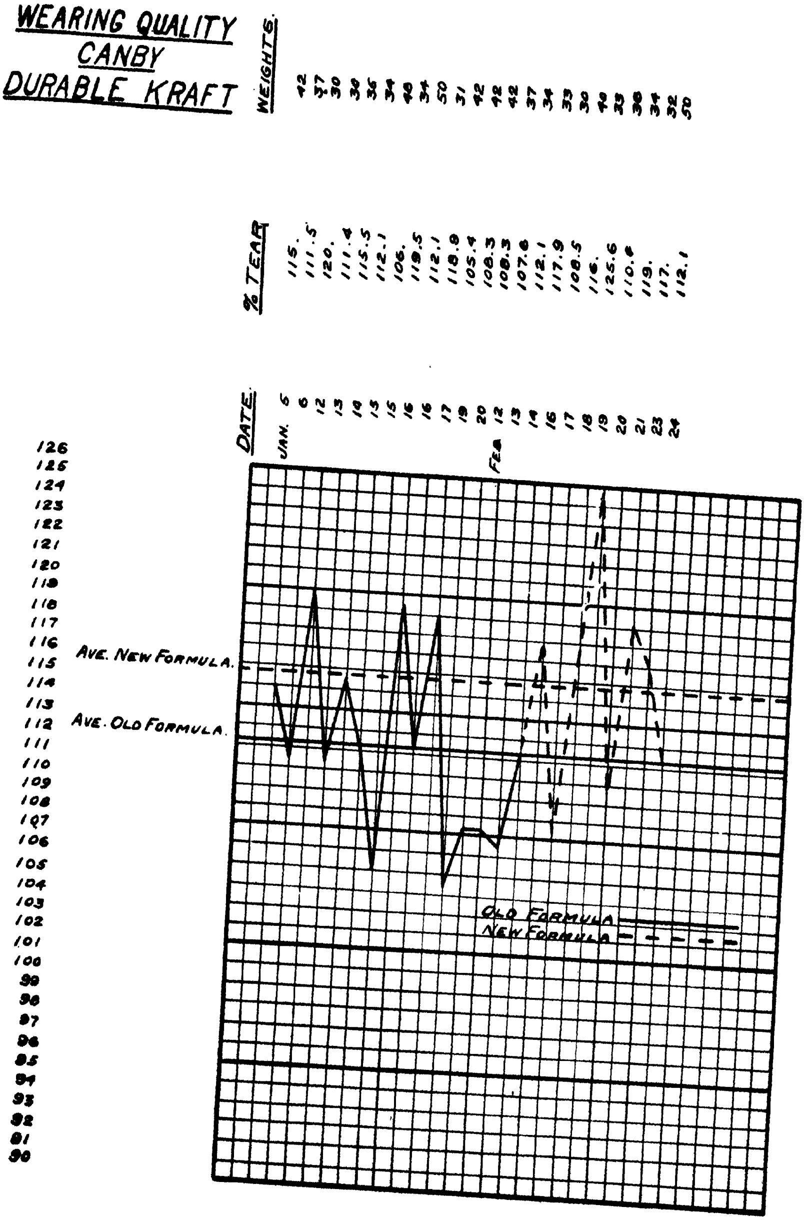

WEARING QUALITY
CANBY
DURABLE KRAFT
WEIGHTS.
42 37 30 36 36 34 46 34 50 31 42 42 42 37 34 33 30 46 33 36 34 32 50
% TEAR
115. 111.5 120. 111.4 115.5 112.1 106. 119.5 112.1 118.9 105.4 108.3 108.3 107.6 112.1 117.9 108.5 116. 125.6 110.6 119. 117. 112.1
DATE.
JAN. 6 6 12 13 14 15 15 16 16 17 19 20
FEB. 12 13 14 16 17 18 19 20 21 23 24
AVE. NEW FORMULA.
AVE. OLD FORMULA.
OLD FORMULA
NEW FORMULA

Fig. 272.

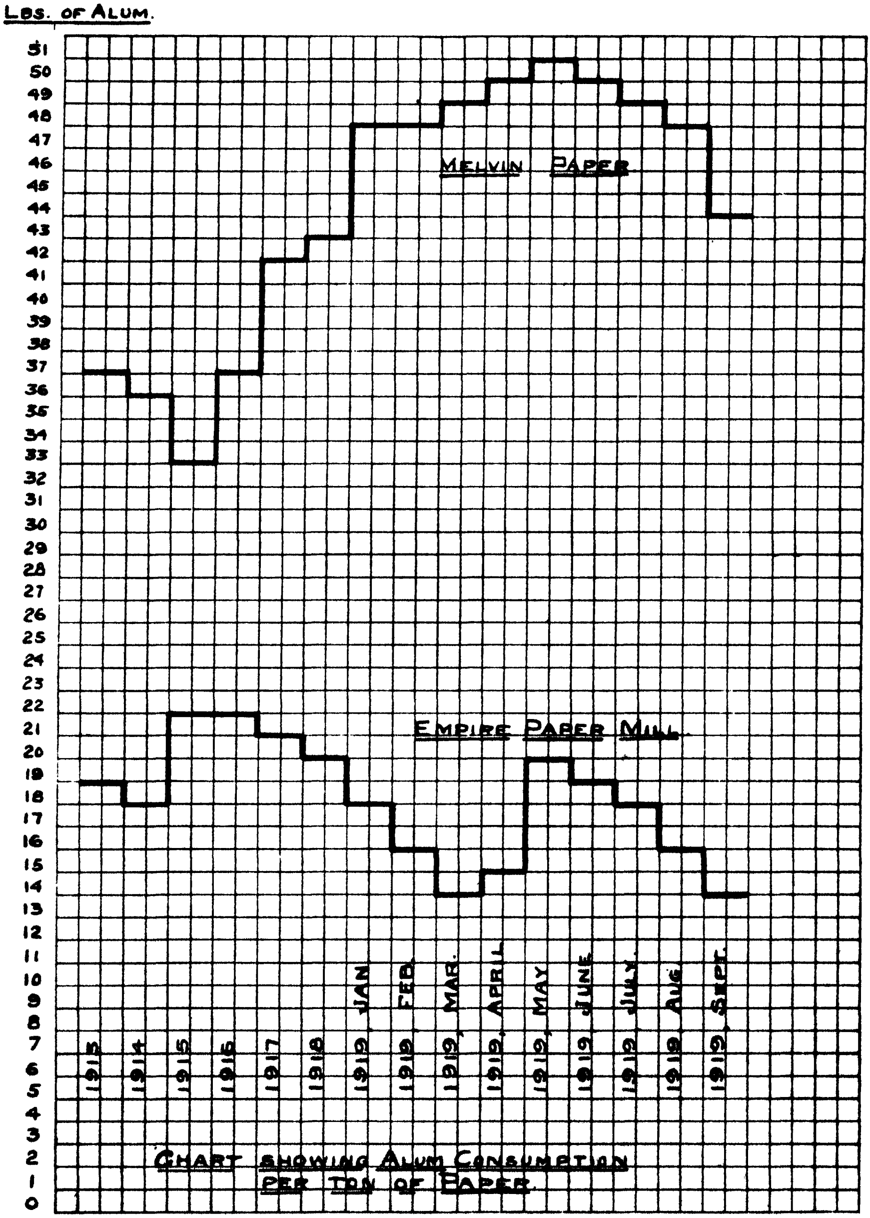

LBS. OF ALUM.
MELVIN PAPER
EMPIRE PAPER MILL
1913
1914
1915
1916
1917
1918
1919 JAN
1919 FEB
1919 MAR.
1919 APRIL
1919 MAY
1919 JUNE
1919 JULY
1919 AUG.
1919 SEPT.
CHART SHOWING ALUM CONSUMPTION PER TON OF PAPER.

FIG. 273.

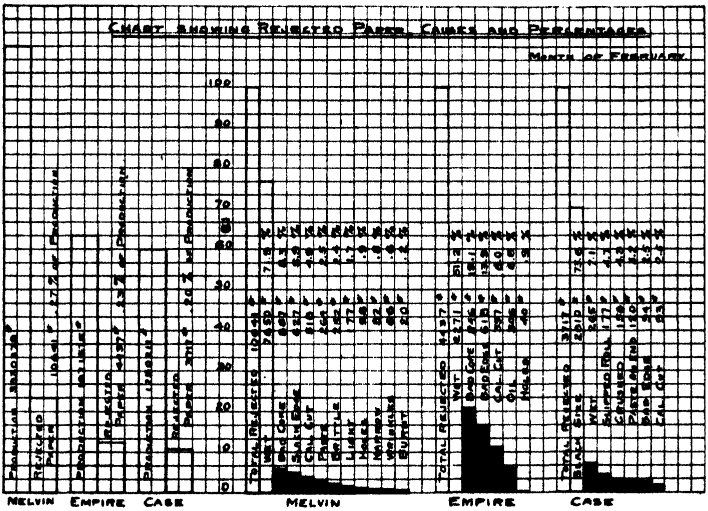


FIG. 274.

presentable form, for here we have each distinct group of sizes separated, with the varying heights of columns, plainly discernible to the observer.

Figure 272 presents a type already described but upon a different form of chart. This form is quite valuable and has found a wide application

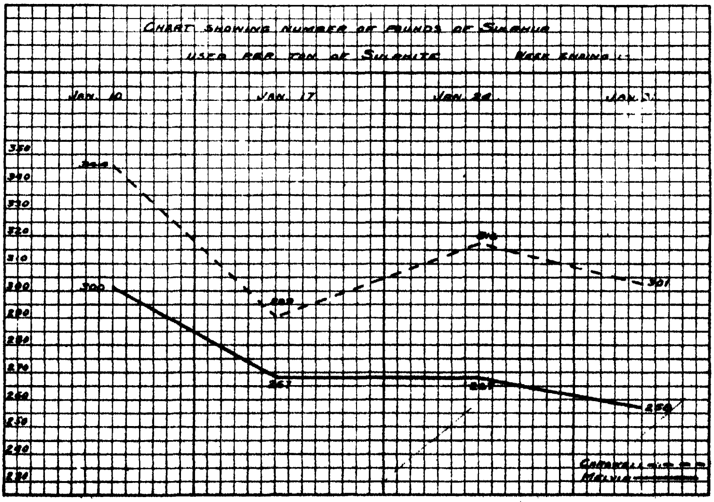


FIG. 275.

which will be described later when costs are taken up. On this form of chart not only a graphic form can be presented but actual figures can be neatly typewritten in, thereby indicating all the data, a picture and figures at the same time.

Figure 273 is an interesting chart showing the increased amount of alum at one mill as compared with another on a monthly basis covering a combination of years and months. This chart is interesting in that these two mills make practically the same grades of paper. A superintendent receiving such a graphic analysis will readily see that something is wrong and will proceed to correct the cause of the discrepancy.

Figure 274 involves principles already mentioned but presents an interesting viewpoint in that reasons for rejection of paper are discernible, and amounts of rejection are shown.

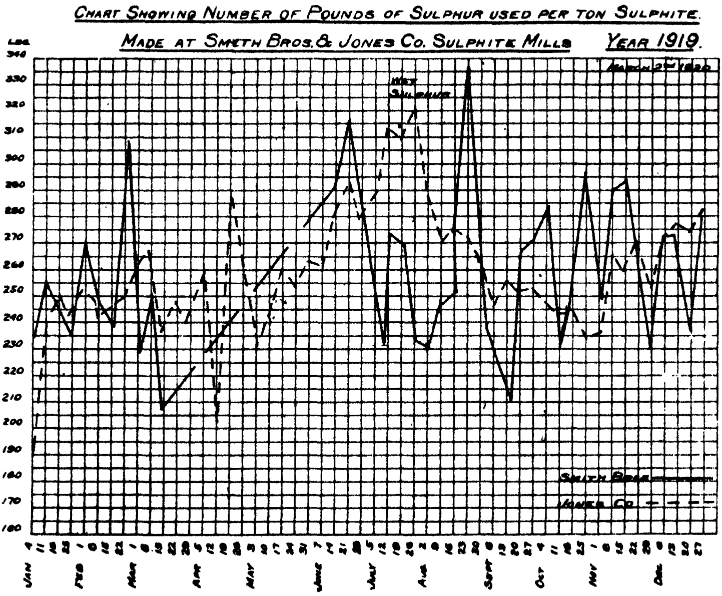


FIG. 276.

Figure 275 again illustrates another point that we constantly watch—the variations in sulphur consumption between two sulphite mills.

This is only one of many forms that illustrate the fluctuations between the workings of sulphite mills. Free, total and combined acids, with resulting quality of finished pulp; steam pressure; temperature; and all the various stages of the process, when tabulated in such a form, often provide the basis for a quick decision by the executive who would frequently be lost if all this data were presented to him in a tabulated form, or as miscellaneous groups of figures.

Figure 277 is a chart showing mean average consumption of coal per ton of product for a period of six months, quickly bringing out important facts. This is a simple form of chart but the facts are there nevertheless and will serve the purpose of a more intricate form that would take more time to make, and more time to analyze.

We have covered briefly in a general way charts that can be made useful to the executives of a pulp and paper mill, covering general mill operations, quality, etc. We will now give in brief form a digest of various cost charts, data of which must come from the Accounting Department and be put into the hands of a reliable man for further interpertation and presentation.

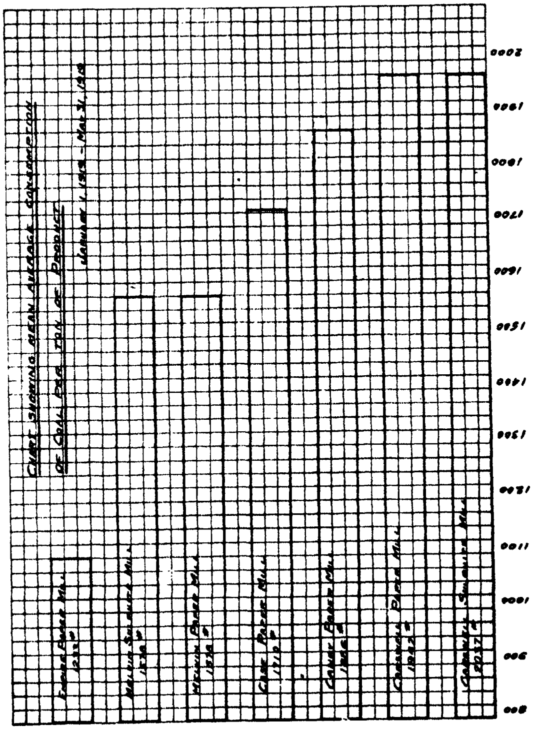


Fig. 277.

Figure 278 shows cost of roll finishing in one Finishing Room. This chart, by means of three lines, shows quite plainly the cost of these various operations from week to week. This chart if it is to cover a period of one year should be made out in a form with 52 divisions in order to cover properly the 52 weeks of the year. Following are illustrations of various forms of cost charts covering weekly and monthly periods for one year. These cover direct costs, indirect costs, various departmental costs as explained by the titles. These charts show fluctuations month to month. If made on tracing paper or transparent cross-section sheets these forms can be superimposed (a chart for 1940 can be placed over one for 1939) covering some one operation, and the trend of affairs grasped in that manner.

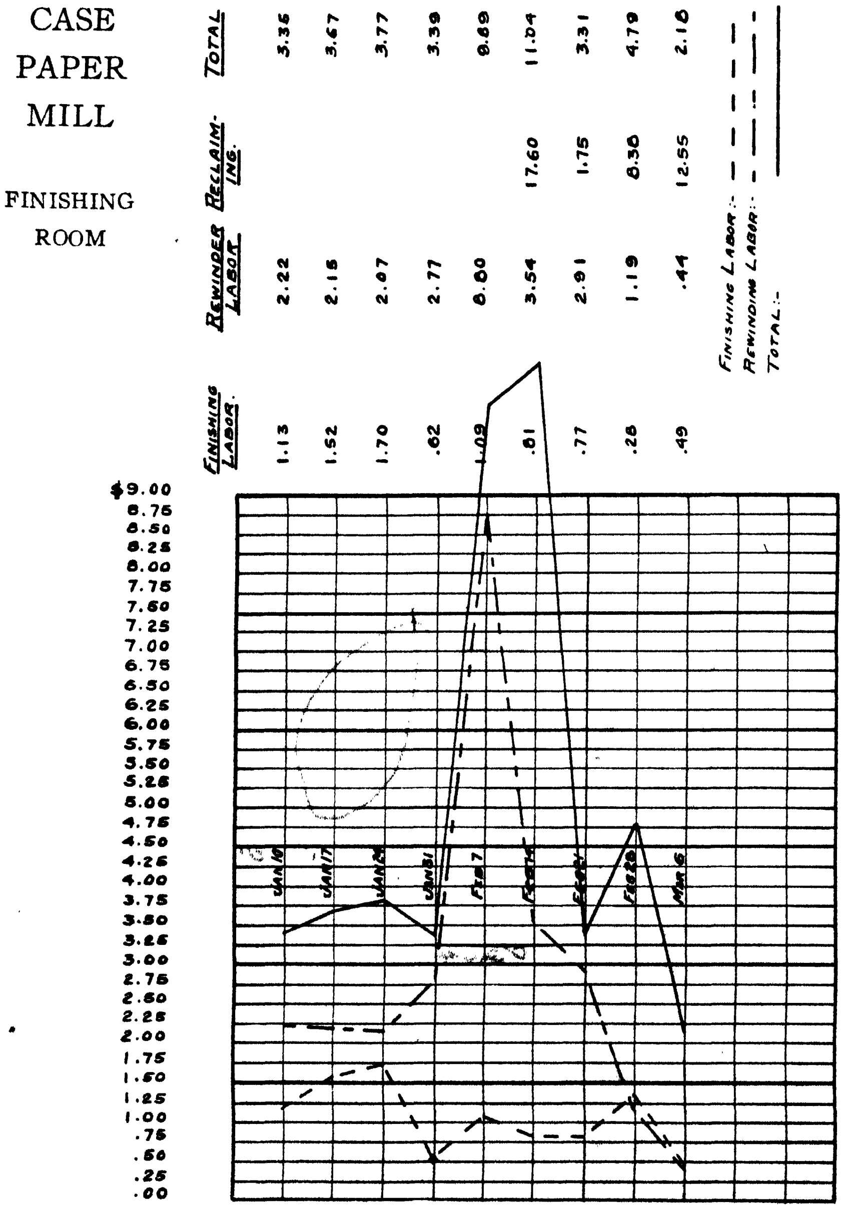

CASE
PAPER
MILL
FINISHING
ROOM
FINISHING LABOR.
REWINDER LABOR
RECLAIMING.
TOTAL
1.13
2.22
3.35
1.52
2.15
3.67
1.70
2.07
3.77
.62
2.77
3.39
1.09
8.60
9.69
.81
3.54
17.60
11.04
.77
2.91
1.75
3.31
.28
1.19
8.30
4.79
.49
.44
12.55
2.18
FINISHING LABOR:-
REWINDING LABOR:-
TOTAL:-
$9.00
8.75
8.50
8.25
8.00
7.75
7.50
7.25
7.00
6.75
6.50
6.25
6.00
5.75
5.50
5.25
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
.00
JAN 10
JAN 17
JAN 24
JAN 31
FEB 7
FEB 14
FEB 21
FEB 28
MAR 6

FIG. 278.

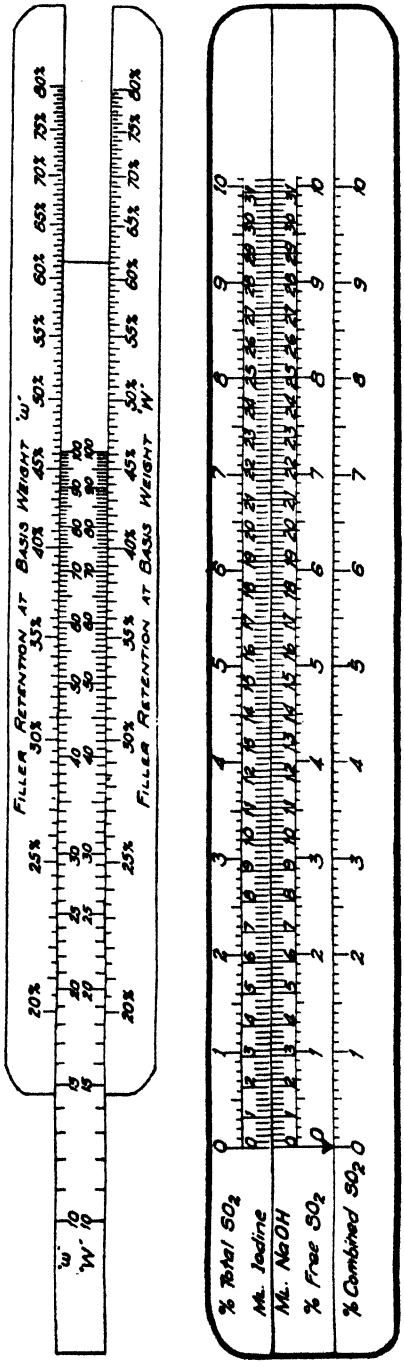


FIG. 279 (a and b).—Special slide rules prepared by O. K. Graef.

Courtesy:
"The Paper Industry and Paper World," Chicago, Ill.

Graphic charts are excellent for keeping a perpetual inventory showing consumption and available supply of such materials as sulphur, alum, pulp, etc. Also of finished products on hand at the mill or at distributing points.

We have but slightly touched on this subject, but hope to have given some ideas as to the applications of graphic charts to the pulp and paper industry. It is quite evident that very valuable information can be obtained in a short space of time, enabling the executive to make rapid decisions relative to all branches of the industry. Further, by means of a Technical Bureau daily checks and test runs can be made, plotted in a presentable form and put in the mills for the benefit of the men. These records are invaluable when presented in the proper form (not as a means of criticism but as a means of arousing interest between individuals and units) so that the men will regard this as playing or scoring in a game. It has been necessary to reproduce all the charts in this book in simple black and white, but in actual work we use different colored lines, columns, etc., although various kinds of dotted lines will do just as well. There is nothing about these charts peculiar to the paper industry. Chemical plants, smelters, machine shops, department stores, banks and all kinds of plants and offices use them constantly.

The preparation of nomographic charts by the chemical and the engineering departments to facilitate the work of the mill is a subject beyond the scope of this book for any detailed treatment. Such charts can be very useful and can often enable workmen to handle jobs where the original calculations required would be quite beyond their ability. Also the use of specially prepared slide rules, such as those illustrated, are very helpful and are great savers of time. Of course great care must be exercised that the original work is highly accurate or errors will be perpetuated and multiplied many times, resulting cumulatively in serious loss and inefficiency. In particular, never adopt without most careful checking a chart or slide rule worked out for another mill. Chemists and engineers sometimes bring such records with them from one job to another, but this practice is fraught with danger.

19. The Power Plant[1]

It is not the author's intention in this chapter to deal with the subject of steam engineering in a general way but rather to note certain aspects of the subject which must be given special attention in the pulp and paper plant.

Steam is used in most pulp and paper mills both for heating and for generating power. Most mills generate their own electricity: some even have surplus electrical energy to sell. Generating equipment driven by turbines (or engines) uses a great deal of steam. The exhaust steam from such generators is still capable of doing much work and yielding much heat. Therefore, there is a constant effort to devise an economical balance between steam used for power, and much lower pressure steam used for cooking, drying, heating, etc., usually called process steam. The effective solution of this problem is the goal of all power plant engineers in the paper industry.

Steam engineering is a subject on which many excellent books have been written. Any man working in a pulp and paper mill who hopes ever to rise very far in the industry must have at least an elementary knowledge of the general principles of steam engineering, and we recommend that all readers of this book (unless already expert steam engineers) secure some good general works[2] on this subject and study them carefully.

Kent's "Pocket Book for Mechanical Engineers" and Marks' "Mechanical Engineering Handbook" contain the various tables necessary in making power plant calculations and will be found a great help, not only in the power plant, but throughout the mill.

It is a good plan to keep a collection of the catalogs and bulletins issued by the different concerns making stokers, boilers, etc. These contain valuable information and most of these concerns are genuinely interested in promoting boiler room efficiency as well as in selling their equipment.

The progressive pulp and paper mill superintendent should subscribe to such papers as "Power" and "Combustion" and should read them carefully, the advertisements as well as the reading matter. Only in this way can one profit by the latest developments in power plant engineering.

