FINISHING METAL PRODUCTS

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FINISHING METAL PRODUCTS

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Second Edition

New York *London*
McGRAW-HILL BOOK COMPANY, INC.
1946

FINISHING METAL PRODUCTS

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.

PREFACE TO THE SECOND EDITION

In the years immediately preceding the war, the operations involved in finishing metal products had been integrated into over-all production cycles and the importance of protection and appearance in finishing had been well established. War, however, had the effect of disturbing trends and established values. It focused attention on protection and diminished emphasis on appearance. It stimulated speed of operations and, in many cases, diminished attention to costs. Now with peace and the expectation of an early return to normal civilian manufacture, the factors of appearance and cost in metal finishing again come into prominence. The rapid progress in plastics and synthetic resins during the war years has been reflected in the development of coatings with new and surprising properties. This edition describes the many developments in the metal-finishing field which took place during the war and during the years immediately preceding. It brings up to date the entire subject as covered in the first edition and adds much new material. Of particular importance are the new chapters on coloring metal, on costs and estimates and on organic coatings.

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NEW YORK, N. Y.,
January, 1946.

ACKNOWLEDGMENTS

In preparing the second edition each authority who had helped with the first edition was asked to bring his contribution up to date. The response to this request was generous and gratifying.

Acknowledgment for much of this assistance is made in the text, but in addition we wish especially to thank: C. R. Bragdon, Research Laboratories, International Printing Ink Division, Interchemical Corporation; The International Nickel Company, Inc.; Louis M. Hague, Hanson-Van Winkle-Munning Company; Richard E. Kellers, The New Jersey Zinc Company; A. M. Brown, Divine Brothers Company; and R. S. Leather, The Lea Manufacturing Company.

PREFACE TO THE FIRST EDITION

A metal product—a wrench, for instance—may be highly satisfactory from the point of view of utility, but under the present complex and competitive conditions of our industrial life this is not enough. It must have a sales value which will place it into the user's hands. Otherwise its purpose is lost. Essential among the items which give it sales value is its surface appearance, and thus the finishing of metal products becomes a highly important factor in the total production and distribution sequence.

In many metal fabricating plants the processes required to give desired surface appearance represent fully a third of the plant's total activities, and for the whole metalworking industry the value represented by finishing—by polishing, plating, enameling and similar processes—probably is close to 10 per cent of the total value of the products thus manufactured. The value added each year by polishing alone is estimated at about $450,000,000. In the cutlery industry, polishing and plating usually exceed 50 per cent of the total production cost. The process of lacquering automobiles in this country costs more than $20,000,000 a year.

Yet with all this, the average manufacturer knows less about finishing than about any other link in his production chain. The selection of finish for his particular product is often left to the whim of a shop foreman or to the bargaining of the purchasing agent, and the advantage of one finish over another, from the point of view of increased sales and even from that of cost of manufacture, is too often ignored.

Ingenuity in finishing metal products has greatly widened the scope of their use. Examples of this are wood-grain reproduction which was largely responsible for the early introduction of metal into the furniture industry, chromium plating, which turned architects to metals, and synthetic enamels, which made possible the prefinishing of sheets for stampings.

The value of bright colors on metal products was emphasized by the experience of the Corona Typewriter Co. some years ago. Today the manufacturer who does not take advantage of the striking development in variety and character of metal finishes may be losing money not only through too high cost of production but through unnecessarily high sales expense.

This book is offered in the hope that it will point the way to more attractive finishes and to more efficient means of producing them. It considers most of the usual types of finish such as galvanizing, polishing, plating, lacquering and painting, and, in addition, many new finishes of a specialized nature. So closely associated with the final finish of a metal product are the preparatory processes such as cleaning and descaling that many chapters are devoted to those processes and to their relation to metal-finishing technique.

HERBERT R. SIMONDS.

NEW YORK, N. Y.,
July, 1935.

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PART 1

COMMERCIAL ASPECTS OF FINISH AND APPEARANCE

CHAPTER I

SALES VALUE OF ATTRACTIVE FINISH

Almost all metal products that are to be marketed must receive some sort of surface finish, even if it is merely tumbling in a burnishing barrel. If two items otherwise identical are given different kinds of finish, one may show greater sales value—greater public appeal—than the other, and thus it is evident that appearance may be translated into profit.

A manufacturer of small tools brought out a new type of screw driver with high hopes of its success. Mechanically the screw driver had unusual merit, but in appearance it was just another screw driver and sales were disappointing. Make a good screw driver, and the world will wear a path to your door, the manufacturer thought, and waited—but nothing happened.

Finally, on an impulse, he did an unusual thing. He called in a style expert to design a machinist's tool, and the screw driver was rebuilt with emphasis on appearance. Among other things it was given a hexagonal shank, a bakelite handle, and an over-all high polish. Sales immediately improved.

This incident is typical of the appearance appeal in the metalworking field. Machine tools and typewriters alike have become style conscious, and the sturdy metal, steel, with the assistance of alloying elements and with new finishing technique, has moved up into high-hat circles—to be used for cigarette lighters, vanity cases and even for jewelry. Chrome-plated watches, chrome-nickel watch chains and bonderized belt buckles now are being worn.

The demand for better finishes, which received its first impetus in the automobile-manufacturing industry, has now extended to cover nearly all marketed materials. Contrary to the general impression that the increased use of stainless steels and other noncorrosive alloys has reduced the field for metal finishes, the opposite seems to be the case. The use of base metals of the stainless variety has apparently encouraged the use of plated metal parts. In addition, the favorable impression that the white metals made on architects encouraged investigation into the possibilities of other metals and other metal finishes in the building industry.

Certainly the need for polishing stainless steel has spread polishing to other metals. Along with the development of nickel-chromium sheets, there came the development of sheet-polishing machines installed at the mill as part of the manufacturing sequence. Polishing was considered essential on a

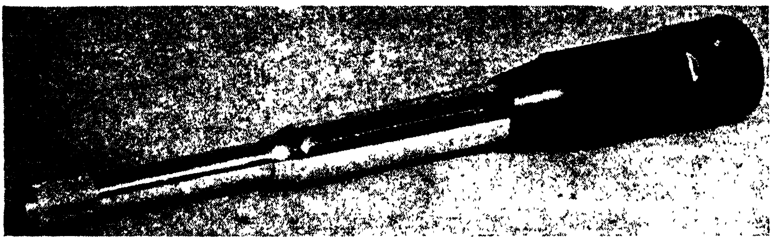


FIG. 1.—Sales of this tool increased when it was given this better finish.

chromium-alloy sheet, for an important feature of this material is its appearance, and the ultimate in this appearance is secured only through polishing. A manufacturer of sheets who had installed a polishing machine for chrome-steel sheets, and who was of an experimental turn of mind, decided to run some carbon-steel sheets through his polishing machine. The result was unexpected. The customers who received the sheets with the new finish were delighted and specified that finish on future shipments.

Competition.—Experiences such as these, coupled with increasing competition, forced more and more emphasis in prewar days on the question of appearance. Today there is evidence of a new demand for attractive finish on utility products that were once considered entirely out of the "appearance" field. An example of this is the demand for a colored hack-saw blade. "Can hack-saw blades be lacquered?" This question was put up to a manufacturer and was successfully solved with a lacquer that gave a bright gold finish at a slight cost. Sales of his saw blade jumped sharply as a result.

The importance of giving any product its most attractive final appearance is rapidly becoming recognized in the industrial world. Everywhere consumer interest is stimulated and sales multiplied by taking an ordinary article such as a kitchen knife, can opener or dust pan, which used to be supplied in plain metal or in dull black, and dressing it up in a neat color scheme. Even tacks and nails now come painted or lacquered. At first thought it might seem that the cost of finish on such humble articles would be out of proportion to the increased selling price or increased volume of sales. Usually the reverse is the case, so that the manufacturer who does not avail himself of the value of a better finish on his product is actually losing money. Much depends upon the choice of method of application and upon the judicious use of color where it will do the most good. The cost of a metal finish, based on the surface area to be covered, may be roughly estimated and varies from two- or three-tenths of a cent a square foot for a single color coating for products such as hack-saw blades, to three or four or more cents a square foot for multiple coats of lacquer or for developing closely imitated wood-grain finishes on metal furniture.

When white enamel was substituted for the old-fashioned black japan finish on bread and cake boxes and other kitchenware, sales were increased by 300 or 400 per cent. When the popular shades of apple green, ivory, orchid and blue came into vogue, there was a further marked increase in sales.

Nature of Finish.—One early proposed definition of a metal finish was "a coat applied or created on the surface of metal to give characteristics differing from those of the base metal." This does not quite cover the case of patina, which is the result of the action of certain minute organisms, and it runs into difficulty with the clad metals, but it is sufficiently broad to include most of the subjects covered in this book. How best to change the surface characteristics of metal is a question that long has occupied the attention of metallurgists and manufacturers. It is a question that involves the nature of the metal, the nature of the desired surface characteristics, and the cost.

Metal may be treated to give it a rough surface which makes for a strong bond with many types of applied coats, and engineers are just waking up to the fact that metal lends itself excellently to almost any sort of surface treatment. Fifty years ago, tintypes were in vogue. Now moving pictures are presented on metal screens. Steel furniture is given a woodlike finish that challenges detection from the original. Wall panels made up of steel sheets backed by sound-deadening composition are made to imitate marble so accurately that close inspection fails to reveal

FIG. 2.—Realistic wood-grain designs are applied to steel furniture by roller.

the difference. The marble design is transferred photographically from actual marble slabs by a process described in another chapter.

Economy in Preparation.—Metal parts that are to receive a high finish usually must be cleaned and pickled before the actual finishing operations start. In the case of an automobile bumper which is to be chromium plated, the sequence may be cleaning, pickling, rinsing, nickel plating, rinsing, copper plating, rinsing, nickel plating again, rinsing, drying, polishing, buffing, cleaning again, rinsing again, and finally chromium plating. The reason for such an extensive sequence, strangely enough, is one of economy. The elaborate preparation makes it possible to use an extremely thin and still effective chromium plate. This general subject will be discussed more fully in subsequent chapters on plating.

Cost.—From the point of view of business economics, the cost of surfacing an article to give it a more attractive appearance must be less than the amount saved in sales expense as the result of the better finish. Otherwise, the article should be left unfinished. Suppose a firm makes a good pencil sharpener but gives it an inexpensive dipped finish and sells 1000 a week at a profit of 15 cents each. The advisability of giving the sharpener a more appealing appearance may be expressed in simple terms,

$$S_2 \times P_2 \text{ must equal } S_1 \times P_1$$

where S_2 represents the new total sales, P_2 the new reduced unit profit, S_1 the former total sales and P_1 the former unit profit. Here $P_1 - P_2 = F$, or the unit added cost of the new finish. But F, of course, must include the cost of equipment and therefore varies with the length of the sales period. It is customary to consider a period of one year in studying the probable effect of a better finish. The pencil-sharpener problem was worked out something as follows:

Present sales	1000 a week
Present unit profit	15 cents
Expected sales after plating	2000 a week
Cost of polishing and plating equipment	$5000
Cost of equipment per week on one-year basis	$100
Unit cost of equipment	5 cents
Unit added cost of materials and labor	3 cents
Unit cost of plating, F	8 cents

Substituting in the equation $P_1 - F = P_2$ gives

$$15 \text{ cents} - 8 \text{ cents} = 7 \text{ cents},$$

which is the estimated new unit profit. The former weekly profit on the 1000-sales basis was 1000 times 15 cents, or $150. The new weekly profit on the 2000-sales basis equals 2000 times 7 cents, or $140.

Strictly speaking, on figures alone, this result would indicate a net loss due to plating the pencil sharpeners. Actually, however, the equipment cost should not be charged to merely a one-year period, and the estimate of increased sales as the result of the finishing may be too low or too high. If the sales should jump to 3000, the new weekly profit would be over $200 or a net increase of $50.

The actual cost of plating, or in fact of any type of metal finishing, has so many variables that it is difficult to give even a rough indication. A large manufacturer of safety razors found that he could put a serviceable gold plate on the razor handle for about three-quarter cent each, but in this case the plating was done on an elaborate automatic continuous machine with an

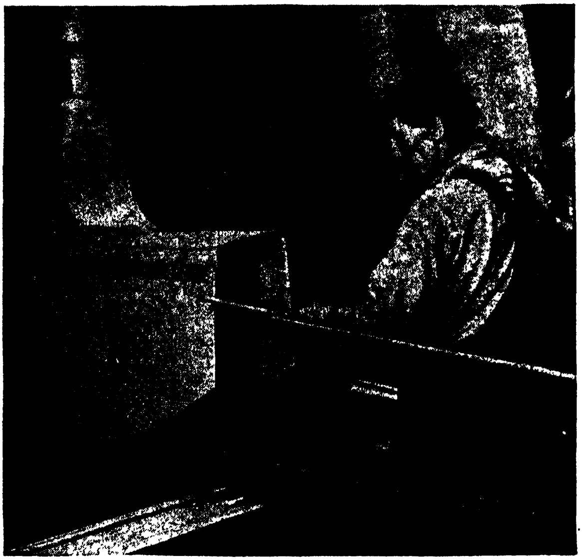


FIG. 3.—An experienced polisher takes great pains in putting a bright finish on parts that are to be used for bank grill work.

almost negligible labor charge and with high recovery of the gold-plating solution from the rinse tanks. Another manufacturer cadmium plates a 3-in. coil spring for one-half cent on a production basis. Formerly the cost of plating this same spring ran as high as 2 cents.

One of the variables in most plating is the cost of electric power. Chromium plating calls for high current density, and this means that the cost of equipment is greater than for nickel plating. For a current density of 1000 amp. the plating equipment, including electrical apparatus, may cost $2500, whereas for a current density of 10,000 amp. the equipment cost will be about $17,000. In the field of buffing and polishing, the cost varies with the increase in fineness of finish. A good polish may be secured with a wheel using No. 120 size of abrasive grain, and a finer finish means an additional operation using a wheel with a finer abrasive, say No. 150 or 220, which of course means additional expense.

Extent of Metal Finishing in Industry.—Some idea of the extent of the metal-finishing industry may be gained from

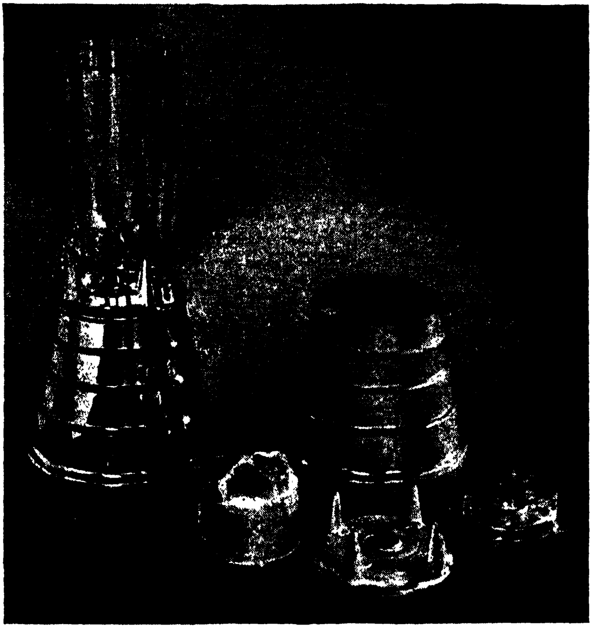


Fig. 4.—An example of value added by an attractive finish. (*Courtesy of New Jersey Zinc Co.*)

manufacturers' figures. The prewar production of buffing and polishing wheels was valued at $4,500,000. One engineer has given a rough average of $100 worth of finishing for every $1 in cost of polishing wheel, but at the same time he admits the difficulty of setting any such average. However, it gives at least a rough basis of the value of buffing and polishing operations. On this basis the figure of $4,500,000 as the cost of wheels becomes $450,000,000 in the value of the polishing and buffing operations.

The value represented by galvanized finish on iron and steel runs into many millions of dollars each year.

A close second to the galvanizing industry is the enameling industry. The value of enameled metalware produced in the United States in a prewar year was approximately $130,000,000. Of this total value $23,000,000 represented vitreous enamel, and of the total of $130,000,000 more than half, or $69,000,000, represented the value added by the process of manufacturing the finished article from the raw material.

Selection of Finish.—With so many types of metal finish, ranging from a coating of rubber latex to a high polish of the base metal, it is difficult for the manufacturer or sales manager to determine the best finish for his product. In many cases the finish must fulfill a utilitarian purpose, and in these instances the selection is more readily specified. If the article finished is the reflector of an automobile headlight, for instance, the problem has been solved through long experience. But where the finish is chiefly for appearance, questions such as relative cost and sales value must be taken into account.

CHAPTER II

THE PROBLEM OF SELECTION

How is the manufacturer of a metal product to know just which one of the myriad of available finishes will be best suited to his purpose? Some of the questions frequently expressed by executives are: Shall we plate or enamel our new adding machine? Can we draw umbrella handles out of steel sheets that already have a finish coating without having the coating injured? What finish shall we use on washing machines, tobacco cans, humidifiers or metal waste baskets?

A piece of plain cold-rolled steel might make a suitable toaster as far as toasting bread is concerned, but few people would buy it because it lacks attractive appearance. The same toaster made with nickel- or chrome-plated steel is an entirely different item from the sales point of view. Similarly, a piece of plain black stovepipe vents gases effectively, but nickel-tin or chrome-tin pipe gives the added touch desired by the discriminating home owner. These are self-evident examples in the manufacture of metal products. It is the less obvious cases that often puzzle or baffle executives responsible for sales volume. If a manufacturer of metal signs does not know that he can buy lacquered and lithographed steel sheets ready for the stamping machines, how can he solve his own finishing problems? Apparently one of the important factors in nearly every metalworking problem is a knowledge of available finishes and their relative costs as well as a sense of that highly elusive quality "public fancy."

Even if the problem is chiefly one of rustproofing, a large number of methods are available. The question is frequently asked: Which is the best process—galvanizing, sherardizing or parkerizing?

There is no general answer. For each article there is one particular rustproofing process best adapted. Items to be considered in determining that one best method are ease of applying, nature of bonding with the base metal, degree of durability desired and cost.

Take a specific example of a casement window. First it is necessary to clean the metal. This must be done after the window has been assembled, and experience indicates that a sandblast will not reach certain corners and hidden spots, whereas acid solutions will permeate to all exposed surfaces. Here the recommendation is for standard practice of alkali cleaning followed by acid pickling. The advantages and disadvantages of different processes of rustproofing with reference to one item only, steel casement sash, are the following.

RUSTPROOFING PROCESSES

Galvanizing.—This is a good coating, but it warps sash and, when straightened, the coating is destroyed in some places. It also interferes with the fit of accurately made parts. It is difficult to paint unless treated.

Sherardizing.—It is possible to sherardize sash of large size only before it is assembled because sherardizing is destroyed by welding and there would therefore be no rustproofing at these parts.

Zinc plating would be good if plated heavily enough, about 0.001 in. thick, but for commerical purposes this is rarely done. In addition, the zinc does not plate uniformly but leaves a very thick coating on irregular surfaces and a very thin coating in some corners. Furthermore, if the sash is assembled with projecting parts, some overlapping sections would not be properly plated.

Cadmium Plating.—The statements about zinc are more or less true about cadmium. In addition, cadmium will deposit better in irregular places and recesses. However, it is difficult to get paint to adhere properly to cadmium.

Parkerizing.—This is a chemical method of rustproofing which will take all over on a sash because the sash is simply immersed in a solution. It is a cheaper process to apply than any of the above, and, when painted, the paint will hold without any difficulty.

Bonderizing.—One process of rustproofing that is gaining wide acceptance is to zinc plate first and then bonderize. Material thus processed can be stored preliminary to painting. American Rolling Mill Co. sells sheets coated in this manner.

Other items can be processed in this manner by handling them on conveyors and plating the zinc for, say, 5 min. before bonderizing.

In the case of the steel sash, parkerizing seems to have fewer defects than the other processes. Here the question of painting is one of the chief considerations. Sash is almost always painted, and the best rustproofing process, therefore, must be one that leaves an excellent base for paint.

Advantages of Various Finishes.—The first consideration in the problem of selection of metal finish is a knowledge of the many available finishes and their characteristics. The manufacturer of metal furniture must consider the advantages and disadvantages of dipping, spraying, silk screening, coating with a composition roll or a coating machine, tumbling and brushing. The manufacturer of almost any metal product should know a great deal about the various prefinished sheets, strip and wire he can buy that can be fabricated without marring the surface.

One of the most interesting and far-reaching developments in metal finishes is an enamel that will stand up under severe forming. An example of this is the familiar metal drugstore bottle cap. These caps are manufactured out of enameled sheet stock which is blanked and formed without surface injury.

Many other types of finish are proof against some forming or fabricating processes. A familiar example is metal snap cases for eyeglasses, which are frequently lined with plush or felt. One of the largest manufacturers buys plush-coated sheets and then does the required stamping and finishing without injury to the plush. The problem of an attractive appearance is often greatly simplified when coated or plated sheets can be used.

Wood Grain.—The wood-grain finish on metal received its greatest impetus in connection with a sales-development program of the National Cash Register Co. The usual finish of early cash registers was a bright nickel. One important customer who was fixing up luxurious offices asked for a good job of imitation wood-grain finish on his order of cash registers. Shortly before this the Von Webern graining process had been developed, and it was used in filling this order. Previous to the Von Webern method, most wood graining was a hand operation.

A familiar instance of this hand process was seen in the finishing of Pullman cars built at about that time. The new process transferred the design photographically from actual examples of wood grain to rolls and finally to flat sheets of metal.

The finish on this first order for office furniture proved so attractive that the National Cash Register Co. started using it as its chief finish for its complete line, even though this meant some radical changes in design. Heretofore the registers had been made largely of castings that were embossed and nickel plated. The wood-grain finish cost slightly more than the nickel plate, but this was more than offset by the saving through

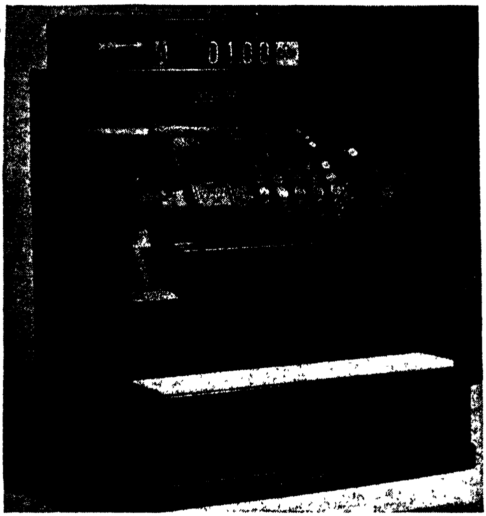


FIG. 5.—The National Cash Register Co. was one of the first to use a wood-grain finish on a standard metal product. It proved so popular that now it is almost a universal finish with this company.

the use of rolled-steel products and by the increased appearance value.

An interesting collateral development in finish occurred in the design of tables and stands used for supporting registers. A manufacturer of wooden tables was so pleased with the new National Cash Register wood-grain finish on metal that he used the same finish on wood. He made his tables of birch, covered them with a ground coat and then applied the imitation wood grain on top of that.

The technique of photographic copying has been so well developed that accurate replicas of wood-grain finish and of marble are relatively inexpensive to produce. Several methods are offered for reproducing wood grain on metal. So natural are some of these that metal paneling and wainscoting are used in some of the finest residences where the cost is in no way the determining factor.

Adaptation of Finish to Product.—Whatever the surface requirements may be, the actual method of finishing used must be adapted to the individual product. Some pieces, for instance, are so shaped that they cannot be properly coated by dipping,

FIG. 6.—Appearance is the paramount consideration in selecting the finish for this article. Resistance to corrosion and wearing qualities are the next considerations. But the "eye appeal" is so great a factor in the whole merchandising scheme that cost of the finish is relatively unimportant.

and this single condition may make it advisable to switch to an entirely different form of finish.

In selecting a finish for a given metal product, it is desirable first to determine the desired appearance. Any one of many methods may give a satisfactory appearance on an article adapted to its use, but, when the quality of appearance has been set and the nature of the article is fixed, the selection of finish narrows down to comparatively few types. Some products have parts impossible to reach with a spray gun or a brush, and still other parts may be a combination of surface peculiarities calling for two or more methods of applying a finish. In plating, it is often necessary to go to an entirely different metal in order to secure sufficient throw to reach recesses in the article. Spraying is the most common method of applying enamel, lacquer or paint, and the technique of spraying has been so highly developed that barrels are now automatically spray coated in two or more colors in a continuous process. The emphasis in this field of finishing has brought with it a development of auxiliary equipment which tends to cut the unit cost to a comparatively low figure.

Appearance and cost are not the only considerations in selecting a metal finish. The utilitarian features are often paramount. A case in point is a metal display rack for storage batteries. Here the finish must resist the attack of battery acids which may occasionally be spilled on the rack. Refrigerators are another example. In this case the changing temperature conditions, the extreme humidity and the need for a finish impervious to food acids and food vapors determine the selection. In the design of condenser tubes, the appearance of the finish has no value from a decorative standpoint but has a decided value when it comes to accepting or rejecting the finished article. That is, inspectors accept or reject condenser tubes to some extent from a visual examination, and appearance goes a long way. The American Brass Co., for instance, brought out a tube produced by a new method of manufacture, extrusion. Here the better surface finish helped greatly in getting the product accepted for its real worth.

Plating.—Plating as a manufacturing process is still in its infancy, and development in this field is perhaps as active as in any other at the present time. One engineer has said that the possibilities in the use of chromium plating for industrial machine parts have hardly been touched. The life of heavy and costly rolls in the paper industry has been increased as much as thirty times by chromium plating. In the textile industry, Schreiner rolls used for finishing cloth formerly had a life of about 200,000 yd. Now, when plated with a chromium alloy, they have shown a life of 8,000,000 yd. In the appearance field, new methods of plating are strongly competitive with lacquer and other finishes. One manufacturer has produced unusual color combinations by chrome plating sheet copper and then etching and lacquering it. This material is used with success in the manufacture of a high-grade washing machine. In the bicycle industry, plating in two or more contrasting colors is done successfully. The method here is to use masks to shield one part of a surface while another part is being plated. Nickel plate is now used for ferrules on paint brushes, and a

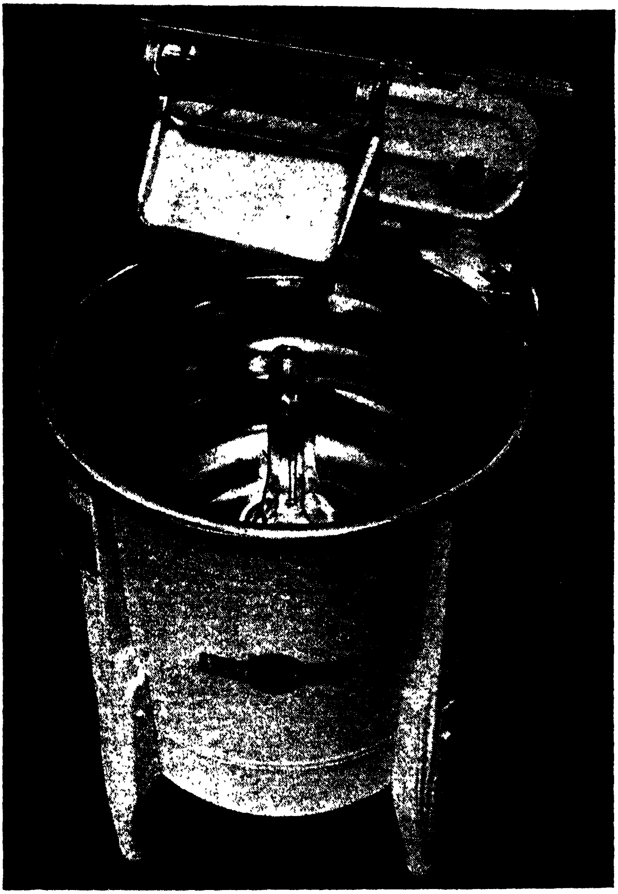


FIG. 7.—Corrosion resistance is the first consideration in the finish of a good washing machine. Appearance and cost are important secondary factors. (*Courtesy of The International Nickel Co., Inc.*)

coating known as nickeloid is finding extensive use for the clip that seals the ends of toothpaste tubes.

Lithographing and Specialty Finishes.—Progress in lithographing on metal has been rapid. It is now possible to put special designs of many colors on steel sheets and have the finish remain unmarred through subsequent forming operations. An example of this type of work is shown in Fig. 8. In this case a large manufacturer of dolls' eyes receives as raw material lithographed sheets containing a multitude of individual eye designs. These are stamped and formed into shapes approximating a complete sphere, with the lithographed design on the outer surface.

Success in this unusual process has been dependent upon close cooperation between the manufacturer of lacquers and inks, the manufacturer of the steel sheets and the designers of the forming dies. Heat is used at one or two places where the most

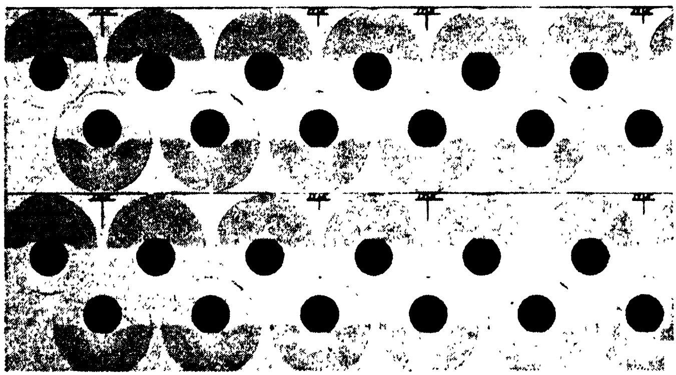


FIG. 8.—A large manufacturer of dolls' eyes buys flat steel sheets lacquered and lithographed with hundreds of the eye designs in color. These he stamps and forms into the finished eye shell without surface injury.

severe movement of the metal occurs, but engineers feel that even this precaution will be unnecessary after some further research with lacquers and die processes.

Lithographed sheets carrying special designs are used in the manufacture of toys, radio cabinets, andirons, electric fixture parts, faces of watches and clocks, cans, waste baskets, etc.

Specialty finishes are available in a great variety of color and design. Some of these are known as crystalline, stippled, wrinkled, veiled and spattered surfaces. The wrinkled finish consists merely of a varnish that of itself wrinkles up under the action of heat. Originally this particular tendency of certain varnishes was considered a defect, but someone seized upon the defect to create a new finish. Many of the highly individualized novelty patterns are actually less expensive to produce than a plain smooth one in a solid color.

Veiling.—One of the most ingenious of the modern specialty finishes is that produced by the Ault & Wiborg Corp. and known as a veiling lacquer. Here the spray nozzle has tubes leading from two or more different kinds of lacquer reservoirs, and by regulating the various air pressures an almost unlimited variety of finish and pattern is secured.

A novelty made of metal, but at the same time a practical display item, is an imitation open candy box. Here the finish for the individual candies is accurately reproduced on thin steel sheets in imitation of chocolate and other coatings. After these sheets have been formed into exact shape in the subsequent die operations, it is almost impossible to tell the finished product from an actual piece of candy.

A special soft lacquer is available, which melts at a low temperature and which therefore can be used as a glue in process. An example is a metal bottle cap having a thin cork disk on the inside. In the manufacturing sequence, these caps with the soft lacquer on the inside are carried upside down on a conveyor past a point where they receive the cork disks and on to a heating zone that melts the lacquer and causes permanent adherence of the cork to the metal.

A special method of applying finish has been developed for the familiar collapsible tin tube. These tubes are made by the extrusion process. A small lozenge of pure tin about the size of a nickel is placed in the extrusion machine that forms the thread and shoulder and then extrudes the sides to form the tube. The tube is then placed on a mandrel and is rolled over a plate to pick up the finish, a reversal of the usual method of applying finish where the design is transferred by a roll to a flat sheet.

Rubber covering on steel has proved a practical means of resisting the action of chemicals. This covering also is used for its decorative effect. Usually the rubber is applied before vulcanization. A process called the anode process has been developed for coating steel with a thin latex film.

Cost of Lacquering.—The cost of finishing a metal product in relation to the total production cost varies greatly, depending upon the nature of the product being finished and the nature of the finish. In the case of cutlery and reflectors, the cost of finish is obviously high. In the case of wrenches, the finishing must represent a comparatively small percentage of the total cost. Some decorative metal signs, where the color combination and finish texture give the article its chief value, may have a finishing cost of two or three times the cost of the metal stamping itself. One manufacturer estimates that throughout the metal-working industry the cost of finishing products will range from 3 to 10 per cent of the total cost of the product. In the case of lacquering, some more definite figures of cost and importance in the industry are obtainable. In one typical case a modern cash register costing $150 and weighing about 50 lb. requires for its finish 1 pt. of lacquer at a cost of 50 cents, and the labor and overhead cost runs to about $1. This means that for work of this particular type it costs $1.50 for finishing a $150 item, that is, 1 per cent for the cost of the finish. From another angle in this particular case, the finish cost is 3 cents a pound. From this example it would be possible to make certain generalities, and a rough estimate of the total value represented by the finishing of certain types of product could be made. The value of a finish naturally bears no direct relation to its cost. Often when a sales manager has advised a new and more expensive coating, resultant sales have increased entirely out of proportion to any increase in manufacturing cost.

An average automobile body takes a gallon of lacquer, and in one rather typical example, in round numbers, this lacquer cost $3, the direct labor of application totaled $3 and the overhead $4, which means that the finish on an average automobile body represents approximately $10, or, roughly, $30,000,000 for the United States prewar output. The plating of bumpers, hubcaps and other parts may run to $5 per car.

The cost of producing a finish, of course, usually is one of the most important considerations in making the selection in any given case, but sometimes the increase in sales appeal is such as to make the comparatively slight cost of finishing a minor item.

Two trends are apparent in recent years. The demand for more attractive finish, through its stimulation of research work, has caused the development of a great number of surprising finishes for metal, and on the other hand this very development of new finishes has stimulated the interest in appearance possibilities on the part of the manufacturer of metal products. The familiar story about Mr. Kettering of General Motors illustrates one phase of the excessive demand made of a metal finish.

When it took about 48 hr. for automobile-body enamels to dry, Mr. Kettering called in a group of varnish and paint experts and pointed out the necessity of developing a quicker drying enamel. He told them how expensive it was to delay production of automobiles because of the slow finishing process. This, he said, tied up an immense amount of capital, and the slow drying meant added danger of dust collecting. This in turn meant added expense for closely sealed drying rooms. He told the group that he wanted them to give him a quicker drying enamel that would have fully as good an appearance as the regular 48-hr. enamels. After a good deal of work in many laboratories, the experts returned and said they had succeeded, and, when Mr. Kettering asked them how quickly the new product would dry, they rather jubilantly told him "24 hours," or just half the previous time. Instead of being pleased, however, Mr. Kettering was greatly disappointed and told them that they had not even started on the problem. When asked how quickly he thought the finish should dry, he replied: "in one hour." This seemed utterly impossible to the leading paint and enamel experts at the time, but a group of chemists and others less bound by the traditions of the varnish industry have since fully met Mr. Kettering's forecast with a lacquer that dries within an hour.

Finishes for Quality.—One of the lessons ground into the manufacturer of metal products during the last few years is the importance of putting the right finish on the right product. Every product requires a finish that talks quality in a language every purchaser understands—eye appeal.

Difficult as it is to give an exact definition of quality, it may be generally stated that the best finish for a metal article is one that will give the most efficient service for which it is intended, protective, or decorative or both, for the expected life of the article.

It is not always practical to provide the best possible finish. Often a shorter lived finish is replaced at regular intervals, as on plumbing fixtures that are replated whenever apartments are redecorated. The purpose of the finish on inexpensive merchandise is to afford either a slight protection for utility articles or decoration at very low cost for the life of a short-lived article. Here imitative plates are resorted to: cadmium plate for imitating chromium, lacquer coatings for imitating gold and tin plate with drop black to imitate oxidized silver.

Such imitative finishes are not necessarily "bad" finishes. Some are suitable for higher priced articles. They are usable on low-priced products simply because their methods of application allow considerable latitude. Of course, some higher priced articles have such distinguishing characteristics as genuine gold, silver and rhodium plate and greater care in application and uniformity in the use of chemical colors.

Although all coatings, even those primarily decorative, act as protectors, many products are coated solely for protection against corrosion and wear (physical and chemical attack). For this service, the finish must be hard and tough or resilient. The purpose of the finish is to provide a resistant surface to protect a cheaper nonresistant metal. Here, therefore, specifications are most common; in fact they are indispensable to satisfactory performance. Thickness or weight of deposits and freedom from porosity are specified and tested.

It may seem confusing that many finishes may be used for both high- and low-priced articles and have no distinguishing marks to stamp their quality. The chrome finish on a 5-cent article also appears on a $25 article; but the 5-cent article has only a flash directly on the base metal, whereas the $25 article is likely to have a heavy nickel coat covered by chromium at least 0.00002 in. thick. Here the finish will be firmly adherent to the base and free from porosity. Consequently it not only will have a good appearance but will also be protective and long-lived.

Another comparison could be made between cheap novelty work in which the use of thin gold plate 0.000001 in. thick is considered "quality finishing" (since the cheapest work is given only a gold-colored lacquer), although a gold-filled watch requires at least 3000 times this thickness on the outside (Federal Trade Commission ruling for Jan. 25, 1923). Both are quality finishes for their price classes depending on the types of service and the life of the article.

Merely increasing the thickness of the coating may not change an "inferior" coating to a "quality" coating. Appearance is important today in even strictly utilitarian products like the lowly garbage can, which has generally been hot-galvanized. Even in this extreme case, quality is brought to the attention of the buyer by the use of a white air-drying or baked enamel. Cans so finished are in universal use in hospitals and have made deep inroads into the modern kitchen. The superiority of the enameled can over the galvanized is obvious at a glance.

Organic finishes should be nonporous and should also withstand tests to indicate their life in their special end use. Among such tests are abrasion, bend, resistance to discoloration by heat and light, exposure to atmosphere and resistance to various chemicals.

CHAPTER III

CHARACTERISTICS OF ELECTROPLATING SOLUTIONS AND ELECTROPLATED COATINGS[1]

The manufacturer of almost any metal part, say for a radio, a washing machine or an electric refrigerator, is faced with the problem of selecting the most advantageous finish. Many factors determine his choice: sales value, durability, utility, cost and others.

A relatively small group of coatings offers a broad array of characteristics. Some have excellent decorative value but give little protection of the base metal against corrosion; others possess corrosion-preventive properties but have no "eye appeal"; one or two others have an advantageous combination of the two. To give a ready picture of the various properties, the essential characteristics have been summarized in Tables I and II.

In both tables a distinction has been made between acid and cyanide baths when normal practice prevails. The reason is that the composition of the bath is often selected to suit the type of work to be done. It should be noted that there is also a difference between various nickel baths, and between some others, and that the data given refer to results obtained with the best available baths in each case.

Some Combinations.—Chromium coatings are generally applied as thin flash coatings over nickel, or over copper plus nickel, to prevent the tarnishing of these undercoatings and to provide new appearance characteristics. These thin chromium coatings, 0.00001 to 0.00002 in. thick, by themselves cannot be expected to add much to the rust resistance. Some of the most frequently used combinations are cyanide copper nickel chromium, cyanide copper acid copper nickel chromium, and nickel chromium. Ordinary nickel plate without chromium is also frequently applied over a preliminary cyanide copper coating. Advances in nickel plating are discussed in some detail in Chap. XXII.

[1] Prepared in collaboration with Dr. R. B. Saltonstall, technical director, Udylite Corp.

TABLE I.—COATING CHARACTERISTICS

Coating	Main purpose of application	Commonly used thicknesses, inches	Protective value	Appearance: Initial	Appearance: After exposure	Resistance to abrasion
Acid zinc	Rust protection	0.0002 –0.001	Excellent	Bluish satin	Dark gray	Poor
Cyanide zinc	Rust protection	0.0002 –0.001	Excellent	Matte white	Dirty gray	Poor
Cyanide zinc, bright	Rust protection and appearance	0.0002 –0.001	Excellent	Bluish white lustrous	Dirty gray	Poor
Cyanide copper[1]	A. Base for "oxidized finishes"	0.0001 –0.0003	Poor	Colored and lacquered		Fair
	B. Base for nickel plating	0.0001 –0.0006	........[6]	Salmon red[8]	Black to green	Fair
	C. Stop-off for selective carburizing	0.0005 –0.003	....	Salmon red[8]	Black to green	Fair
Acid copper	Base for nickel plating[2]	0.0003 –0.0006	........[6]	Salmon red[8]	Black to green	Fair
Nickel[3]	A. Appearance and rust resistance directly on steel[4]	0.0003 –0.001	........[6]	Matte yellowish white[8]	Dark to brown	Good
	B. On steel over copper plate	0.0003 –0.0008	........[6]	Matte yellowish white	Dark to brown	Good
	C. On copper or brass	0.0002 –0.0006	Good	Matte yellowish white	Dark to brown	Good
	D. Directly on zinc	0.0003 –0.0005	Fair	Matte yellowish white	Dark to brown	Good
Chromium	A. Appearance[5]	0.00001–0.00002	........[6]	Bluish white—mirrorlike	Unchanged[7]	Fair (thin!)
	B. Abrasion resistance	0.001 –0.005	Excellent	Frosty bluish white	Unchanged	Excellent
Cadmium	Rust resistance and appearance	0.0002 –0.0006	Excellent	White lustrous	White	Very poor
Tin	A. Corrosion resistance on copper and brass	0.0003 –0.001	Excellent	Frosty white	Grayish	Very poor
	B. Minimizing piston wear	0.0010	Good	Frosty white	Grayish	Very poor
Brass	Appearance (often colored and lacquered)	0.0001 –0.0003	Poor	Satin yellow to bronze[8]	Black to green	Fair

[1] High-speed bright copper-plating processes are available, some of which are plated from solutions containing neither cyanide nor acid.
[2] Sometimes substituted for part of cyanide copper—never direct on steel.
[3] Bright nickel-plating processes are available for purposes A, B and C.
[4] As plated, buffed or scratch brushed.
[5] Over *nickel* and *nickel plus copper*—also rust resistance.
[6] Total coating of copper plus nickel plus chromium on steel should not be less than 0.001 in. thick for outdoor exposure.
[7] Also resistant to oxidation at high temperatures.
[8] Luster is obtained by buffing or analogous mechanical treatment after plating.

The thickness of the coating has little to do with its appearance, except that a certain minimum thickness is necessary when the coating is to be abraded by buffing or scratch brushing. The thickness, however, is most important when the durability of the coating is considered. If properly applied, the thicker the coating, the longer it protects against corrosion.

Table I gives general coating characteristics and Table II gives the approximate corrosion resistance obtained by the application of different coatings and for thicknesses noted. Generally speaking, the more severe the exposure, the thicker should be the coating. A combination of two or several coatings will generally increase the protective value. Thus, when one talks about the protective value of a chromium coating, one really considers its protective value plus that of the under-coatings. This is proportional to the total thickness.

TABLE II.—PROCESSING DATA

Coating	Efficiency in coating recesses	Control of plating process	Total plating costs per usual thickness	Extra operations
Acid zinc	Poor	Very simple	Low	
Cyanide zinc	Fair	Fairly difficult	Fairly low	
Acid copper	Poor	Very simple	Low	Polishing of base metal, buffing of coating[1] (Acid copper, Cyanide copper, Nickel)
Cyanide copper	Good	Fairly difficult	Fairly low	
Nickel	Poor, fair	Fairly difficult	Fairly high	
Chromium	Very poor	Simple	Fairly high	
Cadmium	Good	Simple	Fairly low	
Tin	Good	Difficult	High	
Brass	Good	Difficult	Low	Lacquer coat

[1] These operations may be greatly reduced or eliminated by the use of bright rolled steels and bright copper- and bright nickel-plating processes.

Corrosion and Appearance.—Most coatings will stay unchanged for a long period of time if they are kept in pure dry air, but when they are exposed to moisture and corrosive atmosphere their appearance changes a great deal. This is indicated in Table I under Appearance after Exposure.

The softest coatings, which do not withstand abrasion at all, frequently are used for "wearing in" tight-fitting parts because they flow instead of crack. Thus, tin coatings have been used on automobile pistons.