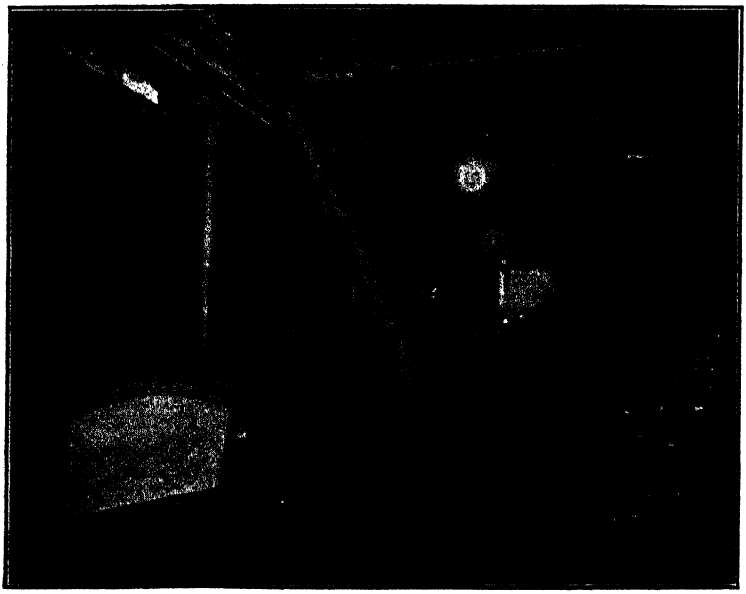
Were the present writer to take space to describe in detail some one excellent paper industry power plant it would be of little use, because hardly any two power plants in America are alike. The possible combinations of the variable factors—load, available fuel, proportionate share of power and process steam, additional power from water turbines or hydro-electric developments, location, etc.—are so numerous as to baffle the imagination.

[1] With the collaboration of George S. Witham, Jr.

[2] Especially: Barnard, Ellenwood and Hirshfield, "Elements of Heat-power Engineering," Pts. 1-3, New York, Wiley, 1933: and Croft, "Steam Boilers," New York, McGraw-Hill, 1937: also the current edition of "Steam" published by Babcock & Wilcox Co., New York.

The leading papers serving the industry from time to time print very detailed articles telling how various concerns have solved their problems in building new power plants, or modernizing old ones. The alert reader will find such articles a stimulating source of suggestions too potentially helpful to neglect.

Pulp and paper plants—sulphite, soda, kraft and paper mills—run constantly, night and day, 24 hours per day and six days per week. This makes necessary the very best equipment and the very best firemen and engineers possible in the power plant. In order for a plant to run constantly in 144-hour stretches without breakdowns demands that everything should always be in the best order.



Courtesy: American Engineering Co., Philadelphia.

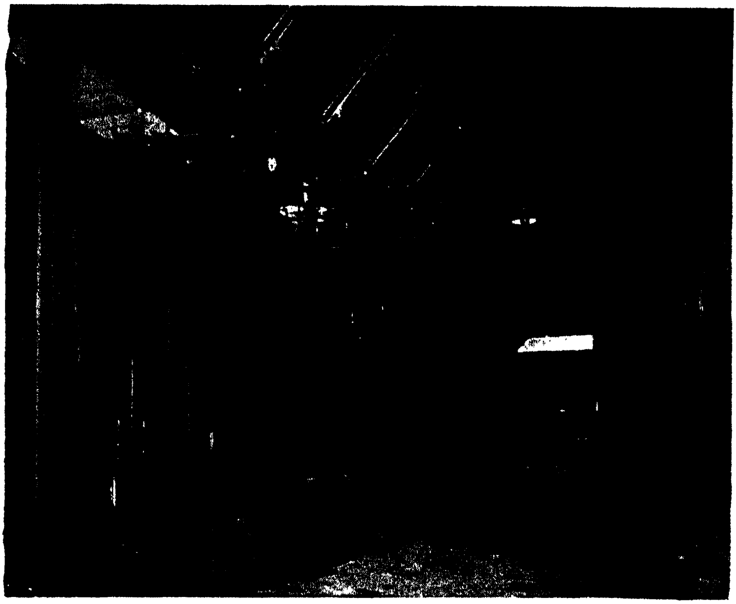
FIG. 277.—Boiler room of paper mill before introduction of automatic stokers.

However, after an experience covering almost 50 years in the pulp and paper industry, the writer has come to the conclusion that no department is so frequently neglected as the power plant.

In some mills the boiler house is still called a "fire hole" and around the town one will hear firemen discussing it. Each fireman will be bragging about how hard he has had to work and how much coal he has had to shovel in a desperate effort to keep steam anywhere near the proper working point.

Such conditions were more common in the days when automatic stokers were not so common as they are now. Then boilers were mostly flat or hand fired. Of course, this method, if well conducted, can be made to yield the highest possible economy, but owing to the high cost of labor, people have encouraged and urged the use of automatic appliances, which have been developed to a high point, and any saving that would exist with hand firing is more than offset by the high cost of such firing.

It has been customary in most mills to make necessary repairs to the boiler plant on Sundays, the only time when they well could be made. The writer has frequently been forced to believe that executives, although interested in plant economy, do not have the necessary technical or practical knowledge to analyze the boiler room conditions personally, so that the burden falls on the operating engineer, and in many such instances either the owners need a new engineer or else the engineer needs a new boss. There



Courtesy: American Engineering Co., Philadelphia.

Fig. 278.—Boiler room of same plant as shown in Fig. 277 after introduction of automatic stokers.

are plants where the superintendent is constantly being nagged because of the high cost of production where the blame can all be traced to the boiler plant.

Those responsible for a modern pulp and paper mill should not hesitate to provide all approved boiler plant accessories. The plant should be equipped with indicating and recording instruments and these instruments should be made use of. Water should be metered. Flue gases must be tested. All these things must be done regularly and systematically to know whether the plant is being operated on an economical basis or not.

A steam plant serving a paper, sulphite, kraft or soda mill does not differ essentially from any other up-to-date steam plant, except that in the case of the chemical pulp mills the steam plant is frequently called on for sudden and unusual steam pressures on account of the intermittent operation of the digesters. Whenever the digesters are filled and ready to steam the inlet valve is opened. These valves are not usually less than 4 inches in diameter, so it will be seen that this is a rather sudden and drastic call on the boiler plant, and if the boiler plant is not able to meet these requirements to the full a great deal of trouble will be caused.

In modern pulp and paper plants sulphite, soda or kraft (any or all of these) are made in the same plant where paper is made Also there may be rag pulp made and bleaching carried on. All these processes comprise a single plant in many cases and, naturally, one boiler plant serves them all.

Paper manufacturing is a steady operation and should not call for extreme overloads of power; the speed must be uniform and the steam pressure constant in order to make uniform and standard weights of paper, so that if the paper mill steam supply is taken from the same boiler plant as the sulphite mill, for instance, any uneven pressure or unusual load caused by the operation of the digesters is reflected in the paper mill by causing the steam engines which run paper machines to slow down or speed up as the case may be and there is hardly any limit to the harm such a contingency can create.

Apart from the introduction of electric drive for the machines (as is the case in many modern mills) there is no real thorough-going cure for this except to have the paper mill supply from a separate set of boilers and a separate steam line, and in some cases, this is being done. The next best solution is to have good co-operation between digester operators and the firemen in the boiler house. There should be a system of signals, or a telephone, so that at least an hour before the digester valve is expected to be opened the firemen may be warned to be ready for the excessive pull on their plant. In this way such times can be passed without any unusual condition.

When slack coal could be placed in the stoker hoppers for about a dollar per ton, there certainly was not much incentive to work out and maintain more efficient methods of combustion, and as a matter of fact in many cases the expense involved in obtaining better results was not justified by the saving produced. But that condition does not obtain now. The present price of fuel will justify the expenditure of money for better furnaces and the various instruments that are necessary to obtain and maintain proper combustion. From 75 to 90 per cent of the cost of steam is represented by cost of fuel. That the consumer is wide awake to the necessity of economy in the use of fuel is evidenced by the unprecedented demand for boiler and furnace instruments.

It is here that a warning should be sounded. The writer has seen many cases where a plant has been equipped with expensive indicating and recording instruments and then left alone with the idea that somehow the instruments would automatically secure the desired results. The object here is to call attention to the wrong use made of, and the wrong impressions that may be gained from the carbon dioxide (CO_2) recorder.[1]

Although this instrument still leaves something to be desired in its construction and operation, it is highly enough developed to be of great value in obtaining proper combustion, but, in the majority of cases, the instrument is installed and the fireman is told to maintain a certain percentage of CO_2 in the escaping gases. He soon learns that if he has a deep fuel bed and a small amount of air a high CO_2 reading will result, but what he does not know is that such a condition is also a good one for the production of CO and that a high percentage of CO_2 in the flue gases very often means a high percentage of CO.

Thus the record from the CO_2 recorder may show that very good results have been obtained, whereas just the opposite may be true and large quantities of fuel in the form of incompletely consumed carbon have passed out with the products of combustion. There are conditions that will produce CO other than the one just mentioned. It should be kept in mind that the kindling temperature of CO is rather high, about 1200 deg. F., so that if there is not a thorough mixing of air and fuel before coming in contact with the comparatively cool heating surfaces incomplete combustion will result.

It is vitally important that the results from the CO_2 recorder be checked frequently by making a complete gas analysis with the Orsat apparatus. This checking with the Orsat serves two purposes; first, it shows whether or not the recorder needs adjustment, and second, if there is any CO present.

There is a tendency at times to surround the Orsat apparatus with mystery and to create the impression that its use is limited to technically trained men. This attitude is unfortunate, for there is not an engineer worthy of the name that cannot master the use of the Orsat apparatus in two hours or less. Such a man has been setting valves and determining the horse power of reciprocating steam engines by means of the steam engine indicator for years, and the Orsat is easier to use and the results more easily analyzed. A knowledge of chemistry is not necessary. The solutions can be secured from any dealer in chemical reagents.

The Use of the Orsat.

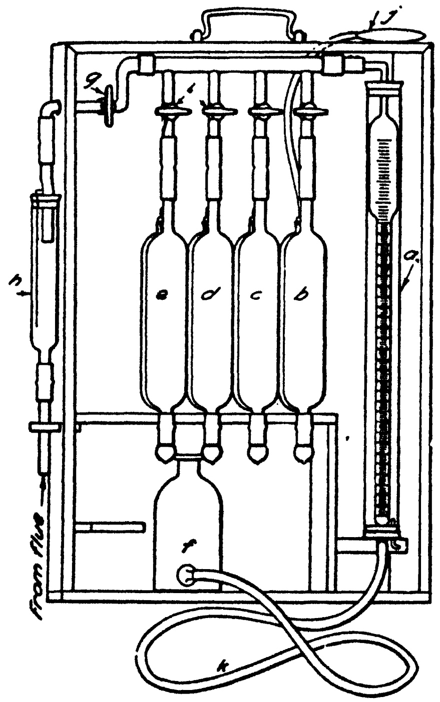
The burette *a* is graduated in cubic centimeters up to 100, and is surrounded by a water jacket to prevent any change in temperature from affecting the volume of the gas during analysis.

For accurate work it is advsiable to use four pipettes, *b, c, d, e,* the first containing a solution of caustic potash for absorbing carbon dioxide, the second an alkaline solution of pyrogallol for absorbing oxygen, and the remaining two an acid solution of cuprous chloride for absorbing carbon monoxide. Each pipette contains a number of glass tubes, to which some of the solution clings, thus facilitating absorption In pipettes *d* and *e* these

[1] For descriptions of the various types of CO_2 records, see "Finding and Stopping Waste in Modern Boiler Rooms," Vol. II, pages 151 to 156. Harrison Safety Boiler Works.

tubes contain copper wire to strengthen the cuprous chloride solution as its absorbent power becomes weakened. The rear half of each pipette is fitted with a rubber bag, one of which is shown at *j*, to protect the solution from the action of the air. The solution in each pipette should be drawn up to the mark on the capillary tube.

The gas is drawn into the burette through the U tube *h*; which is filled with spun glass, or similar material, to clean the gas. To discharge any air or gas in the apparatus, the cock *g* is opened to the air and the bottle *f* is



(a) burette;
(b) caustic potash pipette;
(c) alkaline pyrogallol pipette;
(d, e) cuprous chloride pipettes;
(f) levelling bottle;
(g) 3-way cook;
(h) U-tube;
(i) cock;
(j) rubber bag;
(k) tube.

FIG. 279.—Diagram of Orsat apparatus for testing flue gases.

raised until the water in the burette reaches the 100-cubic centimeter mark. The cock *g* is then turned so as to close the air opening and allow gas to be drawn through *h*, the bottle *f* being lowered for this purpose. The gas is drawn into the burette to a point below the zero mark, the cock *g* then being opened to the air and the excess gas expelled until the level of the water in *f* and in *a* are at the zero mark. This procedure is necessary in order to obtain the zero reading at atmospheric pressure.

The apparatus as well as all connections leading thereto should be carefully tested for leakage. Simple tests can be made. For example, if after the cock *g* is closed the bottle *f* is placed on top of the frame for a short time and agai. brought to the zero mark, the level of the water in *a* is above zero mark, a leak is indicated.

Before taking a final sample for analysis, the burette *a* should be filled with gas and emptied once or twice, to make sure that all the apparatus is filled with new gas. The cock *g* is then closed, the cock *i* opened, and the gas driven over into *b* by raising *f*. The gas is drawn back into *a* by lowering *f* and when the solution in *b* has reached the mark in the capillary tube, the cock *i* is closed and a reading is taken on the burette, the level of the water in the bottle *f* being brought to the same level as the water in *a*. The operation is repeated until a constant reading is obtained, the decrease in volume, in cubic centimeters, being the percentage of CO_2, in the flue gases.

The gas is then driven over into the pipette *c* and the apparatus manipulated in a similar manner. The difference between the resulting reading and the carbon dioxide reading gives the percentage of oxygen in the flue gases.

The next operation is to drive the gas into the pipette *d*, the gas being given a final wash in *e*, and then passed into the pipette *c* to absorb any hydrochloric acid fumes that may have been given off by the cuprous chloride solution, if old; such fumes would increase the volume of the gases and make the reading on the burette less than the true amount.

The sum of the percentages by volume of CO_2, O, and CO is subtracted from 100 and for practical purposes this difference is taken as the percentage by volume of N.

The gas must be passed through the burettes in the order named, as the pyrogallol solution will absorb carbon dioxide and the cuprous chloride solution will absorb oxygen.

As the gases in the flue are under less than atmospheric pressure, they will not of themselves flow through the pipe connecting the flue to the apparatus. The gas may be drawn into the pipe in the way already described, but this is tedious. A rubber bulb aspirator connected to the air outlet of the cock *g* will quickly draw a new supply of gas into the pipe. Another form of aspirator draws the gas from the flue in a constant stream, thus insuring a fresh supply for each sample.

The analysis made by the Orsat apparatus is volumetric; if the analysis by weight is required, it can be found from the volumetric analysis as follows:

Multiply the percentages by volume by the molecular weight of each gas, and divide the products by the sum of all the products; the quotients will be the percentages by weight. For most work the use of the oven values of the molecular weights insures sufficient accuracy.

The even values of the molecular weights of the gases that appear in an analysis by an Orsat are:

Carbon dioxide (CO_2)	44
Carbon monoxide (CO)	28
Oxygen (O_2)	32
Nitrogen (N_2)	28

The following table indicates the method of converting a volumetric flue-gas analysis into an analysis by weight.

Conversion of a flue-gas analysis by volume to one by weight:

CONVERSION OF A FLUE-GAS ANALYSIS BY VOLUME TO ONE BY WEIGHT

Gas	Analysis by Volume (per cent)	Molecular Weight	Volume times Molecular Weight	Analysis by Weight (per cent)
Carbon dioxide (CO_2)	12.2	12+(2×16)	536.8	$\frac{536.8}{3022.8} = 17.7$
Carbon monoxide (CO)....	.4	12+16	11.2	$\frac{11.2}{3022.8} = .4$
Oxygen (O_2)	6.9	2×16	220.8	$\frac{220.8}{3022.8} = 7.3$
Nitrogen (N_2)	80.5	2×14	2254.0	$\frac{2254.0}{3022.8} = 74.6$
Total	100.0		3022.8	100.0

From the flue-gas analysis the weight of air actually used for combustion can be computed from this formula provided the percentage by weight of C in the fuel is known:

$$\text{Weight of air} = 3.036\left(\frac{N}{CO_2 + CO}\right) \times C$$

Where N, CO_2 and CO are percentages by volume in the flue gas and C is the percentage by weight of carbon in the fuel.

The quantity of heat (B. t. u.) lost in the flue gases per pound of fuel is $L = 0.24W(T-t)$.

Where W = weight in pounds of flue gases per pound of dry fuel.
T = temperature of flue gases, °F.
t = temperature of atmosphere, °F.
0.24 = specific heat of flue gases.

The weight W of the flue gases per pound of dry fuel is computed from the analysis by the formula:

$$C\left(\frac{11\,CO_2 + 8\,O + 7(CO + N)}{3(CO_2 + CO)}\right)$$

where CO_2, O, CO, and N are the percentages by volume, by analysis of the flue gas. C is the percentage by weight of the carbon in the dry fuel.

The quantity heat (B. t. u.) lost per pound of fuel burned through incomplete combustion of carbon and the presence of CO in the flue gas is in B. t. u. obtained by using the formula:

$$L = 10{,}150 \times \left(\frac{CO}{CO + CO_2}\right) C$$

where CO and CO_2 are the percentages of the gases by volume in the flue gases and C is the percentage of C by weight in the fuel.

Design of Steam Plants for Pulp and Paper Mills.

In considering the design of a steam plant as applied to the paper industry, consideration should be given to the following main headings.

Logical fuel to burn.
Various kinds of boilers.
Various types of stokers or grates.
Kinds and types of auxiliary equipment for the boiler house.
Fans and engines for producing draft.
Soot blowers.
Boiler feed regulators.
Balanced draft.
Gauges and gauge boards.
Distribution of steam throughout the plant.
Types of steam units used for driving the paper machines.
Heating system for the mill.
Reclamation of heat units.

Choice of Fuel.

While it is conceded that the use of anthracite and bituminous coal predominates in most industries in this country—and the paper industry is no exception—the exact type of fuel used must be determined by the general location of the plant, freight rates, freight facilities, flexibility of coal deliveries, nearness to mines and large coaling stations, nearness to supplies of oil or other fuel, tank steamer facilities, etc.

In addition to coal natural gas is used as fuel in the paper industry in some instances (chiefly in the Virginias) and crude oil is used in mills on the Pacific Coast and in some mills in Maine and in the South.

Coal: A pulp and paper mill engineer should secure government and other publications describing the coal from different seams. If not competent to judge himself, he should avail himself of the services of a combustion engineer in selecting his coal and drawing up specifications for it. All coal should be bought on specification based on sampling, testing and chemical analysis. The U. S. Bureau of Mines will supply literature on this subject.

Until quite recently the different grades of anthracite (usually screenings) were burned in the paper industry with induced draft, i.e., with natural draft produced by chimneys or by fans. Then followed a combination of induced and forced draft. Hand fired installations used approximately ½ inch to 1¼ inch of draft in the pit. Hand firing, with various types of grates, and with an air space of approximately 9 to 11 per cent, was fairly satisfactory and in many cases really economical. However, it had its limitations, and a steaming capacity of from 20 to 30 per cent and many times as much power, could be obtained from bituminous, with more modern firing equipment.

Today with the exception of a very few Eastern mills, all coal-burning mills in the industry use bituminous or semi-bituminous coal, mostly from Pennsylvania and Virginia.

The large percentage of ash, and the consequent increase in coal required to equal bituminous steaming, makes the labor cost of the hand fired anthracite operations approximately twice as high as with an automatic stoking installation.

Oil: Oil has the advantage of simplifying firing, high evaporation, high capacity per square foot of grate surface or radiating surface, lessened labor cost, cleanliness, flexibility, i. e., ability to change quickly to maximum or minimum supply of steam. On the other hand, we believe that the impingement of the flames on the tubes necessitates a lot of tube renewals. In some localities fuel oil is the logical fuel. Full information about every detail of the use of fuel oil in power plants is given in the copiously illustrated booklet entitled "Efficiency in the Use of Oil Fuel," published by the U. S. Bureau of Mines.

Natural Gas: Of this fuel we cannot speak from personal experience. We understand, however, that its advantages are high steaming capacity, flexibility, reduction in labor costs, cleanliness, compactness, and (in certain localities) cheapness.

Stokers.

There are a number of excellent stokers on the market and we would not have any reader infer that the particular ones we have happened to illustrate here are, in our opinion, the only ones to use in pulp and paper mills.

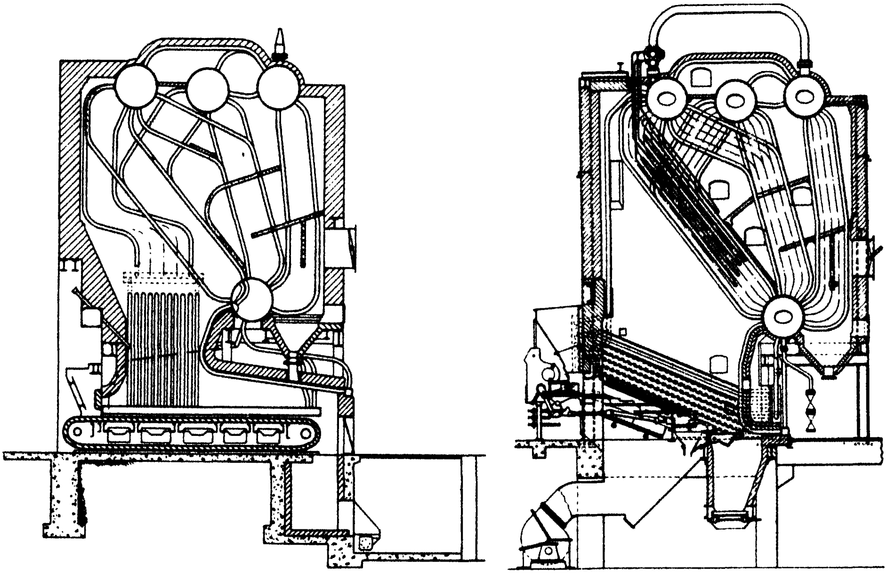
The main thing is, apart from mechanical efficiency in the stoker itself, that the stoker installation should have a high reserve capacity (several per cent over-rating frequently being required) because sometimes, owing to two or more digesters being blown in at about the same time, wash-ups on the paper machine, etc., sudden very large demands for steam are made. This possibility of sudden, irregular, excessive demands for steam is the principal unique factor in power plant design for the pulp and paper industry.

For that reason the underfeed stoker is favored in the paper industry more than any other type. They permit operating up to at least 250 per cent of rating. For high grade caking bituminous coal the multiple-retort underfeed stoker is highly efficient, especially if equipped with forced draft and clinker crusher. The single-retort underfeed stoker is not nearly so desirable if high combustion rates are sought.

However, the underfeed is by no means the only useful stoker for pulp and paper mill power plants. Many mills especially in the Middle West are getting good satisfaction from the chain-grate stoker, especially when equipped with sectional forced-draft. In this stoker the rate of feed is determined by the speed at which the chains move.

The writer would rate the various overfeed stokers as the least suitable for paper industry service but even at that they are rendering good service in some mills and are better than hand firing.

No matter what the type of stoker, it is necessary to have plenty of draft. In the case of forced-draft installations have a good, generous force draft fan, preferably two units of sufficient size to furnish the required draft in the pit (zero to at least 6 inches) without the fan engine speed exceeding 50 to 150 r. p. m. The fan engine (if used) to be enclosed, preferably horizontal with forced feed lubrication for both engine and cylinder oil. Today most fans are motor-driven.



Courtesy: Combustion Engineering Co., Inc., New York.

(a) Travelling grate stoker under boiler generating 40,000 lbs. steam per hr. at 200 lbs. pressure, bent tube type with water cooled walls.

(b) Multiple retort stoker under 4-drum, bent tube boiler generating 27,500 lbs. steam per hr. at 450 lbs. pressure and 725° F. temperature.

Fig. 280.

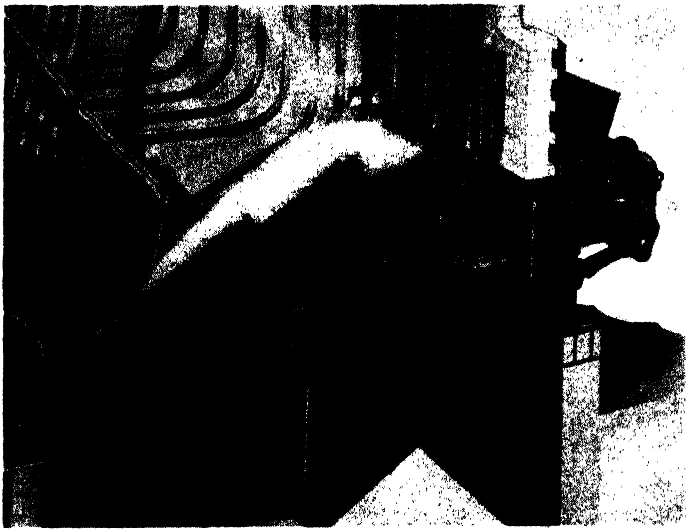
A good stoker should be scientifically planned to utilize the peculiarities of bituminous or semi-bituminous coal, or of mixtures of such coal with limited amounts of anthracite steam sizes. It is not merely a device for feeding coal; rather, it is a complete system of combustion, comprising means for feeding the coal in quantities as needed, supplying air in proportionate amounts, causing the air and distilled gases to mix and burn without smoke, burning the solid fuel (coke), discharging the ashes.

All these processes are carried out with a high degree of precision by mechanical means, and with minimum dependence on the human element.

Specifically, the following results should be accomplished:

(1) Coal-burning capacity, and therefore steaming capacity should be enormously increased. Continuous operation at from 200 to 300 per cent of rating is often secured, according to the boiler design and the coal used. Operation at even higher rates is possible. Note: A "boiler horse-

power" is equivalent to 34.5 pounds of water per hour evaporated into steam at 212° F. and atmospheric pressure. In an actual boiler the water (unless pre-heated, as is now usually the case) starts at less than that temperature, is evaporated into steam at a higher temperature and pressure, and is probably superheated also. Hence, the weight of water per horsepower actually evaporated is less than 34.5 pounds, to allow for the heat added before and after evaporation.



Courtesy: American Engineering Co., Philadelphia.

FIG. 281.—Taylor stoker, water-cooled, showing continuous ash discharge.

The original idea was that the "boiler horsepower" would operate an engine of equal horsepower. With improvement in engines this became absurd. Today it refers solely to the evaporative capacity. This is today more usually expressed in 1000 lbs. steam per hr.

Water-tube boilers were formerly generally rated at one boiler horsepower for every ten square feet of heating surface. "Operation at normal rating" means that for every square foot of heating surface the boiler is evaporating 3.45 pounds of water per hour "from and at" 212° F., or its equivalent for the actual conditions.

"Operation at 200 per cent of rating" means that the boiler is evaporating double the rated quantity of water per hour. It does not imply higher steam pressure.

A hand-fired boiler will deliver only its normal rating or a little more, and its efficiency falls very rapidly as the output is forced.

(2) A saving in fuel is effected of from 10 to 20 per cent for equal steam output, as compared with hand firing at normal rating, assuming that the same degree of intelligence is exercised as would be the case with high-class hand firing.

(3) Response to varying loads should be almost immediate. With good stokers it is unnecessary to incur the stand-by losses of many banked boilers held in readiness for a sudden demand.

(4) Smoke is greatly reduced or wholly eliminated.

(5) By proper adjustment of feed and draft, varying grades of fuel are successfully burned.

(6) Repair expenses should be nominal.

(7) Labor expense is minimized. With fuel of average quality, one operator can look after a number of modern stokers of ordinary size, representing 10,000 rated boiler horsepower. (The above exclusive of ordinary boiler-house labor such as laborers, ash-handlers, chartmen, foremen, etc.)

Stoker Engines: These should be of a modern enclosed type and should be approximately $\frac{1}{3}$ to $\frac{1}{2}$ larger than ordinarily recommended by the makers themselves. In one plant a 7 x 8 vertical steam engine drives 4 underfeed stokers which operate 4 boilers of 400 bhp each, and also a draft fan. For 212 days in the year the exhaust from this engine heats the plant. In the 153 remaining summer days there is excess exhaust steam. Such an engine, operating continuously 365 days a year provides very simple, reliable and economical regulation over the wide range of speeds necessary in obtaining greater over-all boiler efficiency.

Pulverized Coal.

Pulverized coal has come to the paper industry from the cement mills and the public utility stations where it was first employed. As the name betokens, coal is pulverized by hammer mills, ball mills, roller or bowl mills until upwards of 90 per cent will pass through a 200-mesh screen.

In central power stations there was formerly one large pulverizing plant, including drying equipment, where the pulverized coal is prepared for all the boilers. Only a few very large plants in the paper industry could economically use this plan.

In the average paper industry application of pulverized coal, as in modern central power stations, there is a pulverizing unit (consisting of one or more suitably selected mills) feeding its product directly into the boiler.

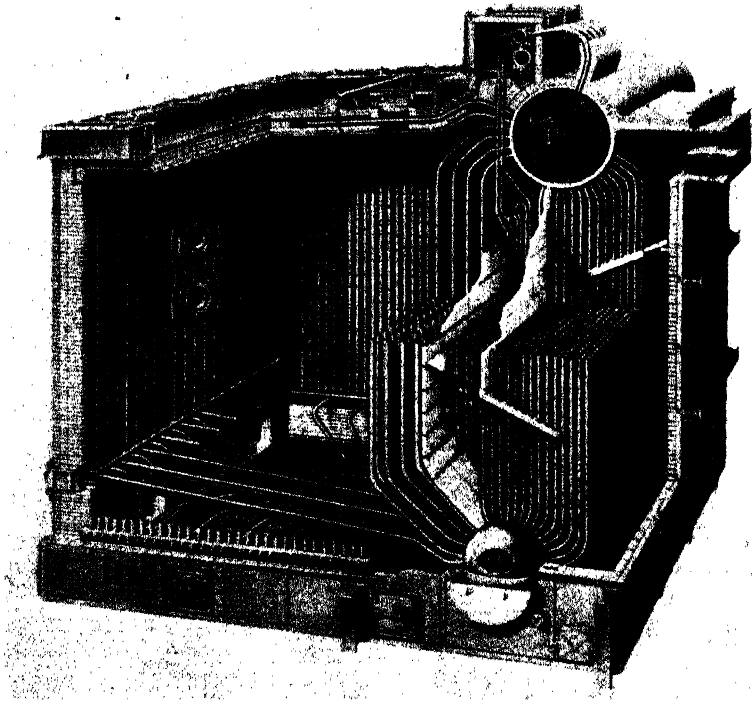
Pulverized fuel is superior to even the best stokers for quick adaptation to changes in the load. It will use almost any grade of coal, but it cannot use wet coal, i.e. with more than about 10 per cent moisture. It is not applicable to small boilers. It calls for a relatively larger furnace than a stoker, and the first cost of the equipment is greater. For large plants there would seem to be little question of its desirability. See Fig. 282, page 638.

Boilers.

Boilers used in pulp and paper mills are of two main types: ***Return Tubular*** boilers and *Water Tube* boilers. The latter are today in use in almost all mills with capacity over 40 tons per day, and in many mills of less capacity than that.

Return Tubular boilers have fire-tubes surrounded by water. Through these tubes pass the hot gases from the furnace. These boilers are less adaptable to automatic firing with stokers and seldom exceed normal rating[1] in performance.

Water Tube boilers are those in which the water passes through tubes arranged in a heated furnace so as to extract the heat of the fire as quickly and as completely as possible. There are many satisfactory makes. They all have one or more "steam drums" where the tubes terminate. The tubes may be horizontal, vertical, or bent into various positions. In the paper



Courtesy: Combustion Engineering Co., Inc., New York.

FIG. 282.—Typical 2-drum self-contained steam generating unit fired by pulverized coal.

industry such boilers are used in units ranging from 300 to 1500 bhp. Some mills have recently installed much larger units, however, some equalling those of public utility power stations, 2000 bhp and upwards designed for operation at from 250 to 500 per cent of rating.

Combined fire-tube and water-tube boilers have been used in some of the smaller mills. These are really merely a fire-tube boiler with a bank of water-tubes inserted in the furnace, acting as a preheater for the large volume of water in the main boiler. It is because of this large volume to be

[1] Rating means the arbitrary practice of considering that normally each 10 sq. ft. boiler surface develops 1 bhp (or evaporates 34.5 lb. water per hr. at 212° F. So if a boiler actually evaporated twice that amount of water, *viz.* 79 lb. water per hr. per 10 sq. ft. it would be operating at 200 per cent of rating, a mode of expression constantly used in discussing power plants.

heated that the cost of operating fire-tube boilers rises so rapidly when performance is forced above normal rating.

In pulp mills suitable provision should be made for burning refuse. For such work combination forced and induced draft is preferable. For a furnace of approximately 8 ft.×7 ft. size, grates of Herringbone type are very satisfactory, embodying quick dumping features, making it possible to burn down the refuse quickly, before the brick-work would become cooled down. In such a case approximately 1.1 square feet of grate surface and 45 cubic feet furnace capacity should be provided for each ton of pulp made. This is in case the wood is prepared with a barking drum. The power capable of being generated from refuse from a barking drum, in which 125 cords of green wood is being barked, is equal to approximately 200 hp per hour for 20 hours.

In considering the available power from refuse made in preparing wood with disc barkers, it is safe to assume that 62 boïler hp can be obtained from every cord of wood prepared.

Ordinarily a 13-ton digester will require a minimum of 300 hp at the time of steaming, a maximum at the time of starting (about 2½ hours after steaming) of 700 and an average of 550 hp per hour for the period covering a 9-hour cook.

As before mentioned, the personnel of the plant has a large bearing on the boiler capacity necessary to operate a pulp mill, especially a sulphite mill. For example, in a mill operating two 13-ton digesters, cooking 50 tons of high-grade unbleached stock, there will be from 4¼ to 5 cooks per 24 hours. It will be obvious that the efficiency of the operation, viz.: the reclamation of the acid, the making of the acid, and the general efficient operation of the plant will be dependent on the proper timing of the cooking operation. If the digesters are bunched in such a 50-ton sulphite mill, it is possible to pull on the boiler house to the extent of 1,200 horsepower. On the other hand with proper spacing of the cooking operation, the maximum horsepower might well be in the neighborhood of 850 hp.

Anyone with any practical experience in making pulp will recognize that it is impossible at all times to space the digesters perfectly, because, owing to the various contingencies, such as steam and water conditions, blow pit conditions, screening, etc., it will often be necessary to bunch the digesters. It is for this reason that in designing boiler installations for sulphite mills, generous provision must be made for taking care of just such unavoidable contingencies.

Table of Approximate Cubical Capacity of Boiler Room, Coal Bunker Space, Etc., Required per Ton of Paper in Manufacture of Grades Running from 100% Sulphite to 100% Kraft Sheet—Weight from 30 to 50 lb. Basis

Cu. Ft. Boiler Room	Cu. Ft. Bunker Space	Sq. Ft. Floor Space	Sq. Ft. Heating Area	Sq. Ft. Economizer Surface
2588	240	96	296	148

Note: These figures can be safely used for manufacturing of most papers from sulphite.

TABLE GIVING SIZE AND TYPE OF BOILERS IN TWO TYPICAL MILLS
One with Two 13-Ton Digesters and One with Four 13-Ton Digesters

No. Digesters	No. Boilers	Nominal Capacity	Type	How Fired	Per cent of Rating Operated
2	2	1740	Water Tube	Stoker	137%
4	4	1200	Water Tube	Stoker	120%

Auxiliary Equipment for Boiler Use.

We consider this one of the most important items in the proper design of a power plant for a pulp and paper mill. The most important point to be considered under this heading is boiler feed apparatus with which to supply raw water for boiler purposes. We have found that beyond a possibility of a doubt, it pays well to have at least three independent means by which to supply the water to the heaters and the boiler feed pumps.

Provision should be made so that the water can be by-passed from the heater direct to the suction of the pumps. For instance, one might provide an emergency connection direct from the underwriter pump, whether it be duplex or turbine type. Moreover, there should be two different sources of supply, one electrically driven and one steam driven for water for the heaters proper. The water should in all cases be filtered and if necessary softened so as to be free from ingredients tending to form scale. This subject has already been dealt with in Chapter 17, under the heading "Water Supply."

With specific reference to the various methods for feeding boilers, there is first the old stand-by, the individual large inspirator or injector. For pulp and paper mill work of any size this equipment is practically obsolete, although there are instances where its utilization for emergencies has proved to be a good investment. More to be recommended are the usual single and duplex plunger pumps and direct connected turbo units. The writer has found a unit embodying a turbine direct connected to a four-stage centrifugal pump entirely satisfactory for this service. However, numerous manufacturers, both of turbines and pumps, are capable of supplying excellent equipment for this purpose.

We will not attempt in this chapter to deal in detail with figures on the proper amount of power which should be utilized for auxiliary boiler room equipment under various conditions. Such information can be found in the various standard text books on steam engineering. In considering pulp and paper mills, it is almost immaterial what type of auxiliary units are used provided that the capacity is sufficient and that proper provision is made for the utilization of the excess exhaust.

To return to the question of boiler feed pumps, there is one important fact on which we can hardly lay too much emphasis. A dual supply should always be arranged, for instance, one motor driven and one turbine driven pump, or a generous duplex or triplex pump might be retained in place of one of the above. However, under no circumstances depend on a single boiler feed pump installation.

We would consider the following an ideal installation for a 50-ton sulphite mill and 50-ton paper mill: (1) One motor driven triplex pump, size 8 x 10, 200 gpm capacity. (2) One steam driven duplex outside-pack plunger pump, 200 gpm capacity. (3) One direct connected turbine driven centrifugal pump of 200 gpm capacity. (Note: This type preferable when accurate Venturi meter readings are required.) The valves in the plunger pump should be of good quality composition backed by some stiff metal.

Ideal specification for the turbine driven pump: 4-inch Horizontal two-stage split case, centrifugal pump, equipped with bronze impellers, bronze covered steel shaft, and having an extended base and flexible coupling direct to 40 hp steam turbine. Pump to have a capacity of 300 gpm against a pressure of 175 lbs. Efficiency 55 per cent. Steam turbine to be of single stage, horizontal type.

All units when possible should be properly regulated on the basis of steam pressure and the pressure on the boiler feed line.

When figuring capacities for boiler feed pumps, particularly of duplex type, first see to it that at least sufficient head is provided for hot water purposes, to maintain a pressure of at least 9 pounds (this pressure contingent on the temperature of the water being pumped) on the suction proper, figuring normal rating of the boilers. In fact if the actual boiler horsepower readings are available, take actual and add one-half to the theoretical, and you will then have what we have found from experience to be a good boiler pump installation.

Under no consideration would we consider a piston speed much to exceed 40 ft. per min. In the event of other units which might be well considered as auxiliary equipment such as the various draft generating apparatus, be this induced or forced, we have found that the manufacturers' suggestions as to sizes best be multiplied by approximately 50 per cent. This is based on actual experience in operation. The average engineer figuring on this work does not anticipate some of the dangerous contingencies that arise.

We will cite one example—bunching of digesters; perhaps the steaming of two or three beaters simultaneously, the starting of two machines in unison. With the above, while pulling the normal rating of say 100 horsepower, the mill will sometimes pull as high as from 1,200 to 1,500 horsepower, particularly during the starting up of the machines or in the event of their pulling a full 1½ inch to 2½ inch steam supply, when the paper is running wet, etc., etc.

Soot Blowers.

The author is decidedly of the opinion that soot blowers are a good investment and add materially to the efficiency of modern boilers. However, a soot blower, to be a profitable investment, should be used in an intelligent manner. The blowing should be done several times a day because when soot and ash first collect on the tubes it is easier to remove, whereas, if it is allowed to remain, the heat will fuse it into a hard substance which can only be removed by scraping. There are a number of excellent soot blowers on the market, any of which will soon pay for themselves by the savings effected.

Boiler Feed Regulator.

These are sometimes called feed water regulators. Many engineers do not favor the installation of these regulators. It is our experience, however, that they are a good investment. They tend to decrease the variation of pressure when the load on the boilers is heavy, as well as presenting certain other advantages. Although these devices differ in construction, they are all designed to accomplish the same results.

The regulator feeds continuously as long as there is a load on the boiler. On heavy loads it automatically drops the water level so as to increase the steaming capacity. On light loads it automatically raises the water level, and saves the furnace heat which would otherwise be wasted. On steady loads, it maintains a constant water level. The governor maintains a fixed excess in the feed line above boiler pressure. As the pressure varies, the feed pressure varies correspondingly. The same governor, with a charge in connections, will give a fixed constant pressure.

Balanced Draft.

Balanced Draft is obtained by the automatic regulation of both the supply of air to the furnace and the escape of the gases from the furnace in such manner as to maintain at all times a constant predetermined draft in the furnace for all rates of combustion. Its principle is to supply all the air needed for perfect combustion but no more, and at the same time maintain as little suction in the furnace as possible and still have sufficient draft to take away the gases from the furnace chamber as rapidly as they are formed.

These requirements are independent functions. They must be controlled separately and independently if the best results are to be obtained.

Balanced Draft control of the air supply meets the first requirements perfectly. By its use, any required amount of air can be forced through fuel beds of any thickness or density, thus maintaining whatever rate of combustion may be desired.

Balanced Draft control of the flue damper meets the second requirement as the flue damper is kept constantly in its correct position by automatic opening and closing, thus keeping the removal of the waste gases under perfect control.

Pressure in the combustion chamber tends to rise when either the air pressure increases or the flue damper closes, or when the two act simultaneously. It falls when the air pressure decreases or the flue damper opens, or both act simultaneously. If both are controlled automatically, it is apparent that any desired pressure can be obtained in the furnace chamber under all conditions.

Atmospheric pressure or slightly less than atmospheric is found to be the most economical in a great majority of furnaces. At this pressure, whether in hand-fired plants or where stokers are installed there is no inrush of air above the fuel bed from open fire doors, through cracks or pores of boiler settings, through observation doors, or through other openings of whatever kind. The amount of air passing through the fuel bed is also restricted to the amount required for perfect combustion. The excess air admitted to the furnace, therefore,, is reduced to the minimum. Since air is not drawn in above the fire, when Balanced Draft is installed, the hot gases are not diluted. The initial temperature is greater for this reason, and the percentage of CO_2 in the flue gases is higher.

Heat absorption by the boiler is proportional to the difference between the temperature of its heating surface and that of the gases. The temperature of the furnace gases above that of the boiler heating surface is maximum when Balanced Draft is installed. Therefore, the absorption of heat by the boiler is maximum under these conditions.

With the quantity of air passing through the fire reduced to the minimum necessary for perfect combustion, the resulting volume of gases above the fire is also the minimum and the velocity of their passage through and out of the boiler setting is correspondingly reduced. These intensely hot gases, therefore, have ample time to transmit their heat to the boiler. The inevitable result is increased evaporation per pound of coal and per square foot of heating surface. Furthermore, because the gases in the furnace chamber are held back, they diffuse and penetrate to the most remote parts of the heating space, coming into contact with every square inch of heating surface.

By the use of Balanced Draft on boilers formerly operating on natural draft, 250 per cent increase in capacity is frequently obtained without the slightest decrease in efficiency. This feature is of particular value when peak loads have gone beyond the capacity of the power plant. In a plant where several boilers have ordinarily been in use, it is possible to take one out of continuous service for reserve.

The results are brought about by the obvious possibility of increasing boiler capacity economically by increasing the rate of combustion. Greater economy in normal operation is also secured by burning a reduced amount of coal to develop the same power. How so radical an improvement can be effected is apparent from the fact that Balanced Draft combustion produces intensely hot gases and improves the transmission of heat from gas to boiler by increasing (1) the area of contact and (2) the period of their application diffusion of the gases over the heating surfaces.

With the volume of chimney gases reduced by the elimination of excess air, the stack is required to remove only the gases of combustion. Being also relieved of the burden of pulling air through the fuel bed, its effective capacity is increased to such an extent that additional boilers may be attached to a chimney which formerly was overloaded. The troublesome back pressure on the last of a line of boilers operated on ordinary forced draft and connected to an overloaded stack, is relieved by Balanced Draft.

Whenever furnace doors in hand-fired boilers are opened, large volumes of cold air rush in. This occurs also in stoker-fired boilers through openings for inspection of the fires and for the removal of clinker and ash. The cold air, striking the highly heated tubes of the boiler and the interior of the setting, chills them suddenly and causes rapid contraction. When the opening is closed, the quick rise in temperature causes equally rapid expansion. There can be but one result from such violent alternation of contraction and expansion—leaky tubes, cracked boiler setting and linings.

Balanced Draft eliminates the objectionable conditions just described, with the result that the life of a boiler and its setting is greatly prolonged and repairs radically reduced. The decreased maintenance cost is not the only advantage as avoiding the inconvenience of having boilers out of service for repairs is a very important consideration.

Practical economy naturally demands that one fireman in a plant attend to as many boilers as possible. With the fireman's mind relieved of all care of the draft, he is able to give undivided attention to his other duties and so extend the range of his service. This is particularly desirable in stoker-fired plants.

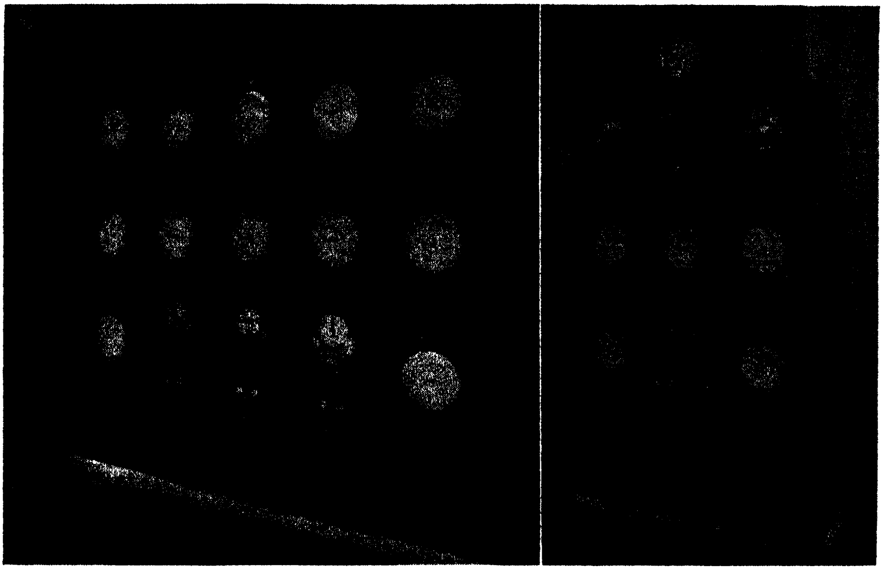
Then, too, Balanced Draft is an assurance that the highest furnace efficiency will be maintained day in and day out, under all conditions of load and weather, even by an unskilled fireman, at the same time effecting very gratifying savings in fuel cost. Since it is not always possible to hire and keep intelligent and conscientious firemen this is a very important consideration.

A very large saving by the use of Balanced Draft is very generally effected by changing from a high grade, expensive fuel, to a low grade, cheaper one. Frequently a local coal can be substituted for one brought from distant mines at high freight rates, and burned with equally good or better results. Surprisingly good results can sometimes be obtained by mixing anthracite and bituminous coal.

As the principle of Balanced Draft relates to perfect combustion irrespective of method of fuel supply, it applies to all hand-fired furnaces, to those mechanical stokers which are already or which can be fitted with pressure air supply, and to furnaces using hard or soft coal, oil or blast furnace gas. The method of application is similar in all cases, requiring only slight modification to suit individual cases.

Gauges.

There is no appliance which, in our opinion, will pay as good returns upon the investment, as a modern segregated control and gauge board. Such a board should contain, (1) master gauge, (2) gauges for recording feed water temperature, (3) indicating and recording flue temperature pyrometers for each boiler, (4) recording draft gauge, (5) individual steam meters for each boiler, (6) U gauges and balanced draft gauges for each unit, (7) instrument for recording time and length of time at which the flues were blown, (8) instrument for recording time and length of time at which boilers were blown, (9) instrument for recording time and length of time at which safety valves were blown, (10) Venturi meter for indi-



Courtesy: Bailey Meter Co., Cleveland.

(a) (b)

(a) Fluid meter distribution panel installed at the Container Corp. of America, Fernandina, Florida.

The meters reading left to right, top row, measure the following factors: steam to desuperheater, steam to turbine, 50-lb. bleed from turbine, condensate from turbine, steam to feed water heater. Second row: steam to digesters, steam to evaporator, steam to pulp machine, steam to causticizing, mill water supply. Third row: steam to yard, 125-lb. steam pressure reducing station controller, desuperheated steam temperature controller, 50-lb. steam pressure reducing station controller, fuel oil tank level.

(b) Boiler control panel for a 100,000 lb. per hr. capacity bark and oil fired B. & W. integral-furnace boiler installed at the Container Corp. of America, Fernandina, Florida.

At the top of this panel is the indicating steam pressure gage. In the first row, left to right, is a Bailey oil flow-air flow ratio controller, a multi-pointer draft gage, and a master steam pressure indicator-controller.

The meters in the center row measure (1) feed water flow, feed water pressure and steam pressure; (2nd meter) steam flow, air flow and steam temperature; (3rd meter) boiler drum water level. These three meters are the actuating elements of both the combustion control system and the three-element feed water control system.

Below is mounted a temperature recorder for flue gas and preheated air temperatures, and flow meter measuring boiler feed makeup water.

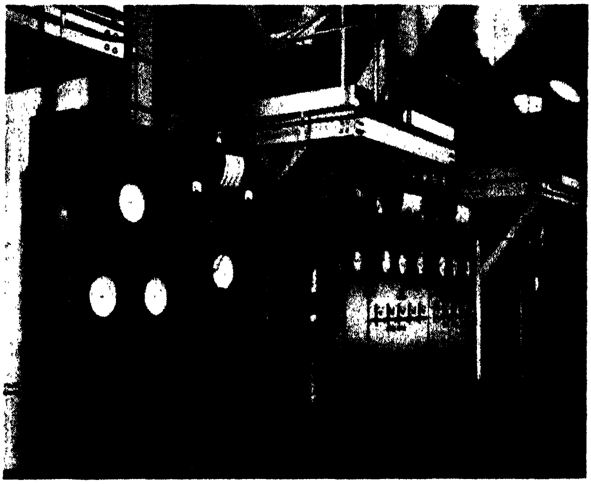
FIG. 283.

cating volume of water furnished to boilers (various types of flow meter can be substituted for this), (11) CO_2 recorder of any good make.