In Table II an attempt is made to evaluate the efficiency of the baths in respect to surface recesses. All plating baths tend to cause the heaviest coatings to be built up on protruding points. Some baths, however, and particularly the alkaline baths, distribute the plate more evenly. This is most important from the standpoint of cost, because it is the thinnest portion of the plate that determines its value for corrosion protection. When a bath is used that is efficient in coating the recesses, there is no

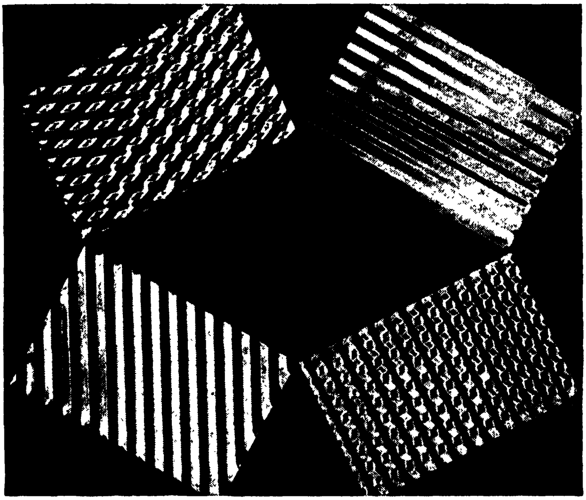


FIG. 9.—Sheets and strip are now available in a great variety of decorative finishes. This shows several forms of crimped sheets as produced by the American Nickeloid Co.

need of an extremely heavy average thickness of plate to get the required minimum thickness.

Under the heading of Costs, such factors as depreciation of equipment, materials, labor costs and power have been included to give the total shown in Table II.

Factors in Cost.—Of course, the total cost depends also on the number of extra operations necessary. Cadmium and zinc, bright or matte, are generally applied without any mechanical finishing operations. Formerly, it was usual practice in copper-nickel-chromium plating to polish the base metal and buff the copper and nickel coatings prior to chromium plating. The cost of such polishing and buffing was often greater than the cost of plating. Furthermore, buffing operations remove plate from sharp edges and protruding points, which often leads to poor protection against corrosion. The advent of copper- and nickel-plating processes that produce bright deposits and the production of bright finish steel for manufacture of articles to be plated have resulted in appreciable savings in labor and resulting economies.

There is still another angle to costs. The reader will note in Table II that the cost of the chromium coating is designated as "fairly high." This statement refers to the chromium coating alone and does not include the cost of the composite coatings used in conjunction with chromium. When the cost of the copper and nickel undercoatings, together with that of the buffing and polishing operations (if necessary), is added to the cost of the chromium coating, the total is considerably higher than is indicated in the table.

For the purpose of explaining the function of the tables in choosing the proper electrodeposit, it may be well to take a few practical examples.

A manufacturer of hardware for refrigerators wants a brilliant, permanent finish; in other words, appearance is his primary consideration. Although cost is a factor, appearance is paramount. Corrosion prevention is not unduly important since exterior refrigerator hardware is not usually subjected to severe exposure conditions.

Being chiefly interested in appearance, the manufacturer looks under Appearance in Table I and runs down the column until he comes to nickel, chromium, cadmium and brass. Nickel, cadmium and brass he discards because they tend to discolor, as indicated by their change on exposure, and frequent polishing to restore luster might cut through the coating, exposing the base metal. By a process of elimination, therefore, he arrives at chromium, which retains its luster. The cost of chromium he has found, from the cost data in Table II, to be higher than that of the other finishes, but in this instance cost was not of primary importance. Since only a fair amount of corrosion resistance is needed, relatively thin undercoatings of copper nickel or nickel alone can be applied, which decreases the cost somewhat.

Finish for Steel Radio Chassis.—Let us next consider a more complicated problem—the proper finish for a sheet-steel radio chassis, which is formed in such a fashion as to present several deeply recessed surfaces. The considerations here are rust prevention, cost, appearance and ability to deposit into recesses. Looking first at the column headed Protective Value, we find acid zinc, cyanide zinc, cadmium and very heavy copper nickel chromium coatings, as those providing steel with excellent protection. Proceeding to the next classification, namely, Cost, we see acid zinc having a slight advantage. Heavy copper nickel chromium is eliminated because of its high cost.

Next comes appearance, which serves to eliminate both zinc coatings because they are apt to discolor upon exposure. Furthermore, the acid zinc bath does not "throw" efficiently into recesses of any appreciable depth. In this respect, cyanide zinc is better. A properly formulated cadmium bath has the faculty of being able to "throw" into recesses, a fact that further contributes to the low cost of the cadmium coating.

Appearance and Protection.—The choice of the proper finish for steel suspension arms for filing cabinets involves considerations similar to those just cited, except that "throwing" into very deep recesses is not particularly involved. The relatively poor appearance of cyanide zinc after weathering is a drawback to its use, which explains why many manufacturers of office equipment are using cadmium.

If a part has a rather flat surface, and rust protection at low cost is the big factor, with appearance of secondary importance, acid zinc is broadly and profitably used.

Many parts can be nicely finished with any one of several coatings. Take, for example, a lighting fixture. Cyanide copper that is oxidized, relieved and lacquered produces a pleasing effect; buffed or brushed nickel gives a nice appearance; chromium, though effective, often requires composite coatings of copper and nickel underneath and is used only for more expensive fixtures; cadmium can be applied directly and, when properly done, makes a pleasing appearance, with no extra operations necessary to increase the luster; lacquered brass coatings frequently find favor because of their color and comparatively low cost.

CHAPTER IV

IMPORTANCE OF COLOR

Sales of a wide variety of metal products have been increased through the use of different colors or color combinations in finishing. The simpler colors were used at first because of the cost and technical difficulties involved in the use of the more complicated shades. Now, however, lacquering and enameling processes have so far developed that the manufacturer is not handicapped in his selection of color. The question naturally arises, what color will have the best sales appeal?

A manufacturer of typewriters found sales lagging and called a board meeting to discuss means of stimulating trade. Someone at this meeting made the startling suggestion that typewriters, which until then had been offered in a black finish, might be advisedly finished in various bright colors. After considerable hesitation this was finally done, and sales immediately started to improve. Here in a very real sense was a case where rainbow shades took the company out of the red.

The Victor Saw Works, Inc., was another company to take the initiative in using a colored finish, and here perhaps the experiment was even more unusual, for few would have thought that a gold finish would help the sales of prosaic steel hack-saw blades. But it did.

The color vogue in kitchenware of some years ago increased sales of one company by more than 30 per cent. Other examples of the advantage of color could be cited in almost every branch of the metal industry. Farm machinery sells better in bright colors, and machine tools are no longer black. The depression years of color in industry occurred in 1909 and 1910 when practically all automobiles were black. One reason for this was the clamor for more and more cars, which left no time for experimenting with colored finishes.

Dark Colors Easily Applied.—Japanning, which is a process of baking a dark coating material on metal, fitted right into the spirit of the times, for metal articles could be produced with a fine glossy black finish overnight. They would be dipped or sprayed one day, baked during the night and delivered the next day. Manufacturers simply had to use black because no other color could be applied quickly.

Even as late as 1927 the japanning finish was in vogue, and in one plant an average per furnace of 4800 lb. of automobile parts

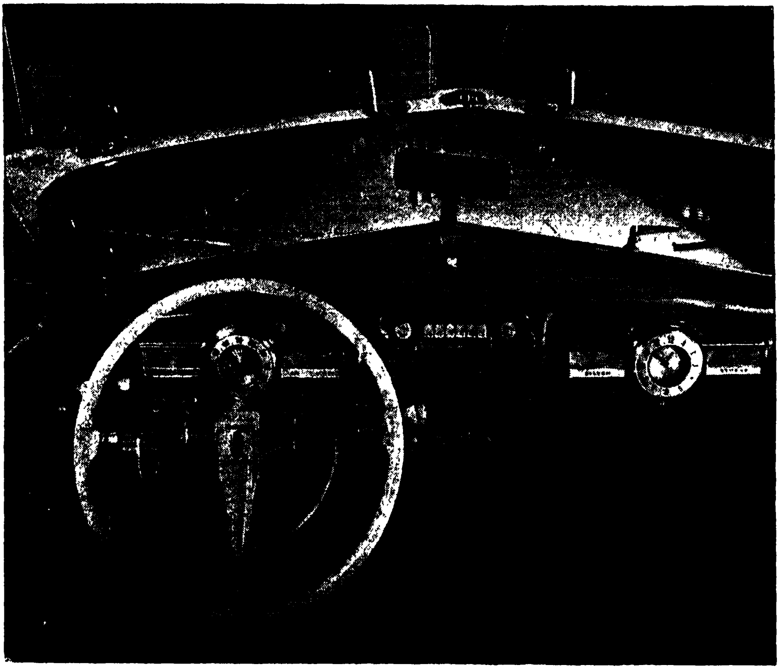


FIG. 10.—Here bright chromium and an organic coating are combined in an attractive assembly. (*Courtesy of New Jersey Zinc Co.*)

would be baked, unloaded and transferred to the shipping room in less than 1 hr. Twenty years before, each one of these loads would have taken 4 hr. to bake; today the same operation can be performed in 20 min.

The nonmetallic materials proved the sales value of color before the metals. Notable in this line were plastics, bricks, terra cotta, glass, cement and wood. But the metals soon caught on and started in to make up for lost time.

A wide demand developed in the metal industry for color to get away from the black, black, black which at one time was so closely associated with metal that many felt the two in some strange way were inseparable. If you wanted an article made of metal, it had to be black.

Bright Colors.—The first serious break from black in metal finish occurred in connection with automobile bodies about 1924. Since then, the use of color has spread rapidly to include almost all metal products. A visit to a typical hardware store will disclose red stew pans, green metal cups and yellow sugar cans. Small tools may be found with handles in almost every shade. Even silver-colored ranges and gold-colored lawn mowers are available.

Cost.—Several manufacturers of popular metal items, who were questioned on the subject of color, said they would not return to black even to save the entire cost of finishing. The new lacquers of today, according to many authorities, give everything to be desired in physical and chemical properties and in meeting psychological demands. It is true that many of the colors are still relatively expensive as a finishing material, but each year the increased use of lacquers and the research in synthetic enamels make possible a greater coverage per dollar invested in the coating material. In general, the cost of nonmetallic coating is lower than plating.

Lacquers suitable for the finish of automobile bodies were slow to develop. There were manufacturing difficulties, and fast dyes in quantity were hard to obtain. In addition to this, it was not apparent at first that an associaton of bright color and metal would be favorable in the minds of the public. "The period of transition from black to color lasted from about 1924 to 1928," states one authority. "During the early years, manufacturers of many practical metal products noticed but little difference in the sales value of a bright color as against a dull one."

What Color Is Best.—A manufacturer of cream separators observed that one particular model finished in a light-blue enamel showed an encouraging increase in sales. Investigation seemed to indicate that at least some of the credit should go to the color. Since that time, definite experiments have been made, which indicate positive increased sales value in certain colors for certain products.

The most pronounced increase in sales value seems to derive from a pleasing combination of two or more colors on one product. It is difficult, however, to lay down any definite rules because the element of style is so large a factor, and a color for a certain product may have high sales value for several years and then lose this value almost entirely.

Manufacturers generally are coming to appreciate the importance of knowing what color will have the highest sales value, and to find this answer some large organizations have added to their staffs experts whose duty it is to introduce factors of design and color to products sold to the public. A chain-store system has organized a sort of sales advisory department that constantly studies the reaction of the public to different colors and different styles of packaging. When asked which colors created the best sales appeal, one investigator said:

It is impossible to state definitely, but an indirect approach may be made. Take, for example, an old kitchen stove finished in the natural iron finish. The best you could expect to get for such a stove would be a little more than the cost of labor and material entering into its production. But dress up that same stove in cream and buff colors and add a few incidental frills and notice what happens to its value. If it sold for $20 unfinished, it might easily be expected to sell for $50 in the finished form. Thus, by the medium of color, the product is lifted out of the category of price per pound, into another world where price per unit is the custom.

As a rule, light delicate pastel colors that appeal to women have the highest ratio of sales value, while the darker, cold and somber colors are less stimulating to the buying instinct. Nevertheless, a delicate color would seem decidedly out of place on a motorcycle.

From this it may be judged that color alone is not the solution. It must be the right color for the right product at the right time. Industry is in an experimental stage as to color and finish. Means exist for finishing metal in almost any desired shade or tint. Wash bowls and bath tubs in delicate lavender, supplied with satin nickel hardware, may appeal to some buyers, but the attention-getting value of the unusual is undoubtedly a factor here. This is shown by the fact that some manufacturers are turning to the now unusual black as a finish for bathroom equipment.

The foreman of a machine shop decided to use colors throughout his plant and asked the opinion of several experts as to the shades. He found many plants where the traditional battleship gray had been discarded in favor of brighter colors, but he could find no agreement on any one standardized scheme. He finally decided to let the workers themselves make the selection.

FIG. 11.—Even manufacturers of technical instruments find an advantage in using different colors for finishes, to make it easier to give instructions for use.

Colors for Machine Tools.—In describing his experiment, he says:

In order to avoid too much of a rainbow effect, we laid down a policy that all machine tools in the same room were to be painted in the same color scheme, but we let the machinists working in each room decide the colors for that particular room. This privilege of decision gave a more personal interest in the matter and resulted in a mild rivalry between the different rooms. We suggested painting movable parts a different color or a contrasting shade, and the room that we finally considered most successful has the following colors: The floor is a dark gray. The walls for a distance of 6 ft. above the floor are gray, but two or three shades lighter than the floor. Above the 6-ft. level the walls and ceiling are eggshell white. The bases, frames and stationary parts of all the tools, including electric motor frames, are marine blue, and the movable parts are all straw yellow. Such parts include the spokes of wheels and in fact all unmachined surfaces that have movement during the operation of the tool.

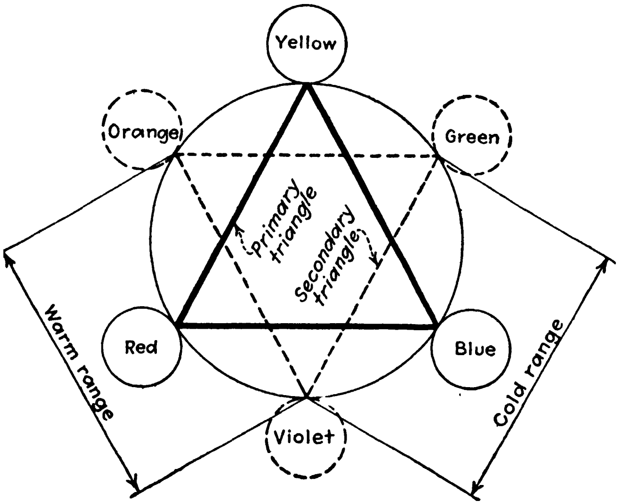


FIG. 12.—A color diagram helps to visualize the scheme of color mixing and blending. All the colors used in industry may be derived from the three primary colors, yellow, red and blue.

Color Characteristics.—A few of the basic characteristics of color should be considered by anyone selecting color combinations for metal products. A popular fallacy, for instance, places the combination of black and white as most legible, whereas tests indicate that it comes far down the list. One investigator, Le Courrier, places white on black as No. 10 in a comparative legibility table in which black on yellow comes first. This list is shown in Table III. It is interesting in this connection that several watch manufacturers are now departing from the use of the traditional black and white for dials, to use combinations such as blue or green against white, which are more legible.

Lacquer spraying of metal dial disks for watches and clocks was once a standardized automatic process. Present demand for varied colors and types of dials, however, has led to a return to hand lacquering with a spray gun.

Another quality of color that should be recognized is visibility at a distance. Blue and violet, for instance, become indistinguishable at a distance of about half a mile, whereas red can be identified at 3 miles or more. The diagram of the primary and secondary colors shown in Fig. 12 forms a good means of visualizing the structure of the spectrum. From the three primary colors, any of the thousands of colors used in industry may be developed. Yellow and red, for instance, make orange, which forms one of the group of three secondary colors.

TABLE III.—LEGIBILITY OF COLOR COMBINATIONS
(*Le Courrier*)

Order of legibility	Decoration	Background
1	Black	Yellow
2	Green	White
3	Red	White
4	Blue	White
5	White	Blue
6	Black	White
7	Yellow	Black
8	White	Red
9	White	Green
10	White	Black

TABLE IV.—COMPARATIVE VISIBILITY AT DISTANCE

Color	Miles
Red	3
Green	2.5
White	2
Yellow	1
Blue	0.5
Violet	0.5

In a similar way, any other two primary colors, blended equally, produce a secondary color, and any two secondary colors produce a tertiary color. For example, the two secondary colors, orange and green, will produce the tertiary color, citron. Violet and green produce olive, and orange and violet produce russet.

Color Variations.—Color variation may be made either by using varying parts of two or more established colors, or by mixing any one color with black or white. Variations of the latter character are known as tints and shades of the foundation color, the tints usually designating the blending with white and the shades the blending with black. However, the metal-fabricating company need have no actual contact with mixing or blending, as most of the companies manufacturing enamels for

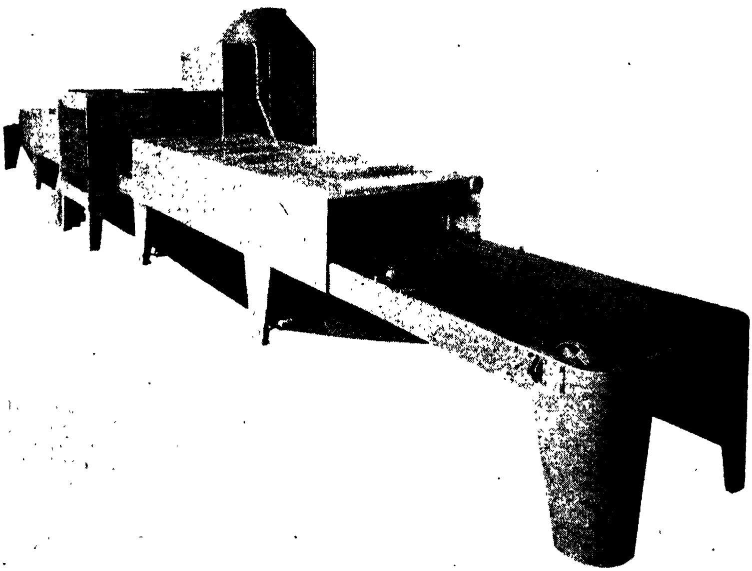


FIG. 13.—Alloy metal conveyors help transport miscellaneous parts through the cleaning operation.

use on metal products have developed colors and processes to meet a wide variety of conditions. Different colored enamels, for instance, formerly required different lengths of time for baking, and the manufacturer of a metal product often would base his color selection on this feature rather than on the actual appearance value of the color.

Colors produce varying emotional reactions which seem fairly well standardized for most people. Thus a blue is known as a cold color, whereas a red is a warm color, and most color variations take on either a cool or a warm connotation, depending upon whether the blue or red element predominates. Russet, for instance, which contains both blue and red, is a warm color because the red predominates.

When metal products are finished in the cool colors, they usually appear larger than they actually are, and, conversely, when finished in the warm colors, they appear smaller. If a high color contrast is desired, it is more easily secured by using a warm color against a cool color than by contrasting two warm colors.

Color Harmony.—Color harmony is a complicated and highly specialized subject which becomes the life work of some designers. Only the briefest statement of principle can be given here. Harmony in color usually exists when a common color is present. Thus orange and green harmonize with each other because yellow is in each. For the same reason, brown harmonizes with orange, green with crimson, orange with light blue, and gray with lavender.

The addition of a little gray to any two colors tends to make them harmonize, and, in a similar way, white may be mixed with one color and black with another to bring the two into closer harmony. However, in spite of the above, no set rules can be established, for the relative amount of surface covered by different colors often determines the effect, independent of the actual color relationship. For example, a small amount of a discordant color may actually tend to emphasize the harmony of two other and more extensively used colors.

Color and Quality.—The value of any color from a sales point of view is as dependent upon association as upon intrinsic qualities, and a favorable association may develop from advertising or publicity. Thus a red store front, while in itself not particularly pleasing, may become identified with a certain store chain and may thus take on a definite advantageous property.

Perhaps the greatest value of color is now found in the automobile industry where it is frequently the color of a car, independent of anything else, which produces the sale. At automobile shows, it is the attractively colored cars that receive greatest attention. Here the value sought is uniqueness or individuality rather than association with any one make. Designers who have studied the question of value of color on automobiles admit their inability to give any rules for attractiveness on sales appeal. Any one color, however appealing at first, loses its value as soon as it becomes identified with mass production, and from this fact one definite rule emerges. "Break up the uniformity of any one model by bringing out cars in several different color schemes."

Identification by Color.—On the other hand, having once identified a certain product with a specific color, it often becomes important to maintain this color unchanged, and this brings up one of the most difficult points in the whole realm of colors in industry. The human eye is a variable instrument, and even a color expert may see differently when he has a headache. Also, colors appear differently in different lights, and for this reason artificial lights that accurately reproduce the qualities of sunlight are used for most color matching.

Recently a color-measuring instrument was developed which bids fair to be important in industry, as it is based on the principle of the photoelectric cell and is independent of the human eye.

The standard electric eye with known spectral sensitivity is here substituted for the human eye. The instrument can be adapted to the requirements of high-speed production, and it may be relied upon for strict impartiality.

Color is often an indication of quality, and when once established, great care should be taken to maintain its uniformity. In certain chemical operations and in heat-treating of metals, the color in itself is not important, but it is an indicator for controlling operations.

Because of the infinite number of possible hues, tints and shades, colors cannot be described precisely, and, although some international standards have been adopted, color terms in a popular sense are loosely used, and samples tend to deteriorate with age. Because of this, the photoelectric color instrument is of the utmost importance in producing permanent records.

An example of the value of color is seen in lubricating oils where, independent of the lubricating properties, certain popular colors must be introduced for the sales value.

Enamels Extend Use of Metal.—As the technique of applying color in different designs to metal products improves, the scope not only of the use of color but of the very use of metal itself increases. The Ferro Enamel Corp., for instance, developed a method of applying procelain enamels in special designs to sheet metal and thus made it possible to produce decorative mural panels in metal. A description of this method and of the use of colored enamels on metal will be included in a subsequent chapter on Lacquers and Enamels.

Metal Colors.—One of the most satisfactory ways of utilizing color effects in metal products is to take advantage of the inherent properties of different alloys, which basically give the desired color characteristics. In many alloys, particularly those of copper, a wide range of color is possible without materially sacrificing physical characteristics. Beryllium copper may be made to resemble gold so closely that detection by eye is difficult. Unusually rich colors are obtained by mixing the two common elements, copper and zinc. A red brass with 85 per cent copper and 15 per cent zinc is extensively used, to contrast with the white metals, such as stainless steel and aluminum. For further information on the color of metals see the chapter devoted to that subject.

CHAPTER V

PREFINISHED RAW MATERIALS

Obviously, one way to overcome high finishing costs is not to finish. This is accomplished by some manufacturers without sacrificing appearance through the use of prefinished raw materials. Plated and polished strip is made into such items as lamp reflectors and loose-leaf binders, and lacquered sheets in decorative design are made into vanity cases without the necessity of any finishing at the fabricators' plants.

Progress in the development of laborsaving machinery has been so great during the last decade that it has temporarily blinded industrialists to some opportunities for lowering production costs in other channels.

One such opportunity lies in the field of metal finishing. Over and over again in the metalworking industry the weak link in a manufacturing chain exists in a cleaning or finishing process.

The very nature of finishing operations, coming as they do at the end of the production sequence, offers a handicap to their organization and to high quantity output. An assembled unit cannot be handled so efficiently as can the simpler parts from which it is composed.

Thus it is apparent that the further back the finishing process is, in the over-all manufacturing sequence, the greater is the chance of putting it on a low unit cost basis, and it is this factor which has stimulated the recent trend toward plating and polishing of sheet and strip metal at the producing mills. Several other factors contribute to this trend, of which the most important, perhaps, is the development of forming and pressing technique which makes it possible to fabricate parts from the high-polished material without scratching the surface.

Large-scale standardized production of plated and polished sheets makes for economy not possible in the manufacturer's plating department. The use of prefinished sheets or strip of this character is almost invariably less expensive than the cost of maintaining a plating department, if capital investment, depreciation and cost of materials are properly considered. In the case of prefinished chromium-plated sheets, the economy is especially pronounced because it eliminates handracking of individual parts, which is a slow, expensive operation.

Some articles of course cannot be fabricated advisedly from the high-polished sheets, but usually an adaptation of the processing and assembling operations will make it possible to use the prefinished sheets for at least some of the component parts of a product. The other parts can then be plated and

FIG. 14.—Closely wound strip must be loosened or uncoiled for plating.

polished before assembling in the company's own finishing department.

Where the surfaces are irregular, it is often difficult to remove buff marks when plating and buffing succeed fabrication. This difficulty may be overcome in a large percentage of cases by using sheets that are plated and finished in the raw state before fabrication. In addition to this, the large-scale standardized methods of finishing sheets at the mill make it possible to produce a surface superior to that obtained by plating and finishing small individual items.

Handling of Polished Sheets.—Much of the reluctance to use highly polished sheets in fabricating processes comes through lack of experience or ignorance of the possibilities. With relatively few exceptions, polished sheets are as easily and successfully handled through processing operations as are the unfinished sheets. Chrome-plated copper, for instance, is not harder to work than bare copper, and nickel tin is as easily drawn and formed as tin plate.

Certain precautions, of course, are usually necessary in handling polished surfaces. Dies must be kept in better shape than when used on plain material, and they must be properly designed. In forming with a sheet-metal brake, the metal should be greased on the finished side and the paper in which the polished sheets are packed should be used to line the brake.

Where it is desired to solder finished sheets, chrome plated, for example, the chrome surface should be removed from the sheets and a noncorroding solder paste should be used. For small parts, a hand file will remove the plate, and experience will indicate the amount of surface to be removed. Before soldering the complete joint, "solder tacking" at several points is advised to keep the parts lined up.

Strip coatings recently developed eliminate the necessity for such precautions in handling polished surfaces. One such coating is Protektal, made by the Ault & Wiborg Division of Interchemical Corp.

The prefinished colored Tint-Metal of the American Nickeloid Co. is made in a paper-adhered grade that permits bonded metals to meet unusually severe production conditions. With it, draws and bends that were formerly impossible are now being done without any harm to the mirrorlike finishes. The protective coating, adhered to the metals by a special gum, affords absolute protection during shipping, warehousing and all the way down the manufacturing and assembly line. At the end it peels off as quickly and easily as a banana skin. A few swipes of a cloth remove all traces of the gum and leave the finish lustrous and unmarred.

New Designs.—It is often possible to design a product so that the soldered joint will be concealed by a cover piece. However, further designing ingenuity, combined with the excellence of the prefinished sheets now available, often makes a soldered or welded joint unnecessary. Mill-polished sheets can be spot welded and even deeply drawn, and many surprising examples of high-luster finish are to be found today among articles fabricated from such sheets without subsequent finishing. One manufacturer of tableware is successfully producing highly polished products from prefinished sheets, without doing any polishing or buffing at his own plant, except on his dies, which he takes great care in keeping in perfect condition and which are all chromium plated and polished to eliminate even tiny scratches.

Prefinished sheets aid in mass-production processes, for otherwise high-speed presses and forming tools are slowed down by the relatively slow operations of plating and polishing. Some of the products now successfully made on a production basis from polished sheets are loose-leaf notebook parts, name plates, collapsible tube clips, boxes, novelties, toys, trunk hardware and brush ferrules. Larger articles include tabletops, refrigerator trim, electric stoves, office machines, window trim and other decorative building materials and washing machines.

Mass-production Finishing.—Several strip and sheet producers who have taken up finishing of their materials in earnest have developed elaborate automatic and, in many cases, continuous finishing processes. At the plant of the Apollo Metal Works, for instance, cold-rolled strip (steel, brass or zinc) is given a polished chromium finish in one continuous operation. The strip enters the process in its raw state, and the sequence includes cleaning, acid treatment, copper plating, nickel plating, chromium plating, drying, polishing, buffing, paper coating and coiling—all continuous and largely automatic. At the end of the unit, the coils, averaging about 100 lb. in weight, are boxed for shipment.

The paper coating is applied to the highly finished surface to prevent scratches and marring during handling and fabricating operations. It is a special product developed for this purpose. The adhesive is a type that does not "print" or react with the adjacent polished surface, and the paper is provided in rolls having widths corresponding to the widths of the strip being finished.

Sheets are of course more difficult to handle, but even here very nearly automatic finishing has been achieved, and, in addition, the wide strip now available in long coils takes care of a large percentage of the average run of small metal products.

Prelacquering.—Lacquering and painting of sheets are an important part of the general prefinishing of raw materials, and at least one company has developed a lacquer that is hard, yet elastic enough to be used on coiled strip and even under moderate drawing dies. A flexible, transparent lacquer for copper strip has been developed by the Copper and Brass Research Association.

Available lacquering machines are automatic except for loading and apply a uniform coat on sheets up to 60 in. wide. Many machines of this character contain drying units that complete the lacquering processes in one operation.

Sheet-metal Products.—Sheet metal is making a strong bid for business in many fields formerly occupied by cardboard,

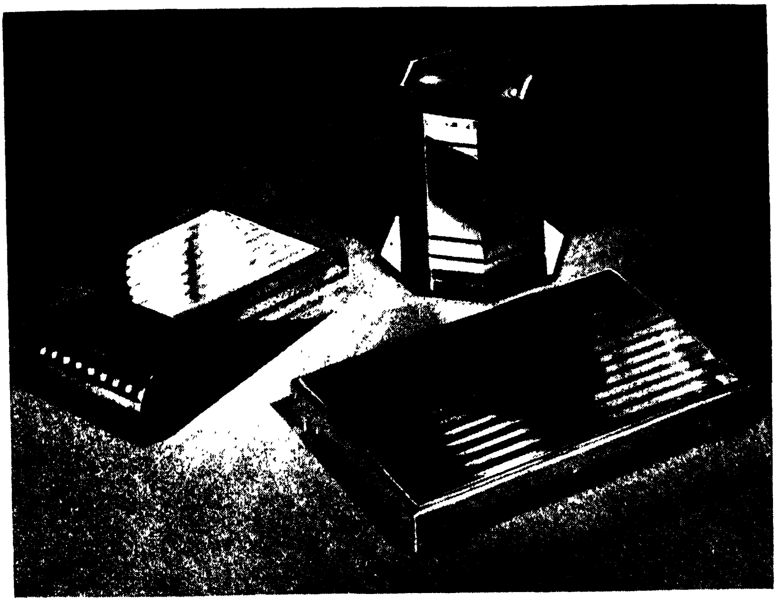


Fig. 15.—Novelty plating adds value to many items.

wood and other nonmetallic materials. One of the most interesting examples of the inroads being made by sheet metal is found in the packing field. Here it may be said that success is dependent upon the use of prefinished raw materials, because otherwise the required low costs could not be met in combination with high appearance value.

One of the companies to take an active interest in the use of metal for unusual and attractive packaging is the Apollo Metal Works. This company makes a specialty of bright or satin finished chromium-, brass-, nickel-, copper- and zinc-plated sheet and strip. These semifinished metals may be formed into a wide variety of shapes, with no further finishing being required on the part of the fabricator. Boxes made from this material have proved satisfactory for packaging foods, oil, jewelry, ordnance material, pen-and-pencil sets and novelties of various kinds.

Chromium-plated Copper.—The decorative effect of polished sheet metal is becoming more and more apparent. Show windows, exhibit booths and, in some cases, permanent wall coverings are being made of chromium-steel sheets. Some familiar uses of chromium-plated steel and copper are automobile mirrors, jewelry-case rims, towel cabinets, letter signs and tops of cardboard powder boxes.

Extension of Prefinishing.—One of the newest developments in the use of prefinished sheets is for roadside signboards. Instead of buying plain sheets and having workmen on a scaffold paint the entire surface with a background for the design, the sheet is painted in any color desired at the producing mill, and then all the painter on the job has to do is to superimpose his design. A new effect in this same field makes use of a matte or brushed finished aluminum surface for the background. The sign is then painted directly on this, leaving the bare aluminum surface for the sky or the background.

Attractive compact boxes are ingeniously made out of prefinished sheet metal. One design uses a mirror-finished chromium copper for the inside stamping and a decorative lacquer-finished steel for the outside or cover stamping. A cross section of this type of box is shown in Fig. 16. The forming of the inner piece is so ingeniously done that the surface which becomes the mirror is left undisturbed. The outer piece is either in a plain color or may be made with a design, in which case the sheets are purchased covered with a series of circular designs each intended as the top piece to one box. Assembly of the two parts is by spinning or turning the edge of the inner part over the cover, leaving a small rim of chromium plate surrounding the lacquer design.

The prefinishing of raw materials is not limited to flat-rolled products. Polished drill rod has long been familiar in industry. Plated and highly polished wire in coils has found many uses, one of which is for the rings of loose-leaf notebooks.

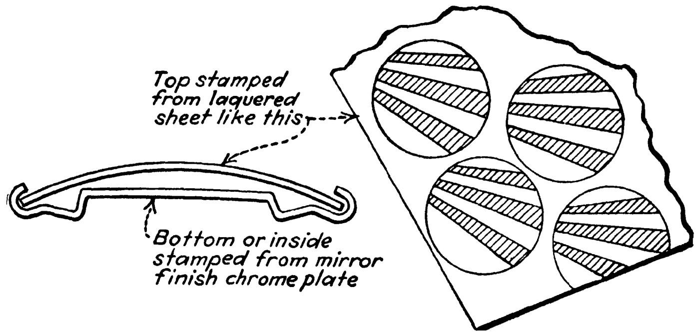


FIG. 16.—Typical design of vanity-case lid made of two stampings, one with a lacquer finish and the other with a mirror finish.

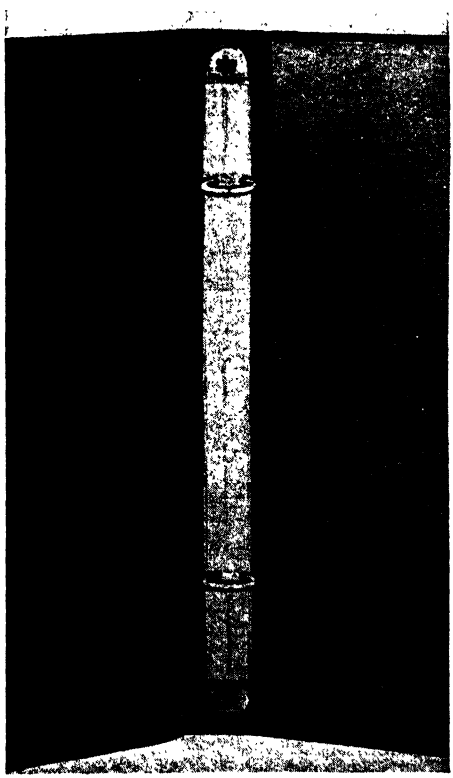


FIG. 17.—All the metal parts used in the manufacture of some styles of loose-leaf notebooks are formed from plated and polished raw material.

Nevertheless, prefinishing still has far to go, and extensive development in this field may be expected in the near future. As the possibilities of the new hard-finish lacquers become better known, lightweight angles, channels and plates may become available in colors, as the raw materials used by manufacturers of farm equipment, sleds, baby carriages and similar items. Bicycle manufacturers may be able to buy preenameled tubing for frames, just as the maker of bicycle wheels can now buy polished strip for making his rims. Some features of enameling and lacquering sheet metal will be described in other chapters.

Several years ago, the Apollo Metal Works developed prefinished tin plate, tin-plate sheets surfaced with special electrodeposited coatings of chromium, nickel, brass or copper, and polished bright, satin or striped. Sheets of this type find usefulness and provide economy in many applications in which added appearance value is desired. The material should not be used where heat is in excess of 500°F. Some of the parts made from chrome-finished tin plate, known as Apollo ChromTin, are oil cans, kitchen accessories, hubcaps, decorative trays and musical instruments.

The Apollo Metal Works manufactures sheets, strips and coils of steel, tin plate, zinc, copper and brass, coated by specially developed electrolytic processes with chromium, nickel, brass, copper or zinc.

Special pure electrolytic zinc coatings are applied to steel sheets, strips and coils by the Apollo Metal Works. These coatings protect the surfaces from rusting, and the normally stamped raw edges will not rust in the salt spray any sooner than a breakdown will occur, with consequent rusting, on the coated surfaces. It is possible to control the thickness of the ductile zinc coating according to the specifications and requirements of each job. The material has found wide application in aircraft, radio and ordnance work.

PART II

PREPARATION FOR THE FINISH OF METAL PRODUCTS

CHAPTER VI

COST AND VALUE OF CLEANING[1]

Demonstrate to a manufacturer an assured economy in a machining operation, and he will usually adopt it. An assured cleaning economy, on the other hand, must be far more spectacular if it is to receive the same consideration, yet cleaning of metal now takes its place as an established production process, closely associated with fine finish and with greater sales value.

A cutlery manufacturer installed a simple agitator in his cleaning tank and cut his cleaning time per batch from 30 to 3 min. Thus did he demonstrate the "out-of-dateness" of his former cleaning arrangement. Except for the cleaning room this particular plant was modern and highly efficient, but economies in cleaning had been overlooked, a condition typical of a great number of plants in all branches of the metalworking industry. Cleaning has been widely discussed, and dozens of articles have appeared describing the technique and the required equipment, but little has been said about the relation of cleaning to sales, or the value of cleaning as a production process.

Why should a manufacturer clean products? Even those who are doing the most cleaning are not aware of just why they do it and just what it should cost. One reason for cleaning is to render a product salable. Another large division of the cleaning process has to do with removing scale, primarily to prepare for following operations rather than to provide immediate good appearance.

Both types of cleaning often are done to facilitate subsequent operations in the manufacturing sequence. If dirty wire, for

[1] Prepared in cooperation with Lionel de Waltoff, specialist in metal cleaning.

instance, is cold drawn, the dirt not only is worked into the wire, creating a poor surface, but it also causes abrasion and excessive wear on the drawing dies. The same thing is true with most other products. Nearly always in the sequence when it is necessary to anneal, it is also necessary to clean, because the annealing forms a scale.

Cleaning in Screen Production.—An example of the importance of cleaning in production may be found by examining the detailed manufacturing operations of almost any metal product. Take, for instance, the familiar window screen. Here the cleaning may start when chippers in the hot mill clean up the billets before they are rolled into wire bars. Some form of descaling may take place when wire rods are drawn from the bars. At the wire mill the usual procedure is to pickle the rods before starting any further operation. This is to remove mill scale and other surface dirt. On steel the scale is nearly always an oxide. On copper it may be sulfides or a combination of sulfides and oxides.

In drawing the wire down to the final size for making screen, it will probably be necessary to anneal two or three times, and this will call for as many descaling operations. Descaling after annealing at the wire mill is usually accomplished by pickling. The wire is then washed in cold water, coated with lime and then baked. The lime is put on to neutralize any acid pickle that might remain after the cold-water rinse, and also to aid in carrying the drawing lubricant into the dies. The baking is to give the lime adherence and also to remove any trace of hydrogen, absorbed during the pickling, which otherwise might embrittle the wire.

Customarily after the last anneal, the wire intended for the manufacture of screens is pickled, although here the practice differs, depending upon the type of anneal used and the type of screen to be made. The cheaper grades of wire frequently are not pickled after the final anneal. At the plant of the screen manufacturer the wire is cleaned before weaving, to remove grease and dirt. This operation usually consists of immersing the coils in a tank of an alkali cleaning solution and following this by a thorough rinsing and drying. After the wire leaves the weaving machine, as screen, it is thoroughly cleaned again in order to put it in condition to receive the final finish, which may be enameling, plating, galvanizing or some other finish.

Cleaning of Nails.—Wire and screen are products having comparatively little cleaning in their manufacture so that the extent of cleaning throughout the metal industry should be judged from the cleaning history of some other items. A listing of cleaning operations in the production of table silverware, for instance, would be a much more formidable affair. Some wire products such as nails are not cleaned during fabrication, but usually this calls for the use of a better grade of wire which has therefore been more thoroughly cleaned at the wire plant. And even in the case of nails, if a finish is used, there must be cleaning. A large proportion of the nails produced each year are either galvanized or cement-coated and therefore receive a final finish that requires cleaning. For such finishes it is customary to wash them in a caustic soda or similar solution, then rinse them and then pickle them. If nails are galvanized without being thoroughly cleaned, a poor job will result. A rusty nail, for instance, can be hot or cold galvanized, but it will not be long before the rust will grow and push the galvanizing off.

Some of the products that call for the greatest amount of cleaning in the metalworking industry are automobile bodies, tin cans, pipe, electrical conduit and strip used for a multitude of purposes, among others, for making BX protective conduit in the electrical industry. The production of BX is an interesting process. Round steel wire received at the manufacturing plant is first cleaned and then flattened. This flattening hardens the metal, making it necessary to anneal. In one large plant the annealing is part of a continuous process. The flattened wire is fed into a machine which has as its first stage a gas annealing oven. After passing through this, the wire continues through a pickle bath, then through a rinse and, in subsequent operations of a continuous chain, is electrogalvanized, rinsed, dried and reeled.

Salvage Cleaning.—Terne plate and tin plate both call for extensive cleaning operations, and, because of the large production in both these industries, highly specialized equipment has been developed. Cleaning preceding vitreous enameling is an important operation, and in this the large industries such as stove, refrigerator and tile manufacturing are big factors. Cleaning in the manufacture of metal furniture is a necessary operation, as it is also in the production of Pullman cars. Most metal elements such as screw-machine products are cleaned to remove the oils and greases of the production processes. An interesting example of salvage cleaning may be found at any large locomotive repair shop. The practice at the Reedville shops of the New York, New Haven and Hartford Railroad is to disassemble the incoming locomotives and put every part through a thorough degreasing process before anything else is done. Proper inspection is thus possible.

Some products are degreased in order to prevent injury in a complete assembly. Gears, for instance, which are used in the assembling of machine tools must be cleaned, because scale left on assembled gears will flake off and become mixed with oil, forming an exceptionally abrasive mixture, which circulates through the moving parts of machine tools to score the gear teeth and cause rapid pitch-line wear. It also cuts and destroys bearings. In the production of airplane engines, cleaning is an important operation preceding unit assemblies. Parts that are to be joined by press fit must be thoroughly cleaned in order to give correct alignment. The great scope of general hand cleaning, which is not dealt with here, is illustrated by the quantity of wiping cloths, rags and cotton waste sold to the metal industry each year.

Cleaning of Stainless Steel.—Another example of necessary cleaning is the degreasing of stainless-steel sheets and strips prior to annealing. Unless all traces of grease are removed before it is annealed, the material becomes stained or spotted, and these spots cannot thereafter be removed. Also, unless all traces of scale or oxide are removed from stainless steel as a part of the final finishing, the steel itself will not remain passive or stainless but will rust rapidly at and around the spots from which scale has not been removed.

What Is Dirt?—In the shop a piece of metal is either clean or dirty. If it is dirty it may be greasy, stained, scaly, rusty, or it may have, on its surface, combinations of many forms of dirt. Usually all dirt is classified as scale or grease.

The conventionalized diagram in Fig. 18 shows the relation of grease, scale and metal of a typical dirty metal product. The metal itself, as shown, is surrounded by a closely adhering layer of scale, and the scale is covered with grease and dirt. In cleaning, the grease that forms the outer layer is removed before descaling operations are employed.

Grease can be removed in many different ways. It may be removed by simply wiping it off with rags or buffs, either by hand or mechanically. Tin sheets that are coated with palm oil as they emerge from the hot-tin dip are customarily cleaned by passing them between revolving cotton disks onto which are fed bran tailings. Grease may be removed by tumbling with a material such as sawdust, by immersion in washing solutions, by steam jets and by centrifuging.

There are four general classes of greases: (1) the nonsaponifiable, or mineral oils; (2) the saponifiable, or the vegetable and animal oils; (3) the so-called "sulfonated" oils; and (4) mixtures of the above, which are usually known as partly saponifiable oils. The principle of degreasing differs, depending upon the nature of the grease to be removed. The first class of greases is usually removed by vapor degreasers or by volatile solvents, sometimes called organic solvents. Typical of the vapor degreasers is trichlorethylene, and typical of the volatile solvents are benzine, gasoline and carbon tetrachloride.