The Venturi meter reading together with the steam output reading and a number of pounds of coal burned makes it possible to calculate very accurately the general efficiency of the boiler installation.

Steam Pressures.

It is not our intention to enter into detail regarding steam pressures. We will simply state that it was formerly pretty generally conceded that 150 to 175 pounds pressure was pretty good practice in pulp and paper mill work. In modern mills the trend is towards from 400 to 700 lb. Whether or not you are operating a steam turbine and generating your own power has a bearing on the steam pressure and degree of superheat. Some arguments have been advanced in favor of the utilization of superheated steam for cooking pulp and for paper making. The author's experience about cooking with superheated steam is limited, and in general, we are not in favor of so doing. Neither do we favor the utilizing of superheated steam for operating paper mill engines and for drying paper. We have found it very unsatisfactory. Saturated steam, after passing through the engines, gives up its heat much more readily, increases the drying capacity of the machine and gives a more uniform sheet of paper. Moreover, our experience tends to show that the use of saturated steam gives a little stronger sheet of paper.



Courtesy: Bailey Meter Co., Cleveland.

FIG. 284.—Boiler control panels for two 100,000-lb. per hr. capacity pulverized coal fired boilers at Hammermill Paper Co., Erie, Pa.

The panels from left to right are: feed water panel, pulverizer control panel, master panel of combustion control system, individual boiler panels, pulverizer control panel. Each individual boiler control panel is provided with a temperature recorder to show air preheater performance, a Bailey boiler meter to control combustion, a boiler water level recorder, draft gages and hand-automatic selector valves for the Bailey combustion control system.

Distribution of Steam Through the Plant.

Considerations as to different kinds of pipe, types of flanges, gaskets, drip systems, etc., are ordinarily taken care of by the designing engineer. We will not attempt to enter into details on this subject in this book. A great deal of data relative to such installations, the proper sizes, velocities, etc., can be obtained from standard text books and engineers' hand books.

After operating several different kinds and types of plants, however, we are frank to admit that there are two respective types of steam mains which we favor. The first is the Holly Drip System which calls for good generous receiver separators at the engine proper. The second system which

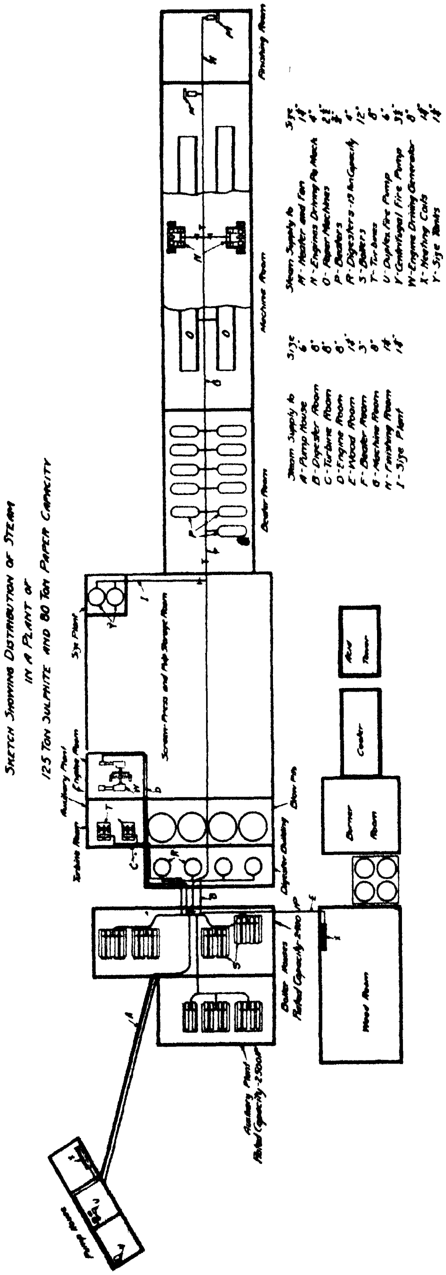

Sketch Showing Distribution of Steam
in a Plant of
125 Ton Sulphite and 80 Ton Paper Capacity
Finishing Room
Machine Room
Beater Room
Screen-Press and Pulp Storage Room
Size Plant
Engine Room
Turbine Room
Digester Building
Blow Pits
Boiler Houses
Wood Room
Burner Room
Cooler
Acid Tower
Pump House
Steam Supply to
A - Pump House
B - Digester Room
C - Turbine Room
D - Engine Room
E - Wood Room
F - Beater Room
G - Machine Room
H - Finishing Room
I - Size Plant
Steam Supply to
M - Heater and Fan
N - Engines Driving Pa Mach
O - Paper Machines
P - Beaters
R - Digesters
S - Boilers
T - Turbines
U - Duplex Fire Pump
V - Centrifugal Fire Pump
W - Engine Driving Generator
X - Heating Coils
Y - Size Tanks

FIG. 285.

we favor is a modern drip system embodying drip connections opposite each boiler connection. In other words, a substantial drip connection on the bottom of all tees in the boiler house proper, this running to a receiver and the utilization of one trap, this connecting to the hot well. Further, a generous size of drip connection on all mains throughout the plant, same being piped to the receiver, and the employment of a drip from which the trap discharges to the hot well.

Closed Loop Trap Systems: The point emphasized by the enclosed trap system makers is substantially that latent heat is lost when condensation is returned to an open heater. On careful examination, however, of heat reclaiming systems, such as we will show later, it will be appreciated that

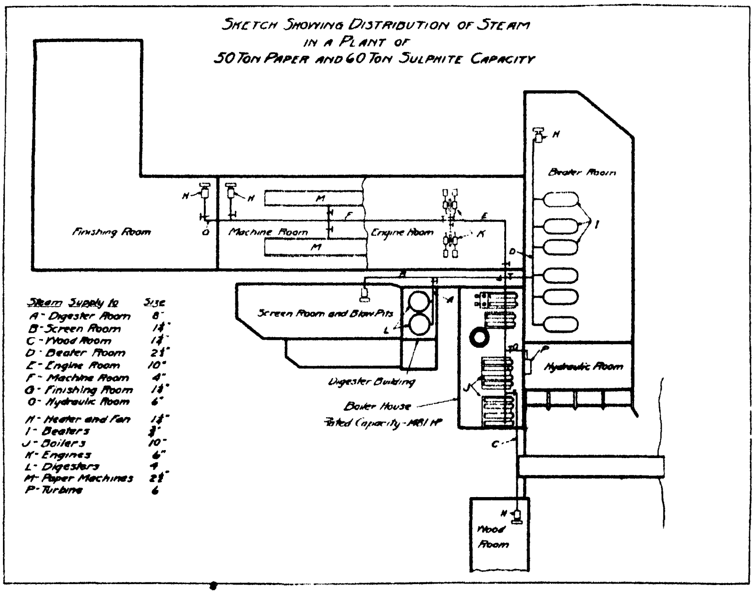


FIG. 286.

it is much better to segregate the waste heat units, convert these into hot water and in turn use this hot water as a substitute for live steam. In this event the alleged loss will be materially reduced primarily because the feed water temperature of the hot water in question will be kept below the flash point and not lost to the atmosphere.

The following is a description of one of the best known closed loop boiler feeding systems. This is the Farnsworth system which calls for a special type of boiler feeder and a special type of condensation pump, both designed by the Farnsworth Company and both, in the writer's opinion, highly efficient.

Figure 289 shows the Farnsworth system applied to a paper machine having a basement underneath it. This system is explained as follows:

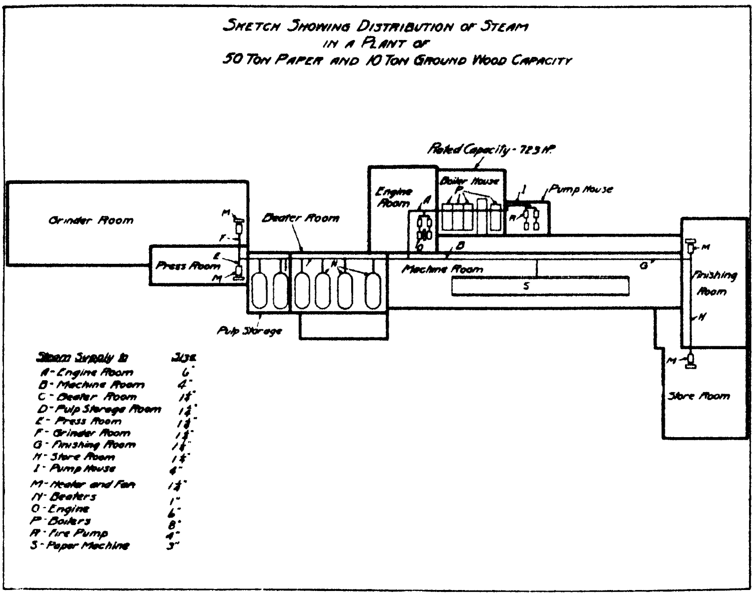


Fig. 287.

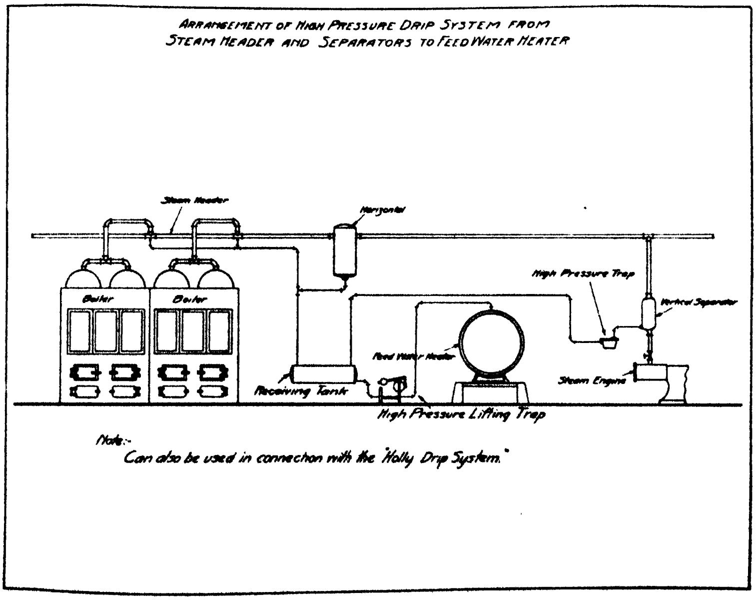
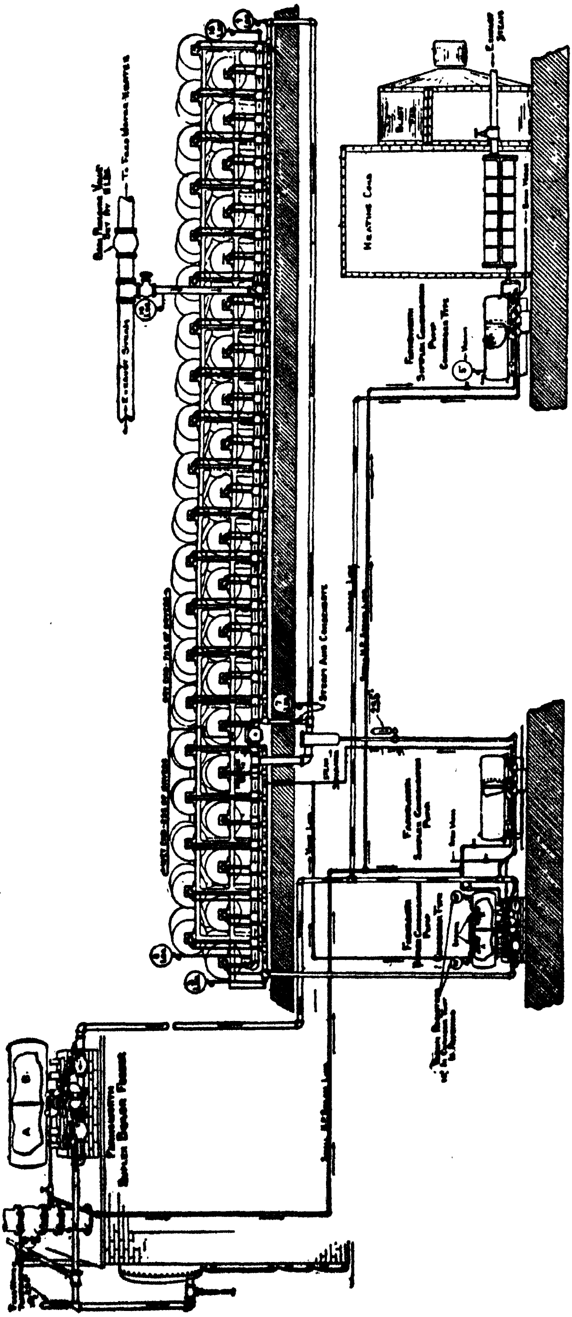


Fig. 288.



Courtesy: Farnsworth Co., Conshohocken, Pa.

FIG. 289.—Farnsworth system applied to a paper machine having a basement underneath it.

The paper machine is divided into two sections, one of these sections to have 75 per cent of the dryers and the other section the remaining 25 per cent. The steam and return headers between the two sections are cut, and a steam separator is placed on the end of the return header for the dry end section which separates the condensation from the steam which has blown out into this portion of the return header. This steam is passed over to supply the steam header for the remaining dryers on the wet end. On the end of the return header for the wet end dryers is placed a duplex condensation pump, condenser vacuum type. This machine has cold water sprays in the top of the tank. The spray water condenses the vapors in the return line producing a forced steam circulation.

In other words exhaust steam enters the dry end of the paper machine and passes through the dryers on the dry end at a high velocity due to the condensing of the steam in the wet end section assisted by the vacuum produced by the condensing sprays in the duplex condensation pump on the end of the return line for the wet end section. This also produces a high velocity of steam through the wet end section with the result that water and air are eliminated from both sections and a constant, even, known temperature at all times is produced.

The dryers on the dry end are hottest with a gradual decrease in temperature as the wet end is approached.

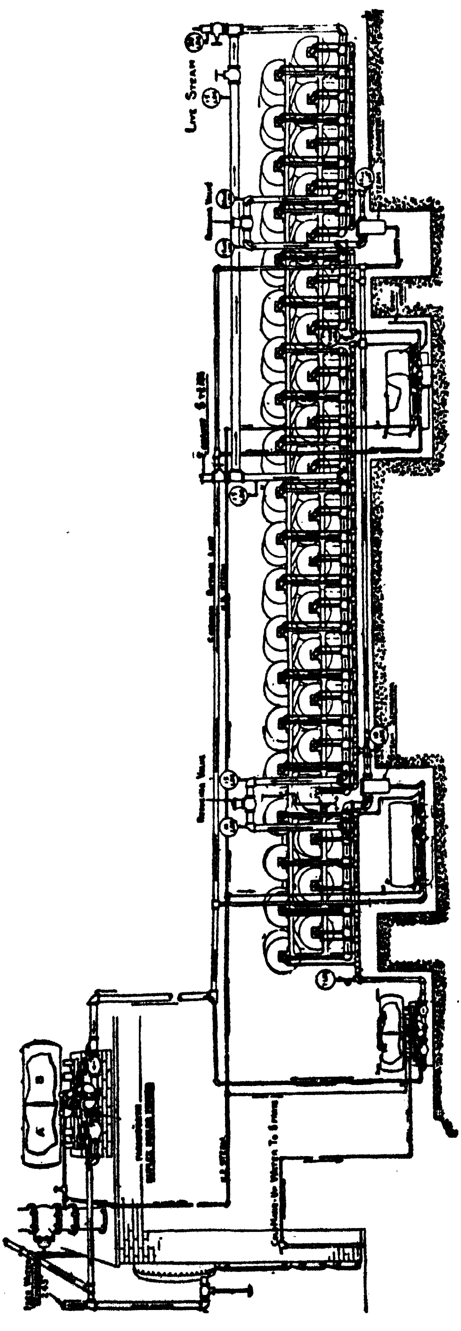
If for any reason insufficient steam should pass through the steam separator to maintain the required pressure in the wet end section steam is by-passed through a reducing valve and the proper amount is supplied.

Summing up, therefore, the steam supply line for the paper machine is connected at or near the beginning of the dry end. Steam is allowed to blow through all the dryers in the dry end section and out into the return line carrying with it all the water and air in these dryers. These dryers are, therefore, nothing more than the steam supply line for the dryers on the wet end.

The condensation is then separated from the steam that has blown through, and this steam is passed over to supply the dryers on the wet end section. The condensation that collects in the separator is drained into a simplex condensation pump. The air which enters the receiving chamber of each machine escapes through the vent.

In the closed loop boiler feeding system the condensation which is collected in the simplex condensation pump and in the duplex condensation pump, condenser vacuum type, is pumped automatically during the operation of the machine to the receiving chamber of the duplex boiler feeder located from 3 to 10 feet above the high water line of the boilers.

The duplex boiler feeder has two chambers—one of which is always receiving while the other is delivering the condensation with all its latent heat directly into the boilers giving a high feed water temperature and saving anywhere from 10 to 30 per cent of the coal. The duplex boiler feeder and the condensation pumps require only one-tenth to one-fourth the amount of steam used by the common pump because in these machines



Courtesy: Farnsworth Co., Conshohocken, Pa.

FIG. 290.—Farnsworth system applied to a board mill.

steam is applied directly in the surface of the water instead of behind a piston.

The condensation from all high pressure traps is discharged directly into the line leading to the receiving chamber of the duplex boiler feeder. The condensation from all low pressure heating systems, fan coils, etc., is drained into simplex or duplex condensation pumps and is forced up to the receiving chamber of the duplex boiler feeder by the application of live steam on the surface of the condensate in the tank while it is in the receiving position.

The Closed Loop Boiler Feeding system is a very efficient method for handling condensation because the pressure is never relieved from the surface which would lower the temperature to correspond with the decreased pressure.

Figure 290 shows the systems applied to a board mill using live steam in the dry end containing one-third of the total number of dryers; the remainder of the dryers are supplied with exhaust steam. In this case the machines which drain the paper machine are set in pits, there being no basement underneath the paper machine.

Under these conditions the live steam division of the paper machine and the exhaust steam division are each divided as in the case of Figure 289. That is to say, each division is subdivided into two sections, one section to have 75 per cent of the dryers, and the remaining section 25 per cent.

With this arrangement live steam blows through the first section on the dry end and out into the return line at a high velocity. It passes through a steam separator and over into the second section of the dry end where it is condensed, and this condensing effect, assisted by the simplex condensation pump, condenser vacuum type, on the end of the return line produces a forced steam circulation system through both sections.

The exhaust steam division of this paper machine is handled exactly as described for Figure 289.

The dryers on the dry end are hottest with a gradual decrease in temperature as the wet end is approached. The hot dryers on the dry end set the paper as it leaves the machine. The condensation which is drained into the separator on the live steam dryers is forced to the receiving chamber of the duplex boiler feeder by the pressure carried on the dryers.

The other three machines pump the condensate to the receiving chamber of the duplex boiler feeder, and, as previously stated, all the condensation with its valuable heat units is delivered directly into the boilers.

One of the main points we want to warn against in laying out steam mains for a plant is to have any kind of installation that will make it out of the question to make repairs in each division without shutting off the complete main. The shutting off of a complete main will frequently do more harm, even if only done once a year, than operating the plant under constant heavy steam pressure for several years. Reliable shut-off valves should be provided for each department, making it possible to repair various units without allowing the mains to become cooled.

In addition to the above, we have found that more damage has been done to steam mains, and more leaks have been caused, by improper dripping than from any one other cause. It is a very easy item to so pitch the pipe, and to so provide separators, that all wet steam is taken care of when the plant is operating week days. But the important item—the neglect of which has (as we have often seen) spoiled otherwise excellent plants—is to make provision for the elimination of water pockets and to provide at least some current through the steam mains on Sundays.

We have seen steam plants leaking in hundreds of places owing to the fact that the plant is shut down dead on Sunday, the management depending on the mains tightening up on Monday. It can readily be seen that, after the pipes have been filled with water, which causes a tremendous strain, and after the joints have been leaking for a few Sundays, the leaks inevitably become chronic, causing high repair cost and coal losses.

Pipe Covering.

Few items in power plant design are more important than good pipe covering. We will not dwell on this subject here because excellent information can be obtained free from the leading manufacturers of insulating materials for steam piping, who have gone to great expense to work out specifications covering all uses. Every operating engineer should have this literature, which will be sent free to any person interested. It will enable the calculation of just the right thickness of covering for any pipe line.

In general we might state, however, that any pulp and paper mill superintendent who has not given serious, careful and scientific consideration to proper pipe covering is simply throwing away money in an inexcusable manner.

Types of Units for Driving Paper Machines.

There are various types of units used for driving paper machines and these are used in several different combinations and connected in different ways to the steam system. It is easier to make this clear by drawings than by verbal explanation, and we have prepared a number of drawings which, we hope, will be clear without detailed explanation.

In general, there are the following systems: Direct drive from water wheels; Slow speed Corliss engines, belted direct to the line shaft (Figs. 291 and 292); High speed turbine units, driving through belts (Fig. 293); High speed turbines with speed reduction gears.

There have been recent important developments along the lines of electric drive. The earliest electrical systems consisted of constant speed motors with mechanical speed changing devices, similar to those used when the machines were steam driven. A later development consisted of adjustable speed motors.

All of the above systems employed the usual mechanical features of paper machine drive (Marshall system) consisting of main line shaft, bevel gears, cone pulleys with vertical belt drives, friction clutches, etc. This has already been touched on in the chapter on the machine room.

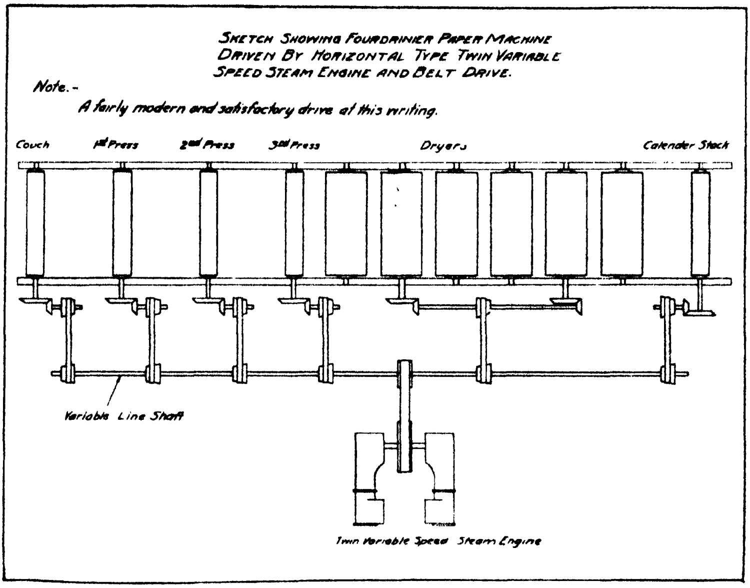


FIG. 291.

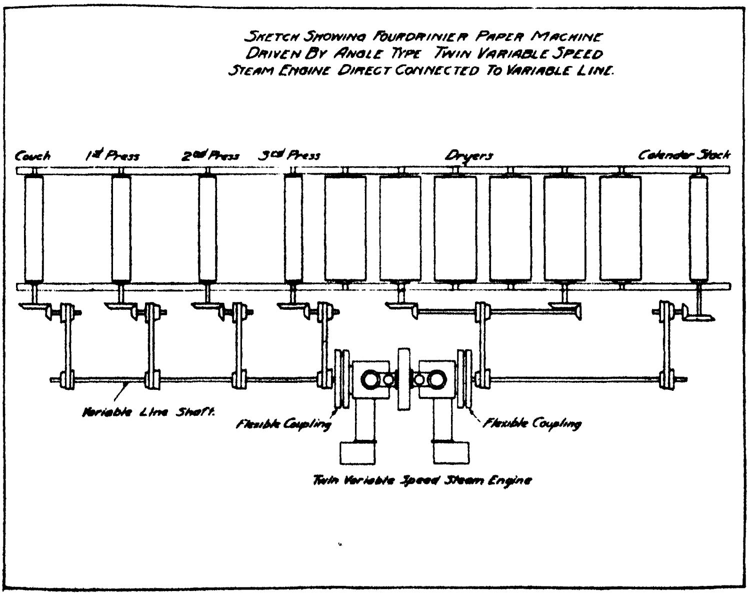


FIG. 292.