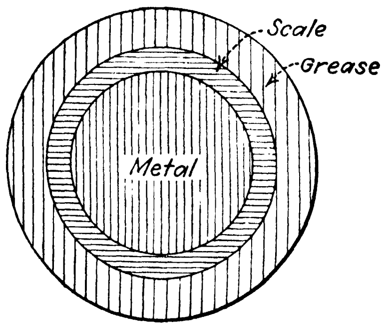


FIG. 18.—This conventional diagram illustrates the relation of metal, scale and grease on most metal parts before cleaning.

The method of using the volatile solvent varies from merely rubbing the surface with the solvent, to the use of elaborate cleaning machines in which jets of the solvent impinge upon the moving articles to be cleaned. Perhaps the most usual method is merely to dip the work in an open tank containing a solution of the solvent.

Treatment of Greases.—Nonsaponifiable greases can be removed by emulsification in alkaline solutions containing soap. They can also be removed by emulsification in electric cleaners, but oils and greases that are completely nonsaponifiable cannot be removed readily in cleaners of this type. The principle of the removal of these greases rests upon the displacement of the greases by a solution that has a stronger tendency to wet the metal than the grease itself. The cleaning solution that has these properties and thus displaces the grease also must be readily removable in a subsequent cleaner or water rinse.

Saponifiable greases cannot be removed in vapor degreasers. They can be removed with volatile solvents, and they are readily removed in alkaline cleaners because the saponifiable greases react with the free alkali to form soaps and consequently to produce the agency required for emulsification.

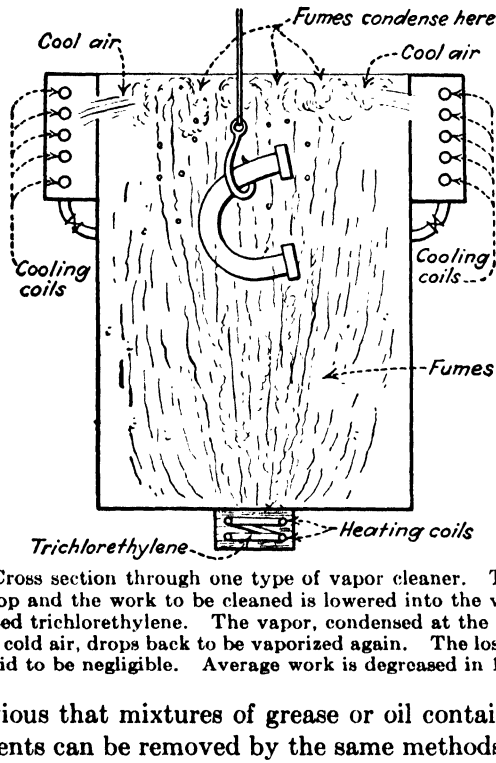


FIG. 19.—Cross section through one type of vapor cleaner. The tank is left open at the top and the work to be cleaned is lowered into the vapor that rises from the heated trichlorethylene. The vapor, condensed at the top of the tank by streams of cold air, drops back to be vaporized again. The loss due to escape of fumes is said to be negligible. Average work is degreased in 15 sec.

It is obvious that mixtures of grease or oil containing saponifiable elements can be removed by the same methods as are used for the removal of the totally saponifiable greases. The difficulty of removing such mixtures is roughly dependent upon the proportions of the two elements that form the mixture.

Vapor Degreasing.—Figure 19 shows a cross section through one form of vapor degreaser. Here the liquid trichlorethylene is placed in the trough at the bottom, and the vapor from this liquid when heated rises in the tank until it meets the cold air escaping from the cooling chambers shown at each side near the top. As soon as the vapor strikes this air, it condenses and drops back to the bottom of the tank. The work to be cleaned is merely lowered in between the cooling chambers, and the condensing vapor washes off the grease. The loss due to escape of fumes is small. Average work is degreased in about 1 min.

This is an excellent method of degreasing, but for its success it requires that the work be free of moisture, because water in contact with the trichlorethylene will produce hydrochloric acid, which soon causes trouble by destroying the properties of the trichlorethylene. The theory of vapor degreasing is simply the reduction of viscosity. It is the viscosity that holds the grease to the material, and if it can be sufficiently reduced, the grease will run off.

A rather common way of removing the partly saponifiable greases is by a modified emulsification. The parts to be cleaned are immersed in a boiling solution, which partly emulsifies and partly reduces viscosity to effect the cleaning. Heat alone, of course, will clean metal parts of grease, but it is expensive and difficult because of subsequent operations. Also, it tends to increase the scale. Heating of steel in an oxygen-free atmosphere does not produce scale, and this feature is often employed in heat-treatment to avoid subsequent descaling. This possibility of reducing the extent of cleaning operations will be discussed at some length under the subject of Descaling.

The saponifiable greases range in hardness from the hard, or stearic acid, types through the softer vegetable waxes to the softest, the vegetable oils. The nonsaponifiable greases may be similarly classified as hard, or paraffin type; medium, or soft-paraffin type; and soft, or petrolatum type. The nonsaponifiable greases are cheaper, and therefore the tendency in manufacturing is to use them more extensively than the saponifiable ones.

Cost.—When an engineer is called in on a cleaning problem, his first thought should be not the cleaning itself but the plant operations that make cleaning necessary. It may be that he can change the cutting oil on the machine tools and by this means alone effect a big saving in cleaning. Cleaning expense is nearly always reduced by increasing the proportion of saponifiable oils in the preceding machine or metalworking operations. A manufacturer can often afford to pay more for a cutting oil that will wash off easily. Sometimes it is economical actually to immerse the work in a saponifiable oil preceding the cleaning; in other words, to add more dirt, but of a character-changing type, to an already dirty part, to aid in removing all the dirt.

Cleaning solutions are relatively expensive, and therefore it usually pays to take some steps to increase the life of the bath. One way is by using a preliminary cleaning operation such as centrifuging. Another way is to use a two-tank interchangeable system. In this, both tanks contain the same solution and the work is immersed first in one and then in the other. The first tank gets dirty more quickly because the bulk of the grease is removed in it, but its use keeps the second tank clean and effective for a much longer period. When the first tank becomes too slow in service, because of dirt, the second tank becomes the first in the sequence, and a new solution replaces the discarded dirty solution in the other tank.

A manufacturer of twist drills uses a continuous washing machine of good but not elaborate design. The tank holds 100 gal. and uses 1 oz. of cleaning compound per gallon of water, or about 6 lb. of cleaner to a tankful. The capacity of the equipment on small work is 2 tons for an 8-hr. day. The solution lasts 5 days with daily make-up additions of 1½ lb. of compound, which totals 13½ lb., at a cost of 8 cents per pound, or $1.08. This is for 5 days or 10 tons, making a cleaner cost of about 11 cents a ton. The labor cost in this case is $1 a ton and the overhead about 60 cents, giving an over-all cleaning cost of $1.71 per ton.

A manufacturer of pressed-steel open boxes, size 9 by 10 by 1 in., uses a cleaning solution of 6 oz. of compound per gallon in an open tank with electric acceleration. The current flows from the work to the anode at a density of 35 to 40 amp. per sq. ft. of work surface. The solution is kept at boiling, and the total cleaning cost is 27 cents for 1000 pieces.

Electric Cleaners.—Electric cleaning for the removal of grease and dirt and also for the removal of scale and oxides, particularly from iron and steel articles, is increasing in popularity. The usual procedure is to immerse the work in a tank containing a suitable solution, the work forming one electrode and the side of the tank forming the other. In some cases insoluble plates replace the tank as a means of completing the circuit. All work that is to be cleaned electrically should be precleaned in some manner if most satisfactory and economical results are to be obtained.

When electric cleaners are used to remove grease and dirt, an alkaline solution is always used. The base of this alkaline solution is caustic soda or soda ash, to which are usually added such chemicals as water glass or trisodium phosphate. The current that flows through such a medium breaks down the water of the solution into its constituent gases, namely, hydrogen and oxygen. Hydrogen gas is liberated at the negative pole while oxygen gas is liberated at the positive pole. It is obvious that the amount of hydrogen gas liberated is twice the amount of oxygen gas liberated for the same amount of electrolysis.

When cleaning cathodically, the work is protected by the hydrogen evolved against tarnishing or corrosion. Many dirt particles are electrically removed by the "plating-off" action of the current. In addition, the minute bubbles of hydrogen have considerable prying and scouring action in removing solid dirt particles adhering to the work.

Tank design for this operation is comparatively simple. Anode bus bars are usually provided, insulated from the tank, from which large sheet-metal anodes are suspended. The practice of making the tank itself the anode is not desirable. The space between the anodes and the work should be carefully determined for even current distribution. The average requirement is 6 to 8 volts potential with a current density of 20 to 40 amp. per sq. ft. of work.

When electric cleaners were first introduced for degreasing, it was popularly supposed that the action of the current was that of deplating the grease, and consequently it was customary to operate these electric cleaners with the work to be cleaned connected to the positive pole. The generally accepted theory of the advantage of electric degreasing now held is that the gas evolved, coming as it does from the surface of the metal underneath the grease film, breaks up the grease film, producing desirable agitation and materially assisting in the act of emulsification by means of which the grease is actually removed from the work. It has become common practice today, however, to use anodic cleaning, especially on steel, to prevent hydrogen absorption.

Since certain types of metal film can be deplated from a dissimilar metal surface in an electrified alkaline bath by connecting the work to the positive pole, it is frequently advantageous to supply an alkaline electrocleaner with a reversing switch so that the work to be degreased can first be connected to the negative pole to gain the advantage of the higher volume of gas evolution and facilitate the removal of the grease, after which it can be connected to the positive pole to strip off these smuts before being removed from the bath. The solution in electric cleaners should be run close to the boiling point so as to gain the reduction in viscosity of the soils through an increase in the temperature.

Where electric cleaners are used for the removal of scale or oxides from metal, the solution is of the acid type and the work is invariably connected to the negative pole. In order to prevent severe pitting and etching, which would automatically occur with a pickle activated by electric current, an electrodescaling bath can be made to deposit a protective metal film on the surface of the base metal itself, this film being deposited simultaneously with the removal of scale or oxide, thus avoiding pitting and etching. This particular method is known as the Bullard-Dunn process and is protected by patents owned by The Bullard Co. It is described in greater detail in Chap. X.

CHAPTER VII

HOW TO MINIMIZE CLEANING EXPENSE

Some manufacturers have made substantial savings in cleaning expense by adopting modern methods and equipment. Improvement in methods of handling material, reorganization of preceding operations, location of cleaning processes in line of production and conservation of cleaning solutions are some of the important means of effecting economies.

A manufacturer of metal products naturally wants to know whether his cleaning costs are too high. He also should be interested in whether they are too low. It may be that a better cleaning job would result in a more salable product, and from this point of view too great economy in cleaning may mean extravagance in manufacturing. Until recently, cleaning too often has been considered a necessary evil in the metalworking industry, and even now the sales advantages of good cleaning are frequently overlooked in the scramble for lower production costs. When a manufacturer has assured himself that he is doing as good a cleaning job as he should, from a sales angle, it then is entirely fitting for him to try to find a less expensive way of doing the same quality of cleaning.

One of the divisions most frequently overlooked by those studying plant-operating economies is unquestionably the cleaning department. Equipment, materials and methods are continually changing, and improvements and innovations in cleaning processes develop just as in other lines. Some of the items considered merely as theoretical possibilities as late as 1929 have since become established as routine practice.

Cleaning Compounds.—Electrolytic cleaning in soap baths, electrolytic acid cleaning, vapor degreasing and the use of solvent soaps and of so-called wetting agents are examples of recent developments. Others are the alkylated naphthalene sulfonic acids, the sulfonated fatty alcohols, the naphthenic acids from petroleum, the orthosilicates and the sodium metaphosphates.

Cleaning is intimately associated with both preceding and subsequent operations, and therefore it must be studied in relation to the complete production problem at any given plant. The nature of the dirt to be removed is dependent upon the nature of the operations that make cleaning necessary, and the dirt encountered in metalworking is so variable that it is impracticable to formulate any definite or close classification. Yet some determination of the nature of dirt is important.

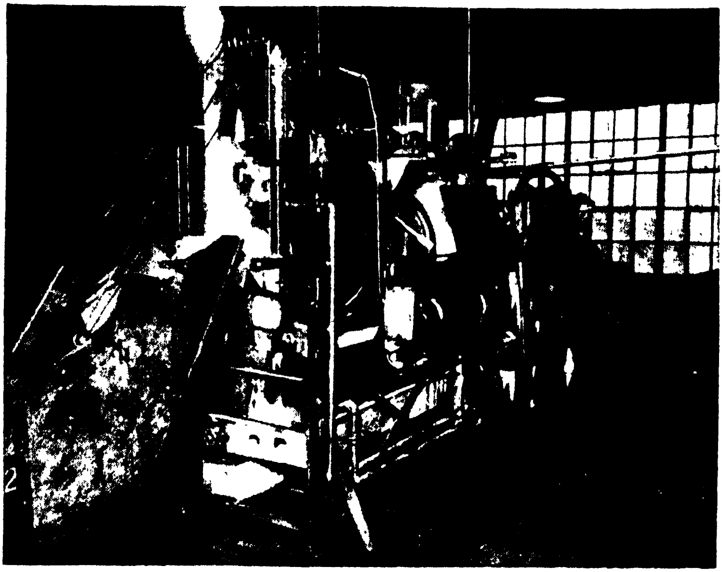


FIG. 20.—Auto kit tools are cleaned and antirusted in one operation. The former practice called for tumbling in cleaning solution for 1 hr. with 10 lb. of compound to 100 gal. After studying the nature of the dirt it was possible to devise a compound that cut the time in half and cut the amount of compound to 3 lb. per 100 gal.

Study of Nature of Dirt.—Most engineers study samples of the actual dirt encountered by trial with various types of cleaning compounds. If the dirt is difficult to clean, or if its proper cleaning requires a specific compound, it may be that use of different slushing oils, cutting oils, or drawing lubricants in machining previous to cleaning will so change the nature of the dirt that it can be cleaned more easily, more thoroughly or with lower cost compounds.

An example of a common problem will help to illustrate this. Straight mineral oil is not saponifiable, nor can it be emulsified by a solution of plain alkali. Most industrial lubricant compounds are mineral oils containing small amounts of fatty oils or their derivatives, and the latter are saponifiable with alkali, forming soaps. Soaps will emulsify mineral oils, and therefore it is possible to clean with caustic or soda ash, both of which are inexpensive. Such a process, however, is slow and incomplete because the soap-forming process itself is slow and the amount of soap thus formed is usually inadequate for the prompt and

FIG. 21.—Bronze castings for coffee grinders and mixers are cleaned on a belt type of semiautomatic washer. The machine has a solution capacity of 100 gal., and this is kept effective by the addition of 1 lb. of cleaning compound per day. The compound is added by merely placing it in one of the wire mesh baskets. No subsequent rinse is necessary.

complete emulsion of the mineral oil. Because of these difficulties, special compounds have been developed to penetrate between the oil film and the surface to be cleaned. These compounds already contain some soap or other wetting agent.

Testing Compounds.—Certain preliminary tests often give indications as to suitability of cleaning compounds. By shaking 10 cc. of the oil or grease to be removed with 90 cc. of cleaning solution, and noting the ease, completeness and stability of emulsion, it is often possible to determine whether a cleaning material will or will not function on a large scale. Several different materials may be compared in this way by making up a set of emulsion tubes and shaking them all together.

Figure 22 shows one such test. In four tubes were placed four different cleaning compounds and four identical samples of mineral oil. All were shaken uniformly and simultaneously and allowed to stand a few minutes, at which time a photograph was taken. Emulsification is clearly shown.

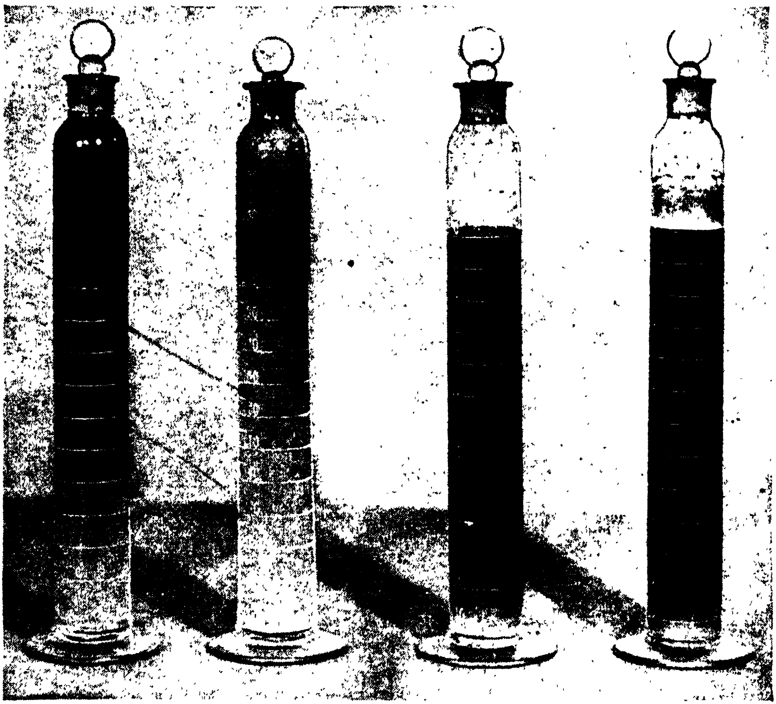


Fig. 22.—Identical samples of grease composed largely of mineral oil were placed in these four cylinders, together with four different cleaning compounds. They were shaken and allowed to stand, and the appearance as shown gives an indication of the relative effectiveness of the cleaning agents. The sample at the left (1) shows no emulsification, and the oil sticks to the sides of the glass cylinder; (2) no emulsification but less adherence of oil to the vessel; (3) good emulsification and no foaming; (4) excellent emulsification, no adherence of oil, but some foaming.

The same kind of a test may be made to indicate the effect of the cleaning material in suspending solid-particle dirt. Weighed equal samples of the dirt may be put in each of the tubes and shaken with the cleaning solution, and the effect of the latter in breaking up and suspending the dirt noted. Some large users of cleaning materials who buy on specification use this testing method and carry it further. The initial cleaning solutions that are being compared are progressively diluted with water and their emulsifying and deflocculating powers with the solid-particle dirt compared. This, to a certain extent, gives a measure of the lasting power of the solution.

Test for Discoloration.—In comparing emulsifying ability, it is a good plan to take several sample tubes being compared, hold them all together uniformly, either in a clamp or by hand, and shake, say ten times, and note the quality of the emulsions produced; then shake twenty times and compare, and then shake thoroughly until all samples are emulsified and allow to stand, and note with a watch the different times of separation. These tests are best made at a temperature of around 140°F., because with a higher temperature there will be trouble with the stoppers blowing out of the tubes when shaking.

In the cleaning of aluminum, zinc or die-cast metal, a small preliminary test in the beaker or bucket will generally allow a sound conclusion to be drawn concerning the suitability of the cleaner in question from the angle of corrosion or discoloration of the metal.

Labor Cost.—It has been said, with a great deal of truth, that 95 cents out of every cleaning dollar goes for labor and overhead. This percentage, of course, varies with different jobs, but in the average case the labor is the biggest single item of expense. It is, therefore, most important, in establishing a cleaning process, carefully to select that cleaning material and method which will keep the other more expensive factors to a minimum.

On the average, an efficient metal-cleaning solution used to prepare work for electroplating or a similar finish should clean 900 or more square feet per pound of cleaner. This applies to heavily loaded work in still-tank cleaning. In electrocleaning or in mechanical washing machines, up to 1000 sq. ft. per lb. of cleaner may be obtained. In a recent competitive test in one of the largest plants in the East, cleaning material costs per 1000 parts ran between 20.6 and 27 cents. The parts were pressed-steel panels and box tops (averaging a little less than 2 sq. ft. each) coated with mineral oil. These were anodically cleaned in 3 min. in a boiling solution containing 6 oz. of cleaner to 1 gal. The cost of various cleaning compounds ran from 6 to 12.5 cents, but the lowest total cleaning-cost figure was achieved with a compound costing 9.5 cents.

In a recent letter from N. Ransohoff, Inc., large manufacturer of metal-cleaning machinery, the following statement was made concerning some of the technical aspects of this work, in connection with batch-process rotary pickling machines:

When scale is present, pickling is usually necessary. For pickling small parts, the batch-process pickling machine built of acidproof materials is recommended. The work is agitated as long as required in a flowing acid solution and discharged automatically by reversing the direction of rotation of the drum. The work is rinsed and neutralized in the discharge screen. This

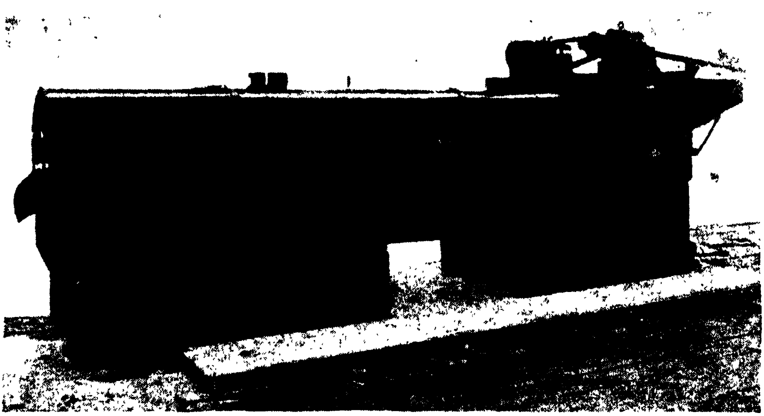


FIG. 23.—This is a new type of automatic cleaning barrel, rubber lined so that dilute acid can be pumped over the work while tumbling is taking place. After cleaning, the drum automatically reverses and this discharges the work. It is claimed that approximately 75 per cent of the labor is saved as against pickling and neutralizing in steel tanks.

method pickles faster and cheaper with less labor and acid than by dipping in tanks. Since the work is constantly rolled in hot acid, pickling is completed in about half the time. A low-strength acid can be used and at a lower temperature, thus prolonging the life of the unit and reducing maintenance costs. The machine is equipped with an acidproof packless pump.

In cleaning tripoli from nickel-silver flatware before electrocleaning for silver plating, 2000 pieces may be cleaned with 1 lb. of soap. Beyond this the solution becomes so loaded with dirt that cleaning is too slow and not complete. The cleaning operation averages 20 min., and the parts are all carefully handpacked in and out of the cleaning baskets to avoid scratching. Cleaning-compound cost on this operation is one of the least important factors. Labor charges and certainty of cleaning are the factors watched.

A steel company gives its rivets added sales appeal by means of a better finish. A process of automatic cleaning and barrel burnishing rivets of all sizes has been worked out, which produces a clean, bright rivet that looks almost as though it had been individually polished. The expense per rivet is extremely low.

Proper Alkalinity.—Ordinarily, to reduce sufficiently interfacial tension between oil and a cleaning solution for rapid emulsion, the pH has to be raised to a high figure, that is, the solution must be made more alkaline. Most metal cleaning preferably is done in solutions of pH 12 or greater. Plain soap gives solutions of pH 9.5 to 10, depending upon the concentration, the type of soap and the temperature. To bring the soap to the more effective higher working level, it is fortified or built up with alkali.

Alkaline silicates probably are the most effective for this purpose. Their alkalinity is of the buffered type, that is, they release alkalinity to their solutions only gradually and progressively. When dissolved, a small part of their "bound" (chemically combined) alkali is released to the solution as free alkali. It is this which raises the pH or the degree of alkalinity of the solution. As this free alkali is consumed or neutralized by the cleaning process, more of the combined alkali hydrolyzes, thus maintaining the balance of the solution in the proper cleaning range until the solution is exhausted.

Caustic potash, or caustic soda, and phosphate are often combined in these buffered built-up soaps to achieve certain desired results. The silicates have an added advantage in that their solutions possess colloidal properties that appear to augment the colloidal properties of the soap in deflocculating and holding dirt in emulsification and suspension. Complex phosphates are particularly valuable where sequestration of the insoluble lime compounds in the dirt is necessary, as in removing lime-soap greases.

The type and amount of soap used are of importance. Only relatively small percentages of soap can be used in cleaning solutions, and it must be of a soluble free-rinsing type, either of rosin soap or of sulfonated-oil stock. Many soaps have poor solubility in solutions of high alkalinity. Tallow soaps, laundry soaps or the ordinary hand soaps are entirely unfit for metal cleaning.

By designing manufacturing processes to use lubricants and cutting compounds that have a high percentage of saponifiable oils, it is usually possible to clean with an inexpensive solution containing an alkaline soap. Pennies may be saved on cutting down or buffing compositions, but this often adds dollars to subsequent cleaning operations.

The nature of the article to be cleaned is, of course, a necessary consideration. For instance, zinc and aluminum or their alloys are rapidly attacked by solutions of greater alkalinity than pH 10, while tin is spangled or even etched by solutions above pH 11. Brass tarnishes slowly in solutions up to pH 12, while above pH 12.5 it tarnishes heavily. Iron, if high in silicon, can be pitted above pH 13. Mineral-oil pitches and waxes are best held in permanent emulsion at pH 8 to 9. In making up cutting-oil emulsions and paste lubricants for drawing, this range should be kept in mind. But in removing these by cleaning, other factors enter.

Where the dirt consists chiefly of oil, a more alkaline cleaner works faster, although it gives a less stable emulsion. And yet this very instability can be turned to advantage, for, if allowed to stand idle, the solution will permit a large part of its suspended oil to separate, making it possible to remove both the oil and the sediment and thus "regenerate" the solution as described in a previous chapter.

Many other factors are important in studying cleaning in relation to the nature of the article to be cleaned. Some of these are the fact that cast aluminum is more porous and sensitive to alkali than rolled aluminum, that lead brass is more sensitive to alkali than a brass containing no lead and that a flat piece may call for one solution whereas a threaded or knurled piece may require another.

Mechanical Economies.—Having selected the cleaning process best suited to the work, the next consideration is the design of the equipment itself. Much has been done in recent years in the modernizing of cleaning equipment, and the economies here fall under two headings, better cleaning and better handling.

Do not do by hand what can be done mechanically. This applies, of course, to production work where volume is being handled. There are very few cleaning operations today that cannot in some degree be handled mechanically.

Proper heating units and automatic thermoregulators provide economies in steam or gas bills. Inadequate heating does not run up fuel bills, but it may be costly in slow cleaning, tied-up production, extra labor costs and sometimes refinishing costs. Insulation and in some cases tank covers to prevent steam loss are worth while on large installations.

With steam heat it is a good idea to have both an open steam pipe and a closed steam coil in the cleaning tank. In the morning the solution can be quickly brought to the boiling point with the open steam line. The condensate so formed is sufficient to float off oil that has separated out overnight. This oil escapes over the overflow dam. The closed coil then suffices to maintain the solution at the boiling point.

With hot rinses the open steam pipe alone is used, for a continual overflow is needed to keep the rinse surface clean.

Where running rinses or spray rinses are used, water may be saved with a series of rinses on the counterflow principle; that is, the rinse water in several compartments flows against the work travel.

Economy in the purchase of the cleaning materials is best secured by analysis of costs for the final result. Choice of cleaning compounds should be based upon over-all cost per unit cleaned and upon performance. Many large concerns today buy cleaning material on the basis of lowest cleaning cost figured from cost per pound multiplied by a rating factor that they have determined by actual production test on the material. Of the suppliers whose materials have been tested, the three best (say, on the basis of unit-price rating) are asked to bid on each purchase. This not only ensures the best cleaning value but keeps the situation competitive.

CHAPTER VIII

CLEANING AS A PRODUCTION PROCESS

When chromium alloys and chromium plate were selected as trim for the Empire State Building, engineers were reluctant to estimate the life of the bright reflecting surfaces because the dust of New York contains oils and greases that adhere to and gradually darken any exposed area. Now, however, after many years, it appears possible that the scouring action of the wind, especially at the upper levels of the Empire State Building, may keep the metal surfaces reasonably bright for years to come. This is an exceptional case, for usually cleaning problems must be solved without assistance of the elements. Much may be done, however, in the metalworking industry to reduce the amount and expense of cleaning by considering the operation as a link in the production chain and by coordinating it with other manufacturing processes.

In a foundry the gates may be designed to facilitate their removal, and the molding sand may be selected to give better surface to castings and thus reduce the job of cleaning. In a forge shop, by a change in the design of dies it may be possible to eliminate fins, and by forging at correct temperatures the surface density may be increased so that the subsequent cleaning operation is shortened. These and other similar features are important in analyzing the whole cleaning problem, but details in most cases are of such a special nature as to be outside the scope of this book.

Heat-treating and Cleaning.—Heat-treatment, on the other hand, is so nearly universal an operation that it affects most parts to be cleaned, and the resultant scales and oils of heat-treatment constitute a major consideration for cleaning in the metalworking industry. By using a liquid heating medium for the heat-treatment, it is possible in some cases to avoid oxidation and oil and thus to reduce or even entirely eliminate certain cleaning operations. The Bellis Heat Treating Co., for instance, has specialized in the development of liquid heating mediums for this very purpose. An installation of its equipment at the plant of a manufacturer of sterling silver heats bars and strips in 900-lb. charges by immersion in a salt bath and in this way entirely avoids a cleaning operation preceding the next roll. When the material has been worked down to finished size, it is given a quick dip in a customary cleaning solution, but at least

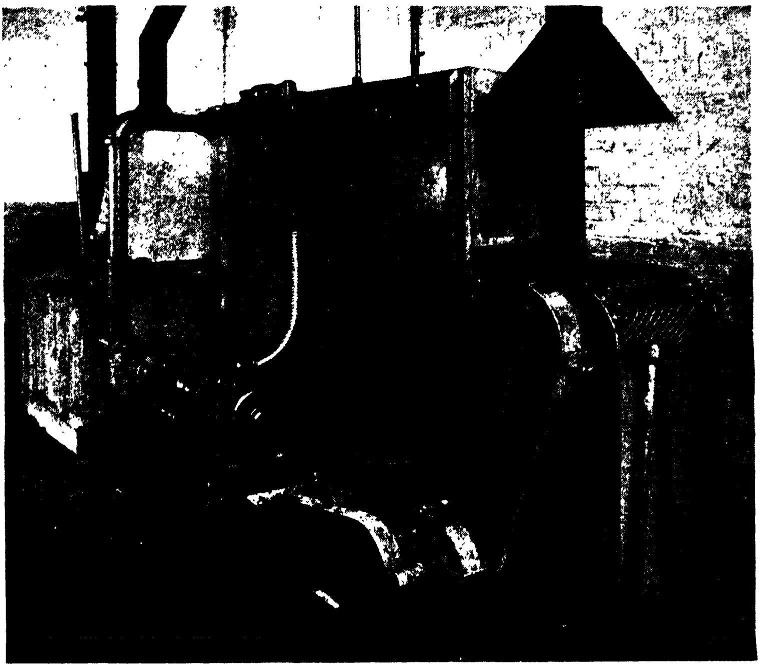


FIG. 24.—Continuous pickling operations are possible on machines of conventional design in which acid-resisting materials are used.

four previous cleaning operations have been eliminated. One exclusive Bellis feature is the starting coil, which makes it possible to use the full rating of the electrical equipment at the beginning of the heating, thereby shortening the time to melt the salt and bring the furnace to operating temperature.

A basic feature is placing salt-bath material in a crucible having electrically conducting wall structure and passing the alternating electric current through the salt bath. This makes possible a neutral bath with flexible regulation of heat.

New bath materials that maintain the bath free from oxides cut down radiation losses, economizing electrode and pot cost.

One new salt-bath feature is the balancing of chlorides, resulting in less "drag out" and the elimination of the high heat and quench baths.

Quenching and Tempering Oils.—Heat-treating in a liquid bath or other form of reducing atmosphere is often impractical, and, generally speaking, material after heat-treatment is covered with quenching and tempering oils. Glycerin occasionally is used for quenching and has the advantage of being more easily removed. Increased production and lower operating costs are usually obtained if the tempering or quenching oils left on the work are removed. If the subsequent operation is grinding, removal of the oil will make the parts easier to handle and will facilitate the wheel action. Where oxide or scale is to be removed by sandblasting, prior removal of the oil will allow the sand to cut the scale much easier. It will also prevent loading the sand up with oil and resultant gumming of the machine.

Parts coming from oil baths should be so handled as to allow the oil to drain freely for a short time to recover the oil and to avoid loading the cleaning tank. While still warm, they should be cleaned by soaking in a suitable solution. Parts should not be allowed to stand long before cleaning, for the oil then becomes thick and gummy and more difficult to remove.

Cleaning after Polishing.—Inasmuch as most electroplated surfaces are prepared by grinding and polishing, cleaning before plating may resolve itself into removing the polishing compound and other dirt picked up in these operations. The removal of slushing or machining oil from steel is important. The work may be classified as follows:

1. Iron and steel.
2. Brass, bronze, copper, nickel silver.
3. Die casting and other soft metals.

The general practice is to use an electric cleaner for such work, because current is of course available in a plating shop. Overpickling must be avoided before plating. Pitted steel or iron, even after thorough cleaning and good nickeling, has been found to be poorly resistant to rust. A trace of ferrous hydroxide left in the bottom of the pits or capillaries prevents good bonding.

This emphasizes the necessity for proper cleaning before pickling to ensure the minimum of time in the acid, and to ensure even action.

Many buffing and coloring compounds contain stearic acid, and others contain wax and grease. The former is readily saponifiable even in a mildly alkaline solution. But the soap-formed sodium stearate is a very slowly soluble compound. Washing solutions used after buffing often leave a thin film of this slowly soluble soap upon the work, which takes long soaking or scrubbing to remove.

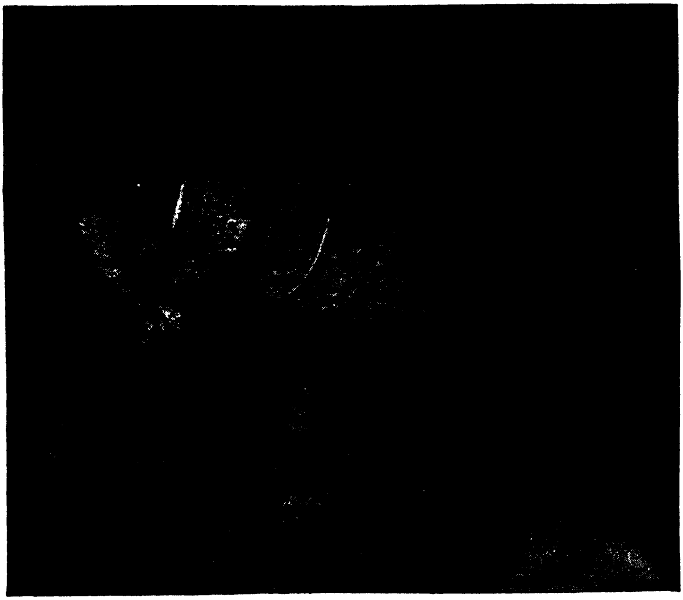


FIG. 25.—These barrels use sawdust for cleaning metal punchings.

A proper cleaning compound will act to form a readily soluble compound instead of the above soap. It not only saves time, tank space and steam, but gives better results with less chance of tarnish. These compounds containing grease are quickly emulsified. Fine solid particles of abrasive are not left behind upon the work but are floated off into the cleaning solution, and green chromic oxide compositions, ordinarily very difficult to remove, are readily washed off.

Selection of Cleaning Method.—Having done all that is possible in reorganizing general manufacturing practice at a plant so as to make cleaning as easy as possible, it becomes necessary to select the means of cleaning best suited to the work in question. A steam gun may be advisable in some cases as, for instance, in locomotive repair shops, or perhaps a sawdust tumbling barrel may be best as in the case of metal stampings that are to be plated.

Although there are many special types of cleaning in use, the bulk of the washing of metal as a production process in industry may be classified under three headings:

1. Still Tank Cleaning.—Simple immersion of the dirty work in baskets or on racks in the cleaning solution, usually at boiling temperature, without or with agitation of the work. Soapy cleaners are best here.

2. Mechanical Washing Machine.—Here the impact and shearing action of high-velocity jets give mechanical aid to the cleaning action of the solution. Because of foaming difficulties, cleaners containing soap may not be used unless antifoaming acids are added. Completely soluble cleaners should be used to avoid plugging nozzles and loading conveyors.

Cleaning materials for use in mechanical washers must be quick acting, because the work usually goes through on a conveyor and is in the wash zone for only a short time.

3. Electrocleaning.—The general features of this method have been presented. The details in each case must be adjusted to conditions.

Aluminum when electrocleaned uses the cathode method. Die castings should not be cleaned in the same bath used for copper, brass or other copper alloys. Copper and brass may be cleaned either anodically or cathodically; the latter is more commonly used. Iron and steel may be cleaned either anodically or cathodically. The best practice is to do both by means of a two-pole double-throw switch, reversing the polarity during cleaning. It is best with heavy work to start it as the cathode and, after about 1 min., to reverse current, making the work the anode. Some reverse again, making the work the cathode for the second time just before removal.

If the principal part of the dirt to be removed is scale, that will call for pickling or descaling operations, which are described in considerable detail under the heading of Descaling in the two following chapters. Oils and greases may be partly removed by centrifuging.

The Steam Gun.—The steam gun as a cleaning tool has so many possibilities that some further description of its use may be advisable. Essentially it is a device for projecting at high velocity an atomized cleaning solution against the surface to be cleaned or stripped. In principle it is an injector with suitable control valves and hose connections. In variety of design it may use almost any steam pressure and may use one or more supply lines from cleaning-solution reservoirs. The use of steam is not always necessary, as some manufacturers are successfully using compressed air, but usually the temperature of the steam jet is a valuable aid. In practice the mist of hot cleaning solution striking the dirty surface at high velocity cuts through and emulsifies the oil and dirt and then, by merely shutting off the supply of cleaning solution, the surface is thoroughly rinsed.

Many different classes of work are effectively handled with the steam gun. One of the chief of these is found in railway locomotive repair shops where incoming parts, particularly the large unwieldy parts, are cleaned with a steam gun at lower cost than by any other method.

Stripping Paint.—By proper choice of cleaning compound and adjustment of impinging pressure, oil or dirt may be cleaned from a painted surface without injuring the paint. In other cases the compound may be so changed as to cause complete stripping of paint.

The design of tips on a steam gun should suit the particular material being cleaned. For a flat surface a flat nozzle tip giving a sheet of spray is best. For irregular surfaces a round nozzle may be best. The actual size of the opening must be determined by the pressure of the steam used and the nature of the dirt being cleaned. Often test operations with varying steam pressures will determine the most economical method. Some manufacturers use a relatively low steam pressure in two operations; that is, one operator uses a gun chiefly to apply a coating of cleaning solution, and he is followed by a second operator with a second gun that finishes the job.

Where steam is not available, small portable steam-gun cleaning outfits may be used. These units containing oil-fired boilers and suitable tanks are each mounted on a small truck that may be easily moved throughout the plant.

Preparation for Cleaning.—Many parts such as screw-machine products can be freed from considerable oil by draining or, better, by centrifuging before cleaning. This not only makes cleaning easier but allows recovery of the oil. In large parts that have been machined, chips may be blown out of holes and pockets to advantage by a compressed-air blast. Proper procedure and careful work in the polishing and buffing room can cut down considerably the amount of composition loaded onto the work. Prompt cleaning of such work makes the cleaning easier.

Preliminary to washing, partial removal of dirt is sometimes effected by sandblasting, tumbling and mechanical stripping or scrubbing, as with revolving wire brushes or buffs. Sometimes a preliminary dip in a solvent or a cleaning solution aids in the efficiency and cleanliness of the final cleaning operation. Buffed work is sometimes first dipped in a solvent such as benzine or toluene to soften the dirt before the work goes to the electric cleaner.

Mechanical Features.—In cleaning operations, mechanical features such as agitation, circulation, electrolytic action and temperature regulation are often of major importance, and any one of these may be the controlling factor in the cleaning process. Different sizes and shapes of work can be handled best by different methods. Examples are baskets, tote boxes, racks, hoods or any one of the various types of conveyors used in mechanical wash machines.

The selection of the method of handling work through the cleaning cycle is most important, not only in minimizing labor charges, but in getting the best results in the cleaning itself. Obviously, small threaded or slotted screw-machine products will not be well cleaned if they are put through the cleaning process closely packed in tote boxes. Parts with knurled areas or irregular surfaces that catch and hold buffing compound cannot be cleaned as well in a still tank as by means of mechanical agitation to shake out the dirt the cleaner has loosened.

Material Handling.—Proper linking of the cleaning operations with the preceding and subsequent operations by mechanical handling requires that the cleaning operations function uniformly and in proper timing with the other production steps. All the usual types of conveyors are in practical use not only for bringing work to the cleaning operation, but for carrying it through the various stages of cleaning. Work may be handled in and out of the soak tank, the electric cleaner, the hot and cold rinse, the acid or other dips and the hot-air driers by overhead monorail conveyors, chain conveyors and other familiar types. The conveyance may be continuous or intermittent.

Agitation.—For agitation, a number of different means are available. The simplest form is that provided by vigorous boiling and rolling over of the cleaning solution itself. Circula-

FIG. 26.—Monorail-conveyor systems reduce handling through the cleaning operation.

tion of the solution is aided by arranging baffle plates to create convection currents. Circulation by means of pumps is effective and is of course the principle used in most mechanical wash machines. The pump may discharge the solution over or against the work by means of multiple jets, or, when it is necessary to avoid foaming or to keep the work submerged out of the atmosphere, the jets may be submerged in the cleaning tank.

Propellers immersed in the tank are used but are not common. The work itself may be agitated by up and down or traverse motion in the tank by means of cams, eccentrics, rockers or conveyors, which usually actuate rods, holding baskets, racks or trays that dip into the tank. Tumbling barrels or washing machines that contain a rotating helical conveyor furnish another sort of agitation.

The gas evolution at the electrodes of an electrocleaning tank provides another type of agitation, and sometimes agitation is effected by bubbling compressed air or live steam through the solution. Usually compressed air is not recommended, however, because it rapidly cools the solution, causes tarnishing and creates too much vapor in the atmosphere.

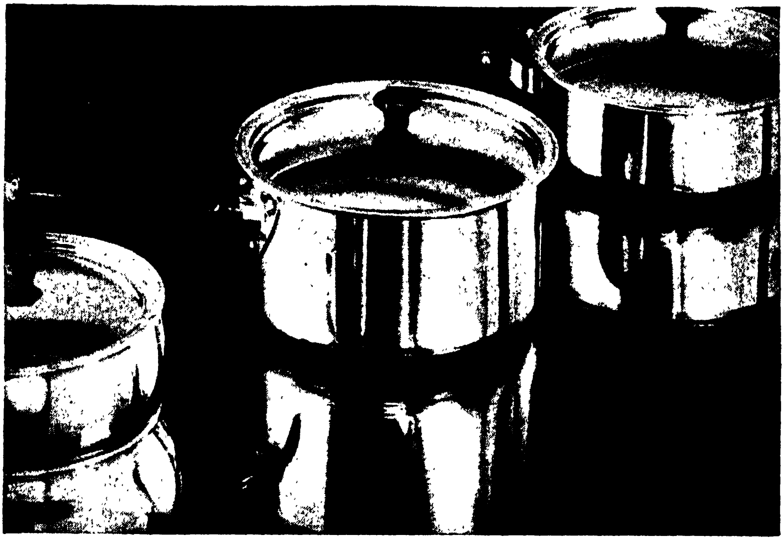


FIG. 27.—Surfaces such as this are possible only after the metal surface has been thoroughly descaled.

Temperature Regulations.—Increase in temperature lowers the tension of cleaning solutions or, in other words, increases their wetting and penetrating power. Slushing oils, lubricating oils, tempering oils and polishing grease have their viscosity greatly decreased with rising temperature. Heat causes expansion of almost all metals, and this tends to loosen dirt or foreign matter caked upon the surfaces, especially in crevices and corners.