All these developments are taking place because of the constantly increasing dissatisfaction with the usual line shafts, gears, friction cones, etc., which, for years, have been a troublesome feature of the back drive of paper machines. When high speeds are encountered, as in modern newsprint and bag paper machines, great trouble is experienced, not met with in the old days at lower speeds.

Consequently, there is no doubt that the new drives have come to stay. They take a long step towards the complete elimination of excessive friction and vibration and the simplification of lubrication.

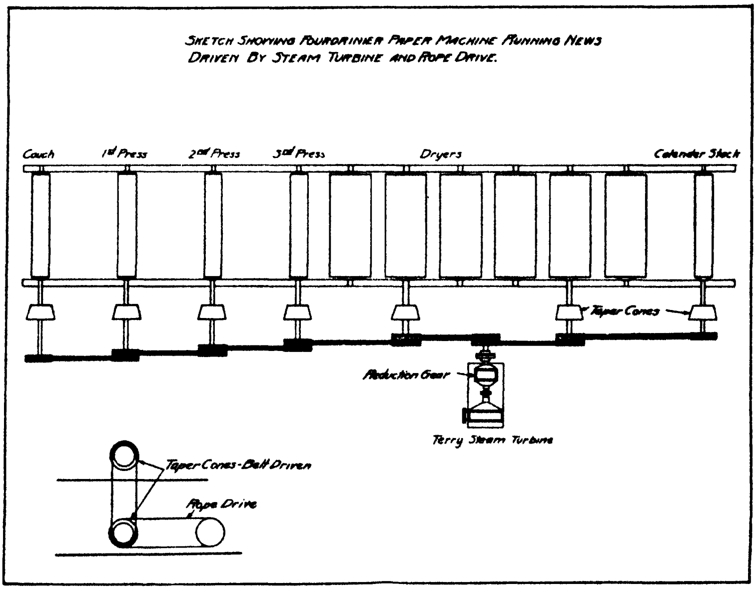


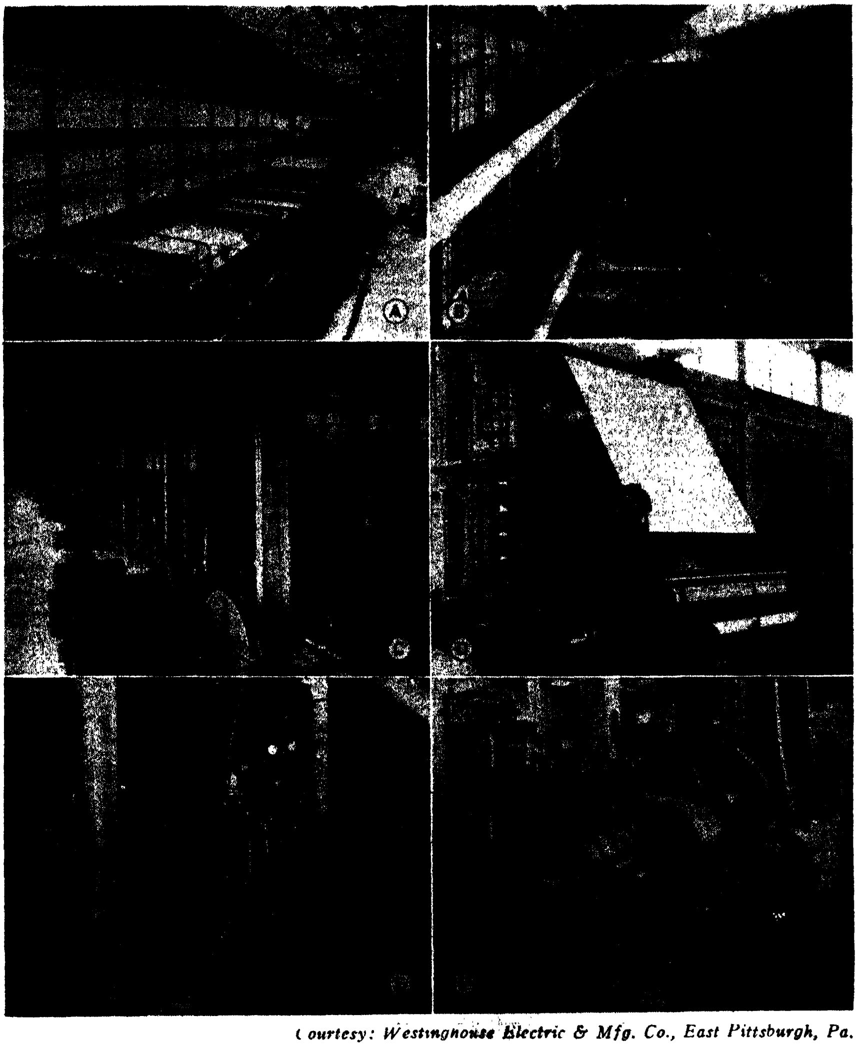
FIG. 293.

Sectional Electric Drive.

It would be quite beyond the scope of this book to attempt to describe modern sectional electric drive for paper machines in detail. This type of drive is now the generally accepted standard for new Fourdrinier machines; is coming to be quite generally used on cylinder machines; and many old machines are being modernized to provide for it.

Detailed descriptions of sectional paper machine drive systems can be obtained from either General Electric Company or Westinghouse Electric and Manufacturing Company.

One of the best known of such systems consists of moderate-speed d.c. motors which drive the various sections of the paper machine through reduction gear units. These motors are automatically controlled by means of extremely accurate speed regulating equipment. Such a drive eliminates all necessity for the use of belts, pulleys, line-shafting and clutches. The



Courtesy: Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Electric sectional paper machine drive.

(A) Wet end of Fourdrinier machine equipped with Westinghouse sectional electric drive. Note the individual motors back of the wire.

(B) Lineshaft-driven cylinder paper machine with wet end auxiliary drive.

(C) Westinghouse sectional paper machine drive applied to modern high speed news machine.

(D) Double finish 10-roll supercalender driven by wound-rotor motor using Westinghouse system of dual-frequency power supply. A synchronized 2-drum winder permits winding to be done directly on shipping core.

(E) Adjustable speed geared turbine driving variable speed paper machine lineshaft.

(F) Two-motor supercalender drive with wound-rotor gearmotor for main drive and induction gearmotor for threading.

quality of the paper is improved because of the absolutely uniform operating speeds.

The efficiency of such systems depends largely on the solution of very difficult problems in electrical engineering, which, as previously stated, are beyond the scope of this book. In view of the general application of this method of drive, however, it is strongly urged that anyone anxious to promote the highest efficiency in the machine room in a modern mill should familiarize himself with this type of equipment.

TABLE OF FRICTION AND FULL LOAD READINGS TAKEN FOR VARIABLE SPEED SHAFTS DRIVING A 156-INCH FOURDRINIER PAPER MACHINE, 60-INCH CYLINDER MACHINE AND 126-INCH FOURDRINIER

Friction Load of 156 inches Fourdrinier Paper Machine	319 Hp
Full Load of 156 inches Fourdrinier Paper Machine when running 30 lb. Manila Paper—Formula 60% Sulphite, 40% Groundwood	391.92 Hp
Power required to drive Variable Speed Shaft on 156-inch Fourdrinier Paper Machine—All machines down	132.78 Hp
Hp per inch width of 156-inch Fourdrinier Paper Machine when running 30 lb. sheet 60-40 formula	2.5 Hp
Hp per inch trim of 156-inch Fourdrinier Machine trimming 146¼ inches	2.7 Hp
Hp per inch of paper on 156-inch Fourdrinier Machine with deckle set at 152 inches	2.6 Hp
Hp required to drive 126-inch Fourdrinier Paper Machine 112-inch deckle when running on Envelope 24×36 inches—63½-lb. basis	237.8 Hp
Hp per inch width of above machines	1.85 Hp
Hp per inch width of paper on above machines	2.12 Hp
Hp required to drive 96-inch Cylinder Machine running with 84-inch deckle on 144-lb. Bristol Board	110.7 Hp
Hp per inches width of machine on above machines	1.32 Hp
Hp per inch of Paper on above machines	1.23 Hp

Distribution of Steam to the Paper Machines.

This is one of the subjects in pulp and paper engineering on which almost no two men agree. We find many engineers of acknowledged ability absolutely at variance with one another on this subject. We have prepared some drawings illustrating systems which we have found practical and which we hope will be of service as suggestions.

Heating System for Paper Mills.

The nature of the heating system must vary in each and every mill. There are two main methods in use today—the direct radiation system and the hot blast system. In plants of any size a combination of the two is usually best. This is especially true of the finishing room where generally a large force of both male and female (nowadays largely female) help is required. Usually, however, the wood room, digester house, blow pits, screen room, beater room and machine room can be satisfactorily heated by the hot blast system. We show two illustrations of systems we have found useful.

Reclamation of Heat Units.

This subject is so inextricably bound up with the foregoing topics—proper heating of pulp and paper mills, distribution of steam to the paper

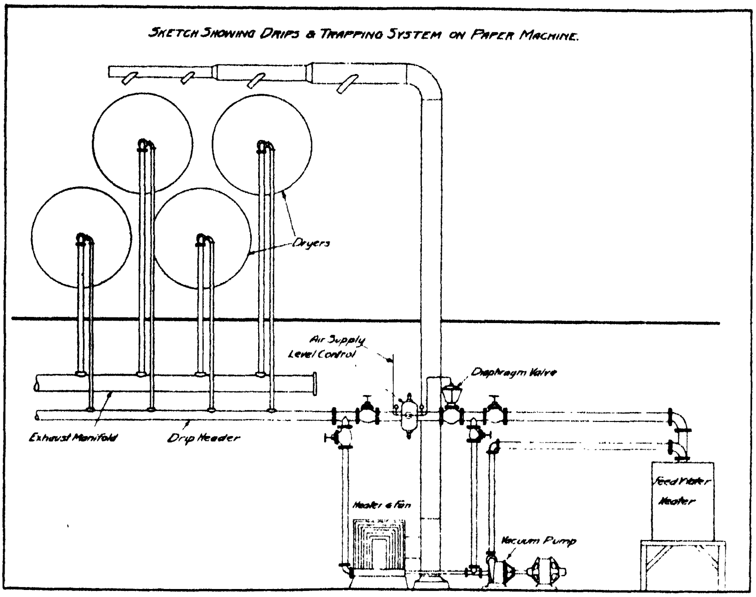


FIG. 294.

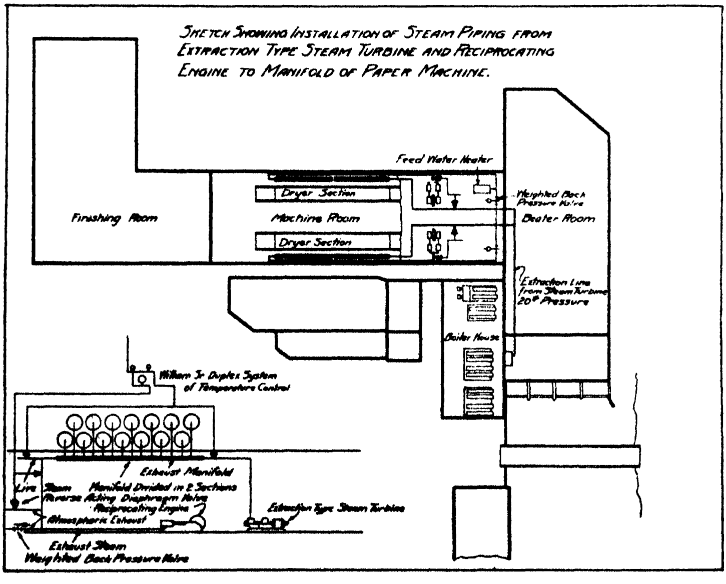


FIG. 295.

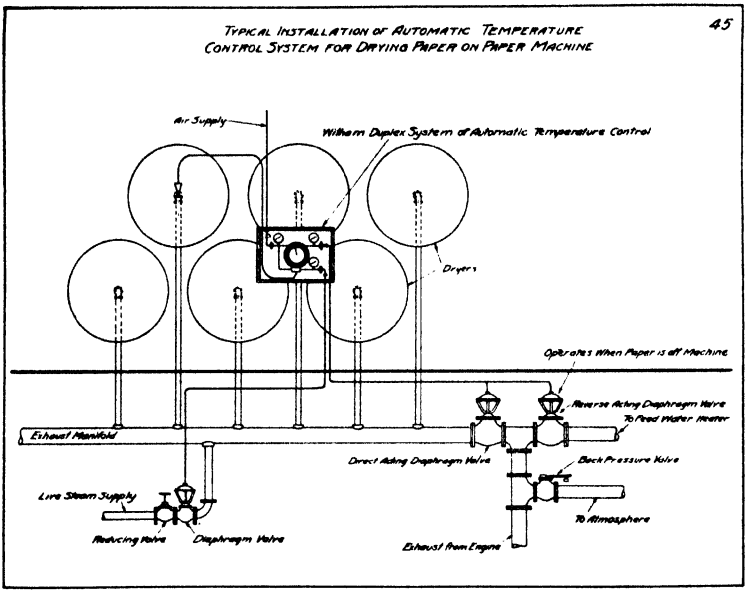


FIG. 296.—There are several types of controllers for regulating the drying of the paper. This subject has already been discussed in the chapter on the machine room. The above is a type of installation which the writer has found to be satisfactory.

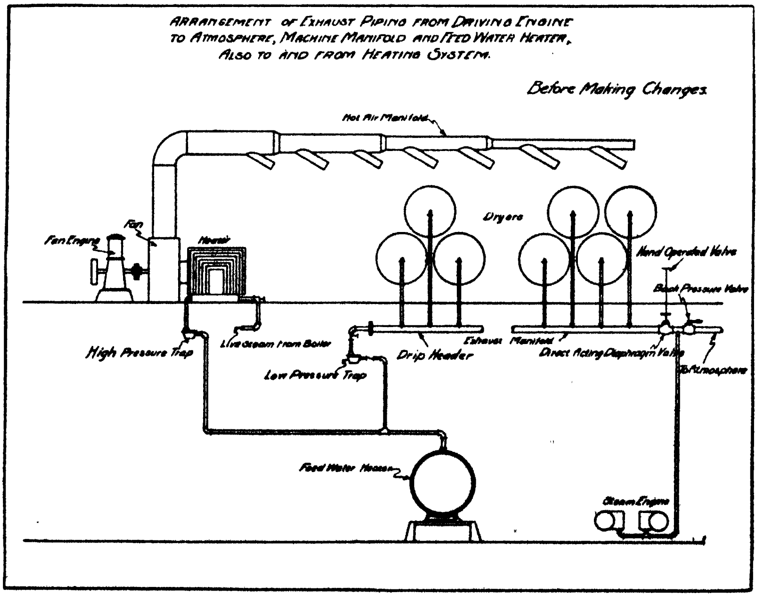


FIG. 297.

machine, etc., that little remains to be said, except to point out some of the writer's opinions as to the advantages. The numerous illustrations present the details of the various systems much better than could any number of pages of text.

As an argument in favor of careful working out of the heat reclaiming system, we will cite the case of a plant formerly supervised by the writer which operated for twelve years under substantially the following conditions:—

The plant produced 50 tons of paper, the grades being bonds, Manilas and envelope papers. There were two beater machines—one 90-inch cyl-

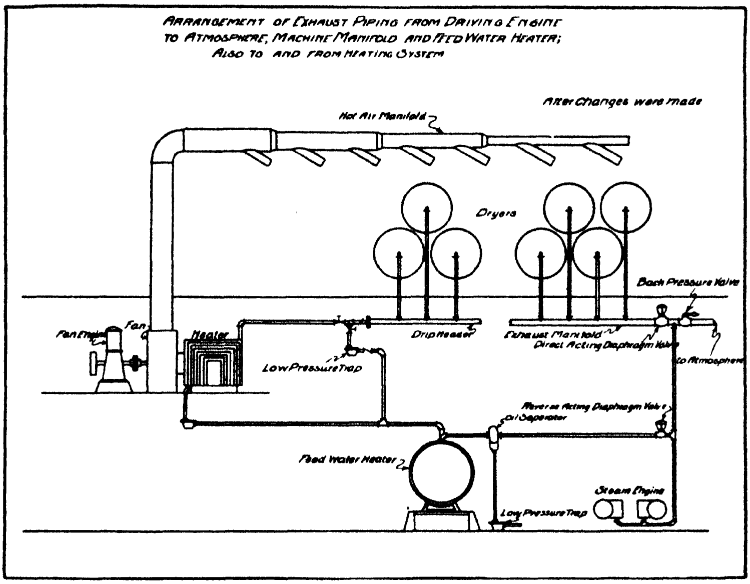


FIG. 298.

inder machine and one 126-inch Fourdrinier machine. The power plant included 5 return tubular boilers and the coal consumption averaged about 80 tons per day. Live steam was utilized for every beater, the size of the steam lines to the beaters being 1¼ inches. There were six 1800-lb. beaters. The bleaching equipment was capable of handling 20 tons of stock and the live steam lines for the bleaching equipment ranged in size up to and including 2 inches. Size was made at the plant, the water being heated by steam. Color mixing was done in the beater room, the color barrels being agitated with steam. In addition to the above barrels all waters were heated and prepared with soap by means of live steam for the washing of felts.

In the above plant under the conditions described, the coal consumption per ton of paper ranged from 1100 to 1150 pounds. After the installation

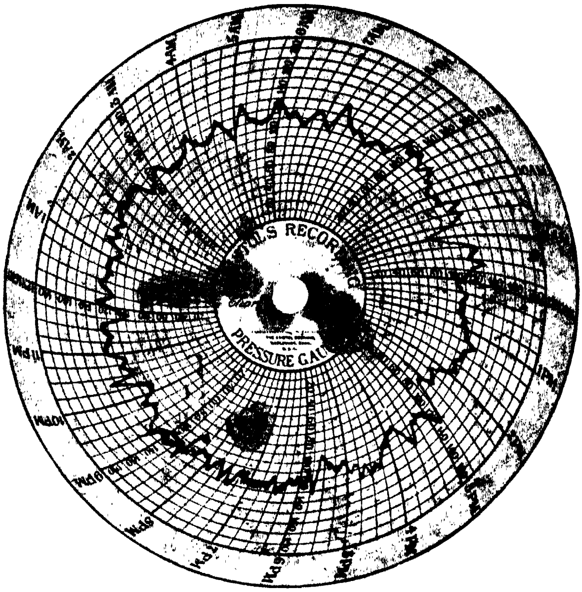


FIG. 299.—Typical boiler room pressure chart before installing modern equipment and methods.

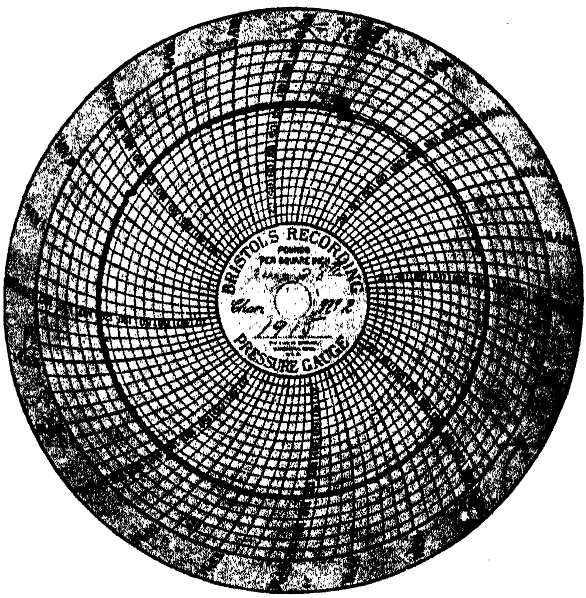


FIG. 300.—Typical boiler room pressure chart after installing modern equipment and methods. (Note regularity of steam pressure line.)

of a few modern accessories and the re-arrangement of the piping with the introduction of an efficient reclamation system, the coal consumption at this plant was brought down to approximately 600 pounds of coal per ton of paper.

TABLE OF POWER REQUIRED PER TON OF FINISHED PRODUCT IN MILL OF 125-TON SULPHITE AND 100 TON OF PAPER CAPACITY

Dept.	Unit	Power Required Hp	Power-Required per Cord of Wood Hp	Type of Equipment
Wood Room	Jack Ladder	40	.32	Endless chain angle type
Wood Room	Saw Feed Carriage	25	.2	Standard saw carriage
Wood Room	Circular Saw	50	.5	60″ Circular Saw
Wood Room	Conveyor	15	.15	Endless Chain V Trough
			Per ton of Groundwood Hp	
Groundwood Mill	Barker	15	6	Disc 60″ Barker
Groundwood Mill	Grinder	350	150	3 Pocket Grinder
Groundwood Mill	Screen	40	4.9	Cent. Screen
Groundwood Mill	Wet Press	8	1	Stand. Felt Type
			Per ton of Sulphite Hp	
Barking Drum Plant	Barking Drum	75	.37	American suspended type
Barking Drum Plant	Conveyor	30	.15	Endless chain "V" type trough
Wood Room	Barker	15	.12	60″ Disc Barker
Wood Room	Chipper	150	.75	4 Knife Disc Chippers 84″
Wood Room	Crusher	30	.15	
Wood Room	Chip Elevator	15	.12	Drag Flight Type
Wood Room	Refiner	15	.12	Rotary Type
Wood Room	Chip Elevator	15	.12	Belt Type
Acid Pump	Acid Pumps	30	.24	2″ Cent.
Digester Room	Acid Pumps	40	.32	8″ Cent.
Blow Pit Room	Stock Pump to Riffler	75	.6	10″ Cent.
Screen Room	Knotter Screen	5	04	Perforated Cyl. Type
Screen Room	Stock Pump from Riffler to Screen	135	1.12	10″ Cent.
Screen Room	Stock Screen	40	.32	Cent.
Screen Room	Tailing Stock Screen	40	.32	Cent.
Screen Room	Wet Press	8	.06	Stand. Felt Type
Screen Room	Screen Chest Agitators	8	.06	Paddle Type
Screen Room	Screen Stock Pump	15	.12	6″ Cent.
Screen Room	Screen Grinder	75	.6	Emerson Plug Jordan
Screen Room	Screen Press	8	.06	Stand. Felt Type
Kraft Shred Plant	Shredder and Pulper	250	2.5	
Kraft Shred Plant	Agitator in Chest	30	.3	Revolv. Paddle Type
Kraft Shred Plant	Stock Pump	40	.4	8″ Cent.
Paper Mill			Per ton of Paper Hp	
Beater Room	Deckers	8	.08	Revolv. Cyl. Type
Beater Room	Agitator in deckered stock chest	10	.1	Revolv. Paddle Type
Beater Room	Stock Pump to beaters	20	.2	Cent.
Beater Room	Beater 1500 lb.	50	.5	Roll and Tub 1500 lb.
Beater Room	Agitator in Jordan Chest	10	.1	Horizontal Type Agit.
Beater Room	Stock Pump to Jordan	15	.15	12×12 Trip. Plunger
Beater Room	Jordan	225	2.25	Wagg Majestic Jordan
Machine Room	Agitator in Mach. Chest	10	.1	Horizontal Type Agit.
Machine Room	Stock Pump to Stuff Box	15	.15	12×12 Trip.
Machine Room	Stuff Pump	30	.3	Cent.
Machine Room	Diaphragm Screen	7	.07	Flat Diap. Screen
Machine Room	Constant speed low	85	.85	A. C. Model
Machine Room	Fourdrinier Paper Mach.	450	4.5	4 Cyl. Angle Type var. spd.
Machine Room	Reels and Winders	50	.5	Upright Reels
Machine Room	Elevators	15	.15	Hydraulic

NOTE.—The plant containing the equipment as shown on this Table was of 125 tons sulphite capacity and from 80 to 85 tons of paper. This paper varied from 100% sulphite to 100% Kraft sheets.

Total Power Required in Mill Manufacturing 100 per cent sulphite wrapping paper was 3150 hp or 63 hp per ton of paper.

Equipment for a 100-Ton Groundwood Mill

Number of Units		Horsepower Required Min.	Max.	Average
1	Log Haul	8	20	15
1	Gang Saw (1-60″ saw slashing 4′ wood)	8	40	20
1	Conveyor to barking drums*	5	7	6
1	Barking drum installation	50	75	60
	or			
10	5 ft. barkers (one always held in reserve)	70	120	100
	or			
1	*Centrifugal pump for pond if wood is floated to barking drums instead of being handled on conveyor	12	12	12
1	Splitter	1	4	2
1	Conveyor to grinder room	6	9	8
Total for Wood Room				45 (24 hr. av.)
Using barking drums (operation 9 hours only)		78	155	121 (9 hr. av.)
16	assumed to be connected in lines of 4 each. 54 × 27 inch 3-pocket grinders, capacity 6.67 tons per 24 hours. One grinder assumed as idle	6000	6800	6500*
4	Pumps for supplying pressure to grinders (if driven directly by turbines)	70	70	70
1	Centrifugal pump for white water	50	50	50
1	Centrifugal pump for stuff	30	30	30
1	Silver screen	5	5	5
8	Centrifugal screens	120	120	120
	or			
6	Twelve plate screens, coarse	12	12	12
25	Twelve plate screens, fine	50	50	50
1	Pump for general water supply (capacity 3,000,000 gallons per 24 hours)	80	80	80
	Fan pump to deliver stuff to wet machines, or deckers	70	70	70
	Total grinders and screens	6507	7287	6987
Total for Wood Room and Grinder Room		6507	7442	7032 I
	If Pulp Is to Be Lapped for Storage or Shipment			
15	Wet machines, 72-inch face	140	180	160 II
	If Pulp Is to Be Prepared for Immediate Manufacture into Paper			
12	Deckers or pulp thickeners	36	36	36
1	Centrifugal pump to beaters	25	75	40
1	Agitator in deckered stock chest	15	15	15
	Total	76	126	91 III
Total *power required to make 100 tons lapped pulp per day (I + II)		6647	7622	7192
Total *power required to make 100 tons deckered stock per day (I + III)		6583	7568	7123

* For news grade of groundwood pulp. For fine grades, as high as 8000 hp may be used for 100 tons of pulp.

EQUIPMENT FOR 100-TON SULPHITE MILL

Number of Units		Horsepower Required Min.	Max.	Average
(9-hour operation)				
1	Log haul	8	20	16
1	Gang saw (1-60″ saw cutting 4′ wood)	8	40	30
1	Conveyor to barking drums*	5	9	7
1	Barking drum installation (2) drums	100	150	120
1	Barking machine (5 ft.) for handling wood imperfectly prepared in drums	7	12	10
	or			
20	5 ft. barkers (1 always in reserve)	140	240	200
	or			
1	*Centrifugal pump for pond if wood is floated to barking drums or barkers instead of being handled on conveyor	12	12	12
1	Splitter	1	4	2
1	Conveyor to chipper†	8	12	10
1	Centrifugal pump if wood is floated to chippers	12	12	12
3	7 ft. chippers (1 running only part of the time)	120	275	200
2	Crushers	50	80	60
3	Shaker screens for chips	12	24	15
1	Conveyor to shaker screens	3	3	3
1	Conveyor to chip bins	20	30	25
Total for Wood Preparing Plant		342	659	498 (9 hr. av.)
Operating 9 hours only				186 (24 hr. av.)
	Acid Plant, Digester House, Etc.			
1	Pump for general water supply (capacity 7,000,000 gallons per 24 hours. (Newspulp)	100	100	100
1	Elevator for limestone	10	10	2
1	Pump for tower system	15	15	15
5	Digesters 49 ft. high × 15 ft. diameter, holding approximately 26 cords chips and yielding 12 tons pulp (air dry) per cook			
1	Centrifugal pump for pumping stock from blow pit tanks to knotters	25	25	25
4	Knotters	6	6	6
1	Centrifugal pump for pumping stock from riffler to head box of screens	40	40	40

It is assumed that the stock is sluiced from the blow-pits to storage tanks below and is pumped from them to a mixing box from which it flows to the knotters, hence to the riffler, from the lower end of which it is pumped to the head box of the screens.

10	Centrifugal screens, including secondary screens	175	175	175
1	Screenings, Jordan or other grinder	75	75	75
1	Centrifugal pump from screens to wet machines or deckers (not required if mill is arranged so stock can gravitate from screens) which would ordinarily be the case	30	30	30
Total for Wood Preparing Plant and Digester House, etc.		466	1135	654 IV

† Exclusive of power required for heating buildings in winter, providing ventilation for grinder room, regrinding slivers from sliver screen, transportation of lapped pulp by conveyors or trucks to storage or cars, illumination, etc. Neither is any allowance made for hydraulic pressing of pulp taken from wet machines.

EQUIPMENT FOR 100-TON SULPHITE MILL.—(*Continued*)

Number of Units		Horsepower Required Min.	Max.	Average	
	If Pulp Is to Be Lapped for Storage or Shipment				
7	Wet machines, 72 inches face	84	84	84	V
	If Pulp Is to Be Prepared for Immediate Manufacture into Paper				
12	Deckers, 72 inches face	30	30	30	
1	Centrifugal pump to beaters	20	70	25	
2	Agitators in deckered stock chests	30	30	30	
	Total	80	130	85	VI
	Total* power required to make 100 tons lapped sulphite per day (IV + V)	550	1219	738	
	Total* power required to make 100 tons deckered stock per day (IV + V)	546	1265	739	

EQUIPMENT REQUIRED FOR MAKING 100 TONS NEWSPAPER PER 24 HOURS

4	Beaters (25 ft. × 11 ft) usual Hollander type	120	150	140
4	Stuff chests with agitators	30	45	40
2	Pumps for pumping stock from chests to Jordans	40	40	40
2	Jordans	240	300	280
1	Dissolver for clay	5	5	5
2	Agitators for clay water	10	10	10
2	Paper machines, total power required for all parts of drive as well as for stuff pumps, suction pumps, calenders, reels, slitters, blowing system, etc., but not boiler horsepower for dryers	850	1000	950
1	Pump for general water supply, capacity 3,000,000 gallons per 24 hours	60	60	60
	Boiler horsepower required for dryer	800 to 900	Bhp	

* Exclusive of power required for heating and lighting buildings, ventilating digester house, transporting lapped pulp by conveyors or trucks to storage or cars, hydraulic pressing of lapped pulp, operation of save-alls, etc.

This meant a reduction of approximately 40% in the coal consumption in the boiler room. It also allowed of a reduction in labor of one man one each shift, or three men from the total power plant crew.

In connection with this improvement it is interesting to know the difference in the two steam pressure charts shown in figures 299 and 300.

Estimate of Power Required in Pulp and Paper Mills.

It is manifestly impossible to furnish any estimate of the power required for the manufacture of pulp and paper that will cover all different cases, or any particular case, by direct application.

The length of conveyors alone, which will call for a considerable variation in power, will never be the same in any two plants. The boiler horsepower required for the digesters will depend on the manner in which the cook is conducted at any particular mill. Many other factors will vary. However, the figures given here are based on practical experience and care has been taken to mention what is not included in any of the estimates.

It is assumed that the wood is received at the mill in 4-foot or 2-foot lengths and that the preparation begins with the removal of the bark.

It is assumed that log hauls and other conveyors are of average length, not exceeding 500 feet in any case, and of modern construction.

It is also assumed that the entire plant runs 24 hours per day, except Sundays, with the exception of the wood room, which is assumed to run 9 hours per day.

Grinders are to be driven by electric motors or hydraulic turbines through direct connection. All other equipment, except paper machines, is assumed to be motor driven, either direct connected or otherwise. Paper machines are assumed to be driven by their own separate engines, turbines or electric motors.

It is not necessary to add anything to the figures given, as they have all been calculated very liberally so as to be always on the safe side. Allowance is made in all cases for normal stoppages, but it is assumed that all equipment, motors, shafting, etc., is maintained in normally perfect condition by competent mechanics.

Thus, the estimate will furnish a skeleton to which individuals can add, subtract or otherwise adapt, so as to suit the particular conditions with which they are confronted.

The power required to drive paper machines [1] varies greatly with their width, speed and other conditions obtaining at individual mills. In general news machines from 140 to 170 inches in width require from 400 to 500 hp for the entire machine from screens to winder, both constant and variable speed shafts, when running at about 600 feet of paper per minute.

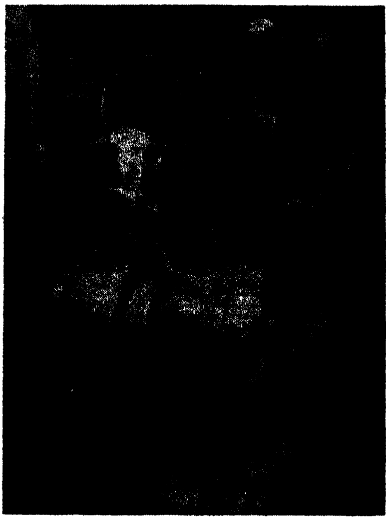
Book machines, ranging in width from 110 to 140 inches wide require from 150 to 250 hp. Machines for fine writings, from 80 inches to 110 inches wide, require from 50 to 125 hp.

The speed of modern news machines generally at least is 600 feet per minute,[2] and more recently built machines are frequently run much faster; book machines run from 150 to 250 and writing machines from 60 to 175.

Use of Estimates of Power Required.

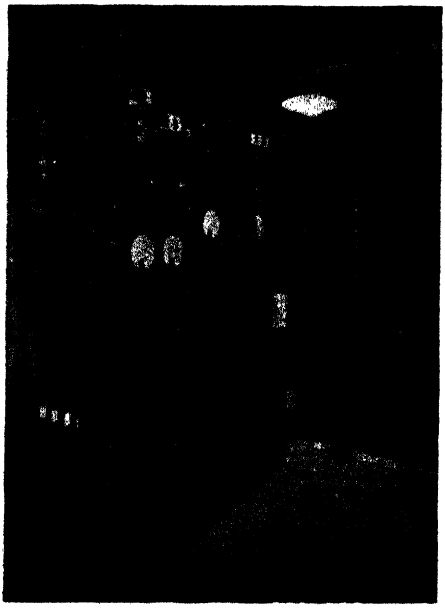
With a little ingenuity, requiring no great amount of mathematical ability, the above estimates can be made the basis for a great many calculations. For instance, the total power required to make a particular grade of paper in given quantity per day can easily be figured out. Suppose the paper is a news containing 20 per cent sulphite and 80 per cent groundwood. Obviously, the power required for the sulphite for 100 tons of such paper will be 20 per cent of the paper shown in the tabulation for a production of 100 tons of sulphite per day. Similarly, the power required for the groundwood will be 80 per cent of that required to make 100 tons of groundwood per day. Adding these together, and to the sum adding the power required to make 100 tons of paper per day, will give the total mechanical horse-

[1] See also table, page 658.
[2] Excepting in the case of machines of considerable age.



(a)

(b)



(c)

(a) *Courtesy: Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Cylinder machine wet end auxiliary drive using totally enclosed ventilated gearmotors coupled to cylinder molds.

(b) *Courtesy: Allis-Chalmers Mfg. Co. Milwaukee, Wis.*

Six 150-hp. Texrope drives operating Horne beaters.

(c) *Courtesy: Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Synchronous motor starter and full automatic combination d.c. motor and generator control for single motor drive for paper machine.

FIG. 301.

power required. To this can be added the boiler horsepower required for the digesters and the dryers on the paper machine. This will give the total horsepower required and the necessary installation of boilers and prime movers can be figured from this from data supplied by manufacturers of such equipment, after a suitable figure has been added to take care of heating in winter, lighting, machine shop, blacksmith shop, carpenter shop, coal and ash conveyors, etc.

The figures given for the manufacture of paper will hold true for most usual kinds of paper, such as newsprint, ordinary book, magazine, writing, wrapping, bag, hanging and other such papers. For fine writings, specialties, etc., the power consumption will, of course, be greater per ton of production.

With some adaptation the estimates made for a sulphite mill will apply to a sulphate, kraft, or soda mill. From the blow pits on the figures will be about the same. The boiler horsepower for the digesters will be different and no general figures could be given for the recovery systems as these vary tremendously in the number of pumps, agitators, etc., they employ.

20. Testing of Paper and Paper Materials

Owing to the constant improvement of chemical and physical testing methods and the possibility of obtaining up-to-date information from the sources outlined below, it is not our intention to give detailed instructions for analyzing the various materials which are used in a pulp and paper mill.

The Technical Association of the Pulp and Paper Industry from time to time publishes paper testing methods which are generally regarded as standard. This work is done in close association with the Paper Section of the National Bureau of Standards, Washington, D. C. There is also close collaboration with the Technical Section of the Canadian Pulp and Paper Association.

The paper research of the National Bureau of Standards consists of studies related to the standardization of paper and the materials and processes used in its manufacture. The work on the standardization of paper leads to formulation of standards of quality, and includes, necessarily, the development of means of measuring quality. For research related to the manufacture of paper, the Paper Section is equipped with laboratory and semi-commercial papermaking facilities. These are used to obtain information which will assist the paper maker in obtaining the desired qualities in paper at a minimum of cost, in developing new or improved paper products, and in utilizing new fibrous raw materials, particularly waste materials.

The following is a list of the available publications of the Technical Association of the Pulp and Paper Industry, 122 East 42nd St., New York. These are ordinarily alluded to in the industry as "TAPPI Standards."

MANAGEMENT	Code No.*
Waste	
Measuring, Sampling and Analyzing White Waters	M 400 p-36
ENGINEERING	
Equipment	
Piping Systems Color Code	E 1 p-34
Flow Measurements of White Waters and Wastes	E 2 p-40
Heat and Power	
Paper Drying Code	E 200 p-36
Standard Power Plant Report	E 201 p-34
Comparison Power Plant Report	E 202 p-34
Materials of Construction	
Specifications for Chromium-Nickel-Iron Castings for Sulphite Pulp Processing Equipment	E 400 s-36

* The code numbers indicate the date of the most recent issue; thus M 400 p-36 indicates that the latest issue of this standard was in 1936.

OPERATING	Code No.
Alkaline Pulping	
Standard Terms Used in the Sulphate Pulping Process	O 400 p-36
Alkaline Pulping Thermal Code	O 401 p-40
Standard Terms Used in the Soda Pulping Process	O 402 p-37
Sulphate Recovery Thermal Code	O 404 p-37
Acid Pulping	
Analysis of Sulphite Waste Liquor	O 403 sm-40
TESTING	
Fibrous Materials Testing	
Water Solubility of Wood	T 1 m-34
Methoxyl Groups in Wood	T 2 m-34
Moisture in Wood Chips and Sawdust by Toluene Method	T 3 m-34
One Per Cent Caustic Soda Solubility of Wood	T 4 m-40
Ether Solubility of Wood	T 5 m-40
Alcohol-Benzene Solubility of Wood	T 6 m-40
Physical Evaluation of Pulp Cord-Wood	T 7 p-36
Species Identification of Wood and Wood Fibers	T 8 sm-37
Holocellulose in Wood	T 9 m-40
Pulp Testing	
Beater Processing of Pulp	T 200 m-40
Isolation of Cellulose by Chlorination Method	T 201 m-37
Chlorine Consumption of Pulp	T 202 m-40
Alpha Cellulose in Pulp	T 203 m-40
Pitch in Wood Pulp	T 204 m-35
Forming and Testing Pulp Sheets	T 205 m-40
Cuprammonium Disperse Viscosity of Pulp	T 206 m-37
Water Solubility of Pulp	T 207 m-34
Moisture in Pulp by Toluene Method	T 208 m-34
Methoxyl Groups in Pulp	T 209 m-34
Weighing, Sampling and Testing Wood Pulp for Moisture	T 210 m-36
Ash in Pulp	T 211 m-40
One Per Cent Caustic Soda Solubility of Pulp	T 212 m-40
Dirt in Pulp	T 213 sm-39
Permanganate Number of Pulp	T 214 m-37
Copper Number of Pulp	T 215 m-38
Spectral Reflectivity and Color of Pulp	T 216 m-40
Paper Testing	
Sampling Paper for Testing	T 400 m-36
Fiber Composition of Paper	T 401 m-39
Conditioning Paper for Testing	T 402 m-36
Bursting Strength of Paper	T 403 m-36
Tensile Breaking Strength of Paper	T 404 m-36
Paraffin in Paper (Quantitative)	T 405 m-40
Reducible Sulphur in Paper (Quantitative)	T 406 m-39
Amount of Coating on Mineral Coated Paper	T 407 m-35
Resin in Paper	T 408 m-39
Machine Direction of Paper	T 409 m-35
Basis Weight of Paper	T 410 m-36
Thickness and Density of Paper	T 411 m-36
Moisture in Paper	T 412 m-35
Ash in Paper	T 413 m-39
Tearing Resistance of Paper	T 414 m-40
Casein in Paper (Qualitative)	T 415 m-40
Proteinaceous Nitrogenous Materials in Paper (Qualitative)	T 417 m-34
Proteinaceous Nitrogen in Paper (Quantitative)	T 418 m-35
Starch in Paper	T 419 m-39
Mineral Filler and Mineral Coating of Paper	T 421 m-38
Folding Strength of Paper	T 423 m-36
Gloss of Paper	T 424 m-35

	Code No.
Opacity of Paper	T 425 m-35
Bulking Thickness of Paper	T 426 m-40
Saturating Properties of Roofing Felt	T 427 m-34
Water Soluble Acidity or Alkalinity of Paper	T 428 m-39
Alpha, Beta, and Gamma Cellulose in Paper	T 429 m-39
Copper Number of Paper	T 430 m-38
Ink Absorption of Blotting Paper	T 431 m-40
Water Absorption of Bibulous Papers	T 432 m-36
Water Resistance of Paper (Dry Indicator Method)	T 433 m-40
Acid Soluble Iron in Paper	T 434 m-35
Hydrogen Ion Concentration (pH) of Paper Extracts	T 435 m-34
Arsenic in Paper	T 436 m-36
Dirt in Paper	T 437 m-39
Zinc Pigments in Paper	T 438 m-37
Titanium Pigments in Paper	T 439 m-37
Alkali-Staining Property of Paper	T 440 m-37
Water Absorptiveness of Nonbibulous Papers	T 441 m-40
Spectral Reflectivity and Color of Paper	T 442 m-40
Water Permeability of Paper and Paper Boards (Ground-Glass Method)	T 443 sm-39
Silver-Tarnishing Test of Paper	T 444 m-39
Identification of Specks and Spots in Paper	T 445 sm-39
Creasing Quality of Paper	T 446 sm-40
Moisture Expansivity of Paper	T 447 m-40
Water Vapor Permeability of Paper and Paperboard	T 448 m-40
Nonfibrous Materials Testing	
Analysis of Formaldehyde	T 600 m-36
Analysis of Gasoline	T 601 m-35
Analysis of Sulphuric Acid	T 602 m-35
Analysis of Sulphur-Burner Gas	T 603 m-36
Analysis of Bisulphite Cooking Liquor	T 604 m-35
Sampling and Analysis of Coal	T 605 m-33
Preparation of Liquid Analytical Reagents	T 606 m-36
Analysis of Casein	T 607 m-33
Calibration of Volumetric Glassware and Analytical Weights	T 608 m-33
Indicators for Volumetric Analyses	T 609 m-33
Preparation and Standardization of Volumetric Solutions	T 610 m-37
Analysis of Bleaching Powder, Bleach Liquor and Sludge	T 611 m-33
Analysis of Soda Ash	T 612 m-40
Analysis of Sodium Hydroxide	T 613 m-40
Analysis of Alum	T 614 m-37
Analysis of Mineral Fillers	T 615 m-37
Analysis of Sulphur	T 616 m-34
Analysis of Lime	T 617 m-34
Analysis of Limestone	T 618 m-34
Analysis of Salt Cake	T 619 m-35
Analysis of Water	T 620 m-35
Analysis of Rosin	T 621 m-35

The National Bureau of Standards also publishes an annotated bibliography of books and articles on paper testing and related subjects. This is very useful and can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. This bibliography, which is published in multigraphed form, is brought up to date from time to time.

(1) *Chemical testing or analysis,* covering all raw materials such as sulphur, lime, soda ash, sulphate of soda, bleach, alum, size, etc. Also coal, water, lubricating oils, building materials, paints and miscellaneous materials used in the construction and operation of a large modern industrial plant.

(2) *Paper Testing,* that is a series of standard tests made on the product being produced by the mill at regular intervals so that an accurate record can be kept of the quality of the product and the efficiency of the plant, and so if anything is going wrong it can be detected and remedied before much harm is done. The nature of these tests will be described more in detail later on.

(3) *Microscopic Testing.* Frequently examination of paper or of pulp with a microscope is necessary to detect the presence of particular materials. Certain solutions are used in connection with the microscope to give characteristic colorations with different fibers.

Chemical Control of the Mill.

Chemical control enables a manufacturer to know and realize the value of his product so that he can guarantee every pound of it. Such a guarantee is a liability, for it must be lived up to at all times, in spite of variations in raw material, labor difficulties, weather conditions and other variable factors.

Chemical control is one of the chief items in the list of factors which enable a manufacturer to convert this guarantee, which he is compelled to give, into an asset instead of a liability. Moreover, continued watchfulness for defects helps to build up the good will of the concern and to establish a firm reputation as a reliable producer.

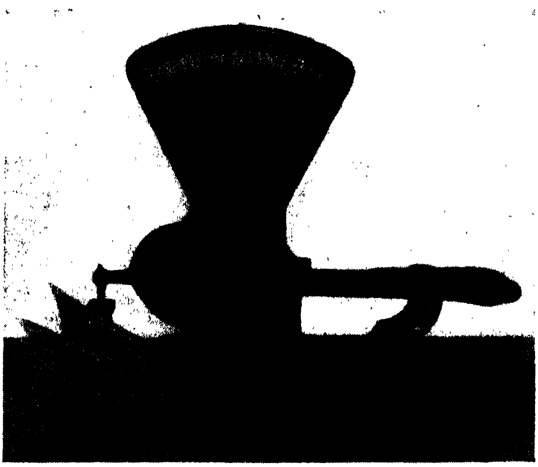
Paper making is a peculiar industry in that it is in part mechanical and in part chemical. The chemical and mechanical aspects of the problem are so interwoven that it is hard to say where one begins and the other ends. There are some paper makers who have risen from the ranks to be superintendents who almost ignore the chemical aspect of the industry, leaving whatever attention is paid to the chemical operations of the plant to the part of a chemist, who may or may not be competent to discharge such important duties. On the other hand, there are men trained as chemical engineers in charge of large paper industries who pay little attention to the enormous and important problems in mechanical engineering constantly arising. Either of these attitudes is wrong.

Chemical control does not mean having a laboratory with some glassware and balances and a man (usually a young chemist just out of a technical school) confined to the laboratory, testing and analyzing such samples as are sent to him from time to time. It means having a man experienced in the art of making pulp and paper, and at the same time with a broad chemical education, so that he can investigate all mill problems and work out new ideas, and such a man must have sufficient prestige and authority to be able to carry out such improvements as may suggest themselves to him after they have been submitted to careful analysis and discussed with his associates. Such men are not easy to find and the mill is to be regarded as fortunate which possesses such a man.

With increased introduction of chemical control in pulp and paper mills there has come about a more efficient utilization of fuel and of many of the raw materials consumed, such as clay, sulphur, limestone, soda ash, bleach, dyestuffs, etc.

Some of the problems the mill chemist will have to wrestle with are investigations into water conditions from time to time, making size emulsions, determining proper proportions of alum, the proper furnish of raw stock, the proper colors, etc.

In the sulphite mill the need of a chemist or chemical engineer is perhaps more obvious than in the paper mill since the process is more distinctly chemical. Chemical control steps in at the very first stage of the process—regulation of the burner gases in order to prevent formation of SO_3 and consequent formation of the undesirable calcium sulphate or gypsum in the digesters, etc. Following this is the proper preparation of the raw acid and



Courtesy: Toledo Scale Co., Toledo, Ohio.

FIG. 302.—Typical scale especially designed for rapid accurate weighing of paper samples. Because of the extended beam extremely fine readings are possible.

cooking acid and the whole subject of reclaiming, the maintenance of high free and low combined. There is an opportunity here for the chemist to apply as much theoretical chemistry as he knows. The problems are very complex and it is generally realized that many improvements are yet to be made which must wait for adequate scientific consideration of the general laws governing the various reactions.

One of the most important opportunities for chemical control is in the cooking operation itself. Moisture in the wood must be ascertained in order that the cook may know the nature of the raw material he is handling.

Chemical control does not necessarily imply having a large force of trained chemists. There are many chemical tests which any intelligent workman can be taught to make at regular intervals. The workman may not understand the underlying causes of the reactions, but that does not prevent him from following directions, and entering up the burette readings on a form. Frequently the chemist can greatly simplify such tests by adjusting his standard solutions so that burette readings will give percentages directly without any calculation. For instance, acid makers can be taught to make the necessary iodine and caustic titrations to estimate total and free SO_2. If the standard solutions supplied to them by the laboratory are made up exactly 1/16 N., then a 2 cc. sample of acid will give a burette reading which will give the percentage of SO_2 directly when the decimal point is moved one place to the left. This method assumes the specific gravity of the acid to be 1, which is, of course, incorrect, but the error introduced in this way is not enough to vitiate the result for practical purposes.

Similarly, men can be taught to make simple chemical estimations instead of using a hydrometer in making up bleach. The use of the hydrometer in this connection is very inaccurate, on the other hand many mills have no chemist, and in many mills which do, the trouble of taking samples and sending them to the laboratory is considered not worth while.

Practically all the chemical tests connected with the operation of boiler feed water treatment systems can be handled by workmen once they are shown the routine of the operation.