Many large cleaning installations, where uniformity and reliability of results are important, have the temperature of their cleaning solutions controlled by thermoregulators. An unnoted lowering of 10° or 20° in the temperature of the cleaning bath may seriously decrease the cleaning efficiency. In the cleaning of aluminumware, maintenance of the temperature just below the boiling point, at say 180° to 200°F., is desirable to prevent attack. In the same way in the cleaning of brass, maintenance of the solution at, say, 200° to 210°F. is an aid to avoid tarnish.

In the removal of some buffing compositions, washing seems to go faster in the range of 160° to 180°F. In such cases the advantages of automatic temperature regulation are obvious. In general, however, it can be stated that increase in temperature almost always increases cleaning action. It is never safe to assume that one is getting a boiling temperature in the solution from any other indication than the reading of a thermometer. An undersized heating unit for a cleaning tank is always a costly economy.

Cleaning for Inspection.—Obviously, for satisfactory inspection all parts should be cleaned; otherwise gaging and visual inspection are hampered. No inspector or assembly man should have his work slowed up by parts that are not *strictly clean*. Often "bare-metal clean" is not desirable, as finger prints, etc., may cause subsequent rusting. For such cases a method of cleaning and antirusting in one operation should be used.

Finished parts for storage or transport should also be most carefully prepared for final handling and inspection by the purchaser. Today, all industries are becoming more and more particular about this. Tins no longer reach the consumer greasy with oil; they are washed clean. Steel tools and hardware today seldom will soil the skin of the customer who handles them. They may be antirusted by a thin nongreasy film but are seldom flooded with slushing oil. Kitchen utensils, motors, machinery—all are put in the best possible condition to appeal to the eye of the purchaser. No greasy, grime-holding, hand-blackening, clothes-soiling surface ever improved the chances of a sale. Methods have been so well developed for mechanical cleaning that today even the cheapest 10-cent-store hardware and kitchen utensils can be cleaned and ball burnished to an excellent finish.

TYPES OF CLEANERS[1]

One of the first problems that confronts the operator of a metal-fabricating or metal-finishing shop is that of selecting the

[1] Prepared in cooperation with the Optimus Detergents Co., Matawan, N. J.

proper cleaning compound for the job being studied. The types most frequently encountered in American industrial plants are the following:

1. Alkaline cleaners—usually sold in dry powdered form to be mixed with water to form the cleaning solution.

2. Petroleum solvent cleaners such as Stoddard's solvent, kerosene and gasoline.

3. Solvent emulsion cleaners—to be mixed with petroleum spirits before use. In special cases, the emulsion cleaner is mixed with water to prepare the cleaning solution.

4. Chlorinated hydrocarbon solvents such as carbon tetrachloride, trichlorethylene and tetrachlorethylene, used mainly in degreasing equipment.

5. Acidic cleaners. The development of this type of cleaner is quite recent, and applications are as yet highly specialized.

Alkaline Detergents.—Alkaline detergents are compounds created to meet a wide variety of demands of metal cleaning. Various types are now available, such as "heavy-duty" and "light-duty" cleaners for steel, etching and nonetching cleaners for aluminum and brass, cleaners containing natural or synthetic soaps (wetting agents) for use in soaking tanks, electrocleaners for anodic or cathodic cleaning and cleaners for plant maintenance.

Solvent and Emulsion Cleaners.—Solvent and emulsion cleaners are compounds of several types, depending on whether the cleaning to be done can be accomplished best by a simple solution of the foreign material in the solvent or whether an additional emulsifying agent should be present. The emulsifying agents are selected on their ability to disperse foreign materials rapidly and to keep them dispersed for suitable periods of time. Petroleum-base solvents are widely useful where heavier petroleum products are to be removed and are made thin and rinsable by such solvents. Another large group of solvents are liquid hydrocarbons containing chlorine, such as carbon tetrachloride and trichlorethylene, which have a superior strength as solvents.

A limitation of these solvents is that they leave part of the original soil untouched because it is not soluble in the solvent. This will always be the inert material present in the soil, such as abrasives in metal-finishing compounds or sooty carbon in lubricants, also difficultly soluble heavy organic materials such as sludges.

The use of emulsifying agents that are compatible with the solvents improves the handling of inert forms of dirt. The time of wetting and lifting the solids from the surfaces is reduced, and they are dispersed so that they are almost completely removed on rinsing. The same physical cleaning action takes place, with small drops of the fluid part of the soil being removed. A simple example of an emulsifying agent is an ordinary soap. For industrial uses, a number of natural soaps and many synthetic soaps or wetting agents are available for use with different solvents, including hard and soft water.

Acidic Detergents.—Acidic detergents are compounds designed to remove oxide films, especially from ferrous metals and aluminum, under conditions where ordinary pickling procedures cannot be followed. Those used with ferrous metals either may remove the oxide as a soluble salt of iron or may convert it into a more stable, less soluble form that imparts passivity or rust resistance to the surface. Acid compounds for aluminum are used as a treatment prior to spot welding and require the study of the specific metal used to provide a surface that can be welded properly. Equipment is available that will analyze the surface condition of the metal and point to the treatment that will give a surface that will weld satisfactorily and economically.

Selecting the Proper Cleaner.—The factors that influence the selection of the proper metal cleaner for any and all purposes are as follows:

1. The subsequent operations to be performed on the work being cleaned.
2. The kind of metal to be cleaned.
3. The nature of the material to be removed, its tenacity and the general surface condition of the parts.
4. The degree of cleanliness required.
5. The equipment available or necessary.

The kind of metal to be cleaned has a definite bearing on the cleaner selected. A highly caustic heavy-duty cleaner suitable for use on dirty iron or steel parts would be entirely unsuitable for use on aluminum or relatively sensitive metals.

The nature of the dirt to be removed, its degree of tenacity and the general condition of the parts to be cleaned are also important to the problem of selecting a cleaner. Kinds of dirt commonly met in metal-cleaning operations are oils, greases, machining compounds, polishing or buffing compounds, dust, dirt, metal chips, etc. Not all oils, greases or compounds respond alike to the same cleaner, nor will all pieces with the same dirt on them clean as uniformly and quickly in the same cleaning tank. A part coated with buffing or polishing compound that has been allowed to dry out on the work will be more difficult to clean than will a similar part with the same compound on it that is put in a cleaner tank immediately after polishing.

The degree of cleanliness required must be known in order to meet the customer's requirements. A job that called for only a physically clean surface, for instance, would usually require only a simple cleaning setup with a relatively inexpensive cleaning compound. (A "physically" clean surface is one from which only the gross surface dirt has been removed.) On the other hand, a job that called for a chemically clean surface with no water break would require a much higher degree of cleanliness and a careful selection of cleaning compounds to produce the desired result. The cleaner and cleaning cycle must be suited to the requirements of the job.

The equipment available for performing cleaning operations will also influence the selection of the cleaner. In a power-spray washing machine, for instance, it would be poor policy to use a detergent containing a soap or wetting agent. Such a material would foam right out of the machine and waste money as well as cause poor cleaning.

CHAPTER IX

PICKLING FOR BETTER FINISH

Finish and pickling are closely related in the metalworking industry, for, in general, the better the appearance or finish of a metal part, the more prominent pickling has been in its production. Today there is an insistent demand for better and better finish, which means that the trend in pickling as a manufacturing process is definitely upward.

How long the trend will remain upward is hard to say, for there are forces opposing pickling just as there are other and stronger forces favoring it. In the long run metallurgical ingenuity may perhaps largely eliminate pickling, insofar as it is descaling, from metal-fabricating technique.

Putting scale onto metal in one operation and removing it in another is manifestly inefficient, but so is the cumbersome process of converting grass into milk, and yet the cow seems destined to be with us for many years to come.

Not long ago most of the pickling in the metalworking industry was done on semifinished material such as sheets and rods, but a demand for a better finish on nearly all metal products started with the unusual flair for fine finish in the automobile manufacturing business, so that the most promising postwar market for pickling equipment is not in the steel production field, but rather is with the secondary fabricating interests and particularly with the large group of metal-enameling and finishing plants. The most extensive pickling is to be found in connection with the manufacture of refrigerators, radios, steel furniture, typewriters, cash registers and similar products.

Pickling in one form or another is a usual operation after annealing, before lacquering, japanning, tinning or plating and is common practice in most other types of metal finishes. One authority has said that the manufacturer who must galvanize or tin in the regular course of production cannot afford to slight in any way the proper preparation of metal surfaces, and pickling in an appropriate acid bath is the approved method of securing such surface preparation. In any method of descaling where the work is oily or greasy, it is first necessary to remove the oil or grease; the problem of grease removal has been discussed in previous chapters.

The extension of pickling processes into many high-production multiple-unit fields has had much to do in bringing the art from the position of a necessary evil to its present prominent place in nearly all manufacturing sequences. The manufacturer who years ago seldom spoke of his pickling department, and who was inclined to be somewhat ashamed of it, now points with pride to a continuous pickling machine that takes its place in his regular production line.

Nature of Scale.—One of the reasons that the descaling process has been slow to become an established science is that the scale coatings are not uniform in thickness or in the tenacity with which they adhere to the base metal. The bond between the scale and the base metal is somewhat in the nature of a mechanical bond, differing from the character of the bond formed by the fusion of adjacent metal crystals that is produced in welding, hot galvanizing and electroplating.

Scales are much harder than the metal from which they are formed. They are exceedingly abrasive, breaking up under impact into sharp-edged fragments that rapidly score or cut the metal itself when scale is rubbed against its surface. Scale is so hard that it will dull and glaze the surface of polishing wheels and will turn the edges of cutting tools. It will score and damage drawing dies.

Scales usually are oxides, or chemical compounds of the metal itself and oxygen. They are formed when a metal surface is exposed to air or to oxygen. Much of the descaling in the metal industry is necessary because heat accelerates the formation of oxides. The heating required for many fabricating processes—rolling, drawing, forging and others—causes scale to form rapidly. Even the relatively low heats of annealing are scale-forming operations unless air is kept away.

Methods of Removing Scale.—There are three general methods of removing scale: (1) frictional abrasion, (2) chemical reaction with the base metal and (3) electrochemical scale separation. Such methods of scale removal as sand and shot blasting, scratch brushing, hand rubbing with abrasive cloth and tumbling fall under the first method.

Pickling, which in simplest terms may be described as immersion of metal in dilute acid, is the second method. Actually this method usually is far from simple and involves such factors as time, concentration of solution, temperature, use of inhibitors, use of electric current and all the production features of material handling and of continuous processes.

The third method is represented by the Bullard-Dunn process of scale separation and simultaneous base-metal protection. It is a combination of the principles of pickling and of plating.

Importance of Pickling.—Descaling lengthens the life of cutting-tool edges and eliminates frequent tool regrinding and the consequent loss of time and, in certain instances, the loss of precision caused by tool resetting.

Savings can be made in nearly all the finishing operations after heat-treatment if the heat-treat scale is removed completely before such finishing operations are begun. For example, the cost of lapping will be less if the lapping is done on a scale-free surface, because less time will be required for the lapping when no scale has to be removed, and, in addition, rapid wear and tear on expensive laps can be reduced materially.

Grinding costs can also be materially reduced by complete descaling before grinding. The time required for grinding is less because fewer cuts are needed when the metal surface is scale-free and there is less danger of distortion or of the development of surface cracks caused by overheating during grinding. Grinding wheels are less apt to become loaded or glazed. Consequently, the life of grinding wheels is materially lengthened as wheel dressings are less frequently required. A smaller variety of grits and grades of grinding wheels will cover the needs of the grinding department, thus reducing the grinding-wheel inventory. As scale-free parts can be located more accurately in jigs and fixtures, complete descaling aids in the practice of gang grinding with its obvious economies.

Inasmuch as pickling is part of the process of manufacturing sheets, the extent of pickling may be partly gaged by the production of sheets. One company producing a metal alloy intended primarily for pickling equipment has assumed the life of a pickling plant to be 2000 days, on which basis, for its particular design of equipment, the company estimates the consumption of 1 ton of its alloy in the pickling plant to each 2000 tons of sheets produced. The average annual production of steel sheets in this country before the war was about 3,000,000 tons.

Technique of Pickling.—By pickling is meant the treating of metals with acid solutions to remove scale and rust. Scales are usually iron oxides, classified under three headings:

1. Hydrated ferric oxide—ordinary brown rust. This is soluble in dilute pickling acid.

2. Anhydrous ferric oxide—the familiar blue scale that is on heat-treated parts. This is somewhat soluble in pickling acids.

3. Magnetic oxide—the black scale formed in hot-working operations. This is slightly soluble in acids.

The scales chiefly encountered in pickling are the last two, and it is therefore apparent that their removal is effected not so much by dissolving the scale itself as by the mechanical action set up between the scale and the base metal by the acid solution. A very thin layer of metal enters into the solution when the acid penetrates the scale, and the accompanying evolution of hydrogen forces the scale off mechanically, after which it falls to the bottom of the tank.

Dilute sulfuric acid forms the solution for a major portion of all pickling, but, whatever the acid used, the solution tends to dissolve both the base metal and the scale. The action is more rapid on the base metal than on the scale, and this is the reason for much of the complexity of pickling technique. Everything possible must be done to reduce the attack of acids on base metal without interfering with the prime object, scale removal. High-carbon steel is attacked more rapidly by the usual pickling acids than is ordinary low-carbon steel. For this reason high-carbon steel requires a sharp, quick pickle. The quicker the scale is removed, the less steel will be dissolved.

Alloy steels are attacked rapidly, owing to the presence of a large number of minute electrolytic couples that are set up between the steel and the alloying elements. This attack results in a roughened or blackened surface unless great care is used.

In normal pickling practice the activity of a sulfuric acid pickling bath gradually slows down, owing to the presence of dissolved iron. This effect is not particularly noticeable until the concentration reaches about 9 per cent iron, which is equivalent to 40 per cent iron sulfate, or copperas. Pickling, though slowed down, can be carried on until iron sulfate starts to crystallize out and attach itself to the bottom and sides of the tank and to the work. It has been found that crystallization starts at ordinary pickling temperatures, when the dissolved iron content reaches about 10 per cent.

During the past few years electrolytic descaling has been brought to a higher state of development by the introduction of a silicon-alloy anode which has stabilized this method of scale removal. This new anode is said to eliminate the necessity of dumping the electrolyte by preventing chemical changes that normally occur in electropickling. As a result the problem of the disposal of spent pickle liquors has been greatly lessened. The new anode was developed by The Bullard Co.

Acids and Acid Containers.—In the case of iron castings, it is usual to pickle in hydrofluoric acid in order to dissolve the silica sand that may be present.

The extensive use of sulfuric acid is due chiefly to its low cost. Concentrations of pickling solutions vary from 2 to 15 per cent acid, the bath being heated in order to ensure the maintenance of a fairly rapid rate of pickling. An unfortunate disadvantage of such hot baths is that the fumes caused are disagreeable for the workman, but in modern plants ventilation systems have eliminated much of this trouble.

Muriatic acid is used in strengths of 10 to 50 per cent commercial acid. Although the pickling action of this acid is more rapid and a lower temperature can be maintained in the baths, muriatic acid is generally not used on account of its high cost as compared with sulfuric acid.

Acid strength and temperature should be considered together, for both factors affect the rate of pickling. Usually it is possible to speed up pickling by increasing the sulfuric acid content up to about 20 per cent actual acid. Beyond this point an increase in acid slows down pickling. In actual practice the acid strength is between 2 and 15 per cent.

Acid does not attack steel uniformly, owing to the crystalline structure of the metal and nonmetallic inclusions, and hence the surface of the pickled metal is generally roughened. This effect increases as the acid action proceeds, so that a prolonged attack results in a badly pitted surface.

Changes in temperature have a greater influence on the rate of pickling than do variations in acid strength. For some ranges an increase of 20°F. will double the rate of pickling. The range of temperature for most pickling operations is between 140° and 180°F.

Individual plant conditions and tank capacities frequently determine the acid content and temperature. An acid strength of 5 per cent and a temperature of about 160°F. are advisable in

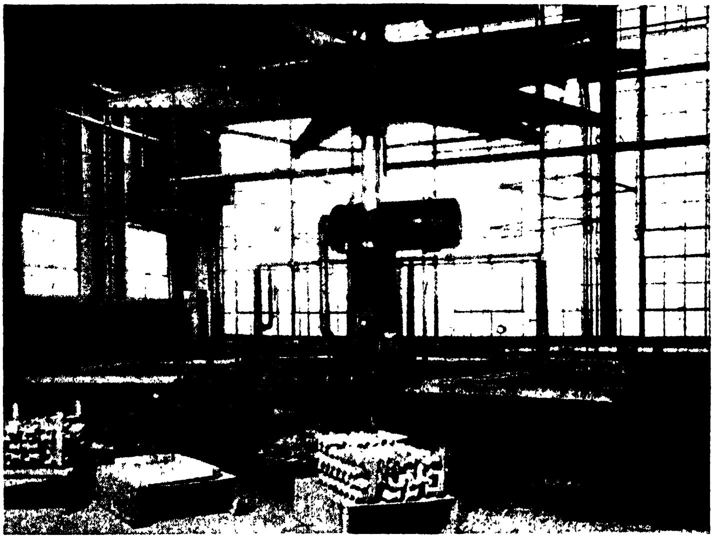


FIG. 28.—Modern handling equipment is being used more and more extensively in the pickling department. This shows a Mesta machine handling castings through several successive dips.

most cases, giving as they do a minimum of fumes and the best working conditions. Stronger solutions and higher temperatures will increase production, but the added tonnage will be attended by greatly increased volume of fumes, together with the danger of overpickling, pitting and hydrogen embrittlement.

Inhibitors.—Many of the difficulties that attend the pickling of iron and steel may be lessened or entirely eliminated by the addition of an "inhibitor" to the pickling bath. Inhibitors for the most part are colloid chemicals of organic origin that have a peculiar influence on the pickling action. They operate by forming an absorption layer on the clean steel or iron, which greatly retards the attack of the acid on the base metal, allowing continued attack on the scale or oxide. Some solution of the metal and the formation of hydrogen must take place for the scale to be removed with any speed.

The real function of the inhibitor is decidedly complex. When an inhibiting compound is present in the pickling solution, it is deposited on the surface of the metal parts being pickled, and its success depends upon its propensity for depositing most heavily where the tendency toward solution is strongest. Thus the deposit is heavy on the clean metal surface and much less heavy on parts still coated with scale. As these colloidal deposits retard solution, action is slowed down where it is not needed and is permitted to take place rapidly where it is needed. In this manner excessive solution of metal is prevented and the hydrogen generated is limited.

Sulfuric acid may be used at higher temperatures and in stronger solutions with a great increase in production when the proper inhibitor is added. Also, there will be a lessening of troublesome fumes, since the hydrogen generation is smaller. Some of the other advantages secured with inhibitors under proper conditions are less base metal in solution, less chance of overpickling and pitting, better control of brittleness and blistering caused by hydrogen and a marked saving in acid.

One of the disadvantages is the frequent slowing down of pickling action.

CHAPTER X

PICKLING AS A MANUFACTURING PROCESS

"Whatever is packed in metal can be dressed up." This is the slogan of a large manufacturer of lithographed metal containers. To be "dressed up," metal must first be free of scale, and this emphasizes the importance of pickling in the production of attractive metal finishes.

If we consider pickling as an established link in the manufacturing sequence of a product, we find immediately that the process is subject to a new type of analysis. It is to be scrutinized from the viewpoint of floor space and of material-handling methods. The significance of preceding and succeeding operations should be studied with particular attention to such subjects as labor and supervision, operators' clothing, different types of floor material, cost of power and fuel, effect of fumes on other operations and eventually, of course, the effect of the quality and extent of the pickling on the product itself. In previous chapters the relation of a clean metal surface to a good finish has been described. When a finish of a definite quality is specified, it becomes possible to investigate pickling on the basis of over-all cost as well as of actual pickling cost.

Many medium-sized plants in the metalworking industry are faced at present with problems in connection with their pickling operations. Most plants with pickling departments would be able to effect an economy by reorganizing to take advantage of recent improvements in equipment and materials. This would be particularly true of a plant having a straight line of production that is interrupted at some intermediate point for a side trip to and from a separate pickling room. The modern method is to locate the individual pickling unit directly in the production line and thus to reduce greatly the handling time and expense.

Difficulties.—The necessity for removing scale from metal in many cases and the economic advantage of removing it in other cases have been described. Pickling often is the most convenient method for such scale removal, but it is not the only method and it is far from being an ideal process. Therefore, in a discussion of the subject, it is only fair to take full account of the difficulties of conventional practice.

The salts of iron formed during the chemical attack of pickling solutions on metal are by-products that so far have proved useless. Because of the formation of these salts, it is necessary to dump or throw away solutions containing still active acids. If solutions are not dumped before saturation has been reached, the deposit of salt crystals creates a new and expensive cleaning problem. When active acids are thrown away, however, that not only represents a definite loss, but frequently presents a problem from the standpoint of stream pollution or of damage to sewers and sewage-disposal systems.

One of the immediate objections to pickling is that it usually pits and etches metal surfaces, thus reducing and unevenly altering dimensions. Cold-work strains produce areas in metal that are more readily attacked by pickling acids than the non-strained areas. Thus, in severe drawing, the thinner sections at corners are usually more rapidly attacked by the pickling acids, and hence the already thin condition is aggravated.

Hydrogen Embrittlement.—When the pickling acids attack iron, hydrogen is formed and the absorption of this hydrogen is apt to cause brittleness, which is known as "acid brittleness," or "hydrogen embrittlement." The conditions that favor the absorption of hydrogen are high temperature, dilute solutions and long pickling time. An acid solution of moderate strength with a temperature not over 150°F. and the use of the shortest possible pickling time will frequently reduce hydrogen embrittlement to a negligible amount. However, the danger of reducing the pickling time to the minimum is that the scale may not all be removed and that subsequent operations may be more expensive accordingly.

This has been explained previously but perhaps may be explained more graphically by Table V, which shows the saving in grinding time due to having a clean surface to start with. Table V was prepared by The Bullard Co., and the electrolytic process referred to is its own process. The scratch-brush cleaning is said to be good average practice.

TABLE V.—ECONOMY IN GRINDING AFFORDED BY CLEAN METAL SURFACE
(This test was on hardened-steel machine parts)

	Time required for surface grinding		Time required for internal grinding	
	After scratch brushing	After electrolytic descaling	After scratch brushing	After electrolytic descaling
Time per piece	54 min.	28 min.	$6\frac{3}{4}$ min.	$4\frac{1}{2}$ min.
Time saving	....	48 per cent	....	$33\frac{1}{3}$ per cent
Total wheel wear per piece ground	0.02 in.	0.008 in.		
Wheel life	12 days	22 days	5 hr.	8 hr.
Gain in wheel life	....	105 per cent	....	60 per cent
Wheel size	$8 \times \frac{3}{4}$ in.	$8 \times \frac{3}{4}$ in.	$1\frac{3}{4} \times 1$ in.	$1\frac{3}{4} \times 1$ in.

Embrittlement Tests.—Another way of avoiding the absorption of hydrogen is to lessen the amount of it that is formed. Some inhibitors have the property of reducing hydrogen, and one of the claims for a good inhibitor is that it avoids the danger of hydrogen embrittlement.

In addition to brittleness is the further difficulty of blistering. Slag inclusions in a rod or billet may be spread out into thread-like formations on the surface of the rolled product, and, in pickling, hydrogen enters these slag inclusions, or sonims, as they are called, and raises the surface of the metal into blisters.

A simple torsional test has been devised for determining the embrittling action of acids on medium- and high-carbon steel wires. It is found that rapid embrittlement ensues immediately as the wires are immersed in the acid and that the rate of deterioration increases with the acid concentration and the temperature. Hard-drawn wire in the large gages is extremely sensitive to this embrittling effect. The deterioration on the wire was less rapid when an inhibitor such as flour or yeast was added to the pickle. A mixture of flour paste and stannous chloride solution was found particularly effective in reducing the embrittling effect.

Overcoming Embrittlement.—Fortunately the embrittling action due to pickling is, at least partly, temporary in character, and the recovery of normal properties of the metal after pickling is facilitated with high temperature. Notched-bar impact tests in several cases gave the surprising result that the steel had become toughened after pickling in sulfuric acid. Some steels showed embrittlement after similar treatment, and the difference in result is attributed to a difference in the characteristics of the steel and possibly to some extent in variations of the pickling time.

One method frequently used to recover the original properties of pickled products is to immerse them in boiling water, and because of this feature it is the practice of some American manufacturers to use a boiling rinse and to keep the parts in this rinse

FIG. 29.—A standard installation of brick- and copper-lined steel tanks in service pickling wire in 15 per cent sulfuric acid solution at 200°F.

longer than would be necessary merely to free them of the residual acids.

Use of Electricity.—Numerous attempts have been made to use electric current to speed up the action of pickles and thus reduce the time required for descaling, but this tends to accelerate the destructive effect of the acid attack on the base metal under the scale and so has been discarded by many investigators. A few modifications of the method have proved successful, however. One of these (the Bullard-Dunn process), as previously mentioned, uses a plating action simultaneous with the descaling action to protect the base metal. In this process the work is usually connected to the cathode rod, and, as hydrogen gas lifts the scale, a microscopically thin, dense and adherent metal coating is electrodeposited on the base metal from which the scale has just been lifted. This metal film protects the base metal against attack during any further descaling treatment. Consequently, areas from which the scale has already been lifted are protected from pitting or other distress during the additional time required to remove the thicker or more tenacious portions of the scale layer. This protective metal film is said to give the descaling bath an excellent selectivity so that the concentration of the process shifts automatically away from those areas from which the scale has been removed to those areas which are still covered with scale.

The complete process consists of one or more of the three main steps: grease removal, scale and oxide removal, defilming.

1. Grease removal is accomplished by using a highly alkaline, anodic, electrolytic cleaner. This bath is operated at 6 volts with the temperature close to boiling and usually at a concentration of 16 oz. per gal.

2. The scale and oxide removal is effected in a bath containing sulfuric acid, a small concentration of tin and an addition agent that promotes a uniform, adherent tin deposit, increases the throwing power of the bath and reduces its surface tension. The bath is run at moderate temperature and high current density. The anodes are high silicon iron except for the one or two tin anodes that are employed to furnish the bath with its tin content. This bath operates over a wide range of conditions which makes it exceedingly practical.

When this bath has completed its function, the work is free from scale and oxide and is covered with a film of tin. This tin not only protects the basic surface during the scale removal so that no etching whatever occurs, but it also imparts to the bath an exceptionally good throwing power enabling it to clean out holes and recesses.

3. Defilming or stripping of this tin, when desired, is very simple, being performed in the bath as described in step 1. Work is stripped clean and free of tin in 30 sec. to 1 min. without any discoloration of the work.

The complete sequence of treatments for descaling work is as follows:

1. Alkali—degrease.
2. Cold-water rinse.
3. Acid—descale.
4. Cold-water rinse.
5. Alkali—defilm.
6. Cold-water rinse.
7. Hot-water rinse.

Whether or not to use all these steps is determined by the condition of the work and whether it is desired to leave the tin film on the work. For example, when work has no grease or carbon, steps 1 and 2, that is, alkali—degrease and cold-water rinse, are omitted. When the tin film is left on the work, steps 5 and 6 are omitted. When cleaning work for plating, a dip in cold muriatic acid (about 5 per cent) follows step 6, after which the work is rinsed and then placed in cyanide or directly into the plating bath, depending upon the plating bath used. The cycle can be interrupted after the acid step before plating because the tin will protect the work until it is ready to be plated. At that point the operator would then proceed with the usual sequence, beginning with tin stripping.

Continuous Pickling.—The equipment used for this process is similar to that required for electroplating. The current usually is supplied by standard 6-volt direct-current motor-generator sets and stationary dip tanks, or full automatic chain conveyors can be employed. In connection with the use of conveyors the sponsors point out that since there is no attack on a clean metal surface in the descaling bath of this process the wear and tear on submerged parts of conveying equipment is small.

Another electric process is known as the Hanson-Munning bright dip. In this, the products are immersed in two acid baths, as cathodes in the first and as anodes in the second. Quicker pickling and greatly lessened attack on the base metal are claimed.

The extension of pickling into an increasing variety of semifinal and final manufacturing operations has centered attention on the development of special forms of handling apparatus. In line with the general tendency to use conveyors in large manufacturing operations, pickling in continuous machines has been worked out successfully in many new applications. An example is the recent use of continuous pickling machines to handle automobile wheel rims. In some cases a machine is lined up with a conveyor that carries the parts in a continuous sequence in and out of pickling baths, through electrogalvanizing or cadmium-plating operations, through tanks where lacquer or paint is applied and finally through an automatic drying machine.

Such a continuous process has presented many difficult maintenance problems. Avoidance of leaks in tanks is more important than ever. Fortunately, the items pickled in this way do not often require a deep tank, and a good job of lead lining is one way of securing a leakproof tank. For general pickling in large tanks, however, lead lining is not always satisfactory because of the high maintenance costs arising from the need of frequent patching if the lead starts to sag and crack. However, since there is no jarring or mechanical abuse such as is likely to occur to linings of tanks where the loads are lifted in and out by cranes, the average life of a lining in a continuous pickler may be longer than in the dip tank.

As already pointed out, one of the problems in the construction of continuous pickling machines is to find materials for the moving parts which will stand up under the severe action of the acids. The conveyor chains, the rails on which the chain rides and the carrier hooks must often pass through plating baths, alkaline baths and sometimes into tanks of lacquer and the drying ovens.

Location of Tanks.—More recent requirements in manufacturing call for the location of pickling tanks right in the middle of factory buildings, and this means marked changes in design. Wholly or partly enclosed units are frequently used with quick-opening covers and adequate exhaust systems. Floor space must be conserved, and this frequently means the use of deeper tanks with the attendant problem of tank lining. Other features are the use of elaborate hoods on open tanks and the introduction of corrosion-resisting alloys in the construction of continuous units.

Continuous pickling of metal parts in the secondary fabricating field is one of the outstanding developments of the last few years. The design of the machines for this work has been taken from the previously perfected continuous plating machines, but within the last few years modifications have been made and belt-type continuous pickling machines are now coming into more common use. Wire, strip and sheets are now being pickled in continuous processes, the sequence often including other processes.

The introduction of these new ideas in sheet and tin mills has led to a greater study of pickling operations, so that changes have been introduced in many mills. A number of modifications of the old-fashioned tin-mill pickling rack have been developed with increased efficiency. Further details in this connection are given in the next chapter. The introduction of sheets of acid-resisting alloys placed along the sides of tin-mill racks to baffle the surge of pickle solution as the pickling machine rises and sinks is said to raise the over-all efficiency for the load by 2 or 3 per cent, a figure not to be scoffed at on a 100-ton-day output for each machine.

New Economies.—As pickling took its place in the line of production processes, its previous inefficiencies became untenable, and the importance of coordinating all direct-line operations became apparent. Acceptable and economical cleaning is obtainable only when the preceding heating and cooling practice has been properly adjusted, for such practice directly affects the time of descaling, the use of simply compounded solutions, the convenience and comfort in working pickles, the uniformity of action in removing the scales, the freedom from etching, frosting and pitting, and, on top of all these, the cost. The methods of heating for forging and annealing must always enter into the plans for the pickling operation.

The thickness and tenacity of the scale depend, to a large extent, on how the scale is formed, that is, whether it is a forging scale, whether it is an ordinary heat scale, or whether it is what might be called a reheat scale, that is, a heat-treat scale superimposed on a scale formed during hot forging. The type of quench affects the time required for descaling in two ways. (1) When oil quenches are used, a degreasing treatment is necessary before descaling, and this is usually and perhaps rightly charged to the cost of descaling. (2) Oil quenching appears to increase the tenacity of the bond that holds the scale to the base metal and thus lengthens the time required for descaling. These factors, in combination, have an unpredictable influence on the time required for descaling, and consequently it is not possible to determine the cost of descaling by a mere inspection of the parts to be cleaned. Therefore, the time cycle should be determined by actually cleaning representative samples.

Acid Waste.—Some of the more usual forms of waste in pickling will be illustrated by an example from actual practice, which was considered average not long ago. The test case was the cleaning of 500 sq. ft. of steel on which 1000 sq. ft. of surface (both sides) were exposed to the action of the pickling acid. This was immersed 15 min. in a bath containing 2 gal. of sulfuric acid for every 100 gal. of water and heated to 200°F. By this process 6 lb. of scale was removed. This was the purpose of the cleaning; but, while removing this 6 lb. of scale, 65 lb. of metal was dissolved and 11 lb. of acid was required to do the useful work, while 120 lb. of acid was wasted dissolving the metal.

This case covers the more obvious direct inefficiencies. The other losses are more easily overlooked. If equipment is not properly designed, there will be handling losses, heat losses and leakage. Leakage may be as high as 5 lb. of acid per ton of steel. A pair of tanks will handle, say, 100 tons of steel a day. If the tanks last only 500 working days and if acid can be bought at ½ cent per pound, leakage at 5 lb. of acid per ton of steel will cost $1250 on a pair of tanks. This might be saved by spending only a small part for better equipment.

Breakdowns in pickling equipment are expensive. Pickling crews and foremen often must be paid for the idle time during repairs. If each man of a crew of 10 men loses only 1 hr. per week at 50 cents an hour for 78 weeks, the total is close to $400. The loss of acid is but part of the loss due to a leaky tank. Excess steam consumption is required to heat the extra amount of water and acid needed to maintain the level of a leaking tank. Shutdowns for emergency repairs while acid continues to attack steel mean poundage going into the sewer that should go into the shipping room.

Importance of Good Equipment.—The difference in cost between a satisfactory tank lining and an unsatisfactory tank lining is often small. To give an idea of the price of rubber linings, a three-layer soft-hard-soft lining costs about $2 a square foot for an over-all thickness of 3/16 in. Because of the relatively high price of acid-resisting metals, thin-gage metals are frequently used, and in this a simple principle of economics is overlooked. In one installation a monel-metal sheet 0.025 in. thick was replaced by a similar sheet 0.062 in. thick, and by making this change the life was increased by nearly ten times, although the increased cost was but two and one-half times.

On most hoods it is found that corrosion starts from the outside rather than from the inside. This is because the condensed vapor from the acid bath keeps washing the inside and limits corrosion to the normal rate of the metal in the acid. On the outside, a coating of metallic salts and dust tends to accelerate corrosion. As a result it has been found good practice to provide for washing off the outside of ventilating hoods with a hose or other means. Also some special paints and greases have been developed for use on such hoods.

The extent of possible descaling economies may be judged from one example. Two men are required in place of 20 to 25 formerly employed for descaling on the same schedule of production. Grinding costs also have been reduced, with less than one-third the previous inventory of grinding wheels. Assembly costs are less, and the accuracy of manufacture has been improved. The plant manager says:

> Our repair parts and replacement parts records show that the life of our machines in service has been lengthened noticeably since our adoption of a process for thorough descaling. We have found the new process to be materially less expensive than sandblasting, scratch brushing or hand rubbing.

CHAPTER XI

SELECTING THE PICKLING EQUIPMENT

Designers of pickling equipment were long handicapped by lack of adequate materials. The result was a makeshift—open tanks that leaked, racks that corroded and fumes that relegated the pickling department to an isolated building.

Now new materials and methods are available, and proper pickling equipment may be selected for nearly any place or purpose.

The farther a manufacturing process is removed from the initial raw material, the more specialized it tends to be. Thus, finishing operations are frequently of an individualized or nonstandard character, and the equipment is often custom-made for the job. Pickling, however, is associated not only with the finished product but with the raw material as well, and the range of equipment varies from highly standardized apparatus to elaborate machines designed for the pickling and handling in mass production of one particular product.

In previous chapters it was pointed out that full economies in pickling could be effected only through full coordination of processes before and after descaling. Take, for instance, a plant that manufactures bicycles. Here pickling may be introduced at various points in the production sequence. Many small parts are machined, heat-treated, pickled and plated. Other parts are forged, pickled, machined, heat-treated, pickled again and then ground. Certain frame parts such as the front fork tube may be heated and formed and then pickled and enameled.

Some of the factors pertaining to pickling, which the manufacturer of such a plant should consider and which already have been discussed at more or less length, are relation of good pickling to good final finish, selection of cutting and quenching oils to facilitate cleaning and scale removal, use of reducing atmosphere in heat-treatment to avoid one or more pickling operations, importance of proper pickling technique and economy in correct location of pickling equipment.

Assuming that the manufacturer has studied all these features, he then is ready to consider the selection of pickling equipment. Today, he is fortunate in having adequate materials and a great variety of ingenious designs to choose from. Initially, design provides the important advance; eventually, in any type of mechanism, material becomes the determining factor.

The first advance carried the design of pickling equipment far beyond the ability of materials to cooperate, and it is only now that the fabricator of pickling machinery has materials suitable for all parts and for all types of pickling solutions.

The rapid increase in the development and use of corrosion-resisting alloys brought a close association and interdependence between these materials and the pickling process. Some of the nickel alloys seem to be particularly resistant to the acids commonly used in pickling steel, and their life even under severe service in pickling may exceed 6 or 7 years.

Wire Baskets.—Despite a rapid advance in belt-type continuous pickling equipment, the wire basket in one form or another still remains the usual container for small parts that are to be pickled. Wire baskets are usually made of aluminum, monel metal, copper, brass, nickel chromium or stainless steel. However, in addition to these, many new alloys are appearing. The nature of the pickling process, of course, determines to a large extent the material best suited for equipment.

Aluminum is attacked slowly by both nitric and sulfuric acids but is more rapidly attacked by alkalies and by nearly all concentrations of hydrofluoric acid. Monel metal, which is an alloy of nickel and copper, is resistant to nearly all acids used in pickling except nitric and has a long life in alkalies. Brass is used in a good many of the alkali solutions but is not suitable in cyanide and is not so strong in its usual form as some of the other alloys. It is used to some extent in dilute solutions of sulfuric and muriatic acids. It is attacked by hot concentrated sulfuric acid and by nitric acid. When the cycle embodies both an alkali and a nitric acid dip, nickel chromium is frequently used. This material is not attacked by alkalies and is resistant to the common acids used in pickling. In addition to this, it has high strength value and is not affected by any temperatures normally encountered in pickling.

Suitable wire for making baskets is obtainable in all the above-mentioned materials, and these wires lend themselves to welding and other usual forms of fabrication.

Tanks.—The bugbear of the pickling business for many years was the tank or container, and shortcomings in this line were responsible for the early separation of the pickling department from the rest of the plant. Now greatly improved tanks and lining materials have been a big factor in bringing the pickling operation back into the main production room. The more common types of tanks are wood, either lined or unlined, steel, masonry and concrete lined with rubber or the new synthetics. Each material may be used with a varity of linings. The wood tank is still commonly used because of its low first cost. A recent study of wood pickling tanks indicates that the expected life will range from 1 to 5 years, depending upon the way the tank is made and upon the nature and temperature of acids used. Usually wood pickling tanks require much repair and maintenance and, in addition to this, they leak.

A leaky tank not only causes a direct loss of acid but is a source of much indirect loss. First, it causes damage to floors and surroundings, and second, and more important, it creates operating inefficiencies and, as mentioned, necessitates an isolated location. Wood tanks with lead linings have proved successful in many installations where the operations are of a jobbing or intermittent character. Lead linings in steel tanks have the disadvantage that if a seam opens up or the lead is punctured the acid may fill the space between the lead and the steel and may practically ruin the tank before the leak is discovered.

Masonry construction is often highly satisfactory, but it is hard to install and when cracks develop they are difficult to repair. One of the good designs consists of two 4-in. courses of acid-resistant brick with a layer of asphaltic material between them. This is expensive but, when properly installed, is satisfactory at almost any temperature or concentration of acid. The usual rubber linings have a short life at high temperature, but where the maximum temperature is below 150°F. they offer many advantages. If punctured, they are easily repaired, and they may be vulcanized intimately to a steel or metal surface.

This means that, in case of a puncture, the acid is limited to one spot and therefore eats a hole through the metal container and so is discovered before much damage is done.

New Materials for Tanks.—Some designers of pickling equipment have now turned to the simplest of all types of construction, a metal tank made of some resistant alloy such as monel metal without any lining or backing. The first cost of such a tank is high, but for certain processes it has offsetting advantages. One of the disadvantages is heat dissipation when high temperatures are used.

New materials for pickling tanks are constantly appearing, so that the best construction one year may not be the best the next year. It is important for the manufacturer who contemplates buying pickling equipment to keep in mind that the first cost is the least of his troubles. A poorly located machine or a leaky tank will offset the initial economy in a surprisingly short time.

A quotation from F. E. Herstein, development engineer of the General Ceramics and Steatite Corp., will illustrate what may be expected in the line of new materials for pickling operations.

> Chemical stoneware offers many advantages for the modern pickling plant. It is unaffected by corrosive agents other than hydrofluoric acid and strong caustic. Pipe and fittings, pumps, tanks, both cylindrical and rectangular, and special shapes made to order are available in chemical stoneware. In the last 10 years, ceramic bodies having greatly increased resistance to thermal shock and mechanical abuse have been developed. Chemical stoneware tanks for handling corrosive solutions are made in one piece, thus eliminating the seams and joints that are necessary in other types of construction. These tanks have rounded corners and a smooth bright acidproof glazed surface that makes them easy to clean. A judicious use of chemical stoneware will solve many corrosion problems in metal-finishing plants.

Special Machinery.—Automatic machinery has been developed for pickling nearly all products that have sufficient mass production to warrant the expense.

A rotary drum type of pickling and cleaning apparatus has been developed for medium-sized stampings such as conduit boxes. This consists of a series of six or more tanks, in each of which a drum is partly immersed. The drums are all mounted on a large central hollow shaft that provides the means of conveying the parts progressively forward from one drum to the next.

A semiautomatic pickling, cleaning and acid-dipping machine of the hopper type has been developed for knife, fork and spoon blanks and other similar articles. This machine usually operates in conjunction with a continuous hopper chain attachment that carries the parts through a drying oven.

Elaborate automatic cylinder type machines have been built for descaling brass and other stampings after annealing. In one particular case the apparatus includes a chain device that carries a series of wire screen cylinders, containing the parts, through the required pickling and cleaning solutions. The equipment is provided with automatic electric control so that the travel of the cylinders is periodically stopped to permit loading and unloading at opposite ends of the machine.

Large work calling for mass production, such as fire-extinguisher shells, is handled through the pickling operation on a tray type of machine in which the principle is similar to the cylinder type except of course that the feature of the revolving cylinder in the solution is omitted in the case of the trays. If desired in the tray machine, agitation may be secured by submerged pumps.

Small electric-fan and motor parts are pickled before enameling in a full automatic pickling, cleaning and drying unit.

Pickling of electrical conduit requires an elaborate special construction when the operation is continuous through several processes. One machine has been built for an automatic continuous sequence through 17 different operations.

When production is of a less specialized character, that is, when many different parts are to be put through at one time, more simple equipment is available. Typical of such equipment is the batch-process rotary pickling machine manufactured by N. Ransohoff, Inc. One of these units includes a rubber-lined star return barrel with a rubber-lined tank underneath and an acidproof pump for circulating the solution over the work while the tumbling is taking place. By reversing the direction of rotation of the barrel the work is discharged and carried through a draining screen, after which it is subjected to a hot spray of basic cleaning compound. This washes off the tumbling sludge, neutralizes any remaining acids and at the same time brings the work to a sufficiently high temperature to dry of its own heat. The addition of stars to the tumbling process enables a weaker acid to be used, since the acid loosens the scale which is then removed by the the action of the stars, leaving the work with a bright and silvery finish.

Fastenings and Crates.—When wood tanks are used, it is important to have the bolts and fastenings made of a material that resists acids; in fact all miscellaneous equipment that comes in contact with the pickling operation should be studied from the point of view of corrosion either from direct contact or from fumes. Some of the features of tank hoods and continuous equipment have already been described. In the use of general open tanks much special handling equipment is often required.

Surprising economies in handling through the pickling operation may be made by using the proper type of crates and containers. The American Rolling Mill Co. successfully uses a crib type of lead-lined wood tank built by the Hauser-Stander Tank Co. Williams & Co. uses chains made of monel metal for handling bars in and out of boiling sulfuric acid. The Union Steel Products Co. uses metal pickling crates built of angles and flats at its Albion, Mich., plant. A large monel-metal cage is used by a firm in Great Britain for holding hollow metalware as it is revolved and agitated in a pickling bath. One feature of this cage is the use of expanded monel sheet as a lining.

Pickling Solutions.—Some of the standard pickling solutions have been described, and the value of inhibitors has been suggested. The subject is so extensive and the number of variables in each case so great that only certain broad principles can be indicated here. In most pickling there are losses, and these should be carefully balanced one against another in the analysis of each case. There may be a loss of base metal, but the speed of the operation may cause an over-all saving to compensate. The use of an inhibitor is almost always advisable, but in some cases and with some inhibitors the saving in acid and base metal is offset by the attendant production delay. Some electrochemical descaling processes are said to avoid loss of base metal without introducing disadvantages to balance.

In addition to the large number of commercial inhibitors available, some humble products such as flour and yeast are often used to advantage. Another common product, salt, is sometimes added, not as an inhibitor, but to improve the quality of the work. Sulfuric acid reacts with the salt to form hydrochloric acid, and the presence of both acids in the bath helps in particular cases. A typical average proportion is 0.2 lb. of salt to 1 gal. of water.

The strength of a pickle bath is a highly important factor in the over-all economy. Picklers often taste a solution to determine its strength, but at best this method does not indicate the amount of ferrous sulfate in the bath.

The rate of evolution of gas is another makeshift strength indication. Simple strength-testing outfits for pickle baths are inexpensive and provide adequate means for intelligent operation.

Many ingenious devices have been built to regulate automatically the supply of acids and other agents in pickling baths. Proportioneers, Inc., is one company that has designed and built such equipment.

CHAPTER XII

ABRASIVE CLEANING

Sandblasting is usually associated with foundry operations, but in recent years this method of cleaning has been gaining favor in many other branches of the metalworking industry. The costs of blast cleaning have been greatly reduced by careful analysis of the variables involved, by the design of new equipment and by the development of processes that cut handling to a minimum.

In special cases, as where specifications call for the cleaning of only the margins of steel sheets, it has been found advisable not to purchase full-pickled sheets for the job but to buy hot-rolled sheets and blast clean the edges.

Those who have investigated the general practice of blast cleaning in the United States have found that relatively few manufacturers have kept accurate cost records and that hit-and-miss methods are frequently applied to determine the size of nozzles, the air pressure, the size and kind of abrasive particles used and the character of the material-handling equipment. A comparatively few fundamental considerations stand between high cost production and profitable operation in blasting processes.

Sandblasting Defined.—The term "sandblasting" is commonly used to describe the application of an abrasive material under pressure to surfaces to be cleaned or otherwise treated. Even when steel grit is used as the abrasive, the term sandblasting is frequently retained. Compressed air, almost universally today, furnishes the blast power. Steam is occasionally used, and a centrifugal process has met with some success.

Some of the factors governing efficiency of general sandblasting are distance of the nozzle from the work, angle of the nozzle with the surface to be cleaned, character of the work itself, size of nozzle, kind of abrasive and air pressure. Several of these factors in combination govern the amount of abrasive flowing, the amount of power required and the quantity of work accomplished.

Changes in one factor, as, for instance, the nature of the work, indicate changes in other factors. To illustrate: A miscellaneous group of forgings would not be cleaned with the same nozzle angle as that used for cleaning a flat sheet. It is impossible

FIG. 30.—Miscellaneous forgings are prepared for an enamel finish in this modern sandblast machine.

here to give detailed specifications governing different conditions. General practice on flat surfaces, however, indicates an average distance, from the nozzle to the work, of about 8 in., with the nozzle held at an angle of about 40 deg. to the surface to be cleaned.

Scope of Application.—The sandblast now touches almost every phase of metal finishing. It enters into the production of bathtubs, beer barrels, crankshafts, small tools and hundreds of other products. Telephones, the minute drills used by dentists, automobiles and railroad cars, all may find applications of the sandblast in some process of their manufacture.

As is the case with pickling equipment, sandblast equipment has undergone radical changes during the last few years, and blasting machines suitable for production-line use are now available. The resistance to the purchase of elaborate equipment in the sandblast field is high because most users are familiar with the fact that they can merely attach a nozzle and an abrasive reservoir to a compressed-air line and clean a surface. Dust is an annoyance, to be sure, but its actual cost to the manufacturer is seldom appreciated. Similarly, the user too frequently overlooks the cost of operating inadequate blasting equipment, which mounts with surprising rapidity.

This may be illustrated by a few actual cases. An engineer made an analysis in an Ohio foundry. He first listed the material cleaned, that is, the quantity and the weight of each item. He then listed the labor, the cost of air and the cost of abrasives. Comparing his unit costs thus obtained with standard costs that he knew were obtained elsewhere, he found that the cost for many kinds of castings was far too high, and this indicated the advisability of separating the work so as to handle part on one type of equipment and part on other and more suitable apparatus.

A 12-ft. diameter rotary table was recommended for much of the small work. The installation of such a table made it possible to use a conveyor system, and eventually a saving of more than $21 a day was effected. Such a table has a first cost of about twice that of a good blast room, but, when conditions are favorable, a rotary table may pay for itself in a comparatively short time and, in addition, may effect a saving in floor space.

A Southern stove manufacturer cleans gray-iron castings for enameling. Here also a room was used, but, as production was increasing, some new equipment was necessary. A 12-ft. table here also was recommended, but to save initial expense an 8-ft. table was installed. After 6 weeks the 8-ft. table was shipped back and the recommended 12-ft. table installed. Just as serious a mistake of course may be made by purchasing too large a table for the service required. An idle machine is also an expensive machine, and too large equipment is either operated inefficiently or else must remain idle part of the time.

Equipment.—Most minor difficulties have now been ironed out of all standard blasting equipment. Common practice is to control the sandblast pressure tank with a single lever convenient

FIG. 31.—Stove parts at the plant of the Florence Stove Co. are prepared on a high-production basis for enameling on a rotary table sandblast.

to the operator. Normal equipment includes an automatic device for refilling the tank whenever operation is stopped. Thus this feature is incidental to operation without loss of time. In a blast room, ventilation is from air inlets in the ceiling, and the dust is carried off through openings at the floor level. It is common practice to use floor gratings with small openings so that such items as fins, wires and gaggers are kept out of the reclamation system.

For work within its range, a sandblast barrel provides the cheapest method of sandblast cleaning on a mass-production basis. A sand barrel, however, must be rugged to stand up under the severe demand made upon it. The load that is being cleaned is in constant movement, and thus for efficiency the cost of equipment and the speed of cleaning must be carefully balanced. Often it is advisable to use more barrels, rather than try to force those in operation. Many different types of

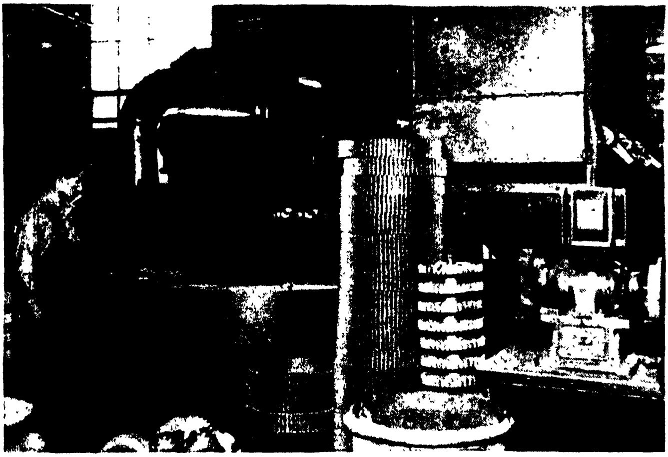


Fig. 32.—This shows a method used for blast cleaning of heat-treated finished gear rings and other similar parts. Note the compact arrangement of table, abrasive storage tank and operating controls.

barrels are available. A perforated one-piece drum offers no lodging place for thin edges or coarse refuse. In New England one company operates 19 barrels, each with a capacity of a ton load and equipped with nozzles with double adjustment so as to bring the abrasive action at the most effective place.

Abrasives.—The abrasives are the cutting tools of the cleaning process, and therefore the correct selection of abrasive is important in determining low cost. The type of finish desired also governs the selection of abrasives to some extent. Thus sands produce a so-called "matte finish." Ordinary bank or building sands are of little value. Ocean sands are much used, but a carefully selected and prepared white silica sand has greater resistance to disintegration, creates less dust and enables faster cleaning.

Sand is graded into about four sizes. The smaller sizes are more frequently used for cleaning sheets and rolled forms of brass, bronze, aluminum or steel. Each time the sand is run through the blasting process, a part of it, usually 15 to 20 per cent, disintegrates into dust. Therefore, in order to recover the good sand it is necessary to have a storage and reclaiming system. Most sands used for sandblasting weigh approximately 97 lb. per cu. ft.

Steel Shot and Grit.—Steel abrasives are a cupola product and are available either in the form of round shot or in grit, which is merely shot that has been crushed. Steel abrasive is subjected to heat-treatment to give added strength and durability. When shot is used, the action has more of a peening effect and does not produce the matte finish. The action of steel grit, on the other hand, may be controlled to approximate that of sand. The average weight of steel abrasives is 197 lb. per cu. ft., or approximately two times that of sand.

Experience indicates that the weight of the abrasive rather than the size of the grain should determine the selection. Thus a much smaller steel particle should be selected to do the same work as the sand grain. Manufacturers familiar with sand in blasting, who switch to steel abrasives, are apt to select too coarse a grade.

Steel vs. Sand.—Opinions differ as to the relative merits of sand and steel. Undoubtedly each type of abrasive may have advantages over the other, and so general results without full details may be misleading. One of the largest electrical manufacturing companies reported the cost of abrasives, when cleaning with sand over a period of a full year, as 46 cents per ton of castings shipped. The following year, with a change to steel abrasives, the cost per ton of castings dropped to 23 cents.

Because of the high initial cost, steel abrasives are generally better suited to larger operations where the entire mass of abrasive can be reclaimed for repeated use. Some other advantages and disadvantages may be stated. Sand has a lower first cost, maintains its characteristics better in storage, has the property of absorbing moisture, which is often an advantage, and imparts to the work certain colors and finish characteristics difficult to duplicate with steel.

Some manufacturers use a small percentage of sand mixed with the steel, merely to get a silvery or aluminum finish.

Steel abrasives alone almost universally give a dark color to the clean surface, and this again is often a misleading factor because those familiar with sand cleaning may be deceived by the dark effect produced by the steel abrasive and thus may apply the blast longer than necessary. Factors that should be considered in selecting abrasives are cost at shipping point, relative life, freight cost, handling cost and cost of dust suppression and removal.

There is comparatively little difference between any of the usual standard abrasive sands, but in the matter of over-all cost, steel shot and steel grit usually show up favorably in comparison with sand.

Sand is composed of many minute crystals held together by a common bond. Impact disintegrates these crystals until all cleavage lines disappear and the abrasive becomes useless. Steel, on the other hand, is a solid, relatively homogeneous mass which does not disintegrate or break up under impact. Instead, it wears away. It is reduced in size only after continual use averaging hundreds of times.

Handling Equipment.—For preparing the surface of cast iron for enamel, the general practice is to use a sandblast with silica sand as the abrasive. Increased efficiency in this connection may be secured by eliminating all unnecessary handling. This means straight-line conveying from the foundry through the sandblast to the enameling spray booth. Racks and containers should be of such design that they fit in the production practice of each department.

The proper timing for delivery from one department to another is important in order to cut down waste motion. One company has found a method of reducing its blast expense by using old castings, which are to be reenameled, as a backstop for green castings during the blast cleaning. In this way rebounding abrasive from the blast operation is utilized for the preliminary removal of the enamel on the backstop castings.

Cleaning Sheet Metal.—The blasting process is being used successfully to clean sheet-metal surfaces for wet-process enameling. Parts such as washing-machine tubs and refrigerator liners are given a chemically clean surface by using steel grit, which is said to eliminate one operation, as against the practice of pickling. A record from a large refrigerator manufacturer gives a general idea of this particular process. The investment was $4000, and the production was two hundred 5 cu. ft. condensers per day. The air pressure was 80 lb. and the nozzle opening 1⅜ in. The total daily cost was about $47, or 23 cents per piece. Of this total the abrasive cost was $10, the labor cost $13 and the air and power cost $19.

The extension of blast cleaning outside the foundry is prominent for removing scale from forgings, billets and alloy-steel parts. One particular advantage is that the equipment can be easily placed in the line of production, and under proper conditions there is no residue left on the clean surfaces that will hinder subsequent operations; also, there is no appreciable loss of metal. An important feature in connection with the manufacture of parts for airplane engines is blast cleaning for inspection purposes. Cracks and faults of any kind show up much more easily after cleaning.

Centrifugal Cleaning.—Centrifugal cleaning of metal surfaces at the Inland Steel Co. uses a so-called wheelabrator for removing scale from billets that later are rolled into bumper stock for automobiles. The wheelabrator has been installed for many services, including cleaning sheets for galvanizing, cleaning the edges of skelp for making electrically welded pipe and, in fact, for almost any cleaning operation ordinarily handled by pickling or sandblasting.

The wheelabrator gives directional control to discharge the abrasive over the exact area desired. In previous attempts to use centrifugal force to discharge abrasive against surfaces to be cleaned, the action of the abrasive has quickly destroyed the wheel. In the successful use of this equipment a combination of centrifugal, tangential and air-dynamic forces is used.

PART III

POLISHING AND BUFFING

CHAPTER XIII

POLISHING IN INDUSTRY

Metal polishing usually pays big dividends in added sales value, yet the art of polishing is complicated, largely unstandardized and often much more costly than necessary. Why should metal products be polished? To answer this question with some degree of thoroughness would require (1) a definition of polishing, (2) an analysis of the buying habits of people, (3) a review of the many practical values of polished surfaces and (4) a discussion of some basic manufacturing costs and principles.

A sales manager of a machine-tool company once stated that competition in the commercial field usually determined the degree of finish applied to a tool or to a metal part. This is undoubtedly often the case, yet there must be some limit or some point of maximum sales appeal. The manufacturer of a wrench might develop a higher gloss finish than that of a competitor, but a third wrench maker might find a still better sales value with a new dull matte finish.

No final or set rules for sales value of finish have been established, and probably none can be, because style is an important factor, and style changes. A few generalities may be given:

1. Suit the finish to the product. Too high a finish on a mechanic's tool may be as poor policy as too dull a finish on a vanity-case mirror.

2. Make use of color and contrast. A dull handle may enhance the value of a polished shank.

3. Novelty is an important attention-getter. Any too well-established routine of finish is dangerous and needs careful watching.

Terms Defined.—The term "polishing" frequently is applied to three distinct processes—flexible grinding, polishing and buffing. All three of these, in contradistinction to grinding and lapping, are not precision processes.

Polishing is defined as a process of brightening metal surfaces by means of a somewhat flexible or resilient wheel coated with abrasives. Its purpose is chiefly appearance. Yet this definition does not always hold, for sometimes the abrasive wheel is omitted. For instance, wire is polished by drawing it through a clamp containing abrasive material.

FIG. 33.—Carefully selected No. 36 alundum abrasive grains. Note the jagged surface of each grain and the uniform size.

Buffing also is a process using abrasives and flexible wheels, but it is distinguished from polishing by the fact that the abrasives are fed onto the wheel during the operation, whereas in the case of polishing the abrasive agent is glued to the wheel before use.

In practice there are other distinctions. The wheels used in buffing usually are made of muslin disks fastened together, and the abrasive is usually finer than No. 220, while the grain sizes used in polishing vary from about 120 to 220.

Buffing is most frequently used to produce luster on plated surfaces or on nonferrous metals. Polishing is used for final finish on such items as shovels, kitchenware and machine tools; in addition it is used as a preliminary operation for most buffing and, as a matter of fact, for most metal finishing of any character.

Polishing and buffing are so closely associated that the processes overlap and the terms are not well defined. A mixture of glue,

FIG. 34.—Gears and other mechanical parts are usually given a high polish for utility reasons rather than appearance. (*Courtesy of The Lea Manufacturing Co.*)

tallow and fine emery is offered in tubes as a compound to use on buffing wheels. When this is used for luster work, it violates many of the features of buffing and yet is called buffing.

The Polishing Industry.—The manufacture of buffing and polishing wheels before the war ran to approximately $5,000,000 a year. This was exclusive of abrasives and compounds. When it is considered that the cost of the wheel is only a small part of the labor and expense of polishing, some idea of the extent of the whole industry may be had.

Yet conditions within this particular branch of metalworking are not up to the standards of some other branches. The polishing industry, in general, is in a state of chaos. "Costs are altogether too high, mechanical operations are often performed in a crude and inefficient manner and standardization is conspicuous by its absence."

For some reason or other, most manufacturers in the metal industry seem to be much more keen on devoting time and money to developing other sections of their manufacture, and the polishing room is left as the "Cinderella" of the works. It is of course, one of the most expensive factors of production in many manufacturing plants and would yield great economies if properly brought up to date.

These statements if taken seriously should have the effect of focusing the attention of manufacturers on their polishing operations. As indicated in other chapters, all finishing processes should take their places in the production line in efficient high-output operation. In spite of the lack of standardization in polishing generally, equipment is not lacking for automatic and semiautomatic processes of specialized character, and individual practice of a high order is to be found in nearly every classification of polishing.

Seven Classifications.—Nearly all polishing and buffing is done for one of the following seven reasons:

1. To give better sales appearance. This includes much of the polishing on miscellaneous products from razor handles to automobile bumpers.

2. To give better wear. Examples are automobile flat-leaf springs and textile parts.

3. To give resistance to corrosion. This includes sheets, rods, certain instruments and some machine parts.

4. To give mechanical smoothness. Examples are shovels, needles and textile parts.

5. To give an impervious surface. Inside surfaces of kitchen dishes and food containers come under this head.

6. To facilitate inspection. Cracks, especially in forgings and castings, show up more readily after grinding.

7. To prepare surfaces for plating, enameling, etc. Nearly all metal surfaces to be plated are first ground and polished, but they are buffed after plating, and the second operation comes under the heading of sales appearance.

Preliminary Consideration.—The character of surface treatment varies to a large extent with the classification under which the polishing falls. If the edges of a casting are to be kept square and true, the polishing technique must be adjusted accordingly. Many details must be considered in working out the proper wheels and methods before any production polishing operation. A few typical questions are asked by Divine Brothers Co. of customers who come to them for recommendations.

Of what material is the part made?

What is the character of the original surface to be finished: machined, cast, pitted?

What character of surface is required on the finished pieces?

Must these be held to accurate dimensions, as for machine parts, or mirror finished on bare metal, or finished prior to plating, painting, japanning, etc.?

Must flat surfaces be kept approximately flat?

What quantity of production is required per hour, per day or per week?

Can the shape of the part be changed slightly to permit more economical finishing?

If initial and final profilometer limits are required, so state. Tell us the hardness of the material if available.

Design for Polishing.—One authority on polishing has said, "Polishing begins in the drafting room." Wheels of large diameter are more economical to use than wheels of small diameter. The article to be polished should be designed, therefore, to eliminate all unnecessary projections, depressions, angles, recesses or reverse curves, which can be polished only with narrow or small wheels at excessive costs. Usually the cost of any extra metal or machining involved in the altered design can be more than offset by the saving in polishing.

A 16-in. wheel presents over 12 in. more of surface to the work than does a 12-in. wheel; it therefore has more time to cool, and its operation is correspondingly better.

For some types of finish a surface that comes from a milling machine will be easier to buff than if it came from a face grinder. In this case design may play a part, but the scheduling of preceding operations is the chief factor.

Preceding Operations.—The cost of correction in the polishing department usually exceeds the cost of correction in the department where the incorrect condition originates. There is often continual strife between the polishing and other departments on this point, whereas care in planning would prevent such conditions. This is one of the underlying causes of the high cost of polishing.

An example of what can be done to help polishing by a study of previous processes is the experience of an ax factory. The forged ax when it left the dies was true to contour, but with an extra thickness of metal to allow for grinding off the scale. The

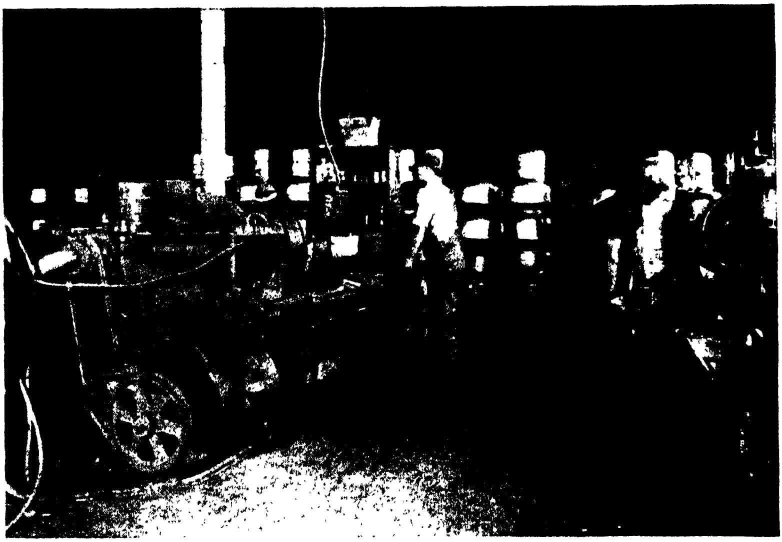


FIG. 35.—A view of a buffing plant, showing two buffing machines used to polish monel metal tubs used in washing machines.

solid-grinding operation to remove the scale destroyed the contour and left the surface in scallops or waves. It required at least three operations, which should not have been necessary, to restore the contour and prepare the surface to take a polished finish. The installation of a cheap and simple process for removing the scale while the metal was red hot eliminated the solid-grinding and several polishing operations and greatly reduced the cost of finishing.

The polishing department receives work either rough or with a machined surface, and when castings are to be polished without previous operations care should be taken to see that sprues, ragged edges, lumps and surface defects are removed; for independent of any trouble these features may cause, the cost of removing them in the polishing department is excessive. With forgings, it is good practice to pickle or sandblast before polishing. Deep tool or grinding marks necessitate the removal of too much metal when the polisher is called upon to reduce the entire surface to the level of the bottom of such marks. Where scratches and drawing marks appear on stampings or drawn work, the labor and expense required to correct the dies or otherwise eliminate the cause of these marks are well justified by the over-all saving. To sum all this up, work should be delivered to the polishing department in a condition that will make it unnecessary for that department to correct the errors of other departments.

Smooth Rolls Make Smooth Sheets.—One rolling superintendent has said that it is better to put the work of finishing on the rolls than it is to try to put it on the sheets. The first case accomplishes the result with less expense. Often the difficulty may be traced back of the rolling to the furnace. Clean material of proper analysis in the furnace is essential to the production of a fine finish. Some material that is properly rolled and properly polished will have many pits, and, when these are polished away, more pits will appear underneath. This is due to defective structure of the material itself.

The cost of polishing sheets is dependent upon the efficiency in rolling the sheets. A better set of rolls will give a better finish and will materially reduce the cost of polishing. Often a polishing engineer will be called in to correct trouble with abrasives or polishing wheels only to find that the trouble is actually with the base metal or with preceding operations.

Polishing at Mills.—The arrival of stainless steel stimulated polishing at the steel mill, and the trend today is toward more and more finishing of material at the source. Polished rolled-metal products are now fairly common raw materials for the fabricator.

Steel sheets are polished at steel mills for appearance and a somewhat increased resistance to corrosion. This operation frequently is performed on either Schulte or Mulholland machines of established character. The sheet is held on an oscillating table while an endless belt passes over a small, revolving flexible roll.

The belt is coated with abrasive, which is thus brought into contact with the sheet.

Polishing is sometimes used to remove scale, in which case a relatively rough polishing wheel is used. Stainless-steel sheets at the mill, after coming from the last rolling operation, are pickled, rerolled and then polished. The pickling leaves the sheets pitted, the rerolling tends to reduce the depth of these pits and the polishing removes the balance of the pits. The polishing

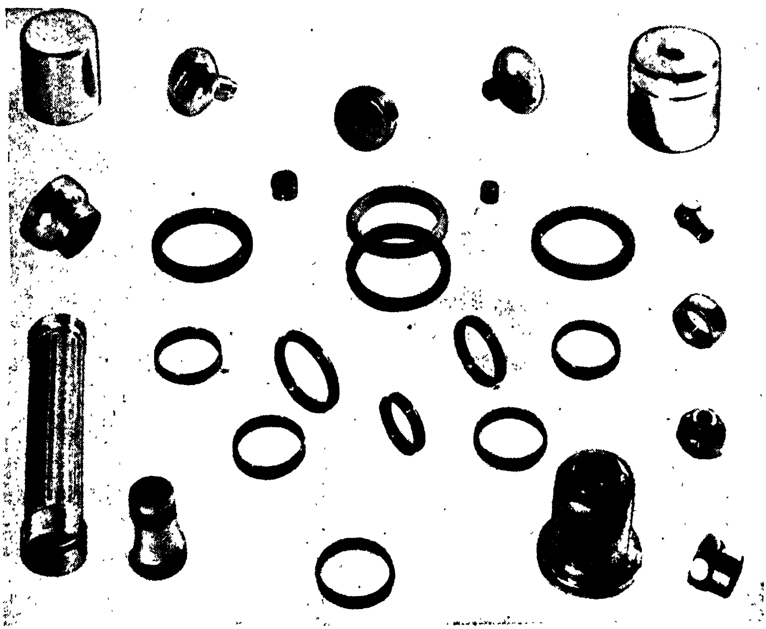


Fig. 36.—Products polished on automatic equipment on a quantity basis at low unit cost.

of stainless-steel sheets is usually a dry operation, using alundum No. 80 or similar abrasive, but practice varies.

Sheets of average size, say 120 by 50 in., are polished in 20 to 30 min. at one plant. The operation here is a dry one, using No. 80 grain. After this, for certain high-grade work, a further polishing using No. 120 grain, still dry, calls for an additional 15 min.; if a still better finish is required, another operation is added, using No. 120 grain with grease—usually a mutton tallow. For a buffed finish the manufacturer adds several other polishing processes, using successively No. 150, 180 and 220 grain and then transferring to buffs.

Electrolytic Polishing of Metals.—During recent years, a vastly increased interest has been evident in a new method of finishing metal surfaces, namely "polishing" by electrolysis. The work to be polished is made the anode in a suitable electrolyte which is so compounded as to produce finishes of various appearances ranging from a white matte up to a high polish.

This process has proved effective for finishing a variety of metals: 18-8 stainless steel, 17 chrome stainless, 12 chrome stainless, nickel and nickel alloys, aluminum and aluminum alloys, straight carbon steel, ferrous alloys with no graphitic carbon and several other metals and alloys. The work usually calls for no pretreatment and needs only a cold running-water rinse after coming out of the bath.

Work with a heavy annealing scale should be descaled before electrolytic polishing. This is done by making the work the anode in a bath of 55 per cent sulfuric acid, 10 per cent hydrofluoric acid and 35 per cent water. As portions of the scale are removed, clean metal is exposed to the electrolytic action of the bath and becomes passive, passing very little current. As a result, the current is concentrated on the parts that are not yet descaled. The total current remains approximately the same; consequently the current density is greatly increased on the areas still covered by scale accelerating the descaling action considerably toward the end of the operation. When all of the scale is removed, the current drops off to a very low value. The surface is then highly amenable to receiving a high luster when later electrolytically polished. The pitting that may be produced by ordinary pickling does not occur.

In the electrolytic polishing bath, when metals dissolve anodically, a film may form on the surface of the anode. The film may be a gas or a layer of a liquid highly concentrated on the anode (the work); or it may even take the form of a partially or even completely insoluble salt. The film may have high resistance to the current. In that case, the film on a surface with minute elevations (such as in scratched or pitted metals) will be thicker in the depressions than at the elevations. As a result, the current density is higher at the less protected elevations and lower in the protected depressions. The points of higher current density are removed and the entire surface of the metal becomes flatter and smoother; the sharp irregularities in the surface and the sharp corners become rounded off.

Another phenomenon usually occurs in the properly formulated electrolyte, that is, polarization which sets up selectively higher resistance to the current. Under such circumstances, electrolytic polishing will also result in the removal of elevations on the surface of the work. However, it will occur only if the rate of solution of the elevations is greater than that of the depressions; that is when the depressions are relatively passive and the elevations relatively active because of the difference in the concentration of the anode film.

Electrolytic polishing is covered by a number of patents. It has not yet been developed to a point where it can replace hand polishing, but is useful on work that is difficult to polish by conventional methods.

CHAPTER XIV

WHEELS AND MATERIALS

Two men were talking, one a manufacturer of building hardware, the other an industrial engineer. After listening to the manufacturer's account of high production costs and general business difficulties, the engineer said, "I think I can locate your trouble. It is in your polishing department." Later, when asked why he had hit upon that particular spot without having even seen the plant, the engineer admitted it was because polishing was the "best bet." In other words, a man looking for an opportunity to lower manufacturing costs would have more chance of success in the polishing room of a metalworking plant than in almost any other department.

In any finishing operation a factor other than production cost enters, for here a poor job may mean reduced sales appeal and thus the penalty for inefficiency is multiplied.

Wheels as Tools.—One of the most important features in the whole polishing process is the conditioning of the wheels, for the wheel is the polisher's chief tool. As already pointed out, a typical polishing wheel consists of resilient base onto which a "head," or abrasive coating, is applied. The coating wears down rapidly in use, and therefore the wheels must constantly be reconditioned.

Different manufacturers have different methods, but almost always added attention to the conditioning of the wheels means increased production and lower over-all cost. In the polishing department the wheel room is in a sense the toolroom. This means that the care of wheels should at least equal the standards set in a good tool department.

Undoubtedly one of the big handicaps in the whole realm of polishing is the fact that even experienced operators are inclined to overlook the importance of proper selection and care of wheels and abrasives. New wheels usually are given special care to get them started right, and where there are several men in the conditioning room, the most experienced one is given the job of starting off a new wheel on its life of service.

One manufacturer has the practice of truing new wheels on a lathe and marking them with an arrow to indicate the direction of rotation. Each wheel as it is removed from the lathe is coated with a thin sizing of glue brushed on in the direction of the nap of the wheel. Glue is also applied to the sides of the wheel to prevent grease and oil from penetrating during subsequent polishing and handling. A base for the abrasive is then prepared with a

FIG. 37.—Material handling is an important consideration in nearly all polishing. Here operators of double-disk polishing machines are served by roller conveyors.

heavier coat of glue, and the abrasive grains are rolled into this base by the usual hand method.

Applying Abrasive.—This particular rolling operation calls for a great deal of skill and experience on the part of the operator. Small metal troughs are used to hold the abrasive grains, one trough for each size. These troughs are slightly wider than the width of the widest wheel to be coated, and the bottom of the trough forms the arc of a circle of considerably larger radius than that of any of the wheels.

Each freshly glued wheel rests on a short shaft through its bore. The operator takes hold of both sides of this so that the wheel itself is free to revolve between his arms. He then rolls the wheel back and forth in the trough until the entire surface has been coated with the abrasive. In this operation all the many variables must be correct in order to give the most satisfactory job, that is, the temperatures of the wheel, the glue and the abrasive must be held within close limits, and the time interval between the gluing operation and the rolling in of the abrasive must be regulated. It is almost as bad to roll abrasive into too fresh a surface of glue as it is to try to apply the abrasive after the glue has set.

Cleaning Old Wheels.—When used wheels are to be coated, the practice is somewhat different. If the surface is deeply pitted or covered with excessive grease or oil, the head is usually soaked off in hot water. If the wheel has been worn through the under, or sizing, coat, it should be resized with a mixture of thin glue and fine abrasive.

In any case the wheel is usually trued up with a carborundum or similar brick which is rubbed across the face and edges while it is revolving. It is sometimes advisable to remove oil and dirt on the face of a wheel by scrubbing with gasoline and then thoroughly drying. After the wheel has been prepared, the practice of coating with abrasive is similar to that in the case of a new wheel except that often fewer coats of abrasive are required on an old wheel.

One manufacturer recommends a temperature of 120°F. for the abrasive applied to old wheels and a temperature of 110°F. with new wheels. This is because practice has shown that the heat conductivity is greater in the case of the old wheel.

Operators usually have a flat steel table close to the abrasive troughs in which the wheels are rolled, and, after coating, the wheel is rolled on the table to determine whether the coating has been sufficient. If glue comes to the surface as the wheel is rolled on the table, it is an indication that further rolling in the abrasive is required. Machines are now available for coating wheels with the abrasive under conditions giving an accurate predetermined pressure and time.

Coating Practice.—Most manufacturers seem reluctant to change to machines in this particular field, and hand coating of polishing wheels with glue and abrasive is still the prevailing practice. In some large shops the equipment in the glue and coating room is elaborate. The room itself is glass enclosed, is dustproof, has its own humidity and heating system and is conveniently arranged. The equipment may include recording thermometers, humidity instruments, glue-density indicators, scales, sieve grading machines and elaborate conveyor devices, in addition to the more standard items such as steel table, drying ovens, electrically heated abrasive pans and gluepots.

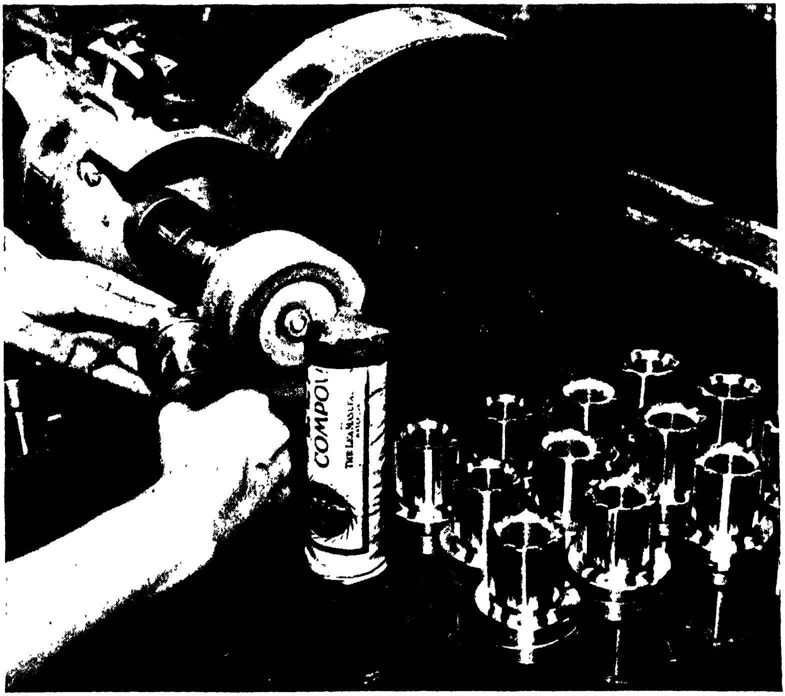


Fig. 38.—Plated steel parts are efficiently polished on buffing stands such as this. (*Courtesy of Lea Manufacturing Co.*)

One manufacturer gives the following instructions for putting the final coat on wheels:

The wheels should be heated to 120°F. in a warming closet to prevent glue chilling. A brush of a width proportional to the wheel thickness should be used to apply a large quantity of glue from a near-by glue pot. It is important to cover evenly the same amount of area of the wheel with each brushful of glue, as it is this point that determines the uniformity of the head when finally coated. The operation should be done rapidly to prevent jellying of the glue. After the final coat of abrasive has been rolled onto the wheel and the wheel itself has been cured, it is important to give the wheel a true balance by the use of lead washers or some similar device. Balance is important to prevent pounding in operation and resultant nonuniform finish.

Selection of Wheel.—In polishing as in grinding there is one particular type of wheel and abrasive for each job. Opinions may differ as to some of the characteristics, and with different types of wheels different abrasive characteristics are sometimes called for. In the final analysis it must be the experience of each individual shop that determines the selection. The head of the polishing department should understand, however, that varying wheel conditions give varying results, and he should not assume that any one wheel is best until he has tried others.

Some of the variables to be considered in polishing are speed of wheel, pressure of wheel against work, character of the base metal, character of the wheel, that is, whether of canvas, leather or other material, rate of feed of material, size and shape of grain, type of glue and nature of lubricant.

Abrasive Characteristics.—Artificial abrasives are usually selected for the preliminary polishing operations. The so-called roughing or dry-finishing operations include the use of grades up to about No. 120. For this class of service one advantage of artificial abrasive grains over Turkish emery, for instance, is that the artificial abrasive fractures when dull and thus constantly presents new sharp cutting edges. The edges of Turkish emery, on the other hand, are apt to wear smooth without fracturing. However, the very property of wearing smooth makes certain natural abrasives desirable for the so-called coloring operations which may be broadly designated as those using a grain size finer than No. 150.

Many details in connection with abrasive characteristics seem trivial to some manufacturers, yet tests have shown that accurately sized grain gave a 25 per cent higher efficiency than an abrasive grain with wider variation between particular diameters. The importance of the shape of the grain has already been mentioned. The shape affects adhesion to the glue, the character of cutting and also the action in the rolling trough. Grains of proper packing quality in the trough give more rapid adhesion to the face and prevent the necessity of pounding the wheel in the trough.

Care of Wheels.—The proper preparation of a polishing wheel is expensive, and for this reason many smaller manufacturers are inclined to slight some of the precautions. One plant that has kept costs over a long period of time has found that the total refinishing of a wheel 24 in. in diameter with a 4-in. face averages about 32 cents. This includes glue, abrasive, labor and incidental direct cost in the wheel room. On heavy polishing work

FIG. 39.—Abrasive grains are sorted through screen trays in a vibrating sieve which forms part of the careful polisher's equipment. (*Courtesy of Norton Co.*)

such a wheel has a useful life of about 1 hr. This same manufacturer cautions against drying wheels too quickly and states that in his experience a slow well-regulated heat sequence for drying prevents the glue from becoming brittle and materially adds to the wheel life.

Polishing Soft Metals.—A different technique is required for polishing soft metals, and because of the great variety of surfaces desired and metals encountered, no set standards have been established. The experience of one manufacturer of aluminum castings may be of interest. He uses 12-in. canvas wheels 2 in. in diameter operating at 4400 r.p.m., and after polishing with a series of wheels up to a fineness of No. 220 he buffs with tripoli cake to remove the polishing marks and then colors with a slacked-lime-composition cake. For finishing irregular surfaces of castings that do not require such a high gloss, this manufacturer uses flexible paper disks coated with abrasive. These disks are operated with a very slight amount of oil as a lubricant.

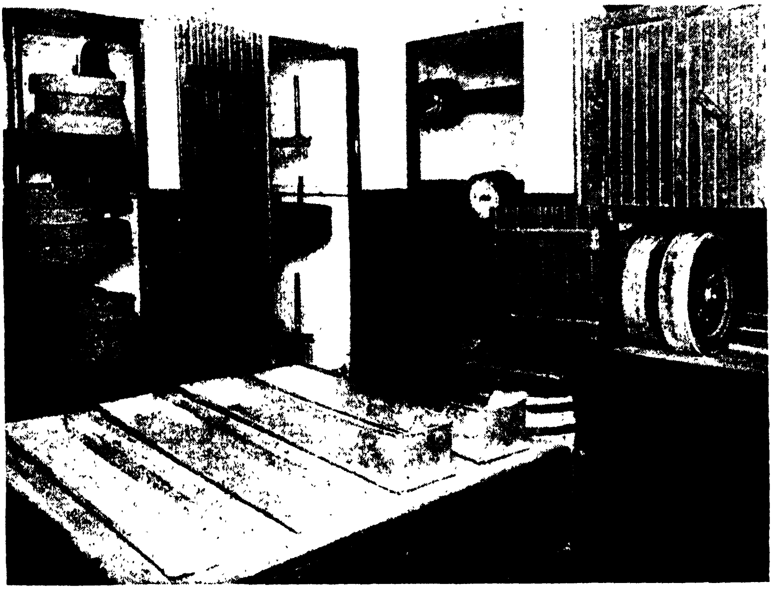


Fig. 40.—The proper care of abrasive wheels is one of the biggest factors in polishing costs. This shows a corner of the gluing room at the South Boston wrench plant of the Walworth Co.

An excess of oil is apt to stain aluminum, and this must be guarded against. Another manufacturer of soft metal products polishes with No. 80 alumina grit used dry and follows this with the sequence of No. 120, 150 and 180 grits, with a slight amount of paraffin wax as a lubricant.

Machine Polishing.—If the quantity is sufficient, nearly any product that is to be polished or buffed can be handled through this operation on an automatic machine. Automatic or semi-automatic machines can be adopted to reduce the cost of more than 50 per cent of the polishing in the metal industry. Such diversified items as thimbles, lamp reflectors, bicycle rims, wrenches, automobile springs, fender guards and axes are included.

In the case of one product, Stillson wrenches, difficulty was encountered in that the capacity of the machine exceeded the ability of one operator to load. This was overcome by providing an extension end table with a conveyor belt composed of indi-

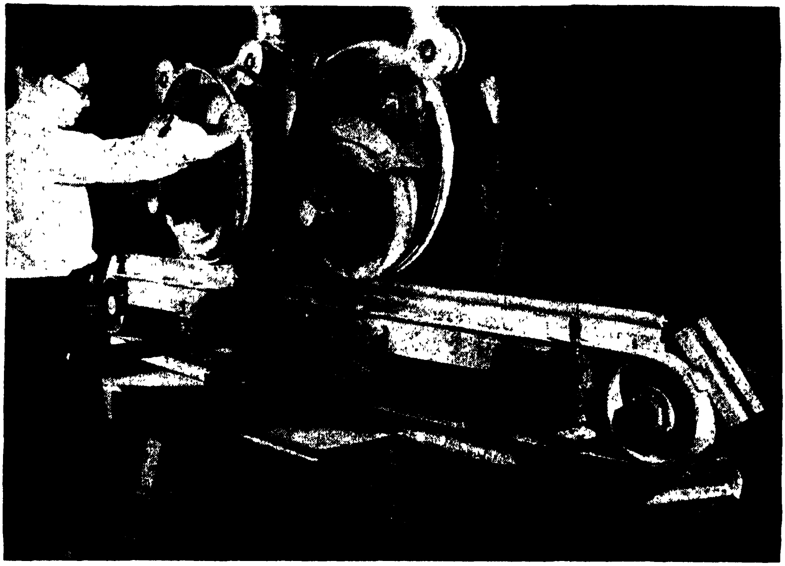


FIG. 41.—For polishing the inner surfaces of wheel rims an ingenious fixture was devised in which the rims were held against the polishing wheels by means of an endless belt with segments having an upper contour to match the outer concave section of the rims. Movement of this supporting belt causes the rims to rotate, thus bringing the full inner surface past the polishing wheel. (*Courtesy of Divine Brothers Co.*)

vidual jigs which were loaded by two men and were unloaded automatically as the conveyor passed over the tail pulley.

An interesting straight-line polishing machine is used to polish automatically the inner surface of bicycle rims. A standard machine was fitted with a track, and the rims to be polished were mounted in fixtures that held them in the proper relation to the polishing wheel at the same time that they rested on the track. The movement of the conveyor belt and its track caused the rim to rotate in the fixture while in contact with the polishing wheel and thus completed the polishing around the entire circumference. Formed face wheels were used, and two operations were necessary, but, except for the loading, the process was automatic.

Side frames of typewriters are automatically polished on straight-line machines with hard compressed-leather wheels. Here the proper design of the fixture was the essential feature. It was necessary to hold the piece rigid against the action of the hard wheel and at the same time to obtain precision in location so that the surface would be flat and true. In the case of automobile valve caps the quantity has been sufficient to warrant considerable special attention, and highly efficient hopper-feeding fully automatic machines have been designed for this service.

Increasing Use of Machines.—Automatic polishing is not new. A machine for polishing tea kettles automatically was developed 30 years ago, and the principle involved is still being used for this class of product. Recently, however, a new movement to extend machine operations in the polishing and buffing fields has appeared, and large manufacturers of products such as adding machines, typewriters and radios are installing long straight-line machines on which parts travel successively past polishing wheels of different grades and characteristics, until at the end they leave the machines with the desired finish.

This calls for ingenious jigs and automatic clamping and releasing devices. One adding-machine company has a straight-line automatic machine in which parts travel past five pairs of wheels. This machine alone replaces 31 hand jobs and reduces the labor cost of polishing of certain parts from $1.12 per 100 pieces to 6 cents per 100 pieces.