The writer suspects that one reason so many mills seem obstinately backward in introducing chemical control is because so many chemists shroud their operations in so much mystery that they antagonize the non-chemical men about them. In reality, the majority of chemical tests are absurdly simple compared with many of the other duties of intelligent workmen, and there is no reason why, wherever a chemical test is absolutely necessary, it cannot be carried out if the chemist will supply a simple method for doing it. Of course, the chemist should not load the help down with so much work of this kind that they will have no time for their more ordinary duties. We have seen mills, in more than one industry, where foremen and others were kept so busy filling out forms and making reports of a complicated nature to send back to the office or laboratory to satisfy some alleged "efficiency expert" that they became mere clerks to the great detriment of the operations over which they were supposed to exercise control.

Paper Testing.

Paper may be examined from three different points of view, physical quality, mechanical quality and composition.

The various tests classified under physical testing are: weight, thickness, bulk, strength, stretch, sizing, etc.

The chief mechanical test is for strength and this is subdivided into tests for tear, punch, bursting, etc.

Under composition falls the determination of the materials used in making the paper and their proportions.

In addition to the above tests, special tests may be used on special grades of paper, viz., absorbency and permeability for blotting papers, resistance to blood in butchers' papers, etc.

In most cases no one of the above tests will give an accurate working knowledge of the paper. Moreover, frequently some one test may show the paper to be of excellent quality, but when this paper is put to use it is found to be worthless; consequently the nature of the test used on the paper must be in accordance with the treatment the paper will encounter in actual use. For example, for testing strength there are several machines in general use which give the punch test, bursting test, tear test, etc. It is often quite desirable to have a sheet of paper comparatively low in punch test but high in tear, for example, a bag paper. A punch test applied to such a paper, or to any paper for that matter, shows the hardness and rigidity of the sheet. However, this is not what should determine the value of a bag sheet. A thin sheet of celluloid would test very high on such a machine and would have no value at all for bag manufacture, and this is only an extreme case of the conditions prevailing with some papers. Consequently, the sheet to be tested must be dealt with in such a manner that its tearing resistance will be shown and the extent to which the fibers will peel when they are torn apart. A wrapping or bag paper that peels when torn will be much better than one that does not. A punch test will not show this peeling quality at all. In fact, if two sheets of bag or wrapping paper were made, one stiff and hard with little crossing of the fibers, the fibers beaten short and the sheet well colored and sized, and the other sheet made soft and flexible, with the fibers brushed out long and interwoven on the wire, the punch test would show the first sheet to be the better of the two, as it would give a higher test. In reality the second, from the point of view of service, would be far the better sheet and a tear test would indicate this, as would also a peeling of the fibers.

System of Making and Recording Tests.

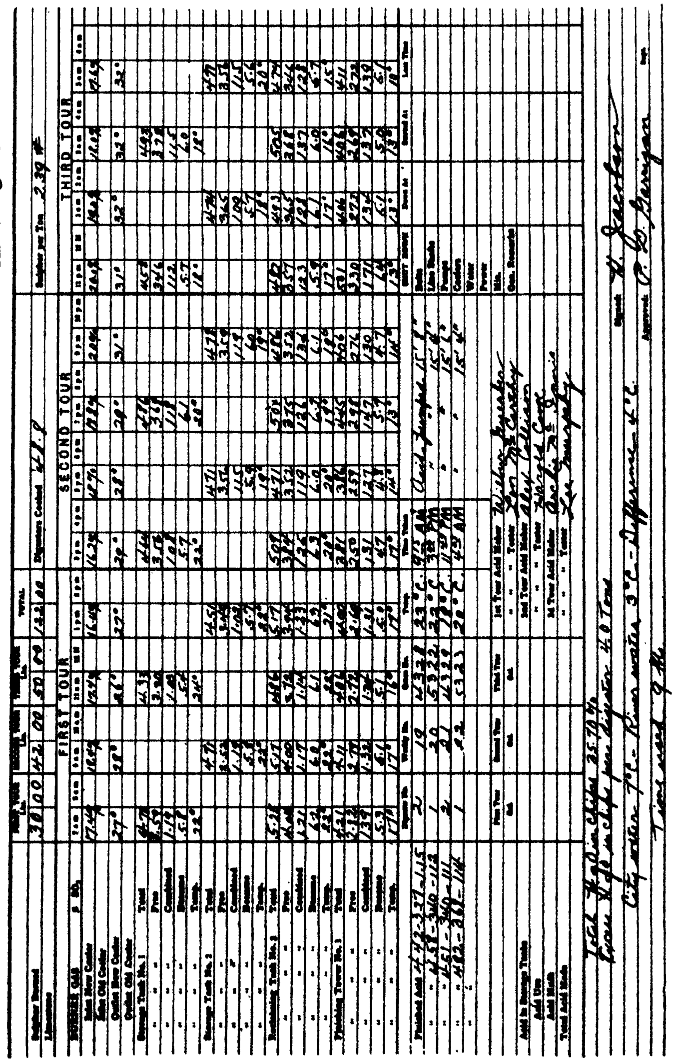
The following is a description of the tests and the method of recording them which the writer has found suitable, after many years of experimentation, for controlling the quality of the product of a large paper mill.

The Technical Bureau.

One of the chief points to take care of in maintaining a Bureau of Tests, is such an organization that the mill men as a whole do not take it as a spying system upon their activities. In other words if the personnel and the activities of the Bureau of Tests can be so woven into the manufacturing end of the game so as to serve for reproducing facts which in turn may be posted on the Bulletin Board for the employee, a tremendous amount of good will come from this organization.

We have stated that it has been our experience that a happy medium may be arrived at, by which a tremendous amount of time is not wasted and money spent on elaborate analyses of materials which usually the seller is capable of furnishing without the mill necessarily maintaining an elaborate analytical department for this purpose. As we have said before the utilization of the Bureau of Tests for checking the paper as it is being made, thereby preventing the manufacture of poor paper and incidentally checking various points of manufacture, as relating to the cost during the operation, to our minds constitutes its chief function.

This system calls for two departments—a Bureau of Chemistry and a Bureau of Physical Tests. These departments work more or less in con-



ACID ROOM REPORT Date 4-2-20

Digesters Cooked 47.8

Sulphur per Ton 2.39 #

FIRST TOUR SECOND TOUR THIRD TOUR

Total Hg in chips 25.70%

Excess H₂O in chips per digester 4.0 Tons

City water 7°C.—River water 3°C.—Difference 4°C.

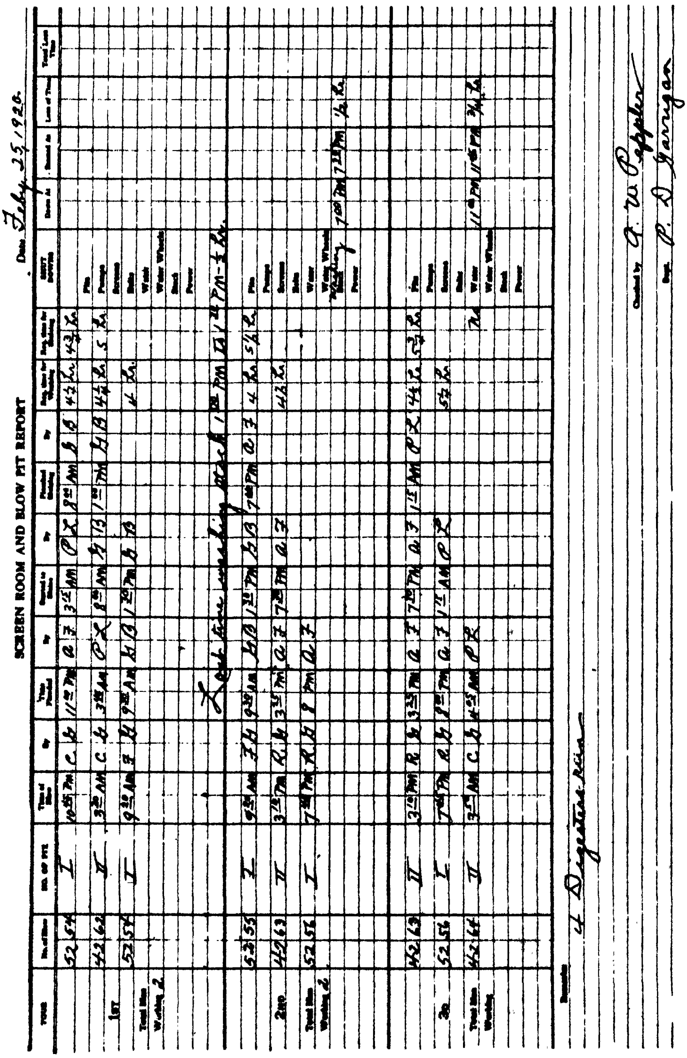
Time used 9 hr.

Signed H. Jacobson

Approved P. D. Garrigan

FIG. 303.

junction with each other but yet each have their definite duties. The Bureau of Chemistry finds its work principally in the scientific valuation of purchased raw materials going into the manufacture of pulp and paper and also is engaged in testing the efficiency of these various purchased raw materials as utilized by machinery and workmen in the plants—such as coal, sulphur, limestone, rosin, alum, etc. In conjunction with the above all stages at which the quality of the pulp is apt to be destroyed, are constantly inspected and checked. The quality of the wood is carefully


SCREEN ROOM AND BLOW PIT REPORT

Date Feby. 25, 1928.

Checked by A. W. Pappler

Supt. P. D. Garrigan

FIG. 304.

watched—its moisture content and soundness. By means of laboratory screens, the efficiency of the sizes of chips made in the chippers is carefully regulated in order to aid the digester cook further on in the process, to secure more uniform cooking conditions. A large blue print is posted on the Bulletin Board for the benefit of the workmen, illustrating various percentages of different size chips from day to day. It is quite essential in the modern sulphite mill of today to have installed a system for checking the various operations of the sulphite process, such as burner gas

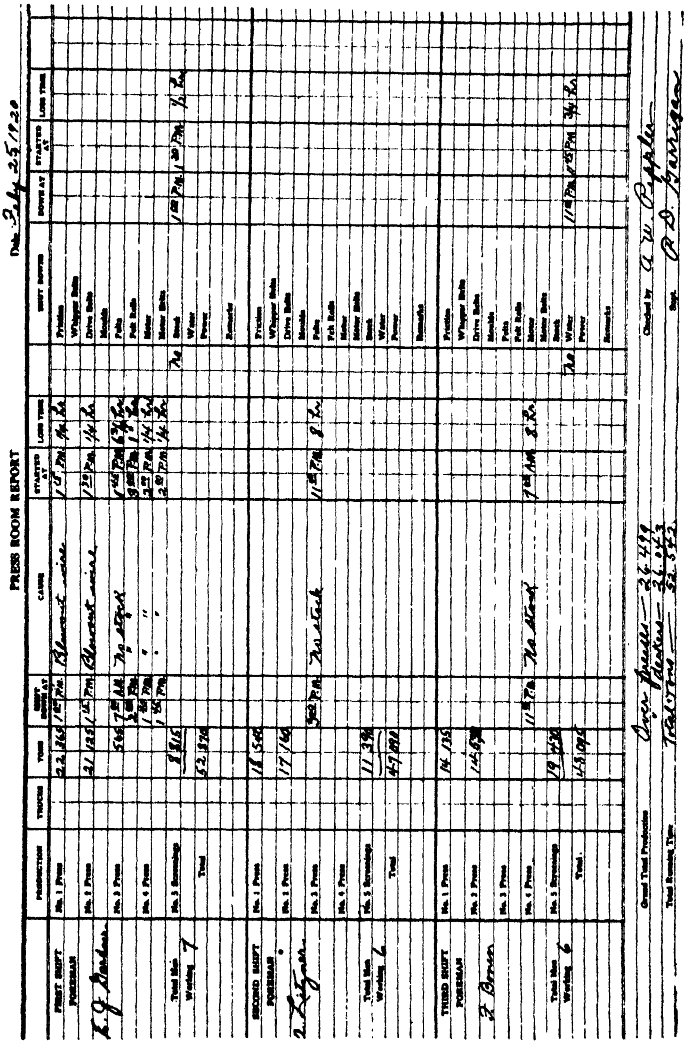


FIG. 305.

temperature, SO_2 content, condition of the acid in the towers and finishing tanks, temperature of cook, blow, etc. The following charts are typical of the manner in which these facts are recorded:

Figure 303—Acid Room Report; Figure 304—Screen Room Report;

Figure 305—Press Room Report; Figure 306—Stock in Water Report; Figure 307—Soda Mill Report.

These all go to show the extreme care necessary in checking up this one operation not only from the standpoint of maintaining quality but also

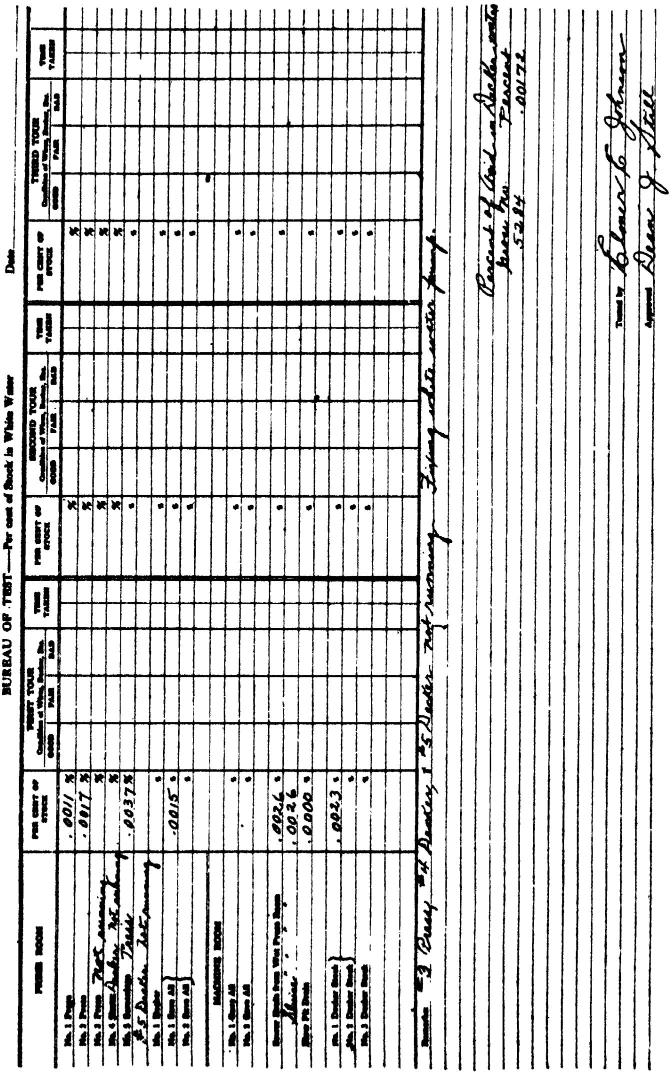


FIG. 306.

of keeping down rising costs of manufacture by the elimination of needless waste of materials. These charts are self-explanatory and by their means the executive is enabled to trace the history of any cook blown beginning with the wood pile up to the time it reaches the wet presses, at which stage further inspection takes another course.

DAILY SODA MILL TESTING REPORT

Date ____________

Digester Room

Cook No. (Consecutive for Mo.)	Digester No.	Type of Wood	Blow Pit No.	Cooking Liquor NaOH—g. p. l.	Cooking Liquor Na_2CO_3 g. p. l.	Cooking Liquor Gals. Used.	Time Steamed	Time Blown	Black Liquor NaOH—g. p. l.	Black Liquor Na_2CO_3 g. p. l.	Na_2CO_3 of Weak Liq. to River g. p. l.	Tour No.

Bleach Room

Brown Stock After Screening: Time	Shives per 100 sq. in.	Phenolphthalein Test	Starch Iodide Test in 1st Stage

Stock From Wolf Bleachers: No. of Engines Bleached for Me	Stock from Cook No.	Bleacher No.	Dirt/100 Sq. In.	Color	Inches Bleach Added	% Excess Bleach	Tour No.

Drainer Room

Stock to Beaters: Time	Dirt/100 Sq. In.	Color	Consistency

Losses

Wash Pit Weir

Gals. Passing Weir in 24 hrs. ______
Lbs./1000 gals.
Na_2CO_3 ______
Fiber ______
Total Lbs. Lost in 24 hrs.
Na_2CO_3 ______
Fiber ______

Sewer Station No. 3

Lbs. Lost in 24 hrs.
Fiber ______
Filler ______
Na_2CO_3 ______
Gals. ______

Time	Brightness: Beater Stock	Brightness: Wolf Eng. Comp.
12 M		
3 AM		
6 AM		
9 AM		
12 M		
3 PM		
6 PM		
9 PM		

Tons of Pulp Produced in 24 hr. Period Ending at 8 A.M. ______
Tons of Pulp in Drainers at 8 A.M. ______

Wood Del'd to Mill

	Cords	From
Pep.		
H. W.		

Physical Properties of Stock to Beaters. Test made on composite sample for ______

Recovery

Cooking Liq. NaOH ______#/1000 Gals.

	Gals. 24 Hrs.	# Na_2CO_3 1000 G.	Total # Na_2CO_3
Cooking Liq.			
Black Liq.			
Leach Liq.			

Hours	0	1	2	3
Beaten				
Freeness				
Mullen				
Tear				
Shrinkage				
Brightness				

Black Ash Waste

% Na_2CO_3 in Black Ash Waste from Leach Pit. 24 Hr. Comp. ______

Remarks

FIG. 307.

In the beater room, as an aid and check upon amounts furnished to the beaters, the beatermen are supplied with data, as in Figure 308. Another such chart indicates the amount of rosin to add for the different basis weights of paper being run.

BEATER CHART

1500 LB. BEATER

SULPHITE-GROUND WOOD FURNISH

% SULPHITE	WET WEIGHT SULPHITE	DRY WEIGHT SULPHITE	% GROUND WOOD	WET WEIGHT GR. WD.	DRY WEIGHT GR. WD.	TOTAL WET WEIGHT	TOTAL DRY WEIGHT
100	4397	1671	0	0	0	4397	1671
96	4229	1607	4	226	68	4455	1675
92	4068	1546	8	446	134	4514	1680
90	3989	1516	10	563	169	4552	1685
86	3824	1453	14	790	237	4614	1690
82	3658	1390	18	1016	305	4674	1695
80	3579	1360	20	1133	340	4712	1700
77	3451	1312	23	1306	392	4757	1704
75	3368	1280	25	1426	428	4794	1708
72	3242	1232	28	1600	480	4842	1712
70	3158	1200	30	1716	515	4874	1715
68	3076	1169	32	1836	551	4912	1720
64	2905	1104	36	2070	621	4975	1725
62	2821	1072	38	2193	658	5014	1730
60	2739	1041	40	2313	694	5052	1735
57	2608	991	43	2493	748	5101	1739
55	2523	959	45	2613	784	5136	1743
53	2434	925	47	2736	821	5170	1746
50	2303	875	50	2916	875	5219	1750
47	2168	824	53	3100	930	5268	1754
45	2084	792	55	3223	967	5307	1759
42	1947	740	58	3413	1024	5360	1764
40	1860	707	60	3536	1061	5396	1768
37	1726	656	63	3720	1116	5446	1772
34	1600	604	66	3906	1172	5506	1776
30	1405	534	70	4153	1246	5551	1780
27	1268	482	73	4340	1302	5608	1784
24	1129	429	76	4533	1360	5662	1789
22	1037	394	78	4663	1389	5700	1793
20	945	359	80	4783	1435	5728	1796
18	852	324	82	4920	1476	5772	1800
16	810	308	84	4983	1495	5793	1803
14	663	252	86	5180	1554	5843	1806
12	571	217	88	5310	1593	5881	1810
10	476	181	90	5440	1632	5916	1813
8	382	145	92	5570	1671	5952	1816
6	287	109	94	5700	1710	5987	1819
4	189	72	96	5833	1750	6022	1822
2	94	36	98	5963	1789	6057	1825
0	0	0	100	6096	1829	6096	1829

% MOISTURE IN GR. WD. 70% AIR DRY PULP 30%

% MOISTURE IN SULPHITE 62% AIR DRY PULP 38%

FIG. 308.

One of the next steps is a careful checking of each roll of finished paper as it is finished on the machine. As the finished reel is cut up into rolls, each roll is stamped with the name of the mill, the machine tender's name, date, grade, weight and also reel number, thus enabling operators who finally pass upon the quality of the paper to reject any rolls that appear to be below standard. At the end of each machine we have a paper inspector responsible to the Bureau of Chemistry, who takes from the finished reel three samples 12 inches wide and in length each sample taking in the full width of the reel.

He then takes one sample, folds it and carefully weighs it in grams on an analytical balance sensitive to .01 of a gram. The sample is then placed in an electric oven and allowed to remain for about two minutes depending

PAPER INSPECTION

Division ________ *Date* ________

Sample No. ________ *Mach. No.* ________ *Tour* ________

Time ________ *Grade* ________

	Standard	*Actual*
Basis Weight, 24 × 36		
Mullen Test		
Points Mullen per Pound		
Moisture, %		
Speed, Ft. per Min.		
Prod. per Hour, Lbs.		
Sets per Hour		
Sizing Quantities		
Girt		
Color		
Folding		

Machine Tender ________

Back Tender ________

Remarks ________

Inspector ________

FIG. 309.

upon the weight of the paper. The dry sample is then weighed and the percentage of moisture computed. The results of this test are recorded on the other two samples and plotted on the Paper Inspection Chart, from which the machine tender can obtain the results of the test.

The inspector then takes another sample, weighs it to .01 gram and multiplies the weight obtained by .528 thereby converting the weight to pounds per ream. This he notes on the form stamped on each sample shown in Figure 309. The sample after being weighed is taken and tested with the Mullen Tester, an average of six readings being taken and reported on the sheet. Following this is the Sizing Test, which consists of floating a piece of the paper about 3 inches square on the surface of a 5 per cent solution of potassium ferrocyanide and when the solution appears to come through the fibers a small brush dipped in a 5 per cent solution of ferric chloride is brushed across the surface of the paper. As soon as penetration has taken place a deep coloration (Prussian Blue) forms. The time taken for the operation is noted in seconds and plotted as such. There are other methods of making sizing tests, but the writer has found

TEST BUREAU

Case No. C 44 –

Date Feb. 14-20

PAPER INSPECTION

Mach. No. 1 Mill ______ Tour 11-7 Machine Tender [illegible]

Reel	Time	Grade a	Weight Stand	Weight Act.	Mullen Stand	Mullen Act.	Ratio	Moist	Speed	Sets	Prod.	Size Mins.
18	12 30	[illegible]	80	82.6	80	62.2	.75	7.6	89	1 1/2	1117	26
19	1 30	"	"	84.4	"	73-	.87	8.1	89	1 1/2	1140	29
20	2 30	"	"	87-	"	65.8	.76	8.8	89	1 1/2	1165	29
21	3 30	"	"	82.8	"	68-	.82	8.9	89	1 1/2	1120	27
22	4 30	"	"	82.4	"	75.3	.91	8.3	89	1 1/2	1113	26
23	5 30	"	"	82-	"	70.2	.86	8.7	89	1 1/2	1108	24
24	6 30	"	"	81.8	"	69.7	.85	8.1	89	1 1/2	1109	25
Average			80	8.33	80	68-	.83	8.4	89	1 1/2	1125	27 Min.

REMARKS

Tested by [illegible] Figured by A. B. [illegible] Approved by ______

FIG. 310.

the above satisfactory for most grades of paper. Along with these other operations the inspector notes the speed of the machine for the hour and the number of sets run off and from the above data computes the production for the hour. The formula used is as follows:

$$\frac{\text{Ream Weight} \times \text{Speed (in feet per Minute)} \times \text{Deckle (in inches)} \times \text{Number of Minutes}}{34560}$$

Any shut-downs are noted and remarks made on same.

This completes the actual operations of the paper inspector. He places the two sets of samples that have all the data placed upon them in a tightly covered galvanized iron can, and at the end of each tour one complete set is forwarded to the Bureau of Chemistry and one to the Department of Physical Tests.

Upon receipt of the samples by the Bureau of Chemistry, they are immediately weighed and placed in a large steam heated oven at a temperature of 220° F. The samples are allowed to remain there for twelve

........................Date.

Grade ....

Sample No. ....

Time ....

Mach. Tender ....

Cause for criticism ....

....

....

By ....

CRITICISM SHEET .... Date ....

Mr. .... Supt. .... Mill ....

Grade ....

Sample No. ....

Time ....

Machine Tender ....

Cause for criticism ....

....

Physical Testing Dept. .... Approved by ....

By ....Gen. Supt.

FIG. 311.

hours, by which time they have reached a constant weight. The figures obtained by the Test Bureau and those obtained by the Paper Inspector are examined and any discrepancies are quickly followed up.

The Bureau of Chemistry next compiles the data obtained from each sheet upon a Machine Tender's Paper Inspection Report shown in Figure 310. The object of this report is to serve as a summary of the work of a machine tender covering (in a general way) the external qualities of the paper produced by him, the amount produced, and any shut-downs that may have occurred under him. As soon as these reports are compiled a copy is forwarded to each mill superintendent, thereby enabling him to keep a close survey of his operations.

........................Date

No. of rolls Rej. ....

Made at .... Mill

Date ....

Grade .... Wt. ....

Roll No. ....

Cause for rejection

....

....

REJECTION NOTICE. Date ....

Mr. ....Supt. .... Mill.

Reject the Following Rolls of Paper

Made at .... Mill ....Date Made

Grade ....

Weight ....

Roll No. ....

CAUSE FOR REJECTION ....

Signed .... Gen'l Supt.

FIG. 312.

The Bureau of Chemistry, periodically checks the operation of all inspectors, taking one inspector each week. In following these proceedings the paper inspectors are never informed as to who is being watched, which fact keeps them under a continuous surveillance in all their operations.

We will now return to the third set of samples: When received by the

Department of Physical Tests, they are arranged in order of roll numbers and from these five strips are torn 12″ × 4″. Two of these strips are carefully noted as to color, formation and any other characteristics that apply to a good sheet of paper, by a practical paper man, who has served many years in the actual running of a machine and has officiated in various departments of the paper mill. Two sets of these strips are marked with the following data:—grade, weight and reel number—they are in turn forwarded to the General Manager and to the General Superintendent.

After proper labelling, the two sets of samples prepared by the practical paper man are submitted to the General Superintendent and General Manager for further inspection. These particular examinations in conjunction with those of the practical paper man are of great utility, as an approximate

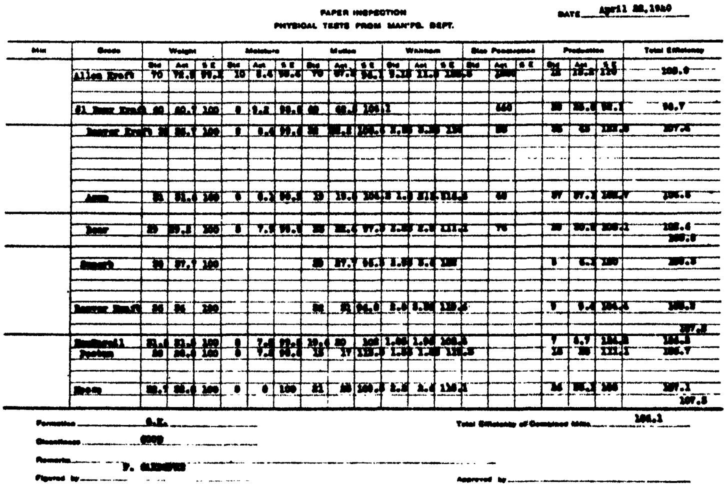

PAPER INSPECTION
PHYSICAL TESTS FROM MAN'FG. DEPT.

FIG. 313.

estimate can be formed thereon. Unfortunately this inspection lacks the fundamental necessity of numerical expression, which must form the basis of any records when any particular point is disputed by equally experienced men representing different interests. The sets of samples as received by the General Superintendent and Manager are given a thorough examination from a practical standpoint. With a long experience in "handling" paper, one is able to judge quality and value within a very few minutes. With the feeling of the sheet, the weight and ream weight are estimated. The drawing of the sheet of paper between the finger and the thumb will reveal the smoothness of the surface and its bulking qualities. By holding the sheet up to the light, and looking through it, one can see the nature of the beating, the length of the stuff, and the manipulation of the stuff upon the "wire."

With the practical tests carried out in this manner, if any question of doubt has arisen regarding the quality of any roll, the numerical figures that have been compiled by the Department of Physical Tests, covering all tests made by them, are analyzed and if the quality of the paper is questionable, a criticism sheet (Figure 311) is forwarded to the Mill Superintendent, stating whatever criticisms have occurred. In accordance with the criticism sheet, a reject slip (Figure 312) is sent to the Shipping Department, requesting that department to reject any paper that is under quality. In this manner no paper is allowed to leave the mill until it has passed successfully through a thorough examination.

The data that are turned in each morning from the Department of Physical Tests, such as grade, weight, Mullen, moisture and size tests, tear, and production, are made up into the Daily Efficiency Chart (Figure 313).

PENALTY CHART FOR MOISTURE

PENALTY .1 OF 1% FOR EVERY .1 OF 1% OFF

Under Standard Moisture	Efficiency	Over Standard Moisture
8.0	100	8.0
7.0	99.9	8.1
7.8	99.8	8.2
7.7	99.7	8.3
7.6	99.6	8.4
* * *	* *	* * *
5.2	97.2	10.8
5.1	97.1	10.9
5.0	97.0	11.0

To find Efficiency
Ex: Sheet with 7.5% Moisture = 99.5% Eff.

TB-6

Fig. 314.

This chart in a condensed form shows the actual efficiency of each mill based on the various Physical Tests. These reports are submitted to the Mill Superintendents who are found to take a great interest in them. In compiling the data on these charts, various penalties have been made depending upon the overrunning of our minimum standards. Figure 314 illustrates the Moisture Penalty Chart. Eight per cent has been taken as the standard percentage of moisture. The average moisture for each grade of paper in each mill is taken and for every .1 per cent above or under the standard (8 per cent) a penalty of .1 per cent is made for that grade.

Figure 315 is used as a Weight Penalty Chart. An allowance of 3 per cent is made for all grades and all weights either above or below the standard. If, after averaging the weight of a grade and making an allowance of 3 per cent the weights are still in excess or under, a penalty of .1 per cent for every .1 per cent is made.

Figure 316 indicates the various sizing qualities that are required of the different weight sheets. Again the average weight is obtained for each grade and the corresponding actual sizing in seconds. This is compared to the standard sizing for that weight sheet and penalized accordingly.

At the end of each week the daily charts are averaged and the data so obtained are indicated on the Weekly Efficiency Chart shown in Figure 317. Figure 318, known as Rejected Paper Penalty Chart, is based on the per-

PENALTY CHART FOR WEIGHTS

Weight of Paper

Lbs. + −	25 26 27 28	29 30 31	32 33 34 35	36 37	38 39 40 41	42 43 44	45 46 47 48	49 50 51	52 53 54	55 56 57 58
.8	.0									
.9	.1	.0								
1.0	.2	.1	.0							
1.1	.3	.2	.1	.0						
1.2	.4	.3	.2	.1	.0					
1.3	.5	.4	.3	.2	.1	.0				
1.4	.6	.5	.4	.3	.2	.1	.0			
1.5	.7	.6	.5	.4	.3	.2	.1	.0		
1.6	.8	.7	.6	.5	.4	.3	.2	.1	.0	
1.7	.9	.8	.7	.6	.5	.4	.3	.2	.1	.0
1.8	1.0	.9	.8	.7	.6	.5	.4	.3	.2	.1
1.9	1.1	1.0	.9	.8	.7	.6	.5	.4	.3	.2
2.0	1.2	1.1	1.0	.9	.8	.7	.6	.5	.4	.3
2.1	1.3	1.2	1.1	1.0	.9	.8	.7	.6	.5	.4
2.2	1.4	1.3	1.2	1.1	1.0	.9	.8	.7	.6	.5
2.3	1.5	1.4	1.3	1.2	1.1	1.0	.9	.8	.7	.6
2.4	1.6	1.5	1.4	1.3	1.2	1.1	1.0	.9	.8	.7
2.5	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	.9	.8
2.6	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	.9
2.7	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0
2.8	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1
2.9	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2
3.0	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3
3.1	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4
3.2	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5
3.3	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6
3.4	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7
3.5	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8
3.6	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9
3.7	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0
3.8	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1
3.9	3.1	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2
Exam	ple									
40 lb.	Sheet	weighin	g 2 lbs.	heavy						
Penalt	y = .8 o	f 1%								

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FIG. 315.

centage of rejected paper based on the total production for the week. The percentage thus obtained is deducted from the total efficiency of the mill and the actual efficiency of the mill is denoted in red.

At the end of each month the total efficiencies of each week are added and averaged and plotted on a chart represented by Figure 319. There are other methods for presenting these weekly and monthly ratings. These are Mechanical Bar Charts manufactured by a concern dealing in such equipment. By means of various colored ribbons different units can be separated and quickly picked out by the mill men, thus enabling them to get the comparative rating between mills. If this outlay of mechanical

SIZE PENETRATION PENALTY CHART

Grade	Wt.	St'd.	100	99.8	99.6	99.4	99.2	99.0	98.8	98.6	98.4	98.2
A	36	45	5	6	7	8	9	10	11	12	13	14
	38	50	5	6	7	8	9	10	11	12	13	14
	42	55	6	7	8	9	10	11	12	13	14	15
	46	60	6	7	8	9	10	11	12	13	14	15
	52	70	7	8	9	10	11	12	13	14	15	16
	58	80	8	9	10	11	12	13	14	15	16	17
B	60	90	9	10	11	12	13	14	15	16	17	18
	70	110	11	12	13	14	15	16	17	18	19	20
	80	125	13	14	15	16	17	18	19	20	21	22
C	30	40	4	5	6	7	8	9	10	11	12	13
	35	45	5	6	7	8	9	10	11	12	13	14
	37	50	5	6	7	8	9	10	11	12	13	14
	40	60	6	7	8	9	10	11	12	13	14	15
	44	70	7	8	9	10	11	12	13	14	15	16
	50	75	8	9	10	11	12	13	14	15	16	17
D	30	30	3	4	5	6	7	8	9	10	11	12
	34	35	4	5	6	7	8	9	10	11	12	13
	36	37	4	5	6	7	8	9	10	11	12	13
	42	42	4	5	6	7	8	9	10	11	12	13
	50	50	5	6	7	8	9	10	11	12	13	14
E	30	45	5	6	7	8	9	10	11	12	13	14
	33	50	5	6	7	8	9	10	11	12	13	14
	35	70	7	8	9	10	11	12	13	14	15	16
	38	100	10	11	12	13	14	15	16	17	18	19
	40	110	11	12	13	14	15	16	17	18	19	20
	42	120	12	13	14	15	16	17	18	19	20	21
	45	130	13	14	15	16	17	18	19	20	21	22
F	38	50	5	6	7	8	9	10	11	12	13	14
	42	60	6	7	8	9	10	11	12	13	14	15
	46	70	7	8	9	10	11	12	13	14	15	16
	48	90	9	10	11	12	13	14	15	16	17	18

NOTE. Standard given in seconds
Figures to right of Standard Column indicate seconds over or under Standard for each weight
Standard in seconds

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FIG. 316.

bar charts appears expensive, the ordinary type of bars on blueprint paper will serve the same purpose.

This concludes the checking and methods of presentation of the daily work of the paper mill, the amount of paper produced, and the quality of workmanship. Further than this the Department of Physical Tests obtains from the Bureau of Chemistry data enabling them to present in somewhat similar form (as has already been explained) the efficiency of the various sulphite and groundwood mills.

In testing one's own grades for deterioration of course it is essential to have all characteristics and data connected with the making of that sheet, in order that the test may be of any value. By this means quality of material is often proved to be below standard when stored under both poor

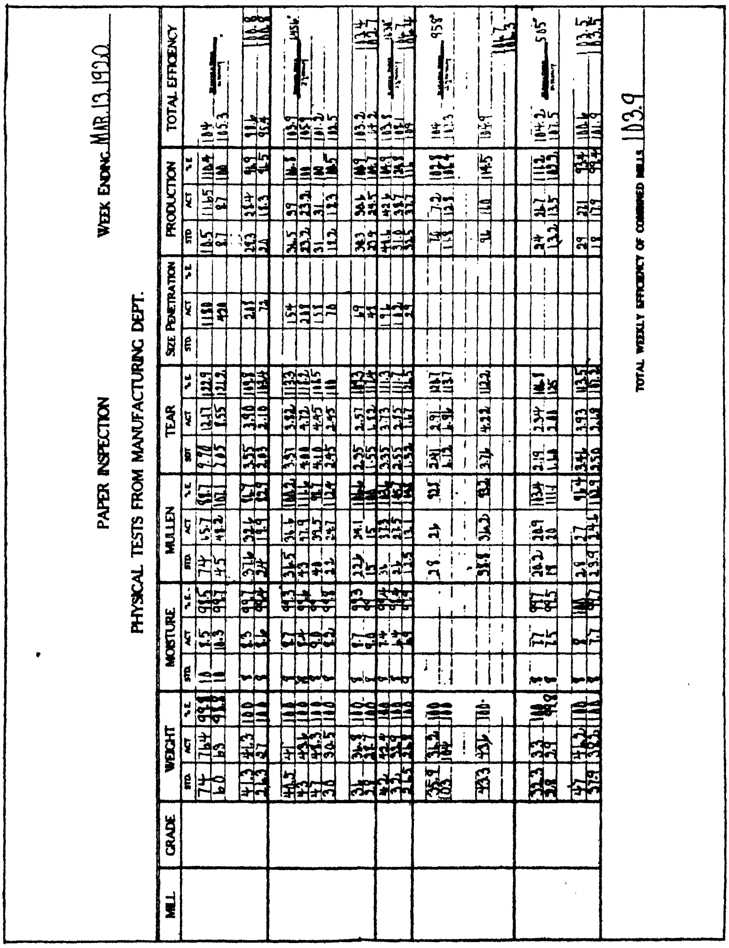

FIG. 317.

and normal conditions, or again it may result in some change in the process of manufacture in an attempt to cure the evil.

The work outlined above is not of a very technical nature and one trained chemist assisted by several conscientious helpers can carry out this program to complete satisfaction. In connection with the Physical Tests Department, a good practical paper maker must be included in its personnel in order to pass judgment on various paper qualities that are not shown up by any mechanical, chemical, or physical tests. By the maintenance of such a department, properly supervised, the security obtained, not only for the good will of the company, but for all concerned, serves as an insurance or protection to all buyers. Of course, the system is not infallible, but it does minimize causes for error and shipment of inferior quality of goods, as well as wastefulness in manufacturing.

General Testing of Supplies.

Very little reliable information can be obtained from sales agents for various supplies for each agent has his own interests at stake, and it is his business to promote the sale of his material.

PENALTY FOR REJECTED PAPER

BASED ON PER CENT OF REJECTED PAPER FROM TOTAL PRODUCTION FOR THE WEEK

% Rejected Paper		% Efficiency
.25		99.5
.50		99.0
.75		98.5
1.00		98.0
* * *	* * *	* * *

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Fig. 318.

The necessity for testing therefore becomes apparent. In a large number of cases the best method is to put the article to practical use and keep accurate record of its service as in the case of wires, felts, etc.

In other cases we have chemical testing; also physical testing as strength of twine, belting, etc.

Meaning of the Word: Testing, in the broadest sense, means any method of procedure with the object of ascertaining facts about the thing, for example:

A car of coal is weighed in order to ascertain its weight more or less than the weight invoiced; this is testing its weight.

If a piece of clay is placed in the mouth in order to observe how it feels between the teeth; this is testing its grit.

If several felts, wires, etc., are used exactly under the same conditions and a record kept to see which gives the best service; this, also, is testing.

Weighing: The invoice weights of all kinds of material should be checked by weighing on accurate scales.

Testing Scales: All scales should be periodically tested as to the accuracy of their calculations.

The principle upon which paper is weighed is as follows: one pound = 16 ounces. 30 pounds therefore 30 × 16 = 480 ounces. If, therefore, the count basis is 480 sheets, one sheet of a 30 pound paper will weigh

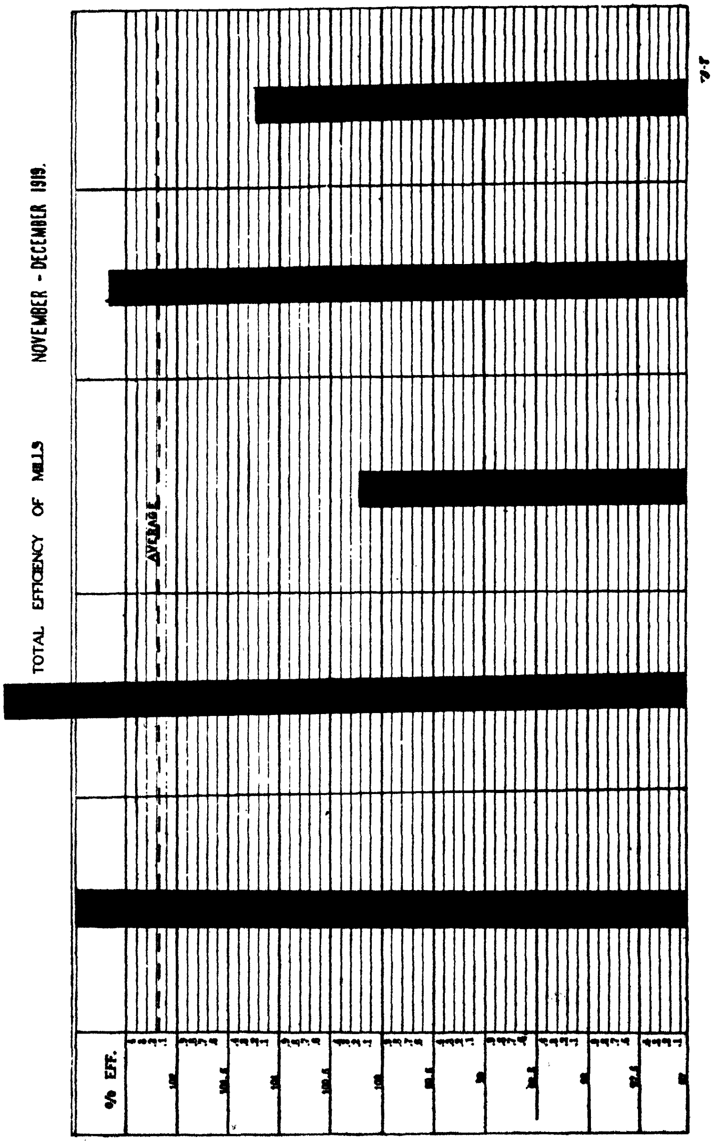
PAPER INSPECTION
TOTAL EFFICIENCY OF MILLS
NOVEMBER - DECEMBER 1919.
AVERAGE
% EFF.

FIG. 319.

exactly 1 ounce so that if a test weight weighing exactly 1 ounce is placed upon the scales instead of a sheet of paper it will register exactly 30 pounds on the 480 count. On the 500 count basis one sheet of a 30 pound paper will weigh 480-500 of one ounce or 96-100 of an ounce.

When test weights of exactly 1 ounce are placed upon these scales, one after another they should, therefore, register as follows:

Count	1	2	3	4	5 Oz.
480	30	60	90	120	150
500	31.25	62.50	93.75	125	156.25

Measuring: Measuring the dimensions of a thing is also a testing process. Measuring is sometimes connected with weighing as, for example, in the case of twine, exactly 1 pound may be weighed and measured so as to calculate the weight per 100 feet and thus get comparative weights for different makes or brands.

Counting is another method as in counting the mesh of a wire with a magnifying glass.

The Drying Oven.

Tests for quantity of water or moisture in anything are among the most important class of testing, and a drying oven is an essential part of the equipment in every mill. These ovens may be either steam or electric. Good dealers in laboratory supplies carry both kinds and can suggest a suitable type.

Among the tests for water or moisture contained in materials we may mention the following:

Moisture of Pulp: Pulp, both chemical and mechanical pulp such as sulphite and soda, and in fact any paper making pulp, is tested for moisture and water by taking a sample, weighing it accurately bone dry and again weighing it. The loss in weight gives the amount of moisture or water in it and from the weights observed the percentages of water or moisture and the bone dry pulp are easily calculated.

It is ordinarily assumed that paper pulp after being dried bone dry and then left exposed to the air will absorb 10 per cent of its weight of moisture from the atmosphere.

This figure 10 per cent is, a fairly approximate average, but, of course, the true amount of moisture absorbed from the air depends on the dryness or dampness of the weather which is constantly changing. At times when the air is very dry a bone dry pulp will not absorb anything like 10 per cent moisture while at other times when the atmosphere is very moist, it will absorb considerably more than 10 per cent. Under ordinary conditions during the year it is nearer to 9 per cent than to 10 per cent, but this again varies with the locality, for one locality during the year is different from another.

Calculating Dry Pulp: In our opinion the true basis for estimating the percentage of air dry material is the bone dry weight, but it makes no difference what percentage is added to this as long as the same percentage is uniformly adopted. 10 per cent is as satisfactory as any although it may not represent the actual percentage of moisture absorbed in the majority of cases.

Moisture in Paper: The percentage of moisture in paper can also be readily determined by means of a drying oven. This is a very important test, being of much value in enabling one to regulate the drying of paper on a machine.

Newspaper when overdried is brittle and unsatisfactory, while if too much moisture is left in it the calendering produces a mottled smutty appearance, but such paper takes a superior finish to that which has been overdried.

As is well known, the best results are obtained when the paper is run as damp as possible without getting mottled or smutty in appearance.

Experiments have shown, in the case of newspaper, that the best degree of moisture is between 9 per cent and 11 per cent, on the average, 10 per cent.

This is the percentage which is added to "bone dry pulp" to convert it into air dry weight upon which calculations as to "production" and loss of raw material are based.

If paper is run (as is frequently the case) with only 7 per cent of moisture in it and calculations are based upon air dry pulp containing 10 per cent of moisture, there is, of course, a loss of raw material due to the paper being run too dry.

By running the paper damper not only is there a gain in the production but the quality of the paper that is run on the paper machine is more or less greatly improved.

Another bad effect of overdrying lies in the fact that overdried paper will absorb moisture from the atmosphere and increase in weight so that if a sample of paper fresh from the machine weighs 33 pounds it might readily take up sufficient moisture to be 34 pounds when tested by the customer and furnish grounds for complaint as to overweight.

The best method of testing the product of a paper machine for moisture is to take as large a sample as the scales can conveniently weigh, weigh the sample immediately and mark the weight on it. Then place it in the drying oven and allow it to remain until bone dry when it is again immediately weighed and the loss in weight calculated into percentage. If less than 10 per cent it shows that the paper has been run too dry on the machine. In case of many papers, such as heavy wrappers, much more than 10 per cent of water can be left in the paper. In all cases a sample of such paper will dry out and lose weight upon exposure to the atmosphere.

Moisture in Clay: The drying oven is also a convenient and accurate appliance for testing the moisture of many other substances. The best method for testing clay for moisture is as follows:

A tin pan is weighed accurately and its weight recorded. It is then filled level with clay and weighed again; the difference in weight is the weights of the clay taken for test. The pan is now placed in an oven until the clay is bone dry and again weighed. The loss in weight is due to water or moisture and is calculated into percentage.

In this connection it may be safe to state that the clay is a material which not only contains water in the form of dampness or moisture but also contains chemically combined water which cannot be expelled by drying in an oven.

This water forms a part of the clay and is not driven off by the heat of the drying oven or by the dryness of a paper machine but remains in the clay in the dried paper even if the paper is dried "bone dry." If some clay is put in a crucible and submitted to furnace heat, as in burning brick, this chemically combined water is expelled and the clay becomes hard like a brick and will no longer dissolve or "break down" into a fine powder when stirred with water. If pulverized, each small particle is hard and gritty and not soft and sticky like an unburnt clay is. It is this fact that renders clay so valuable in the manufacture of pottery. The combined water not being driven off to the slightest extent in the process of manufacture of paper it does not therefore enter into consideration at all in making moisture tests. All clay is more or less damp and it is simply the extent of the dampness which is of importance which is easily determined by drying in an oven as pulp or paper is dried.

Whatever percentage of dampness or moisture clay contains is so much loss for it is bone dry when the paper has passed over the dryers in the machine.

The fibers of paper or pulp when bone dry suck up or absorb moisture from the atmosphere, but dry clay may lie exposed to the atmosphere without absorbing any noticeable amount of moisture.

If, therefore, 100 pounds of damp clay containing 10 per cent moisture are furnished to a ton of paper the 10 per cent of moisture in the clay is all dried out and only 90 pounds of actual clay have been furnished in reality.

In testing the percentage of clay in paper all of the above features of clay must be taken into consideration and a sample of the clay itself must be tested as well as the sample of the paper used in order to obtain the correct and true results.

Testing Stock: In determining the capacity of chests, concentration of liquid stock, etc., it is often desirable to test how much dry stock the liquid contains per cubic foot. This is best accomplished as follows:

Record the weight of a pie pan on the scales. Take exactly 1 quart of the liquid stock by means of an accurate quart measure. Pour this into a piece of cotton cloth and squeeze out as much of the water as possible. Transfer the stock from the cloth to the pie pan. Repeat this until the pan is about full recording the number of quarts necessary.

In the case of thick liquid stock one or two quarts may be enough while with thin stock a number of quarts must be taken to get a pan full. Care must be taken that no stock is lost during the operation.

The pie pan of wet stock is then placed in the drying oven and allowed to remain until it is bone dry. Then it is taken out and weighed. It is well to put in again then weigh again, so that it is perfectly dry. The bone dry weight is calculated into air dry weight as usual by dividing by 90 and multiplying by 100. This gives the air dry weight of stock in the number of quarts measured out for the test, from which the weight in one quart is calculated.

The weight in one quart multiplied by 4 gives the weight in a gallon. The weight in one quart × 30 gives the weight in one cubic foot as there are 30 quarts to a cubic foot (exact figures 29.922 quarts).

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