As automatic machines become more standardized, the errors of the earlier machines are gradually being eliminated. It is important, for instance, to have the contact between the work and the wheel of such a nature that it distributes the wear on the wheel. If a short bar with sides parallel to the direction of the travel passes under a wheel that is revolving in a plane also parallel to the travel, the wear on the wheel will be all in one place and the wheel life will be correspondingly low. By turning the bar at an angle with the line of travel, it is possible to distribute the wear over the full surface of the wheel.

Belts.—Maximum distribution of wear over the face of the abrasive surface is secured by having the line of travel of the work at right angles to the direction of the face of the abrasive wheel or belt, and this feature has led some designers to turn to a greater use of belts. This calls for great care in the application of the glue and abrasive to the belt. Some of the difficulties are discussed in the following chapter.

In the steel industry, belts are extensively used for polishing sheets, as already explained. Two methods for coating these belts with glue and abrasive are used. Where fine grain sizes are required, the general practice is to thin the glue to the proper

FIG. 42.—Two operators press a wooden block against an endless coated belt and in this way put a high polish on unusually large steel plates.

consistency for the particular size of abrasive used and then add the abrasive to form a paste that is spread evenly over the belt. In this method it is important to provide means of continuously stirring the mixture of glue and abrasive to prevent the separation of the aluminous abrasive, which has a relatively high specific gravity.

Two or more coats are usually applied to the belt. This method of mixing the abrasive and glue is known as the paste-head process and is obviously impractical with coarse grit sizes. Another method of coating belts is to apply the glue to the belt in sections and then apply the abrasive onto the glue by sifting. In this case the grains bond readily with the glue, if the surface of the individual grains is irregular or jagged so as to provide surface tenacity. Some large users of abrasive belts have developed mechanical means for applying the abrasive coating. In one machine for this purpose the belt to be coated revolves slowly through the coating zone. An electrical heating device heats the belt just before the glue is applied. The glue itself is heated and is spread evenly onto the belt by means of a roller. The abrasive particles that are held in a heated reservoir are applied by mechanically sifting onto the fresh glue surface, and the operation is completed by means of rollers that even out the surface of the abrasive and glue. On particular work large belts frequently require several days to cure, after which they are trued with silicon carbide brick.

Products Sometimes Redesigned.—Just as buffing compounds are adjusted to facilitate cleaning, so are the design and machining features of metal products altered to facilitate buffing. A case in point is the familiar electric flatiron. Here, because of a double curve, that is, an oval outline to the base and a varying curve to the cover plate, it was impossible to adapt this to automatic operation. After a conference with the manufacturers the oval feature of the base was eliminated, the irons being pointed as previously, but the outline instead of being oval was a modified parabolic curve with a slight continuously increasing width from nose to heel.

Sales and style experts claimed that there was no disadvantage to this new design. In fact it seemed to have some added attractiveness. Also by making this modification it was possible to put the irons on automatic machines and cut the expense of polishing to less than half, as against previous hand methods.

CHAPTER XV

DESIGN OF A POLISHING DEPARTMENT

Selection of Glue.—Pay a dollar a day more for your glue, and save $100 a day in your finishing department. That was the rather startling advice received by a large steel company. The answer to the polishing problem, of course, is not so simple as just quality of glue, but this advice serves to give some indication of the importance of glue to the metalworking industry. The humble gluepot—long associated with the cabinet maker—is in fact the *pièce de résistance* of the metal polisher.

In previous chapters the importance of closely regulating the variables in connection with setting up polishing wheels was emphasized. Some of these variables were listed as temperature of the wheel, temperature of the abrasive, humidity and nature of the abrasive, but nothing was said about the variation in the quality of the glue itself. Actually the problem of the manufacture of a suitable glue for use in preparing the head of polishing wheels has perplexed experts for many years. A delicate adjustment is required between the different properties of a glue. It must set hard and yet not be brittle, and it must hold the abrasive grains after the glued surface has been worn away.

Correct Temperature Important.—The temperature of the glue at time of application is another important feature. One manufacturer now recommends holding the glue ready for use at 165°F., whereas the common maximum some years ago was 140°F. The temperature of the wheel on which the glue is spread has a lot to do with the property of the resultant head. In the experience of one company a difference of 20°F. in temperature of the wheel at the time the glue was applied increased the life of the head by 100 per cent. This temperature difference was an increase from 90° to 110°F. Obviously anything as important as doubling the life of polishing wheels is worthy of serious consideration.

Under severe service, good practice indicates a polishing-wheel life of not much more than 1 hr. The cost of reconditioning a worn wheel, together with the lost time of the polisher and the expense of handling, may run close to 50 cents. From this it may be seen that doubling the life of polishing wheels in a good-sized plant may easily result in an impressive saving at the end of the year.

Kinds of Glue.—The significance of the problem of compounding glue itself may be apparent from a statement by one of the large manufacturers, the Milligan and Higgins Glue Co.

> Starting as a matter of course with a carefully made glue of good test, our experience has shown that it does not necessarily produce a polishing wheel of long life. Something else besides a regular commercial glue is needed to give desirable results in this specialized application. Unlike joints between two solid materials, there is nothing in the case of the polishing wheel to support the glue, and it must stand up by means of its own cohesion and inherent strength. If the glue is brittle, the matrix will crack, and if it is not hard, the grain will rub off. Toughness and resistance are important qualities. Another property must be the ability to endure the heat of friction.
>
> Toughness calls for glue derived from the skin of animals accustomed to rigorous life and hard food. Typical in this class are the ox, the horse, the reindeer and the antelope. For years efforts have been made to reduce the specification of a polisher's glue to a concrete equation, but definite formulas have not been established owing to the variety in the source material. Conditions with the same kind of animal and from the same district vary from year to year, and properties that cannot be measured make up the working character of the glue. Under present conditions it is only long experience in this particular field, combined with practical judgment of the gluemaker, that creates the most suitable product.

Glue alone, of course, cannot be blamed for all the difficulty, because the surface characteristics of the abrasive play an important part in the final result. Many authorities feel that closer sizing in abrasives, with an irregular dull surface to each grain, is as important as the character of the glue. Certainly the nature both of the abrasives used and of the glue must be considered.

Handling Glue in the Shop.—Temperature control of the gluepot is important. Most glues lose strength after being held for several hours at the temperature required for application. For this reason in shops where there is intermittent use of glue, two heats on the gluepots are required, one as a holding heat during the periods when the glue is not used, and the other the heat switched on for the time when the glue is used.

Another item overlooked is the fact that glue itself is subject to bacteria invasion and resultant deterioration. This emphasizes the importance of cleanliness of all equipment and the frequent changing of glue and cleaning up of gluepots and containers.

Some of the methods of applying glue to the wheel have already been described. Different conditions call for varying technique here as well as in other parts of the conditioning process. One polishing shop uses a concave pulley rotating in a hot-water-jacketed trough, which trough contains the glue solution. The pulley revolves in contact at its upper surface with the wheel to be set up and in this way carries the hot glue directly from the pan to the surface of the wheel. Adjustment of the speed and the pressure of the pulley against the wheel determine the force with which the glue is applied to the wheel face. Often this operation is combined with hand brushing as the wheel revolves, and occasionally auxiliary mechanical equipment such as an oscillating brush is used to make the process more nearly automatic and uniform.

Mechanical Application.—Specifications for glue must take into account the nature of these various processes of application, because, for one thing, glues differ as to foaming, and an oscillating brush or a rotating pulley might develop foam with some glues and not with others. A low-foaming property is now frequently specified in a good-polishing wheel glue. Foam means air bubbles enclosed in the glue, and this means potential weakness in the surface.

Another method of mechanically applying glue and abrasive is to mount the wheel on a horizontal spindle with the face resting in a trough of heated abrasive. In this position the wheel is revolved by means of a small motor at the same time that glue is brushed onto the upper surface. Some manufacturers have found difficulty in using this method, although it is one of the simplest of the mechanical processes and can be extended to include many wheels revolving on the same shaft. Usually the shaft is adjustable so as to give varying pressures against the abrasive in the trough. A better way is to have the shaft fixed, and to have the individual troughs adjustable against the wheels.

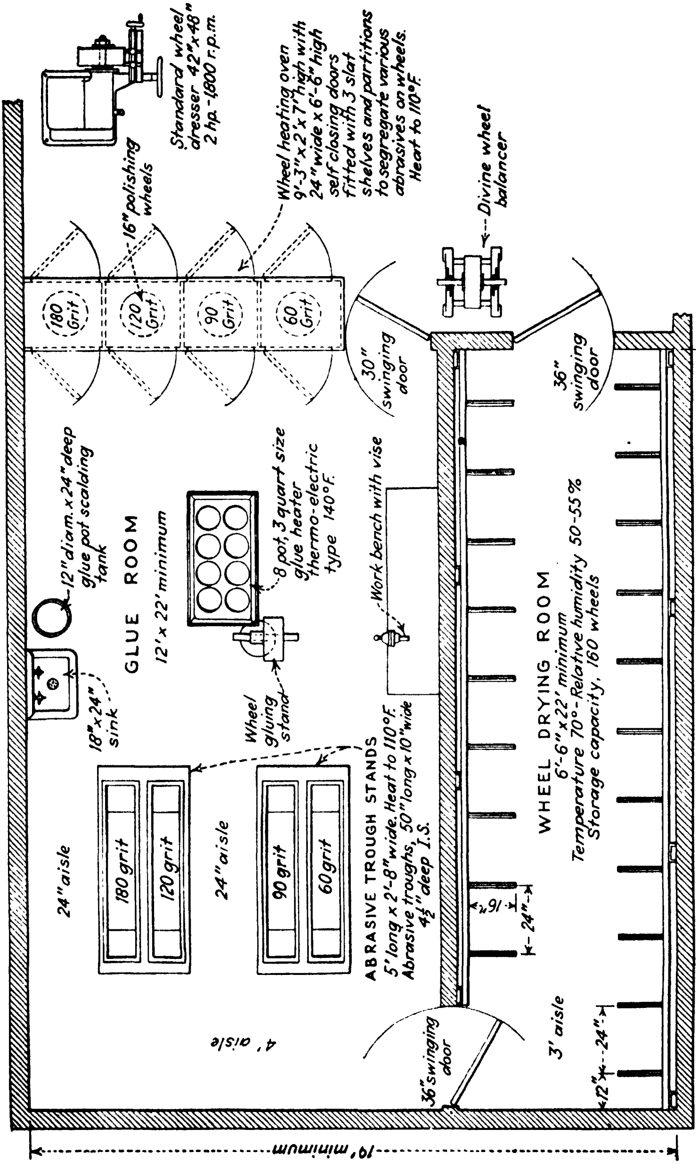


FIG. 43.—This plan indicates a convenient arrangement in the glue and wheel room of a large steel company's finishing department.

On multiple wheels this method permits adjustment due to lower level of abrasive under one wheel than under another.

Special Compounds.—Many special glues and glue compounds are on the market. Some of these are mixed with a solvent that evaporates as soon as the mixture is applied to the wheel and thus obviates the necessity of heating the glue. A compound consisting of glue mixed with abrasive is now available as already mentioned. This is applied to polishing wheels much as a buffing compound is applied, although it is claimed that the resulting surface for light work is similar to that created by the usual separate application of glue and abrasive.

Exact duplicate batches of glue are difficult to produce. Only manufacturers who mix products from many sources are able to overcome variations in the source material and thus produce a glue of consistent qualities. Glue should be stored in airtight containers to prevent change in moisture content, and different sizes of abrasive grain should be set up with different concentrations of glue solution. Coarse grain requires a more concentrated solution. The following table, based on No. 12 grade of glue, is a guide for use of different sizes of abrasive grain:

TABLE VI

Size of Abrasive	Dry Glue in Solution, Per Cent
30	50
36	45
46	40
60	35
80	33
100	30
150	25
220	20

The viscosity of glue decreases as the concentration decreases in a manner which on a graph would be represented by a curve with a sharp bend occurring between the points of 40 and 50 per cent glue solutions. This calls for accurate weighing of the glue mixtures between these points. Glue should never be melted with direct heat. A thermostatically controlled water-jacketed heater is recommended. To overcome deterioration due to high heat some manufacturers mix new glue with glue that has been heated for some length of time, but this is not good practice.

Until recently no technical or scientific attention seems to have been paid to the use of glue for polishing. In developing a glue for this specialized purpose, manufacturers have discovered that there is a conflict between the strength of the glue and the strength of the metal being polished, and from this it is apparent that the utmost possible strength in the glue is desirable.

Glue Standards.—Many cases of complaints of polishing wheels were thoroughly investigated, and in most of these the glue or its treatment was found at fault. Among other factors the effectiveness of the glue varies with the method of soaking, the proportion of water to glue and the kind of glue. In 1844 a standard for industrial glues was set up, known as the Peter Cooper standard, and this still remains the only method by which glues from various makers can be compared. This standard, however, does not consider flexibility.

Ground glue is a more suitable form for the polishing industry. One of the chief advantages is quickness of soaking. In addition to saving of time and equipment, this means less danger of mistreatment through overheating and less likelihood of taking more glue out of storage than required for any one job. In addition to this, ground glue lends itself more easily to blending.

Examples of Wheel Life.—The short life of a polishing wheel head means an excessive amount of lost time in changing wheels and also means reduced production. Short life is usually the result of poor holding power of glue, which indicates that the abrasive grain is torn from the wheel before it has been used up in cutting the metal. This is wasteful and increases the expense of abrasives.

The interested manufacturer will naturally use data on wheelhead life, production and wage rates that apply to his particular case. One method of investigation is as follows:

Find out how long a particular wheel lasts on a given job, how long it takes to change wheels and the annual bill for abrasive grain and glue divided by the number of wheels. Then find out the average time for setting up a wheel.

Assume that the polisher receives 75 cents per hour and that his normal production rate is 60 pieces per hour. Assume that his wheel lasts half an hour and that it takes 2 min. to change a wheel. The loss in wages for changing wheels in this case would be 40 cents per 8-hr. day. Assume that the setting up of a wheel with two heads requires 3 min. and that the setup man receives 60 cents per hour. Then the wage cost of setting up the two wheels is 6 cents.

The cost of abrasive and glue for a 16- by 3-in. wheel, set up with No. 120 grain, should average about 0.025 cent, making a material cost of 5 cents per hour for the two wheels, or a total wage and material cost of $1.28 per day. If the life of the wheel head is doubled, the direct cost will be cut in two and the saving will be 64 cents a day per polisher. In addition there will be the profit on the increased production and the absorption of some

FIG. 44.—Both the quality and cost of hand-buffing operations such as these are materially affected by the type of polishing wheel used.

shop overhead during one wheel-changing period. On this basis a saving of $1.25 or more per polisher can be shown. In a room employing only 10 polishers this would amount to between $3000 and $4000 a year.

Wheel Life and Glue.—From this the question naturally arises, how can the life of the wheel head be doubled? The answer is simply one of proper selection and handling of glue. It is poor economy to buy glue for polishing, on a price basis. First-run glue is the strongest and toughest, and its higher price is negligible in comparison with the saving in setting up polishing wheels. The friction of the wheel on the work generates large quantities of heat which tend to soften the glue. Having selected the proper glue, the following directions for its handling and use may be observed:

1. Use distilled water.
2. Soak the glue for 3 hr. in just the right amount of cold water (not above 65°F.).
3. Melt the glue at 140°F.
4. Prepare a quantity that will be used up in less than 4 hr.
5. Thoroughly clean all pots and utensils.
6. Do not mix old glue with fresh glue.
7. Heat the polishing wheel to 110°F. before applying the glue.
8. Heat the abrasive grain to 120°F. before rolling the glued wheel in it.
9. Dry the wheels for 48 hr. at close to 70°F.
10. Maintain the relative humidity between 50 and 55 per cent.

Use of Hydrometer.—In soaking up the glue in water some manufacturers find it advisable first to mix the glue in a small amount of water and then dilute it to the proper consistency with warm water after the glue has melted. When this is done, a hydrometer is used to determine the percentage of glue and water. Water is added until the hydrometer indicates the percentage called for by the particular size of grain being used.

The effect of varying humidity on the life of the head of a polishing wheel is sufficient to warrant most manufacturers in installing some type of air-conditioning equipment. One manufacturer says, "It took a breakdown in our air-conditioning system to prove its real worth. During the time of our breakdown we used, roughly, twice as many polishing wheels for the same work as required when the system of carefully controlled air conditioning was in service."

An innovation is the use of silicate cements of special formulas instead of hide glue, since the temperature at which the cement and abrasive are applied does not have to be so carefully controlled. Wheels of this type may be operated at higher speeds without burning the adhesive or detaching the grit. In the finer grain sizes, some glazing of the wheel may take place, but if the directions of the manufacturer are followed closely, wheels set up in this fashion operate satisfactorily. When the cement is applied to a wheel formerly set up with hide glue, the glue must first be removed by soaking in water and the wheel then dried. When cement is used, the drying time is shorter than with glue;

higher oven temperature is used because the strength of the cement is not affected by heat.

Buffing Compounds.—After metal surfaces have been polished, the polishing lines may be removed and the character of the surface altered by a further process known as buffing. This process, as already described, makes use of cloth buffs or wheels composed of disks of cloth or similar pliant material. The disks may be sewed together in various ways or may be held together at the center only, leaving the outer portions free. Varying compounds are applied to these buffs, depending upon the results desired. Usually buffing comes under two classifications, the first known as cutting down and the second known as coloring. For the cutting-down process one of the most popular compounds is tripoli, which is a form of silica rock found in natural deposits. The value of this product for buffing results from the fact that each particle is porous and has a fibrous structure with no sharp edges or corners.

Tripoli and Emery Compounds.—The Barnsdall Tripoli Co., one of the largest producers, gives the production of tripoli in prewar years as 10,000 to 15,000 tons. This company obtains the product in open quarries, after which the crude stone is sorted for color and grade and then is placed in drying sheds. Experience indicates that weather drying produces a better grade than artifical drying, and therefore extremely large sheds are needed, for the process of weather drying requires 3 to 6 months. Two colors and three grades of fineness are produced. The finest grade, known as air float, passes through a 200-mesh screen. This is used to make a paste for the most delicate buffing processes.

The best selection of tripoli compound is made by the metal finisher after trial with many grades. When a compound leaves a haze on a metal surface, it is usually a sign that there is too much grease. On monel metal and nickel it is especially important to have a compound made up with a minimum of grease to develop the deep color usually desired. Tripoli is sometimes omitted even where a high luster is produced, but, when it is successfully dispensed with, it means that the previous polishing and emery buffing have been adjusted accordingly. Fine emery and tallow form another compound freely used in the early stages of buffing. Cakes of emery and paste are made up with various sizes of grits. This compound used on spirally sewed buffing wheels is an operation which in a sense is midway between polishing and buffing. Its purpose is to roll down the tiny ridges left after polishing and thus to reduce the operation of cutting down, which, as mentioned, is a true buffing process employing tripoli.

Coloring Compounds.—For final coloring, aluminum oxide or chromium oxide compounds are most popular. These both have some cutting action as well as coloring. The chromium oxide compound is more expensive but produces less friction and gives a bluish color to monel metal and nickel. Some special compounds combining the advantages of tripoli and a coloring compound like chromium oxide are available, but usually the

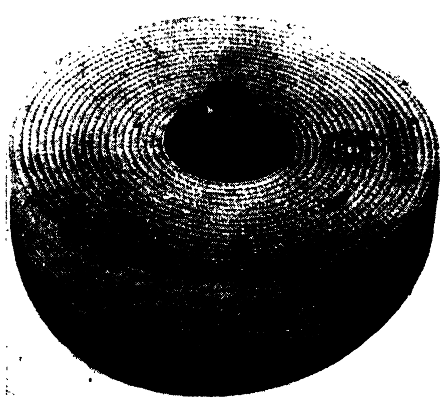


FIG. 45.—This is a typical high-quality polishing wheel with spiral sewing and with face prepared ready for use.

use of these compounds is an expedient to reduce the expense of buffing and is used at some slight sacrifice in the final finish.

One compound put out by the Lea Manufacturing Co. is extensively used on small articles and is said to produce a satin finish with a total of fewer operations and therefore with less overall expense than by most other methods. Certain grades of this compound are advised for removing marks left by No. 150 emery.

Many manufacturers make up their own compounds, and some of these give excellent results. One of these is a paste made up of one part No. FF pumice powder and one part No. F emery mixed with machine oil. Rock pumice and carbon tetrachloride are used to offset the effect of grease. Soap-bark powder mixed with warm water is sometimes used to secure a smooth finish and to protect the metal. Venetian lime sparingly applied to soft flannel buffs is used as the final buffing operation to remove the last trace of grease. The coloring up on a high-luster finish is such a delicate process that a change in the direction of the rotation of the wheel in its relation to the movement of the work produces a marked change in effect.

Adjusting the Buff.—Buffing wheels expand appreciably, owing to centrifugal action when in use, and for this reason some experience is required in setting a wheel on a buffing machine for a given piece of work. Usually the wheel is brought down to just touch and then is fastened in place, the expansion of the wheel giving sufficient pressure. It is impossible to force a buffing wheel, and each combination of compound and operation has a definite maximum speed and pressure. If these are exceeded, the desired result will be lost. One manufacturer who has standardized the buffing of automobile rear-fender brackets uses a pressure of 28 lb. between the work and the wheel and a surface speed of the buffing wheel of 7500 ft. per min. This manufacturer finds that the addition of a small amount of oil during buffing helps the action.

Generally speaking, the higher the speed of the buffing wheel, the brighter the finish, but a large wheel traveling at a slow rate of speed will not cut down so fast as a smaller wheel at a high speed. For cutting down, surface speeds between 5000 and 6500 ft. per min. are the general practice. For producing satin effects, speeds of 3000 to 5000 ft. per min. are common. This means that, for a 10-in. buff, speeds should range from 1200 to 1800 r.p.m.

Typical Buffs.—Buffing in general is divided into two operations, known in the trade as "cutting down," the removal of major defects from the surface of the piece being buffed, and "coloring," producing the final high luster.

To perform these operations, two kinds of buffs are used: full-disk buffs and pieced buffs, made of cotton or other textiles, in varying diameters, from 6 to 20 in. and from 18 to 36 ply. The buffs are operated at peripheral speeds up to 12,000 ft. per min.

Full-disk buffs are composed of separate layers of full complete circular pieces of cloth. Pieced buffs are made with a filler of textile strips and remnants held together between two circular covers by various types of machine sewing.

The regular grades of cotton sheeting used are 48-48, 64-68, 80-92 and unbleached; 84-92 and 68-72 bleached and unbleached. Among the special grades of sheeting used are 68-68 and 88-88 unbleached.

Lead-center full-disk buffs for jewelers and silversmiths are made from all grades of sheeting. Such buffs have a stout lead hub with taper hold, molded and set under pressure. They are made from 80-92 sheeting 3 to 8 in. diameter, ½- to ⅝-in. face.

Jewelers, goldsmiths, silversmiths and workers of molded products require a special type of small-diameter full-disk buff with

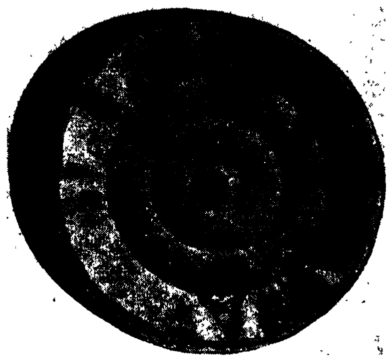


FIG. 46.—This buff is a familiar machine-sewed type for polishing small metal products.

concentric hand or machine sewing. They are made in all sheeting materials including canton flannel and wool cloth.

Pieced buffs are widely used for their economy. The multiple cutting edges found in pieced buffs are an additional factor in their favor.

The essentials of a good buff are good quality new material of close weave and good weight, uniform material throughout the section, tight sewing with good heavy thread and perfect balance.

When new buff heads are put on, some loss is always entailed in truing and combing out the face of the buff. To eliminate this disadvantage, special buffs are produced that have a proper and uniform buff face and are so treated as to take composition at the first touch.

Buffs are widely sewed in a variety of fashions: spiral, tangent, petal, concentric, radial, parallel, radial arc, etc.

"Ventilated" buffs are so made as to induce currents of air through the buffing wheel, to reduce the heat generated by friction between the buff and the work. Such ventilation is effected by special construction such as padding, slotting or perforating the wheels to provide air gaps.

Buffing Compositions.—Buffing compositions are used on buffs for producing a smooth surface (cutting down) and the final luster (coloring) on the articles to be polished or buffed. All such compositions are combinations of greases and abrasives. The melting point of the greases and the ratio of abrasive to binder vary with the type of composition and general conditions under which it is to be used.

The essential facts for proper composition selection are the nature of the metal or material to be buffed, the shape of the piece, the speed at which the wheel is operated and the size and type of buff. Among the buffing compositions in general are tripoli, diatomite, pumice, flint, lime, aluminum, oxide and chromium oxide coloring compositions, polishing tallow, emery paste, emery cake, hard rouge, soft rouge, crocus compositions and bobbing compositions. Each of these materials is peculiarly suited for a special purpose, varying from cutting down brass and other nonferrous metals to coloring precious-metal jewelry.

Many special buffs are produced. Some have cardboard disks between the sections of cloth. Woolen buffs at low speeds are used on precious metals where a minimum amount of metal must be removed. Jewelers' buffs are usually hardened at the centers with shellac or glue. Buffs may be cleaned during operation by applying a buff stick to the face. This stick is merely a piece of wood coated over with glue and allowed to dry, then rubbed over with pumice, again coated with glue, and finally set up with alumina grit.

The amount of composition on the buffing wheel is important and should be applied in a small amount at a time with light pressure. Separate wheels should be used for cutting down and for coloring. The latter require higher peripheral speeds. Work is usually washed after final finish to remove traces of grease. The longer it is left to stand after final buffing, the harder is this grease to remove. It is claimed for some of the Lea compounds that no grease is left and that washing preliminary to lacquering may be eliminated.

CHAPTER XVI

POLISHING DIFFERENT METALS

What kind of finish on metal products has the greatest sales appeal? This is a question that appears again and again. It is a question that if solved for any one product or any one metal must be solved again for another product and another metal. The value of specific surface characteristics of metal products after polishing is often overlooked not only by the shop superintendent but by sales managers and executives as well. Obviously a definite effect in the appearance of a product should be sought; otherwise finishing becomes a matter of chance, and processes cannot be standardized or costs determined.

If it were possible to draw a curve showing the sales appeal of different finishes, and plot with this a curve of costs, the two curves would probably increase together, and yet there could be no fixed relationship between them. A very high gloss, for instance, achieves value only when associated with appropriate products. For some metal articles an elaborate and expensive finish might prove an economy in the long run, yet for others a less expensive finish might have a greater sales value.

Costs of finishing vary through a wide range. A small metal product may perhaps be polished for 10 cents, but a different kind of luster or of color effect on the same product may cost 20 or even 30 cents to produce.

A manufacturer of building hardware, when questioned about polishing, said:

Our trouble is not how to do a particular job of polishing and buffing but, rather, to determine what kind of a final finish we should have. Take our chromium door sets. Do we want a mirror finish that looks fancy when first unwrapped but shows finger marks, or would it be better for us to use a dull finish that keeps its appearance longer? No one can tell you about such things. You've just got to try different finishes and see how they sell, and the strange thing is that sometimes a finish that is a big number in the East won't go at all out through the Middle West.

Comparing Polished Surfaces.—With any type of finish, definite specification is difficult, as shown by the fact that several engineering societies' committees have been working for years in an attempt to describe and standardize some of the more common finishes as, for instance, the finish of a gray-iron casting as it comes from the mold.

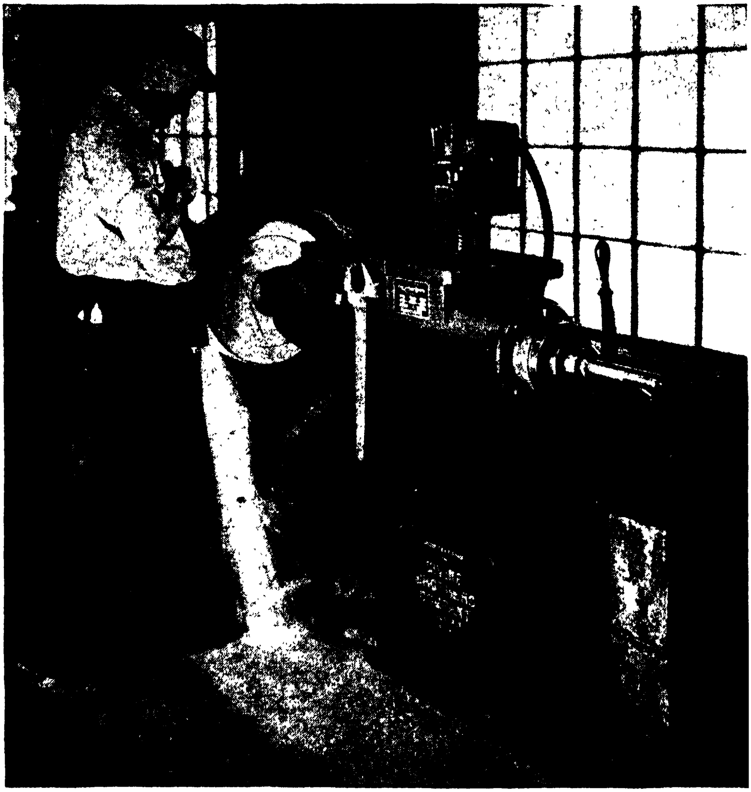


FIG. 47.—Proper wheel elevation is important on heavy work.

In polishing, it is particularly difficult to describe a finish accurately. Usually one polished surface is differentiated from another by the nature of the abrasive grain last used on each. Metal, for instance, may be polished or buffed until all marks left after No. 150 abrasive grain have been removed. A description of this sort can be only approximate because the method of removing the fine grain scratches determines the effect of the coloring. However, if a sales manager determines for any one product by trail and error, as suggested by the manufacturer quoted above, the finish that has the greatest sales value, then it is fairly simple for the head of his polishing department to duplicate this in quantity production, provided that the material from which the product is made runs uniform.

In order to describe the degree of smoothness of the surface and to make a good result reproducible, General Electric has prepared a control board containing 25 samples of surfaces varying in regular sequence from the smoothest to the roughest with a symbol corresponding to each sample.

Polishing Different Products.—Among the thousands of articles on which polishing is considered one of the regular manufacturing operations are the following items, which give some idea of the diversity in this field: stoves, wrenches, tools, hardware, auto trim, cutlery, oil burners, shovels, axes, sewing machines, typewriters, bathroom fixtures, sad irons, plumbing supplies, bicycles, guns, cooking utensils.

Frequently it is desirable for a manufacturer to change the metal used for a certain product, and under such circumstances he may want to keep as close as possible to the original finish. A thimble manufacturer changed from nickel silver to aluminum and desired to keep the appearance of the new thimble the same as that of the old. This was a special problem that finally was solved to the satisfaction of the manufacturer through a combination of acid dipping and buffing with a sequence of different compounds.

A certain type of finish often becomes associated with a product and thus develops a value independent of its actual appearance. For example, a manufacturer of a special kind of edged tool changed from carbon steel to an alloy steel of improved properties, but, in so doing, he changed the final appearance and received complaints from old customers. In this case it was merely necessary to alter a few details in polishing to adjust for the change in material and to maintain the original appearance. Because of the different behavior of different metals under the polishing wheel, it seems advisable to consider the polishing characteristics of some of the more common materials.

Polishing Brass.—A brass surface has characteristics for the polisher similar to steel. However, because it is softer, some of the operations required for a high luster on steel are frequently omitted in the case of brass. Small brass castings such as pipe fittings are frequently water tumbled and then polished on large wheels using a compound of grease and No. 150 emery. For a better finish this is followed by buffing with tripoli and coloring with rouge.

As with most metals, the final finish on brass is determined by the early polishing operations and, even where castings are fine grained, the above method will not remove all the sand marks.

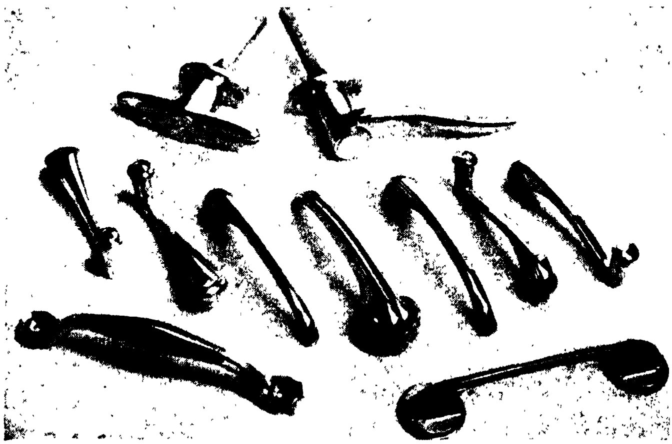


FIG. 48.—Cloth-flex wheels with special contours were used for polishing these parts.

A more careful polishing calls for the use of a series of different abrasive grain sizes in successive operations. Some foundries sandblast, then rough-polish brass castings with No. 80 emery and follow this with a wheel set up with No. 120, and finally buff with a grease and fine emery compound.

Die marks may be removed from sheet-brass products by much the same technique as given above, although some special compounds have been developed for this particular service. The Lea Manufacturing Co. gives the following practice for finishing stamped lighting fixtures made of brass: (1) The parts after they come from the dies are polished on 10-in. sewed pieced buffs at 2400 r.p.m., using Grade C compound. (2) They are then oxidized in liquid sulfur solution. (3) Finally they are relieved on 8-in. loose buffs at 1800 r.p.m., using Grade A compound.

Chromium over Nickel.—A chromium finish is almost always encountered as a plate over other metals or other plated coatings. A chromium plate, particularly when applied over a nickel plate, calls for careful cleaning because the chromium film, being extremely thin, often not over 0.00002 in., must be preserved intact when it is desired to get the full appearance value. In a chromium plate over nickel the nickel must be given a very high polish. One large manufacturer, polishing with wheels set up with No. 120 abrasive, uses the following sequence to prepare nickel for chromium plating: grease coloring with fine emery cake,

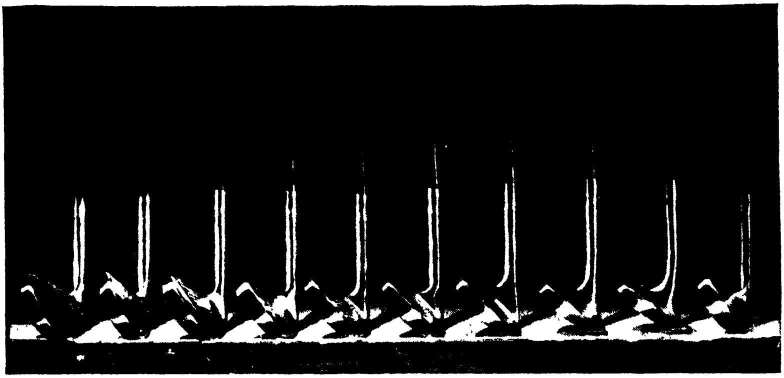


Fig. 49.—A high polish on golf clubs is always associated with quality. (*Courtesy of Burke Golf Co.*)

cutting down with tripoli, then coloring with white finish and cleaning with whiting.

Polishing Monel Metal.—The procedure in polishing monel metal is similar to that for nickel, although many monel-metal products call for a matte finish which does not require so many buffing operations. When cold-rolled monel-metal sheets are polished for cabinetwork in hotels and restaurants, the operations are frequently reduced to two, the first using tripoli and the second a chrome oxide compound. In the case of stampings, it is often economical to remove die marks with emery before using the tripoli. One manufacturer of sinks removes die marks around the corners locally by means of a small portable emery-coated buff.

Another manufacturer of deep drawn monel-metal products uses the following sequence:

1. No. 120 emery dry.
2. No. 150 emery and grease.
3. No. 180 emery and grease.
4. Tripoli.
5. Fine lime.
6. Clean with whiting.

Occasionally the above sequence is modified by introducing a polishing operation with a sheepskin wheel set up with No. 200 emery, and many manufacturers use artificial abrasives in place of emery.

Polishing Zinc.—Zinc is sensitive to alkaline corrosion and calls for special cleaners. For rolled zinc that is to be plated, one company recommends buffing with free-cutting tripoli and then coloring on a soft buff traveling at 6000 ft. per min. using a soft dry white compound, then electrocleaning in a boiling cleaning solution with the work as a cathode, followed by a hot and a cold rinse and an acid dip in 1 per cent hydrochloric acid, then a cold rinse, and finally the nickel-plate process. Interior trimmings for automobiles are frequently made of zinc alloys that are polished on large soft wheels set up with No. 120 abrasive. This is followed with tripoli and then with pumice and water on a tampico wheel, when the parts are ready to be cleaned for plating. After nickel plating, these parts are frequently brushed over with pumice and water on wire wheels.

Polishing Stainless Steel.—In the specialized field of polishing stainless steel, various mechanical features must be taken into account. These include the appearance of the surface of the raw material as it comes from the mill. It may have been polished or burnished, or it may have been subjected to a severe pickling operation causing a rough-etched surface. In addition to this, the actual temper of the metal has an effect upon polishing. This temper is dependent upon the amount of drawing, forming or rolling to which the metal has been subjected.

In the case of articles formed from sheet stainless steel, die marks are usually present, even if minute. A severe bending operation nearly always causes a slight roughening at the point of the bend. This effect, known as the orange-peel effect, requires considerably more polishing and buffing than the unbent portion of the article.

The grain size, type and blending of abrasive, type of polishing wheels—that is, whether hard, medium or soft—the speed of the wheels and the pressure of the wheels against the work, all must be considered and adjusted to get best results in the polishing operation.

A few cases taken from actual plant operations are here offered to indicate general practice, although details must be altered to adjust to each individual set of conditions.

EXAMPLES OF STAINLESS-STEEL POLISHING

A. Table cutlery. Mirror finish desired. Products blanked out of sheet stainless steel.

1. No. 90 artificial abrasive on set-up polishing wheel.
2. No. 120 dry abrasive on set-up polishing wheel.
3. No. 180 abrasive and grease compound on set-up polishing wheel.
4. Buff using flour abrasive compound.
5. Special compound for cutting down.
6. Aluminous oxide and grease.

B. Rim stampings about 8 in. in diameter. High coloring desired.

1. No. 120 dry set-up wheel.
2. No. 120 set-up wheel with grease.
3. No. 180 set-up wheel with grease.
4. Buffing with cutting compound.
5. Buffing with coloring compound.

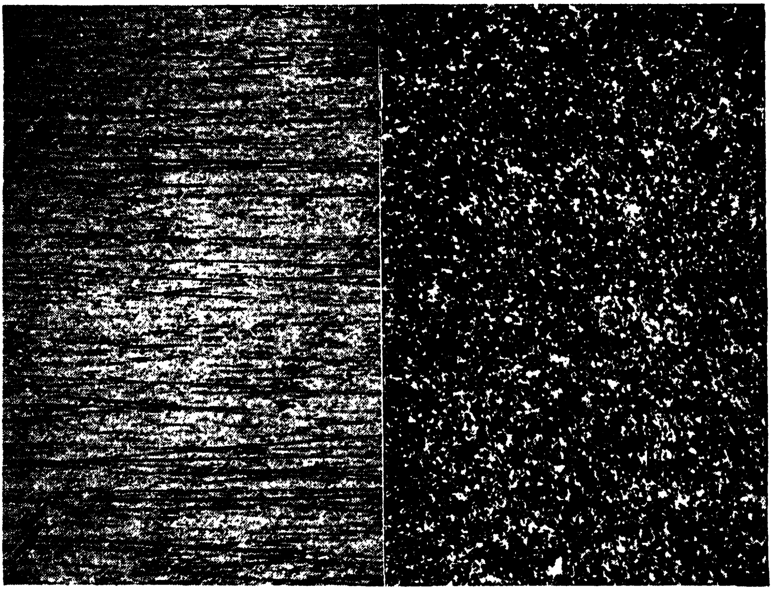
C. Forged golf-club heads. Satin finish desired.

1. No. 120 abrasive and grease.
2. No. 150 abrasive dry.
3. No. 180 abrasive with grease.
4. Cut-down composition.
5. Pumice on tampico wheel.

D. Forged golf-club heads. High color desired.

1. No. 120 abrasive dry.
2. No. 120 abrasive and grease compound.
3. No. 150 abrasive dry.
4. No. 180 abrasive and grease compound.
5. Cutting-down compound.
6. Aluminous oxide and grease.

Use of Special Compounds.—Polishing operations on stainless steel, with the abrasive firmly glued to the surface of the polishing wheel, are often too severe to give greatest efficiency. The grains which are tightly held to the surface of the polishing wheel cause harsh cutting or gouging, and the cuts must be removed in the subsequent polishing or buffing operations. Grease is used on some polishing wheels to reduce this harshness, but it is still a relatively severe operation whenever abrasive grains are held rigid while they are doing the cutting.



(a) (b)

FIG. 50.—Comparison of plain and treated steel. Total micrograph enlarged 100 times. (a) Plain polished carbon-steel sheet; (b) the same material with chemically produced phosphate coating.

To relieve this harsh action the Lea Manufacturing Co. developed a series of special compounds that contain fine but sharp abrasive grains mixed with a binder containing no grease but having the property of adhering to a soft buff as the compound dries. This leaves a very thin layer of dry abrasive attached to the flexible surface of the buffing wheel. The function of the use of such a combination is intermediate between the usual polishing and buffing operations, and in many cases it is found that one or more polishing operations may be thereby eliminated. The surface, after using the greaseless compound, is easier to buff than where work goes direct from a polishing wheel to the regular buffing operation.

Greaseless Buffing.—The following example in the use of a greaseless compound is taken from the experience of a table-cutlery manufacturer. The products are stainless-steel forgings. The former method of polishing was

1. No. 90 dry set-up wheel.
2. No. 150 dry set-up wheel.
3. Cutting burrs off tines with loose buffs set up to a hard face with No. 180 grain.

The new method uses

1. No. 90 dry set-up wheel.
2. No. 150 dry set-up wheel.
3. Lea compound Grade E on 4-in. loose buff operated at 3300 r.p.m.

The use of the greaseless compound on a flexible wheel enables the operator to cut burrs and give a final finish in one buffing operation. Sometimes beeswax is used on the wheel as an aid to cutting and to give a somewhat higher finish.

A final coloring and buffing operation in which there is no free grease in the compound has been developed by the Lea Manufacturing Co. The usual compounds melt at a point sufficiently low to allow the composition to transfer from the bar to the wheel by the aid of the heat caused by the friction of the revolving wheel, and by this same process some of the grease is transferred to the work, owing to the heat of the friction between the wheel and the work. The grease on the work, especially in ornamentations or contours, is difficult to remove, and the parts frequently must be soaked or scrubbed. The compounds with no free grease leave the work clean or else covered with a slight loose deposit that is easily removed.

Polishing Aluminum.—The recent increase in the number of applications of aluminum as, for instance, for railway equipment, roofs, furniture, airplanes, tank cars and fencing calls the attention of the polisher to the technique of finishing this metal. In general, aluminum requires special treatment in polishing. As with other soft metals, many polishers use greased wheels to avoid tearing the surface. A dry wheel tends to load when used on aluminum. To avoid this, kerosene is occasionally used as a lubricant, and some experienced polishers say that it is just as good as any of the prepared products for this purpose. Other polishers successfully use ordinary tallow as a lubricant.

In some special cases, such as ice-cube trays in refrigerators, an electric finish known as the anodic finish is used to give the familiar gray slate color and at the same time produce an abrasion-resisting surface.

Another type of dull-gray surface is produced on aluminum by the use of rotary wire brushes which are frequently made of nickel silver, stainless steel or nickel wire. One common type of aluminum brushing wheel is 6 in. in diameter, operated

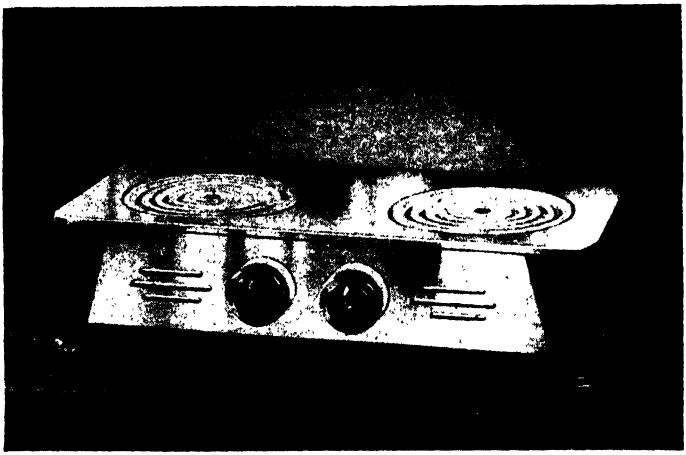


FIG. 51.—Satin finish adds to the attractiveness of this electric stove.

at 600 r.p.m., made up of nickel wire 0.01 in. in diameter. Satin finish on aluminum may be obtained by using fused alumina grits on canvas belts traveling at about 3000 ft. per min. A large manufacturer of small aluminum products intended for ten-cent store distribution uses a composition of tallow and stearic acid to prevent the polishing wheels from becoming loaded with aluminum particles picked up from the article. When wheels do become loaded, they cause scratches on the work. Automatic machines frequently use belts instead of wheels, in which case the same lubricants are used in a thinner mixture.

A practical example of polishing cast aluminum is the familiar heavy skillet. One company first polishes this article around the edges by hand with a sewed buff coated with a No. 120 grit compound. The outside surface is then polished on a semiautomatic machine using compounds first with No. 90 and then 120 grit on bull-neck leather wheels, following this with No. 240 grit on sheepskin leather.

Final buffing consists first of tripoli grease on cloth buffs and then a lime coloring composition on paper wheels. These paper wheels are made up in a manner similar to the cloth buff except that disks of heavy brown paper are used in place of the cloth.

The bottom of the skillet is purposely left with a rough finish. If it were polished, it would act as a reflector and reduce the heating efficiency. A dull finish absorbs heat more readily. A highly polished surface, on the other hand, will radiate heat less effectively than a dull surface, and thus there is a utility value as well as an appearance value in having the sides of a skillet highly polished.

Hand and Machine Operations.—The interior of cooking utensils is finished on a quantity-production basis by using a horizontally revolving chuck that holds the dish at a convenient height with the open interior upward. The polisher then takes a pad made up of rectangular pieces of cloth sewed together much after the style of the buff and coated with fused aluminum oxide and oil. This pad he holds against the side of the revolving dish and in a short time creates the desired finish. Sometimes steel-wool pads are used in a similar way.

Where polishing machines are used for cooking utensils, the work usually revolves at about 100 r.p.m., and the spindle oscillates at six or seven strokes per minute. Aluminum castings when discolored are sometimes heated to around 500° or 600°F. for about a half hour to remove the discoloration. Blasting aluminum castings with fused alumina abrasive is a common finishing operation. One company uses No. 80 grit applied with an air pressure of 40 lb. to secure a matte finish.

CHAPTER XVII

DESIGNING PRODUCTS TO REDUCE POLISHING EXPENSE

Of all manufacturing operations performed on metal products, polishing and buffing are probably the most costly. Two causes for this condition are: (1) the backward state of the art itself, little being known concerning the effect of the several variables involved in the processes of polishing and buffing; and (2) the failure to consider the finishing operations in the design of the product. Established practice in design accounts for almost every other operation. The design is studied to ascertain whether it is the most economical from the standpoint of turning, drilling, planing, milling, welding or forming. But in not a single part, out of hundreds investigated, was the process of polishing a factor in determining the most economical design.

A polishing wheel has several limitations. It cannot work into a sharp corner. It cannot work for any length of time along a sharp edge perpendicular to the axis of the wheel, projecting into the face of the wheel, because the edge will soon wear through the abrasive head and the wheel will cease cutting. It cannot polish against a sharp edge parallel to the axis of the wheel without destroying the edge and in a short time stripping the abrasive head from the wheel. It cannot, unless it is a very soft wheel, adapt itself to changes in the contour of a surface, and even with such a wheel the variation in contour that will be covered is limited. Furthermore, with a soft wheel, the work cannot be held to close tolerances. Hence, changes in contour must be scrutinized closely if the finished surface is to be held within close limits. A polishing wheel cannot climb over projections on a surface but must work around them. These are the principal limitations to the action of a polishing wheel and, with a few minor exceptions, to that of a buffing wheel. Other limitations will appear in the discussion that follows.

Terms Defined.—First, to clarify the subject, the following definitions are repeated, and the words polishing and buffing will be used hereafter according to these definitions. Polishing is the art of producing a smooth, uniform surface on metal by means of an abrasive wheel, of greater or less flexibility, the abrasive being glued to the face of the wheel. Buffing is the art of putting a luster or "color" on a polished surface by means of an abrasive composition, bonded with a wax or grease, which is smeared on the face of a buffing wheel.

Problems Related to Design.—Let us consider briefly the limitations of some polishing applications as related to design. Figure 52 shows two ways in which a wheel may work in a sharp corner. Apparently the surfaces with which a wheel is in contact will be polished right up to the vertex of the angle. Practically,

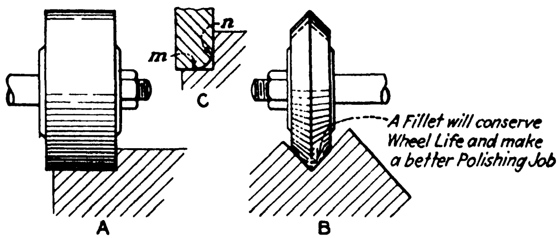


FIG. 52.

however, since a polishing wheel is more or less flexible, and the abrasive head on it is comparatively thin, the sharp edge of the wheel will very soon become rounded, as in *C*, and the surface of the work from *m* to *n* will remain unpolished. The wheel shown at *A* will retain its form longer than the wheel shown at *B*, but two operations will be necessary to finish the two sides of the angle. If the function of the piece is such that there is no necessity for a sharp corner, the provision of a generous fillet in the corner, as shown by the dotted line in *B*, will assure a long life of wheel head and permit polishing in a single operation.

Figure 53 shows the converse of Fig. 52, that is, a sharp edge on the work instead of on the wheel. If the surfaces on both sides of the edge are to be polished, obviously the most economical method is a single operation with a wheel grooved to conform to the surface, as at *A*. In practice, however, the sharp edge of the angle would soon cut through the abrasive head and into the fabric, as at *C*, thus not only failing to polish the vertex of the angle, but also spoiling the wheel.

The alternative method involving two operations is shown at *B*. If this latter method is used, another complication may develop. If the wheel is wider than the work, a groove the width of the polished surface will be worn in the wheel, as shown at *D*. This may be overcome either by oscillating the new wheel axially, or by moving the work across the face of the wheel. The latter is usually possible in polishing by hand at the lathe, but not always possible when the work is done in a polishing machine. The designer, therefore, must take into consideration whether the polishing is to be done by hand or by automatic machine. The form of the work that will permit the most

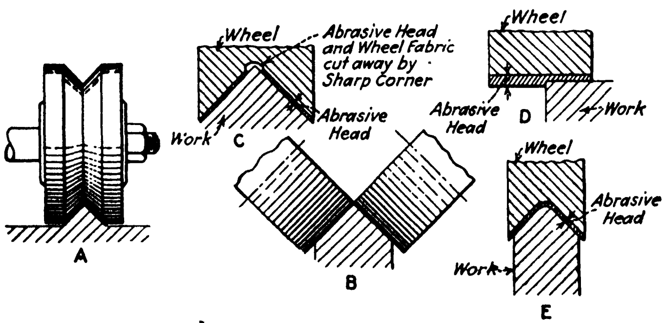


FIG. 53.

economical polishing, obviously, is that shown at *E*, where the sharp corner is rounded off and a grooved wheel conforming to the contour is used.

Difficulty with Sharp Edges.—The effect on both wheel and work, of a wheel working against a sharp edge, is shown in Fig. 54. At *A* a sharp corner is represented, with the wheel in contact with it. The thickness of the abrasive head and of the flexing of the wheel is exaggerated in order to show the action that takes place. The cushion of the wheel is slightly compressed, as shown at *f*, the abrasive head following the cushion into the resulting depression. The sharp corner of the work digs into the head and has much the same effect on the surface of the wheel as a lathe tool has on a piece in a lathe. The abrasive grain is torn bodily from the glue in which it is embedded, and the wheel is soon stripped bare. The effect on the work is shown at *B*. Instead of the sharp corner intended by the designer, a more or less irregular rounded edge is formed owing to the wear of the wheel and to irregularity of pressure of the wheel on the work. The proper relation of wheel and work is shown at *C*. The edge in this case will be left sharp, and the life of the wheel head will be greatly prolonged.

At *D* in Fig. 54 is shown a construction where advantage may be taken of this tendency to round the corners by a wheel working against an edge. The piece in question is a slotted plate. In cutting the slots, slight burrs are left on the edges, which it is necessary to remove. It is also desirable to round the edges to a very small radius. The polishing wheel will be supported on the solid section of the plate at the sides and will project into the

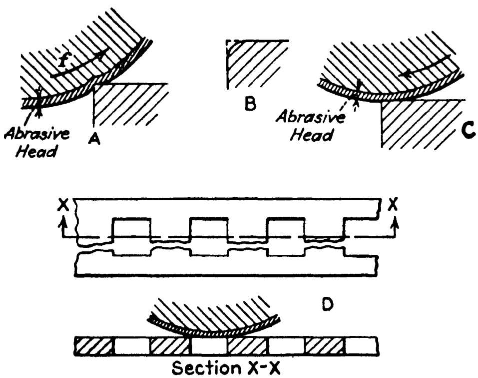


FIG. 54.

slots only a very slight distance. The rounding effect will be minute and the stripping of the wheel head almost negligible. By selecting a wheel of proper density and exercising care in the application of its pressure on the work, almost any desired degree of rounding can be obtained. Reversing the direction of travel of the work will round the opposite edge. If a very hard wheel is used, it will not project into the slots at all, and practically no rounding will occur.

Problem of Change of Contour.—The meaning of change of contour is illustrated in Fig. 55. Change of contour may be the junction of two entirely dissimilar surfaces, as at *A*, where a plane surface intersects a cylindrical one, or a change in direction of the plane of a surface, as at *B*. Another case of change of contour is shown at *C*, where two planes at an angle to each other are joined by an arc of continually increasing radius. These are only three elementary cases out of an infinite number of possible cases of change of contour. Change of contour presents one of the most difficult and expensive of all problems for the polishing and buffing departments, and the designer should make every possible effort to avoid it. The most casual inspection will make obvious the fact that no one formed wheel can be devised that will finish the plane and cylindrical surfaces at *A* at a single

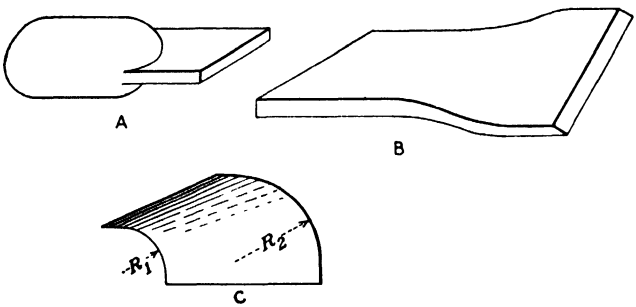


Fig. 55.

operation, or one that will fit the ever varying radius of *C*. The piece shown at *B* can be finished with a flat wheel of the same width as the work, by twisting the work as it passes the wheel. Even so, the warped surface at the twist will require some touching up, at an increase of time and expense. Even if such a part were produced in sufficiently large quantities to warrant finishing in a straight-line automatic machine, the type of fixture necessary to hold the work and so present it to the wheel as to permit covering the entire surface would be extremely complicated, and the cost would probably be prohibitive.

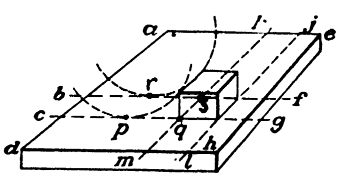


Fig. 56.

A single case is shown in Fig. 56 to illustrate how a projection will vastly increase the cost of polishing. The polishing wheel will traverse the surface until it comes in contact with the projection. The strip *pqrs* will remain unpolished. To polish the surface completely, four passes are required to cover strips *abfe*, *akmd*, *cdhg* and *hejl*. Unless prevented by constructional reasons, the projection could be made a separate piece, doweled or screwed to the primary surface. In such an event the entire surface *aehd* could be finished in a single pass at a much lower polishing cost.

Projections are particularly objectionable in parts where quantity production is involved. In such cases an automatic polishing or buffing machine is indicated, but a projecting part almost invariably precludes the use of such equipment. A lug or a ridge in the path of the wheel will relegate the work to the hand lathe with a consequent tremendous increase in cost. What this increased cost may mean is illustrated by a classic example. Five men with automatic equipment finished the same quantity of work as 30 hand polishers. Where quantity production is involved, the designer should study the form of the parts most carefully, to adapt them to automatic polishing and buffing if at all possible.

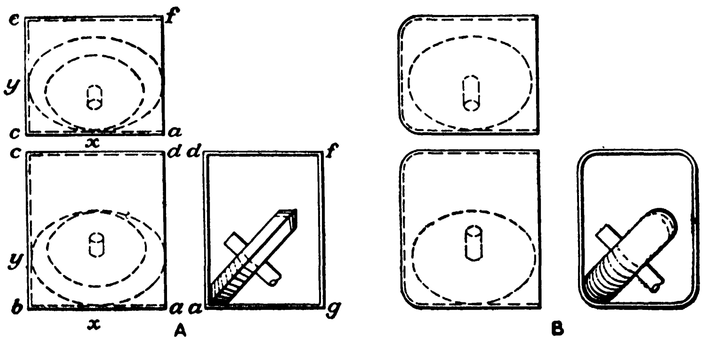


FIG. 57.

Practical Cases.—Having considered the elementary limitations of polishing and buffing wheels as related to design, let us examine a few actual cases. Figure 57 shows two designs of an oven that required polishing over the entire inner surface. The original design is at *A*. In the front elevation is shown the formed face wheel with which it was proposed to polish into the corners. This was impracticable, not only because the wheel would wear out quickly on the vertex of the angle, as previously discussed, but also because it is impossible to reach the bottoms of the corners, leaving unpolished the surfaces between x and y in the plan and the side elevation. The revised design is shown at *B*. The edges are rounded to the radius of the smallest wheel that can be used. Consequently, the corners become sectors of a sphere. A polishing wheel the face of which is rounded to the same radius as the radius of the wheel will then polish the inside of the edges *ab*, *bc*, *ce*, etc., and make perfect contact with the entire surface of the spherical sector forming the corners.

Figure 58 shows two designs of connecting rod in which the polishing cost varies widely, owing to a slight difference in design. Both rods required polishing all over. The deep channel on the two sides of the I section presented the difficulty in connecting rod *A*. The bottom and sides of the channel could be polished easily by a wheel with an abrasive head on the face and both sides. Such a wheel would fail to reach into the corners, exactly

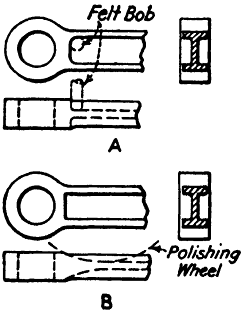


FIG. 58.

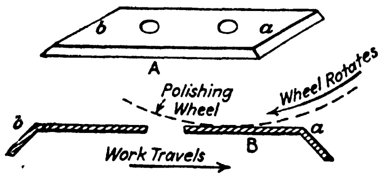


FIG. 59.

as in the previous example. These corners could be finished by a felt bob, as shown, a slow and expensive operation. The connecting rod at *B* shows a design that permits of finishing in the channels with a single wheel. The web is swept upward to the sides of the boss, and a wheel of the same radius as the sweep can then traverse the rod from end to end.

The ordinary wall plate for electric switches (Fig. 59) is an instance of the effect of finishing against an edge parallel to the axis of the wheel. The travel of the work in an automatic machine and the rotation of the wheel being as shown in *B*, the leading edge *a* will be rounded while the trailing edge *b* will remain sharp. While the design might have been changed to provide for rounded edges, the sharp edge was a commercial consideration that did not permit of change of design. The difficulty had to be overcome by other means in the polishing department.

Circular and crosscut saws present another instance of working against an edge parallel, or nearly so, to the wheel axis. The effect here is to strip the wheel head. Here again design change is not possible, and the remedy lies in a change in polishing method. It is for this reason that the polishing of circular saws by means of the set-up wheel has never been successful.

Redesign of Flatiron.—The housewife's ordinary electric flatiron is an excellent example of change of contour causing excessive polishing costs. These irons are produced in such large quantities that from the standpoint of volume alone they are an attractive automatic-machine proposition. The two principal parts requiring polishing are the sole plate, on the bottom and edges, and the

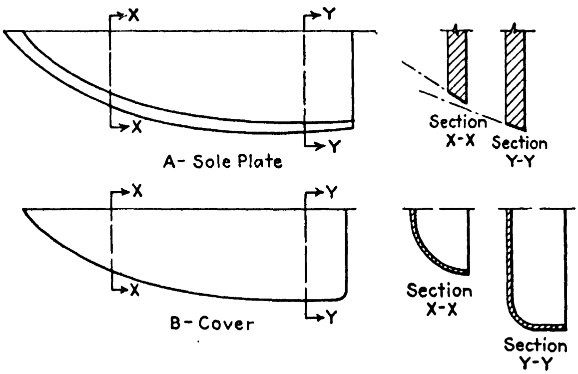
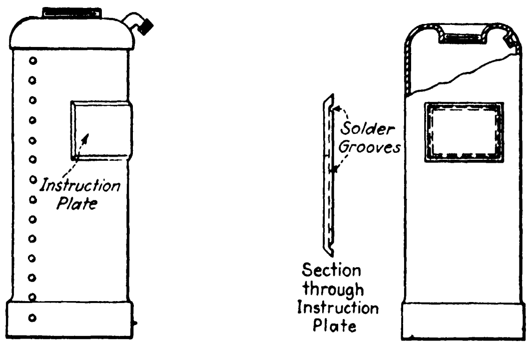


FIG. 60.

cover. The polishing of the bottom of the sole plate in a straight-line machine is comparatively simple. The edges in many designs have presented a most difficult problem, as have also the covers, both for the same reason. In Fig. 60, *A* is a plan of a sole plate and two end sections, at different points along the length of the iron. It will be noted that the angle that the side of the sole plate makes with the bottom is quite different at *XX* than it is at *YY*. A flat face wheel will traverse the edge from end to end and thus would ordinarily present an easy problem for an automatic machine. Because the angle of the wheel axis to the bottom of the sole plate would be continuously changing, a very complicated fixture is indicated whose expense might be prohibitive even if the mechanical construction was satisfactorily worked out. Consequently, sole-plate sides are largely finished by hand. A simple change in design, namely, making the angle between the side and bottom constant, will permit the side to be finished in a machine with a relatively inexpensive fixture.

In Fig. 60 at *B* are shown a half plan and two half sections of the cover. Here the problem is slightly different. The side of the cover at the rear of the iron is straight, curving into the top with a moderate radius. As it approaches the point, the sides begin to slope and the radius changes. The problem introduced here is one not only of fixtures but of the wheel as well. It is manifestly impossible to build a wheel that will traverse the side of the cover from end to end and at the same time come in contact with all parts of its surface. The remedy here is the



(*a*) (*b*)

FIG. 61.

same as before, namely, a new design that gives a constant angle and a constant radius throughout the length of the cover.

Projections.—The example selected to illustrate the adverse effect of projections lies in the field of buffing. The ideas suggested will apply equally well to polishing. Figure 61*a* shows the common 2½-gal. fire extinguisher. As ordinarily made, it consists of a copper sheet formed into a cylinder, a line of rivets extending along the line of the seam. A domed top with a hose outlet projecting from it is fitted to the cylinder. The bottom also is a separate piece fitted in. An instruction plate is soldered to the cylinder body, the solder being run along the edges of the plate. The entire outer surface of the cylinder requires buffing. The work is done by hand, although a cylinder usually is one of the easiest forms to handle in a machine. However, the projecting edge, formed by the seam, and the rivets soon would tear the buff to pieces. The nozzle outlet absolutely precludes finishing the domed top in a machine. Finally, and perhaps most important of all, there is the instruction plate. The extinguisher must be buffed *after* this is soldered on, since the rough edges of the solder require smoothing down. The plate itself could not be buffed separately, because the lettering on it would be disturbed.

Figure 61*b* shows a redesigned form that permits the use of an automatic machine to effect a great reduction in cost of buffing. The body of the extinguisher is formed of a seamless drawn-brass shell without projections. The opening at the top is flanged inward and threaded for the cap. Likewise the hose outlet is flanged inward and threaded on the inside. There is thus no obstacle whatever to the use of a machine. The instruction plate is put on after the extinguisher has been buffed, in such a way that no finishing of the edges is necessary. A groove is cut round the periphery of the plate and filled with solder. After the cylinder has been buffed, the plate is laid on it and an electrical heating pad applied to it until the solder has melted and the plate attached itself to the cylinder.

The foregoing are a few typical examples of ways in which the designer can reduce costs in the most expensive department of the plant. The opportunities before him are legion if he will only look for them.

CHAPTER XVIII

DESIGN OF POLISHING AND BUFFING FIXTURES

The possibility of putting work on automatic polishing and buffing machines, thereby effecting large reductions in costs, usually depends upon the ability to design a fixture that will hold the work securely and present it to the polishing or buffing wheel in the proper manner.

The essentials of a properly designed work-holding fixture for polishing and buffing machines may be listed as follows: (1) It must so hold the work that it cannot become dislodged when it comes in contact with the wheel. (2) It must be easy to load and unload. (3) If the fixture is loaded at the bench and transferred to the machine, it must be light, yet rigid. (4) It must have provision for compensation for wear, and in those pieces where the fixture masks a portion of the work for one reason or another, the masking part should be capable of easy replacement. (5) The fixture should be so made that it can be placed on the machine in one position only.

The failure of many fixtures to function properly is due to neglect of one or more of these essentials.

Polishing and buffing fixtures divide naturally into two classes: (1) those for holding work which is rotating, while in contact with the wheel; (2) those for holding work which moves in a straight line past the wheel. The latter type generally finds its principal application in straight-line machines, although there are some adaptations of machines designed primarily for rotating the work where the work is passed in a straight line against the wheel.

Fixtures also can be classified by the method employed to hold the work. Eight headings thus may be listed:

1. Internal expanding fixtures that grip the work internally by the expansion of suitable jaws.

2. External contracting fixtures that grip the work externally by the contraction of suitable jaws. These two types may be designed for both the rotating and the straight-line machines.

3. Friction fixtures, in which the grip on the work is obtained by friction alone.
4. Recessed fixtures, in which a recess is formed of the same shape as the work and from which projects the surface of the work that is to be finished. Recessed fixtures may be of very elaborate form, or they may be simply cleats between which the work can be laid.
5. Eccentric fixtures in which the work is gripped by means of an eccentric mounted on the axis of rotation of the work.
6. Contour fixtures, for presenting work of more or less irregular contour to the polishing or buffing wheel.
7. Fixtures that hold the work by means of vacuum, commonly called vacuum chucks.
8. Magnetic chucks.

All the foregoing fixtures may be loaded at the bench or on the machine, depending on the character and quantity of production of the work. They all may be, when loaded on the machine, either hand operated, full automatic, or semiautomatic. The full automatic fixture locks the work in position and unlocks and unloads it at the completion of the finishing operation without any attention from the machine operator except the placing of the work on or in the fixture. The semiautomatic fixture may either lock or unlock the work, the operator performing the other operation by hand.

Quantity of Production Determines Fixture Design.—In undertaking the design of fixtures, one of the principal points to be considered is quantity of production in connection with the capacity of the machine. Quite frequently the length of application of the wheel to the work is so short as to preclude the possibility of loading several pieces in the fixture and locking it in the interval that is available between successive operations. At the same time the quantity of production may be such that holding a single piece in a fixture would so cut down the capacity of the machine that the required production would be unobtainable. In such an event a fixture separate from the machine, which can be loaded and unloaded at the bench, is indicated, being transferred to and locked on the machine when loading is completed. Such a procedure usually calls for two or more loaders for a machine or battery of machines. Since loaders are far less costly than polishers or machine operators, the increase in production obtained by the use of multiple fixtures more than compensates for the extra cost of the additional personnel.

Another point to be considered is the adapting of one fixture to various types of work. For instance, the total volume of work might warrant a considerable investment in rotating-type polishing and buffing machines. On the other hand, the quantity of each particular item that would be manufactured at any one time would be so small and the number of different items involved would be so large that the expense of fixtures for all the items would be prohibitive. Frequently, however, it is possible to design what is termed a "master fixture" in which is contained all the mechanism for locking, unlocking and unloading the work.

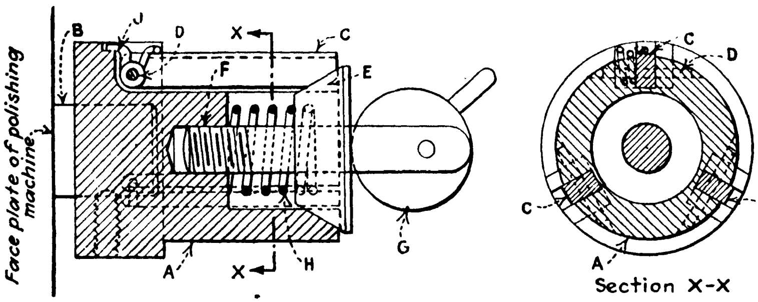


Fig. 62.

To this master fixture are fastened adapters or chuck jaws, operated by the master fixture, which will hold any given piece of work of the same general class. The expense of equipping for a large variety of work can thus be materially reduced, since the adapters can be made for a small fraction of the cost of a complete fixture.

Fixture for Circular Work.—Figures 62 to 68 show some fixtures of several of the classes outlined above. Figure 62 is an internal expanding fixture that may be used for circular work on a rotative type of machine. It consists of the main body *A* set-screwed to the rotating spindle *B* of the machine. Three longitudinal slots at 120 deg. apart are cut in the body *A*, in which are fitted three narrow expansion bars or jaws *C*. These are hinged at the inner end on pins *D* and beveled at the outer end to conform to the angle of the cone *E* which slides upon the stud *F*, screwed into the body of the fixture. The outer end of the stud *F* is slotted and carries an eccentric *G* which bears against the outer surface of the cone *E*. The work to be finished is slipped over the body of the chuck until it bears against the shoulder at the inner end. This shoulder is so positioned that, when the work is in contact with it, the work is in the proper relation to the polishing wheel. The eccentric *G* is then turned to the opposite position from that shown, forcing the cone *E* inward against the bevel of the jaws *C* and causing them to move outward and grip the work. When the position of the eccentric is reversed at the completion of the finishing operation, a spring *H* wrapped around stud *F* forces cone *E* outward, and springs *J*, around each of the pins *D*, move the jaws inward, thus permitting the work to be removed from the fixture.

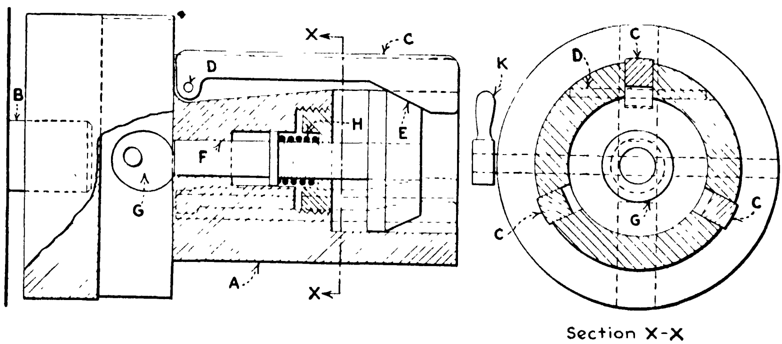


Fig. 63.

Fixture for Bearing Races.—The type of fixture shown in Fig. 62 with its cam-locking device is applicable only to open-end work, that is, work that is in the nature of a ring or a ball-bearing race. For work with a closed end, for instance, a deep drawn shell or a cooking utensil, a modification of the fixture, as shown in Fig. 63, could be made by attaching cone *E* to the outer end of the stud *F* and hinging the jaws *C* at the inner end of the fixture. The angle of the cone is reversed from that in Fig. 62. The stud *F* is moved axially by the eccentric cam *G* located in a slot at the rear end of the body *A*. The cam is operated by the lever *K* attached to the camshaft.

The fixture in Fig. 63 could be made to lock and unlock automatically by providing a hollow spindle on the polishing machine, through which stud *F* would extend. The cam *G* would be omitted, but in its place a fixed cam would be placed in the head of the polishing machine. This cam would be so located as to move stud *F* outward as the fixture indexed into position for presenting the work to the wheel. At the conclusion of the operation, as the fixtures are indexed away from the wheels, a reverse curve on the cam would permit stud *F* to be retracted by the spring *H*, thus releasing the work. If desired, a spring-operated knockout could be attached to the outer end of the fixture to unload the work as soon as the jaws *C* release it.

Fixture for Straight-line Machine.—Figure 64 is an internal expanding fixture for a straight-line machine. This fixture is designed for holding metal backs of loose-leaf notebooks, while being buffed. It comprises essentially two L-shaped jaws *A*,

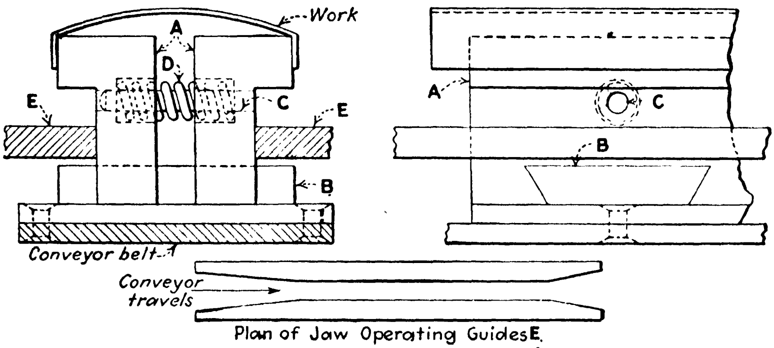


Fig. 64.

set back to back and sliding upon a suitable base *B*. The illustration shows a dovetailed slide, but any suitable form of slide may be used. Dowels *C* in one jaw fit into corresponding holes in the opposite jaw, and around these dowels are helical springs that compress into recesses in the jaws and serve to force them apart.

In operation, as the fixture moves along on the conveyor of the straight-line machine, it passes between tapered guides *E*, which force the jaws together, compressing the springs *D*. While in this position, the work to be finished is laid on the top of the jaws. The further movement of the conveyor carries the jaws out from between the tapered guides, whereupon the compressed springs *D* expand and force the jaws apart, thus locking the lips against the edge of the work and holding it firmly while it passes under the wheels. The fixture is unloaded by causing it to pass between another pair of tapered guides while passing around the head pulley and the conveyor. The jaws being brought together, the work slides off them as they pass around the pulley and drop into a tote box.

Holding with Spring Steel.—A variation of this construction is shown in Fig. 65, where the two lips are on the edges of hinged

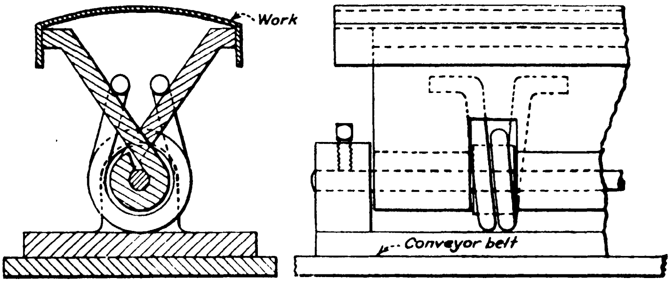


FIG. 65.

sections which are forced apart by springs. The same arrangement of tapered guides may be used for opening and closing them. Where the nature and quantity of the work do not warrant elaborate or expensive fixtures, the same result may be accomplished by a piece of spring steel bent into appropriate form as shown in Fig. 66.

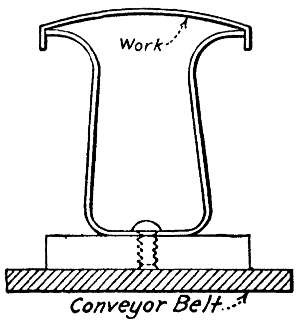


FIG. 66.

Recessed Chuck for Straight-line Machine.—Figures 67 and 68 are examples of fixtures loaded at the bench and then transferred to the machine. Figure 67 is a recessed chuck for a straight-line machine. The fixture comprises a block of hard wood, on the upper surface of which are fastened metal cleats that fit into the slot of the work and also metal plates that conform to the outer dimensions of the work. The thickness of these plates is such that they allow only enough of the work to project above them as is necessary for the proper action of the polishing wheel. The reason for this is that the edges must be held square, and were the polishing wheel allowed to come in contact with the edge of the work as it approached it, the edge would be rounded over and the appearance of the work destroyed. An L-shaped slot, extending the full width of the block, is cut in the undersurface of the fixture. This slot fits over an L-shaped cleat on the conveyor which serves both to drive the fixture under the wheels and by reason of the projecting lug *L* to prevent it from being picked up and thrown by the wheel. Each fixture holds six pieces, and, inasmuch as the machine is capable of passing

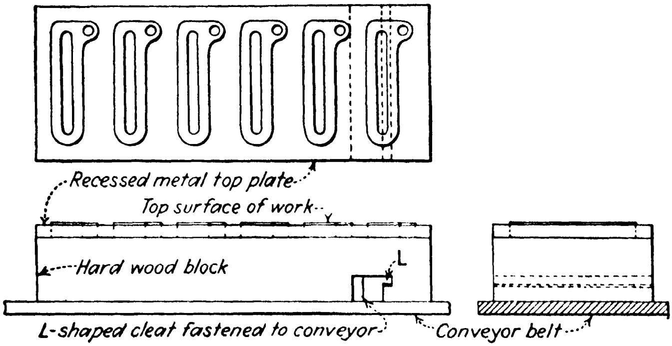


Fig. 67.

upward of 250 pieces per minute under the polishing wheels, it is evident that only a detachable fixture loaded at the bench by a corps of loaders could utilize the full capacity of the machine.

Fixture for Buffing Circular Rings.—Figure 68 is a fixture used for buffing circular rings. It comprises the hollow body *A* upon which the work is mounted, a number of pieces being strung

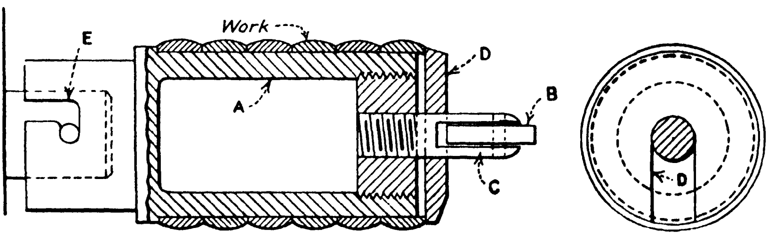


Fig. 68.

along in contact with each other, the innermost one being against the shoulder. On the outer end of the fixture is a slotted stud *C* carrying an eccentric *B*. When the body *A* has been filled with work, a heavy *C* washer *D* is slipped over the stud and clamped by the eccentric *B*. The pressure exerted by the eccentric upon the *C* washer forces the several pieces of work firmly against each other and against the shoulder at the inside end of the fixture body. The fixture body is recessed at its inner end to fit on the spindle nose of the rotating polishing machine. It is locked thereon and driven by means of a bayonet lock *E*, which fits over a pin on the spindle nose.

Rubber Sleeves.—An interesting variation of this type of fixture is shown in Fig. 69. Here the problem was to finish a large number of pieces of the same external diameter but of varying internal diameter. The type of fixture shown in Fig. 68 cannot be used because the chuck body would necessarily be of the diameter to accommodate the smallest internal diameter of the work, in which event the larger diameter pieces would be eccentric to the fixture body and therefore would not be finished

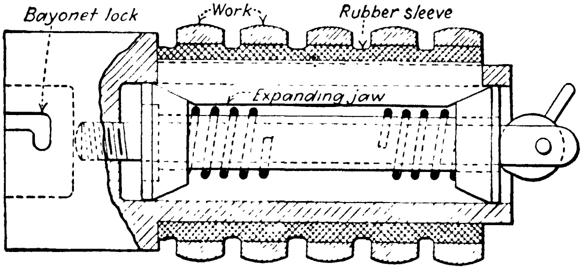


FIG. 69.

all over. A second reason is that it is necessary to finish clear down on the sides of the work to the inside diameter, and this cannot be done with the pieces forced against one another. Without going into the details of construction of the fixture, it may be stated that the idea involved is the same as in Fig. 62, that is, internally expanding jaws actuated by cone and cam. To compensate for the variation in inside diameter, a sleeve of soft rubber is fitted over the fixture body, its outside diameter being equal to the smallest internal diameter of the work to be done. When the work is placed on the sleeve with spaces between the individual pieces as shown and the jaws expanded, the rubber is forced out sufficiently far to engage the larger diameter pieces. At the same time it is sufficiently soft and flexible to flow from under the smaller diameter pieces. The adjustment of the jaws is such that expanding them creates sufficient friction to drive the work when in contact with the buffing wheel.

Since the wheel will cut grooves in the spaces between the work, this form of fixture requires a loading device to ensure that the work will always come at the same relative position in the fixture. The loading device consists of a hollow box (Fig. 70) split in two halves, with the upper half hinged to the lower. The interior surface of the box is grooved to correspond with the position of the work in the fixture. To use the loading device, the work is dropped in the grooves of the lower half of the fixture, the upper half is closed down upon it, and the fixture slipped through a hole in one end. When the shoulder of the fixture has been brought up against the end of the box, the locking cam is operated to expand the jaws and grip the work. The upper half

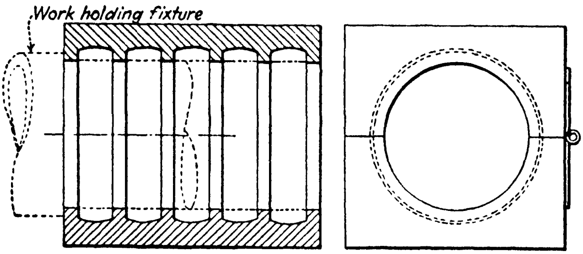


Fig. 70.

of the cylinder is then lifted and the loaded fixture placed on the machine, being held by a bayonet lock.

Fixture for Copper Goblet.—Frequently, when the area of the work is large, the friction between the work and fixture is sufficient to drive the work against the buffing or polishing wheel. Such a fixture is illustrated in Fig. 71, which is for a copper goblet buffed in a rotative-type machine. The body of the fixture conforms to the interior of the goblet and is a nice fit therein. The success of this type of fixture depends upon the maintenance of such pressure between work and fixture as will set up sufficient friction to resist the effort of the polishing or buffing wheel to spin the work on the fixture. This pressure usually can be supplied by an overarm attachment such as shown in Fig. 71. Here the attachment consists of a central stud rotating a spider with as many arms as there are working spindles on the machine. At the extremity of each arm of the spider, a sliding shaft terminates in an end conforming to the shape of the work with which it is used. A heavy spring forces the work against the fixture and supplies the requisite pressure. A cam handle attached to the shaft mates with a similar cam on the boss on the spider. A half turn of the cam draws the shaft back from contact with the work and permits the fixture to be unloaded. The reverse

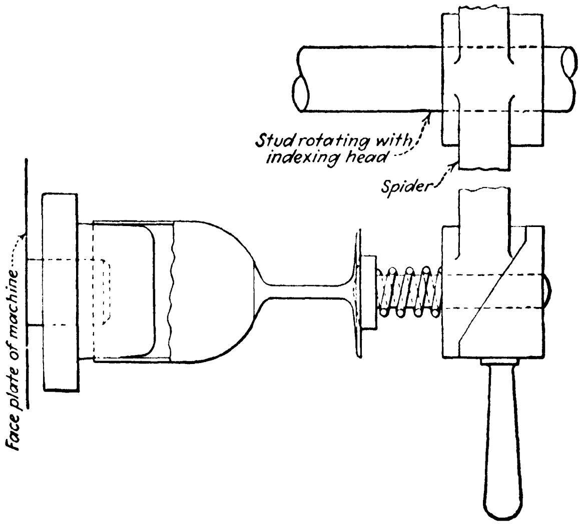


FIG. 71.

movement forces the shaft against the work. The stud rotates the spider in conformity to the rotation of the indexing head of the polishing machine.

Gripping by an Eccentric.—The eccentric fixture shown in Fig. 72 consists essentially of a body, conforming to the interior

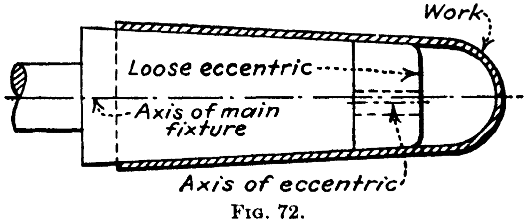


FIG. 72.

surface of the work to be finished, mounted on a spindle that is rotated by the polishing machine. The top of the body is a loose piece free to rotate around an axis parallel to, but slightly eccentric to, the axis of the body. The first contact of the polishing or buffing wheel with the work tends to rotate it around the axis. The loose eccentric piece rotates with it and, owing to its eccentricity, grips it as soon as it has made a small fraction of a revolution. The gripping action of such a fixture is very powerful, and considerable care must be exercised in laying out such a fixture. Usually some experimental work is advisable to determine the exact amount of eccentricity that will give sufficient driving power and yet not grip the work so hard as to make difficult its removal from the fixture. The work can be released by rotating it in the opposite direction from that in which it was rotated in order to lock it. If the gripping action is not too

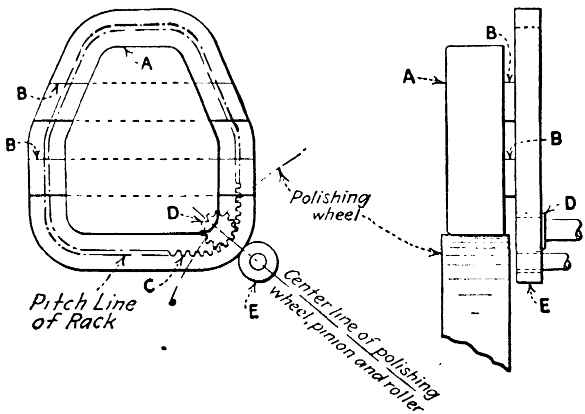


FIG. 73.

powerful, it may be forced off by causing it to come in contact with a pair of tapered guides that bear on the edge of the work on either side of the fixture. Such fixtures are designed for work too small for expanding chucks.

Geared Chucks.—Not the least interesting of polishing- and buffing-machine fixture is the class known as geared chucks. This type of fixture enables noncircular work to be polished or buffed in a rotative-type machine. In Fig. 73, *A* represents the outline of an irregularly shaped article that is to be finished in a rotative-type machine. The work is gripped in any convenient manner on a faceplate that is attached to a base by supports *B*, which base carries a rack or internal gear *C*, the pitch line of which is exactly parallel to the perimeter of the piece *A*. This rack is driven by the pinion *D* mounted upon the rotating spindle of the polishing machine. The outer edge of the rack is parallel to the pitch line and therefore to the perimeter of the work that is to be finished. A roller *E* attached to the frame of the polishing machine bears against the outer edge of the rack. The centers of the pinion, roller and polishing or buffing wheel are in the same straight line. It is obvious that as pinion *D* is rotated it will cause the rack to travel forward and that, as it moves, the roller *E* will constrain it to move in a direction parallel to the pitch line. The work, therefore, will move in the same direction, and, since the polishing wheel is in the same straight line with the roller and pinion, it will always be tangent to the work at all portions of its perimeter.

It is thus evident that pieces of quite irregular shape can be finished by means of a geared chuck, provided that there are no indentations in the perimeter of too short a radius to permit the polishing or buffing wheel to enter.

A limitation of this type of fixture is that the work must always be identical and conform in dimensions and contour within very narrow limits with the contour of the pitch line of the rack. Sometimes an inaccuracy in the chucks, jigs or fixtures used in the machining operations will cause a difference in dimensions of successive pieces that will render this type of fixture ineffective. Before the polishing fixture of this type is condemned for failure to function properly, a careful study and inspection should be made of the accuracy of machining.

Finishing of Hinges.—An interesting type of fixture that does not fall within any of the classes enumerated earlier in this chapter is that shown in Fig. 74. This is a fixture to enable a straight-line machine to finish automobile door hinges from the heel of the curved end and down on the blade the required distance. The earliest application of the straight-line machine with a floating polishing wheel to this type of hinge polished the blade and a short distance around the curve, the balance of the curve being finished by hand. The fixture illustrated was devised to eliminate the hand operation. The fixture carrying the work is an angle plate with a shouldered pin upon which the hinge is hung. A guide forces the hinge against the shoulder before it comes in contact with the polishing wheel, so that it is always located in the fixture in the same relative position as regards the wheel. Opposite each polishing wheel is an attachment that causes the hinge first to rotate about the pin on the moving fixture and then holds it at an angle with the horizontal to permit the wheel to polish the blade. This fixture consists of the angle plate A, on the inner face of which is suspended a bell crank B, which can rotate freely about the pin C. The stop pin D limits its downward movement and holds the pin E, which is carried by the horizontal arm F of the bell crank in a fixed position until it is moved upward by the cam block G coming in contact with the boss H on the vertical arm J of the bell crank.

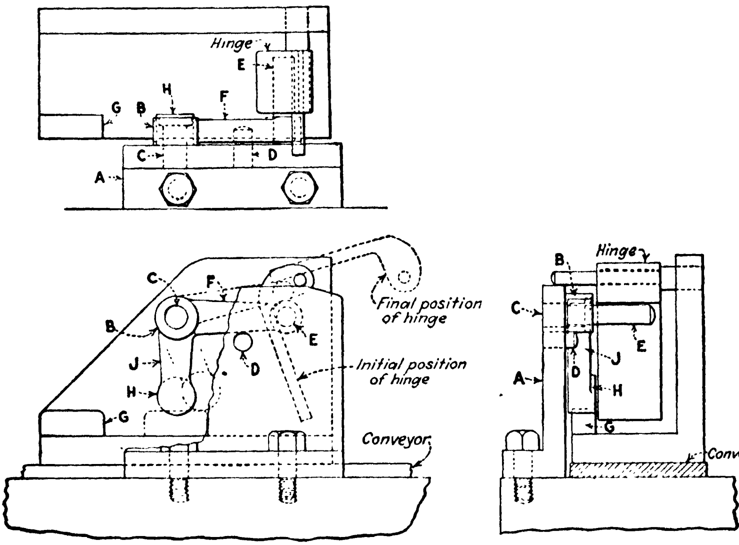


FIG. 74.

The action of the fixture is as follows: The hinge is carried underneath the polishing wheel by the fixture attached to the conveyor of the polishing machine. The angle plate A is so positioned that the blade of the hinge comes in contact with pin E at the instant that the polishing wheel strikes the edge at the heel of the hinge. As the conveyor carries the hinge forward under the wheel, pin E causes it to rotate around the hinge pin. This rotative action about the hinge will cause the polishing wheel to traverse perhaps one-half of the curved surface of the hinge. With pin E in its original position, the angle of the hinge would be such, the conveyor continuing to move it forward, that the polishing wheel would no longer come in contact with the hinge and it is necessary to vary the angle of the hinge from the horizontal. At this point, the forward movement of the conveyor has brought the cam block *G* on the hinge fixture against the boss *H* on the bell crank. Its continuing forward movement causes the bell crank to turn, lifting pin *E* until it attains its maximum desired height, at which it is held by the boss *H* riding on top of the cam block until the polishing wheel has traversed the blade as far along its length as it is desired to polish. The boss *H* then rides down the rear end of the cam block, lowering the bell crank against the stop pin *D* without shock and returning the hinge to its original vertical position ready for contact with the next wheel of the straight-line machine where a similar operating fixture causes it to repeat the cycle. The polishing wheel, being floating, rises and falls with the variation in height of the surface with which it is in contact and covers the entire surface of the hinge from the heel to the end of the blade if desired.

PART IV

PLATING AND SPRAY COATING

CHAPTER XIX

RECENT DEVELOPMENTS IN PLATING

The metals most used for plated coatings on war products were cadmium, zinc, lead and tin for protection against corrosion, and chromium and silver (with lead and indium) for resistance to wear. Silver and gold were deposited on radio parts in which a highly conductive surface is needed for high-frequency currents. Silver plate was used on copper bus bars to reduce resistance at the contacts. Nickel plating was permitted only for those few purposes where it is irreplaceable. Rhodium plating was specified for high reflectivity and tarnish resistance. Copper and copper-alloy plating were much more liberally permitted but were still subject to a long list of restrictions.

In general, zinc furnishes at least as good protection as cadmium for steel against corrosion, but the bulky white corrosion products are more easily formed on it than on cadmium. However, various chromate films retard this corrosion and make its use possible for many purposes. Examples of such chromate films are Cronak, Iridite and Anozinc. Iridite gives an opaque olive-drab coating, which will be smooth and shiny over a bright highly polished plate on a steel base and matte over a dull plate. Impurities in the metal bring about variations in the nature or color of the coating after the dip.

Two types of Anozinc, a yellow and a black, are available. The yellow coating appears to be largely zinc oxide and zinc chromate with some soluble chromates absorbed from the solution. The black coating is similar except that in addition it contains basic chromic chromate.

Cronak is an iridescent-appearing finish on zinc which retards the formation of white corrosion products, especially in salt atmospheres. Many valuable suggestions on the substitution of zinc for cadmium are contained in two publications of the Operating Committee on Aircraft Materials Conservation, *Conservation Directive* 2B and *Conservation Bulletin* 6A.

It should also be noted that baked phenolformaldehyde varnishes also furnish good protection against corrosion of steel. The steel must not be exposed through pores or scratches, however, for it will corrode at such points.

The wartime shortage of tin, which may continue after the war, resulted in the installation of a number of tin-plating lines to electrocoat strip steel for food containers. Much thinner coatings of tin may be deposited by electroplating than by hot dipping. It was regular practice to deposit by plating 0.5 lb. per base box (0.00003 in.), whereas in normal times regular hot-dip tin plate had a tin coating of 1.5 to 2 lb. per base box, and it is not now practicable to reduce this below 1.25 lb. per base box by hot dipping. Great savings of tin are thus obviously effected by electroplating. Electrolytic tin plate will probably be used in somewhat thicker coatings now than during the war and should have a definite usefulness, but it will by no means entirely replace hot-dip tin coatings.

Postwar conversion of some of the tin-plating lines to plating strip steel with zinc or lead has also been under consideration.

Study of lead coatings, both hot-dipped and electroplated, was promoted by the former scarcity of zinc. Lead coatings do not completely protect steel that is exposed in pores or scratches, but if the coatings are reasonably heavy, according to ASTM tests, the corrosion of the steel does not penetrate deeply. The flaws are apparently sealed by the products of corrosion.

Cladding steel with nickel and copper for ammunition was an important contribution of the electroplating industry. One electroplating-equipment maker designed and built such equipment for a leading steel mill, receiving the plating specifications and then developing methods whereby the current density of the nickel plating was increased from an original 10 amp. per sq. ft. of work surface to 150 amp., with almost proportional increase in production.

Restrictions in the use of various surfacing metals recently caused considerable interest in electrodeposition of iron as a substitute metal. Investigations on iron electrodeposition, described in a paper by Schaffert and Gonser of the Battelle

Memorial Institute, were prompted by restrictions on the uses of copper and nickel in the electrotyping and stereotyping industry.

The greater part of the work was confined to the development of an iron plating bath and methods adaptable to electrotyping and surfacing of stereotypes. A combination sulfate-chloride bath was developed and tried out on a commercial scale in several electrotype foundries with considerable success. Later, a more thorough study of the properties and behavior of this sulfate-chloride bath was made in order to determine other possible applications.

"Porous chromium" plate is a new development that has many possible applications. At present it is used extensively for improved lubrication on rolls, piston rings, diesel-engine cylinder liners and aircraft cylinders. It may be produced in a number of ways which, in general, involve three principal control factors.

1. The deposition of the plate.
2. The etching treatment.
3. The finishing process.

The plating operation is much the same as that in regular hard-chromium-plating practice where plating to size is required, but specially close coordination and control of bath composition, temperature and current density are required.

The etching may be accomplished by electrical or electrochemical treatment, or it may be achieved by mechanical means. It is carried out on the plate itself or on the base metal, or on both. Finishing is done generally by polishing, lapping or honing.

The porosity of the plate is determined by the amount of plate removed and the rate of removal in the etching and finishing processes. Hones and inspection devices are the only special equipment needed.

The use of indium, plated and diffused, as a protective coating on various nonferrous metals continues to expand. It has been successful as a lubricant for deep drawing dies where it has enhanced the life of such dies many times. An important use is in airplane bearings. It is applied as a plated and diffused coating, chiefly on lead, cadmium, zinc, tin, copper, silver and gold plates. The diffusion, effected by heat-treatment after electrodeposition, results in amalgamation and the formation of a surface alloy that is corrosion-resistant, nonporous and of increased hardness.

Electroforming, or the creation of metallic articles by electrodeposition, has developed numerous industrial applications, although knowledge of the specific techniques involved is not yet widespread. A listing of some of the more recent applications of the process, however, demonstrates that, in electroforming, industry has acquired a new engineering tool. An interesting paper on this subject was "Electroforming Techniques," by Savage, read at the 1944 Convention of the American Electroplaters' Society.

The process is in operation for the manufacture of sound record masters, metal screens, electrotypes, caskets, patterns, master coin dies, dies for molding rubber, glass and plastics, duplicate intaglio printed plates, mirror reflectors, pipe fittings, seamless copper tanks, float balls for pressure gages and transformer cores. Recently, band instruments such as cornets and trumpet bells were electroformed, and later trombone bells and trombone slides. Probably the most interesting and most difficult job was the electroforming of tympanic bowls or kettledrums. These varied from 25 to 29 in. in diameter and from 18 to 22 in. deep with a hemispherical bottom and straight sides. Valve assemblies with three valve casings and all parts assembled have been experimentally produced in one piece. Techniques for electroforming have been worked out for copper, nickel, silver, iron, brass and alloys of cobalt and nickel.

An interesting development was a process for producing a bright alloy plate, a ternary alloy deposit of copper, tin and zinc. The process, on which patents are pending, was developed by Westinghouse Electric Corp., Meter Division, Newark, N. J., to meet military requirements for which existing single metal or binary deposits were not adequate. G. W. Jernstedt was responsible for a major share of the investigation on which the process is based. The Hanson-Van Winkle-Munning Co. is cooperating with Westinghouse to market the process.

The deposited alloy of copper, tin and zinc is a bright blue-white as it is taken from the plating solution. It is hard and wear-resistant, has excellent tarnish-resistant qualities, is non-magnetic and has a high protective value when applied over copper or copper alloys.

Corrosion resistance is its outstanding property. When the alloy is plated on brass or copper base metals, at a thickness of only 0.0002 in., it will pass the 200-hr. salt-spray test. If the base metal is steel and corrosion protection the prime requisite, direct plating is not recommended. A copper undercoating should first be applied in order to secure the benefits of the low corrosion rates between the bright alloy and the copper. Its reflectivity approaches silver (80 to 85 per cent).

Continuous nickel plating of fine iron wire for electric-light leads is now being done on a large scale. A method has been patented for depositing nickel followed by zinc and heating to an alloying temperature of the two, but a temperature insufficient to cause appreciable alloying of the nickel with the ferrous base.

Schaefer & Mohler developed a high-speed silver bath that could tolerate cast-silver anodes. On rotating cylinder cathodes such as bearings, a dense ductile deposit could be obtained in a cyanide solution operated at relatively high pH and with rather high metal concentration. Bowen & Gilbertson found that thin, adherent deposits of silver could be obtained on magnesium with the use of a boric acid—cyanide solution, after proper treatment of the magnesium base.

Various methods were suggested for plating zinc on malleable and gray iron castings, always a difficult problem: cadmium flashing, mercury and cadmium in the zinc solution, tin flashing, high carbonate zinc bath flashing at high current density, immersion in molten caustic soda and anodizing in sodium chloride prior to zinc plating.

An important disclosure was made by F. Page, Jr., who presented evidence indicating that zinc must not be permitted in contact with stressed steels or stainless steels at elevated temperatures because cracking of the metal results from the solution of iron by the zinc along the grain boundaries. Consequently, although zinc is being substituted for the more scarce cadmium as a protective coating for most purposes, cadmium is still necessary in some applications.

CHAPTER XX

CADMIUM PLATING[1]

Cadmium plating is a relatively young science. Prior to its discovery, it was exceedingly difficult to protect piano wire adequately against corrosion without interfering with its sound-producing properties. A serious problem also existed in plating such items as springs and delicate-edged tools without embrittling them. It was discovered that a thin cadmium coating electro-deposited on these materials gave protection against corrosion and affected neither tone nor temperature.

This first commercial application of electroplated cadmium in 1919 is credited to Marvin J. Udy, a research chemist in the employ of Elwood Haynes, automobile manufacturer. From this beginning, the use of cadmium for protection against corrosion has progressed to all parts of the world.

Cadmium applied as a thin coating (0.0002 to 0.001 in. thick) to most base metals will provide protection superior to that obtained from equal thicknesses of many other metallic coatings. Nearly all electrodeposited coatings in this range of thickness have some inherent porosity, which decreases as the thickness of the coating increases. In addition to this porosity, there is always danger that the base metal will be exposed by nicking or scratching. When the base metal is exposed through thin coatings of tin, lead, copper and nickel, corrosion begins at the point of exposure and spreads until the entire surface is affected. A cadmium coating, however, functions in a different manner, because it is anodic to iron. This means that protection continues even if the ferrous base metal is exposed through pores, nicks or scratches. The cadmium must corrode before the iron itself is attacked.

This phenomenon can be easily proved by a simple experiment. Fill two beakers or glasses with a solution of ordinary table salt. Immerse in each beaker a steel washer, after inserting a plug of

[1] Prepared in collaboration with Dr. R. B. Saltonstall of the Udylite Corp.

solid cadmium in the center hole of one of the washers, and allow both to remain in the beakers for 24 hr. Afterward, examine both washers. There will be visible signs of corrosion on the unprotected steel washer, while no corrosion will be visible on the washer with the cadmium plug. In this case only the protecting plug will be etched by the corrosive liquid.

This experiment illustrates what is known as "sacrificial" or electrochemical protection. When cadmium is in contact with

FIG. 75.—These cadmium-plated parts were carefully polished before plating and then buffed afterward in order to give them a high luster.

the steel, the latter is protected, since the cadmium must corrode away before corrosion of the base metal commences.

Coatings such as copper, nickel, lead, tin and chromium do not offer this sacrificial protection. Although they themselves resist corrosion well, as soon as the base metal is exposed, corrosion begins at that point.

Cadmium coatings, when properly applied, possess an attractive silvery-white luster. The sheen is not so brilliant as that of chromium and is described as having a "satin" appearance.

The luster of the cadmium deposit lasts a long time. However, after exposure for an extended period, the coating takes on a frosty-white hue that is not unattractive. Some tarnishing after exposure is a property that cadmium has in common with all electroplated coatings, with the exception of chromium. Cadmium tarnishes at about the same rate as nickel.

The metal cadmium is rather high priced, at present about 95 cents per pound, but cadmium plating on the other hand is relatively inexpensive. This is due to several factors. The

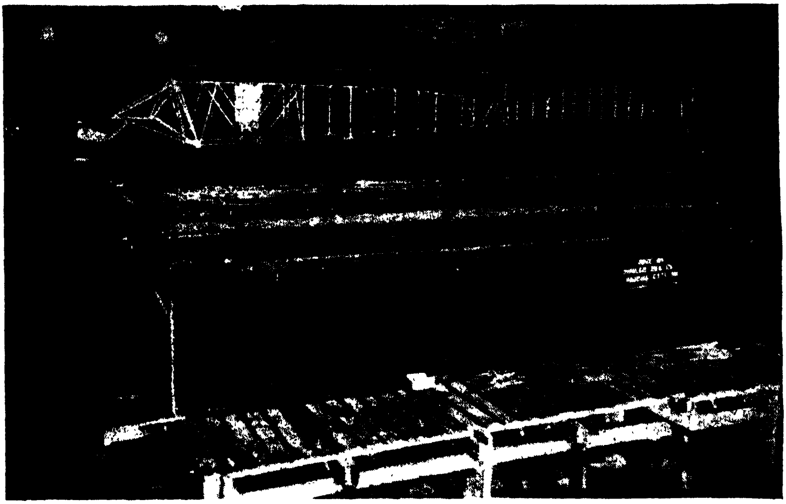


FIG. 76.—Long still tanks equipped with special overhead handling devices are used for cadmium plating airplane frames and parts.

cadmium coating generally applied is thin (a thickness of 0.0002 in. is generally recommended for indoor exposure). One pound of cadmium when applied in a thickness of 0.0002 in. will coat an area of approximately 112 sq. ft. Thus the actual cost of the metal used in coating 1 sq. ft. is 0.85 cent. Furthermore, no mechanical operations such as buffing and polishing are necessary. There are other factors influencing cost, and these will be pointed out when the method of applying cadmium is discussed.

As might be expected from the foregoing discussion, cadmium has many applications. Each of these applications is due to the particular property or group of properties that fit exactly the finishing requirements of the manufacturer. The combination of efficient rust prevention, pleasing appearance and low cost accounts for most of the popularity of cadmium among manufacturers.

Although these three advantages in one finish offer an attractive combination, not all manufacturers are in position to benefit by all three. The manufacturer of tools or lighting fixtures may want a protective attractive finish, but the casket manufacturer generally wants only economical rust protection. He

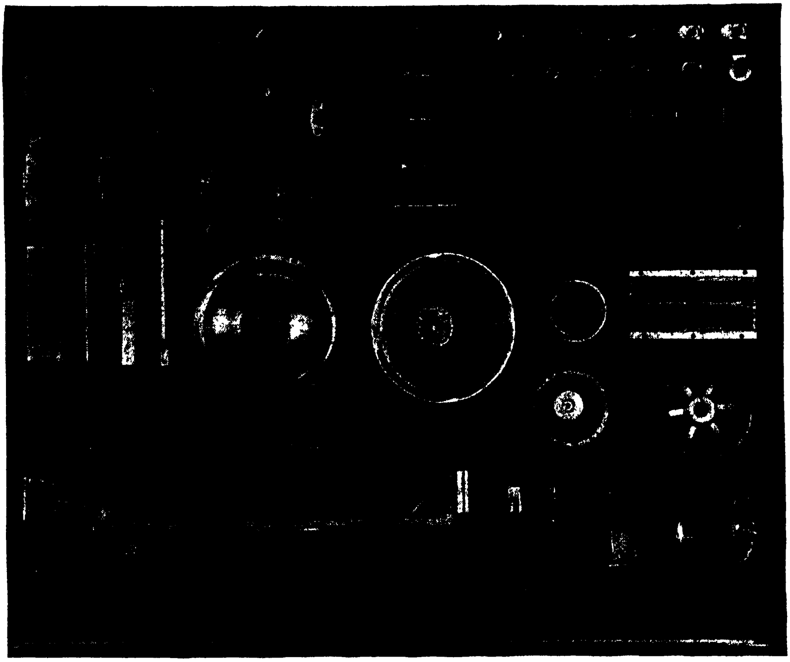


FIG. 77.—The automobile industry is one of the largest users of cadmium plating, and the miscellaneous group of parts here shown gives some of the typical examples.

cares nothing for appearance, since most caskets are coated with heavy decorative lacquer coatings applied over the cadmium coating.

Cadmium has the property of resisting the corrosive action of weak alkalies such as are present in washing soaps and powders. For this reason, practically all prominent manufacturers of washing machines use cadmium as the protective coating for steel wringer parts. In addition, other steel parts of the washer are cadmium plated to prevent corrosion.

In the construction of buildings, such parts as I beams, angles and terra-cotta anchors often are immersed in concrete. In many such instances, a protective coating is desired, since the concrete is porous and permits access of moisture to the steel. Cadmium fits into the scheme nicely, because the concrete is also alkaline to such an extent that it tends to destroy some other protective coatings.

Rust and corrosion of steel members are the causes of many cracks in concrete.

Soldering.—Cadmium-plated surfaces are easily and economically soldered, which is a boon to the manufacturer of electrical products. Tests have proved that soldering may be done as efficiently on cadmium as on tin-dipped surfaces, and at a lower total cost.

One of the most important properties of a coating is its ductility. Many products are deformed on repeated use, and the coating must be sufficiently ductile to conform to the new contours and continue to provide protection.

Some manufacturers have found the ductility of cadmium coatings to be advantageous from a manufacturing standpoint. For example, one maker of radio condenser shells cadmium plates the flat blanks, and, after plating, the blanks are formed into the desired shapes. By this method of preplating, storage space is conserved and a better plating job results, since a flat surface is more easily coated uniformly than is a complex one.

A feature of a good electrical switch is that its parts allow the free passage of electrical current with a minimum of contact resistance. Uncoated copper parts oxidize, and the oxide formed sets up a high contact resistance, causing excessive overheating and still further oxidation.

Cadmium plating of the copper parts that come in contact reduces the tendency to oxidation, and yet the cadmium coating does not increase the contact resistance.

Corrosion of Dissimilar Metals.—In most radio sets, there are copper, tin, brass and steel parts in contact with one another. In the presence of moisture these dissimilar metals set up a battery or "voltaic pile." This battery generates stray currents that interfere with the function of the radio set and prevent clear reception. To overcome this difficulty the parts may be coated with cadmium.

When aluminum and steel are in contact, the former tends to corrode quickly, owing again to the voltaic pile set up in the presence of moisture. Since the electropotential of cadmium is so close to that of aluminum, cadmium plating the steel eliminates the corrosion.

Application of Cadmium.—Cadmium is applied to the surfaces of metals by electroplating in fundamentally the same manner as copper, nickel and chromium. The chief distinction of cadmium plating from other types of plating lies in the fact that (1) well-compounded cadmium baths are very easily controlled, (2) the

FIG. 78.—Small parts are nearly always cadmium plated in plating barrels. This shows a typical line-up. The barrels themselves are made of hard rubber, bakelite or similar nonconducting material.

plating is accomplished at room temperature, (3) no toxic or obnoxious fumes are evolved, thus precluding the necessity of exhaust systems, and (4) the cadmium bath has the ability to deposit metal into deep recesses; in other words, it has a good throwing power.

Since a high percentage of faulty plating of all types is due to poor cleaning, this first step in the plating procedure is of the utmost importance. Cadmium, and other coating metals as well, cannot be properly deposited on other than a chemically clean surface.

Cleaning may be divided into two main parts—removal of oil and grease, and the removal of oxide and scale. Both these processes have been discussed at considerable length in previous chapters.

Following the cleaning, the parts are ready for the actual plating. They are immersed in the plating bath and made the cathode in an electrical circuit. The action continues until the desired thickness of coating is secured. The parts are then rinsed in cold and hot water and dried.

No auxiliary treatment, such as buffing, is required after the parts come from the plating bath. The luster of the coating is generally sufficiently bright without extra handling and additional expense. When a higher luster is desired, special chemical dips accomplish the purpose.

Control of Plating Bath.—The ease with which a cadmium plating bath continues to produce good cadmium deposits lies in the proper control of the bath itself. In the properly compounded cadmium bath, it is necessary to control the quantity of free cyanide and metal. This usually is accomplished by making simple tests. The concentrations of these ingredients vary with the requirements. When the luster of the plate slowly diminishes, a small addition of organic brightener is made.

Bath Composition.—The properly formulated cadmium-plating bath for general purposes and current densities of 15 to 25 amp. per sq. ft. of surface to be plated has a cadmium content of approximately 2½ oz. per gal. of solution. For plating at higher speeds, a cadmium content up to 5 or 6 oz. per gal. may be desirable. It is important that the cadmium content be maintained at the desired value. In other words, as cadmium is plated out of the solution onto the work, this metal must be replaced in the solution in order to maintain proper balance.

The most efficient and economical method of maintaining the cadmium content is to use a soluble cadmium anode. Of course, the cadmium content of the bath might be built up by additions of cadmium oxide or other cadmium salts, but cadmium in the form of salts is more expensive.

In order to eliminate cadmium oxide additions and still preserve a perfect metal-content balance between "income" and "outgo," the ball anode was developed. A view of this anode is shown in Fig. 79. It consists of a steel helical-coil wire container that holds pure cadmium balls about 2½ in. in diameter.

As the ball anodes corrode, their diameter lessens and they descend in the container. As soon as there is room, new balls are fed in at the top. The bottom of the container tapers to a cone where small particles of cadmium balls collect until they are entirely used up.

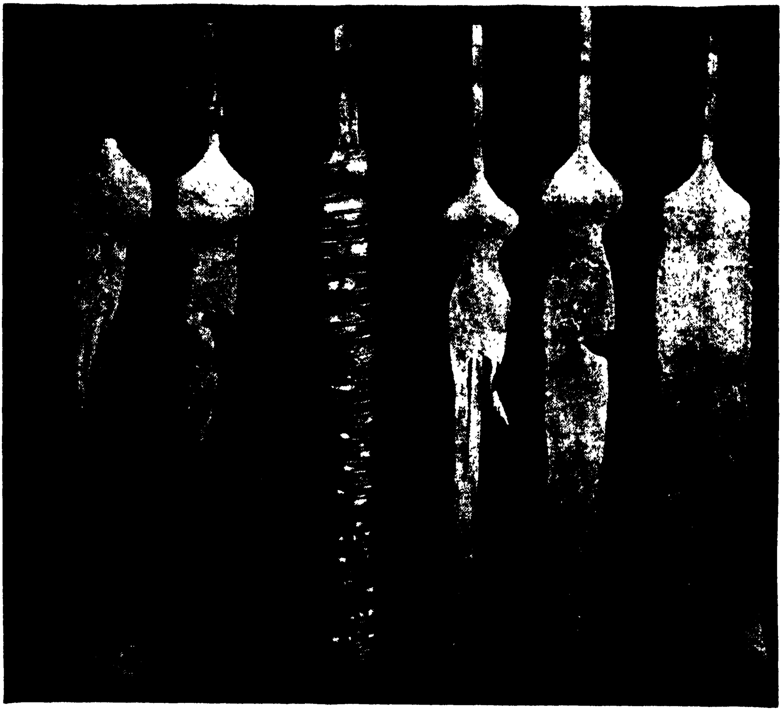


Fig. 79.—The ball anode is here compared with the usual slab anode. Various stages of disintegration of the slab anode are shown. As these corrode, the area decreases, thus disturbing the metal content of the bath. Chunks of cadmium metal fall from the straps to the bottom of the tank where they are useless as anode material. On the other hand, the helical-coil anode, consisting of pure cadmium balls, corrodes evenly. As the diameter of the balls diminishes, they descend in the wire container, and fresh balls are added at the top.

This type of anode is used by the large majority of manufacturers and jobbers doing cadmium plating, because no metal is wasted, because the anode area stays constant, because it maintains proper metal balance in the solution and eliminates the necessity of cadmium oxide additions.

The correct minimum free sodium cyanide content is also an important factor in maintaining the proper cadmium content of the solution, because it controls the rate at which the cadmium anodes dissolve at various current densities. Its strength is maintained by making regular additions of sodium cyanide, based on tests.

Special solution composition may be required for special purposes, such as "throwing" the plate into extremely difficult recesses.

Thickness and Luster.—Mention has been made earlier of the amount of metal deposited, or thickness of deposit. This is undoubtedly one of the most important items to be included in this discussion.

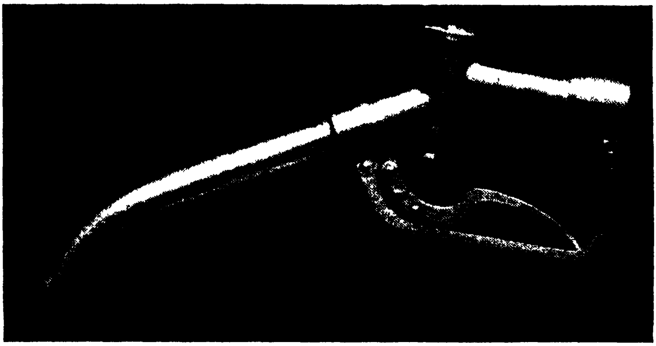


FIG. 80.—One of the most familiar metal parts in modern commercial life is the gasoline hose nozzle at filling stations. This illustrates one of the best applications of cadmium plating.

It has been determined by experience that a coating of cadmium less than 0.0002 in. thick has little protective value. Since the mechanism of the protection afforded is "sacrificial," as previously mentioned, one might expect the service life of the coating to be directly proportional to its thickness, and this has proved to be the case.

At the beginning of the Second World War, most specifications called for a minimum thickness of 0.0002 in. of cadmium on steel for mild or indoor exposure and 0.0005 in. for severe or outdoor exposure. Because of an acute wartime shortage of cadmium and the heavy demands of the aircraft industry for cadmium plate, the higher specification was reduced during the war to a mimimum of 0.0003 in. in most cases. Heavier coatings will now probably be specified again. Where parts are plated to prevent rust while in stock or for a short period of time, a thickness of 0.0001 in. may be permitted.

Uniformity of thickness is the major consideration when the efficiency of rust-protective coatings is concerned. If a coating is 0.0002 in. thick at one point and 0.0001 in. at another, as a rule the thinner portion will fail much more quickly than the thick one. It is of paramount importance, therefore, that protective coatings be deposited as uniformly as possible on the surface of the article.

Some plating solutions have a greater tendency to deposit uniform coatings than others. Uniformity of coating thickness has a direct and intimate connection with throwing power.

Throwing Power.—An electroplating solution that deposits metal upon recessed surfaces is said to have good throwing power. A plating bath that lacks that ability is said to have poor throwing power.

Throwing power will vary from one process to another, depending on the native properties of the metal and on the type of plating solution used. Generally speaking, alkaline and cyanide baths have considerably greater throwing power than acid baths. The following commercial plating solutions are listed in order of their degree of throwing power.

1. Alkaline tin.
2. Cadmium.
3. Cyanide copper.
4. Cyanide zinc.
5. Nickel.
6. Acid copper.
7. Acid zinc.
8. Chromium.

The throwing power of a bath is of importance because it exerts a direct influence on the cost of the plating. For example, a cadmium plating bath with good throwing power will plate a recessed part to a minimum thickness of 0.0002 in. in, let us say, 10 min. In order to plate the same recess with the same thickness of metal in a bath having poor throwing power, it would take approximately double the time, or 20 min. Thus, the amount of equipment necessary to plate a day's production would necessarily be double that required for cadmium plating. Other items also enter in, such as high power consumption and loss of metal being built up on protruding parts of the article.

Uses for Cadmium Plate.—These are legion. A few of the more important ones before the war were as follows:

Electrical manufacturing.
Automobile and motorcycle.
Radio.
Textile equipment.
Nuts, bolts, screws, rivets.
Tools.
Aircraft.
Fasteners.
Household equipment.
Office equipment.
Builders' hardware.

The list was changed radically by war needs. A large part of the cadmium plate was used on aircraft parts. As the conversion program progresses, however, cadmium will undoubtedly again become available for use on civilian goods and will be widely used in the above and many other applications.

Equipment.—The types of equipment used for the application of cadmium plate are fundamentally the same as those used for such other plated finishes as nickel, copper and tin.

Small parts such as nuts, bolts, washers and rivets, machine screw parts and small stampings and castings are usually handled in bulk. The plating of such parts is accomplished in a revolving horizontal barrel that consists of a perforated cylinder made of hard rubber or similar nonconducting material and arranged so as to be lowered into a tank containing the plating solution.

Unlined steel tanks are suitable for cyanide cadmium solution. Ball anodes in containers are hung along two opposite sides of the tank on rods parallel to the axis of the plating cylinder. When the cylinder is lowered into the tank, the electrical circuit to the cathode contacts inside the cylinder is completed, and gears for rotating the cylinder are meshed. Several types of cathode contact are available for different types of work.

Larger parts are plated on hooks or specially designed racks in hand- or hoist-operated still tanks or in fully or semiautomatic conveyor machines. This equipment is similar to that used for nickel plating; but, because the cadmium coatings usually applied are thinner than the nickel coatings, the equipment required is less extensive.

Low-voltage generators or rectifiers are used for power supply; 12 volts for barrel plating and 6 volts or less for racked work.

Advantages and Disadvantages.—One of the objections to cadmium has been that paints, colored lacquers and enamels often do not adhere very well. This difficulty has been overcome by the development of special coating materials. They adhere well and will stand severe bending and deformation without cracking or peeling. Another development is special pretreatments that make ordinary paints adhere quite satisfactorily.

Cadmium, as usually plated, is very soft. In fact some authorities say that tin is the only metal in commercial use which, when plated, is softer than cadmium. Recent progress in copper-plating has been in the direction of control of hardness of the plate, but even at its softest the copper coating is harder than cadmium.

This, of course, is not necessarily an advantage for cadmium, although a definite advantage of the cadmium plate is its ability

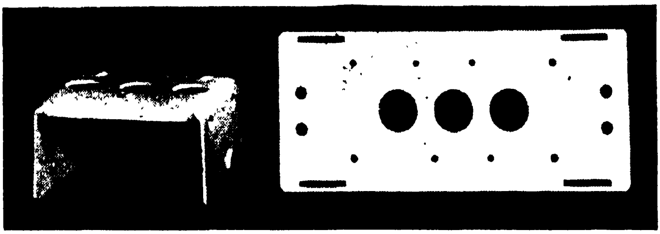


FIG. 81.—On a production basis, and after cadmium plating, the flat blank shown at the right is formed into the shape shown at the left. This illustrates well the ductility of the coating.

to spread and cover exposed areas. It is possible, for instance, so to design dies that stampings out of cadmium-plated sheet steel will have the edges protected. This protection is secured by a squeezing or rolling action just at the end of the stroke, which action spreads or turns the coating so that it covers the cut edge.

One disadvantage of the softness of cadmium is that it is apt to be removed in the buffing and polishing process if the usual speeds and pressures are employed. One extensive user of cadmium recommends getting green men to do the buffing and teaching them to use a very light pressure. He says that he has found it almost impossible to take a man familiar with buffing a hard surface such as stainless steel and put him on to cadmium-plate buffing. Invariably he will polish off the coating and expose the base metal.

CHAPTER XXI

CHROMIUM PLATING

Chromium plating in the metalworking industry may be divided into two distinct types, one a very thin coating used principally for decorative and protective purposes, and the other a relatively heavy coating used for its high wear-resistant properties. In the early stages difficulties in the technique of application handicapped the commercial extension of both types. Now, however, these difficulties have been largely overcome and the use of chromium plating in both fields is increasing.

After long and at times disappointing experience the technique of chromium plating bumpers and other automobile parts has been developed to a commercially satisfactory point, and the process today, although far from simple, is relatively inexpensive when applied by continuous mass-production methods.

At the plant of one of the large automobile companies, steel parts are first cleaned through an elaborate wet-cleaning cycle using an electrolytic alkali process. They then enter the first nickel-plating solution, after which the following operations take place in order: washing, copper plating over the nickel, washing, nickel plating over the copper, washing again, thorough drying, polishing and buffing, further washing by an electrolytic cleaning process, and finally chromium plating to deposit a coating of about 0.00002 in. The alkali solution used for cleaning consists of soda ash, caustic soda, sodium metasilicate and trisodium phosphate. This is used in heated solution, about 5 oz. per gal. of water. During cleaning, an electric current of 25 to 30 amp. is passed through the bath, first in one direction and then in the other, by means of a convenient reversing switch.

Use of Heavy Coatings.—In brief outline this may be considered an example of typical procedure in chromium plating in the decorative field. Coatings ten times as thick, or more, are used for wear resistance for bearings and moving parts in many forms of precision machinery. Among the largest users of this heavy plate are the aircraft and the tool and die industries.

Unlike cadmium and zinc, chromium does not offer intrinsic protection against rust of steel. In fact a highly porous coating directly on steel may tend to hasten corrosion rather than delay it. The protection afforded by chromium depends upon establishing a continuous dense impervious coating, and, since it is difficult to deposit chromium without some porosity, this was one of the bugbears in its development.

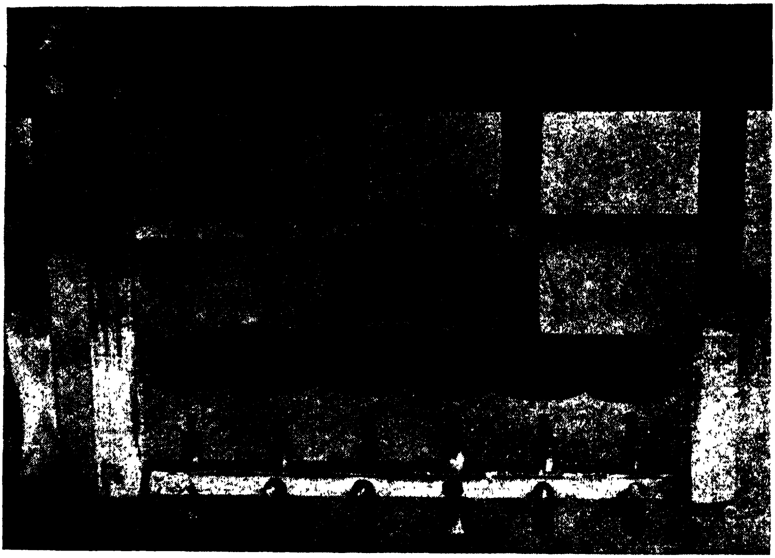


Fig. 82.—A typical setup for heavy plating to a depth of 0.005 to 0.006 in. on steel cylindrical plug gages. This shows how the gages are clamped in position with conforming anodes which will be lowered into place together with "thief" wires to prevent plate build-up on the edges.

Preparation of Base Metal for Heavy Coatings.—Successful chromium plating today must consider preparation of the base metal as well as preparation of the deposit metal. As illustrated in the bumper-plating example, cleaning is a highly important feature of the process. Polishing and buffing of the base metal tend to smooth out the surface and make it easier to spread a uniform chromium coat.

At the first microscopic start of plating, tiny spots appear, well distributed over the surface of the base metal. As the process continues, these spots grow outward until the entire surface is covered, and, as the thickness of the deposit increases, the tendency to spread and thus to cover the entire area also increases. In fact chromium spreads more quickly than most other coating materials, and investigation shows that, when the deposit directly on steel reaches a thickness of 0.0001 in., the metal has spread from the initial points to cover all the surface.

Rate of Plating.—The efficiency of deposit may be expressed in terms of thickness, current density and time, and, if we assume the efficiency of nickel plating as about 100 per cent, the efficiency of deposit of chromium varies from 12 to 14 per cent. As an example, 10 amp. per sq. ft. under certain conditions might deposit a nickel plate of 0.0005 in. in 1 hr., but to get this same thickness of chromium plate in 1 hr. would require a current density of 150 amp. or more.

All things considered, the cost ratio for a given thickness of plate on steel is about 20 to 1 for chromium as compared with nickel. From this it is apparent that chromium plate must have unusual properties if it is to find practical application as a coating directly on steel. The answer is that it does have unusual properties and that coatings directly on steel do find practical applications.

Chromium in Decoration.—However, in the decorative field the reason that chromium can be used extensively at a relatively low cost is, as already described, that extremely thin coatings can be applied over nickel undercoats. Thus it develops that nine-tenths of the technique of chromium plating for appearance is actually the technique of applying a good nickel plate.

This is all on the assumption that the base metal is steel. For most nonferrous base metals the copper undercoat is eliminated. The general scheme of a commercial chromium plate as used extensively today for appearance purposes is that nickel keeps steel from corroding and chromium on top of nickel keeps the nickel from tarnishing and, at the same time, the bright nickel plating solutions produce a high-gloss nickel deposit without polishing. The use of nickel as an undercoat for decorative chromium plating is so extensive as to be almost universal.

Proportionate Equipment Costs.—Whatever the thickness of a chromium plate, the plating process, to be commercially feasible, calls for much greater capacity of electrical equipment than that required for nickel plating. The cost of plating equipment jumps up quite rapidly as the current density increases. Thus, for a capacity of 1000 amp. the complete equipment may run to approximately $2500, whereas for a current density of 10,000 amp. the cost of equipment will be about $17,000. The manufacturer who is to consider chromium plating must therefore figure carefully on the most economical speed through the plating process. Often it is advisable to adjust the speed of plating and the relative thicknesses of coats so as to equalize the relative time cycles and thus make continuous processing possible.

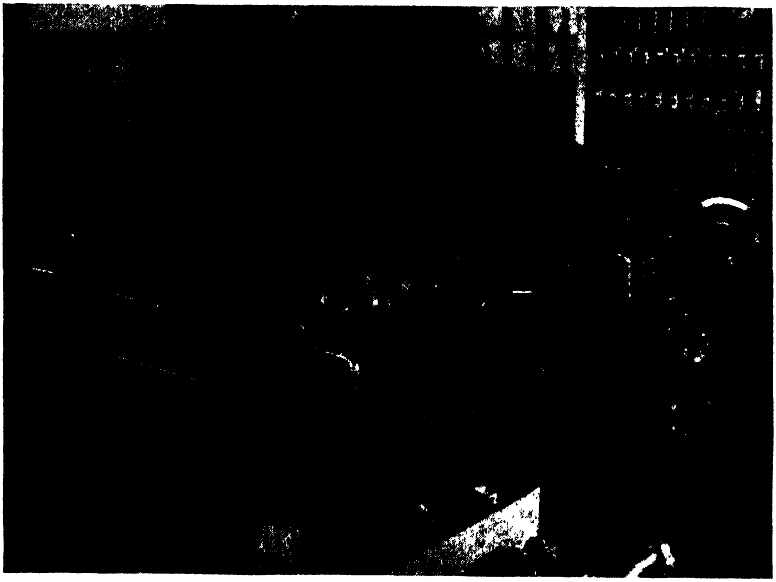


Fig. 83.—A plating tank showing rigid superstructure for holding anodes and cathodes.

Chromium ordinarily is considered brittle, but the extremely thin coats used over nickel do not flake or peel. A very thin chromium plate over a good nickel plate will have the appearance of a highly polished surface and will be practically proof against tarnish or loss of brilliance. Plates of the above character produce a more permanent luster on metal products for interior use than any other commercial coating, and this explains the rapidly growing popularity of chromium. For external use in a city like New York a chromium surface will gradually take on a coating of dust and fine grease particles, and, unless this coating is removed, the original gloss will be lost. However, simply washing will usually reproduce the original surface appearance. It is interesting that chromium finish on tall buildings seems to keep fairly bright over a period of years. The explanation is that the force of the wind at high altitudes is sufficient to give a scouring action that keeps the dust at least partly removed.

The heavier chromium coats used for wear resistance are filling an increasingly important industrial role. Here the depth of plate ranges from about 0.001 up to 0.005 in., although even

FIG. 84a.—A chromium-plating department showing the preliminary cleaning tanks in the foreground and the two plating tanks beyond.

heavier coatings are occasionally employed. This type of coating is applied directly to the base metal and has been successfully used on hardened steel, soft steel, cast iron and some nonferrous alloys. A heavy coat of chromium has some characteristics that to all practical purposes differ from those of the thin coat. It is hard, somewhat brittle and has an especially high resistance to abrasion. Equipment for determining this property of abrasion resistance consists of a special grinding wheel operated under uniform conditions and so mounted that a definite and constant wheel pressure is exerted against the plated test piece. The wear resistance usually is expressed in terms of depth of cut produced in unit time.

Properties.—In general it can be said that chromium plate possesses much greater abrasive resistance than any type of fully hardened tool or die steel. It is somewhat superior to the nitrided steels in this respect. The diamond and the cemented carbides of tungsten and tantalum are the only commercial products that have superior wear-resisting properties.

It has a low coefficient of friction and is not affected by organic chemicals, alkalies, sulfur and sulfur compounds. Nitric acid in any concentration will not react it. However, both hydrochloric and sulfuric acids readily dissolve the plate. Its passivity to certain chemicals undoubtedly can be attributed to the formation of an extremely thin film of chromium oxide, since the metal is readily oxidized. But, the plate and the oxide film are not continuous. Fine cracks and porosity in the form of pinholes develop in plating.

COEFFICIENT OF FRICTION

	Static	Sliding
Chromium plate on chromium plate	0.14	0.12
Babbitt on chromium plate	0.15	0.13
Babbitt on steel	0.25	0.20

Chromium melts at 2930°F. and will retain a bright surface up to 1200°F. It therefore serves well on some high-temperature applications. However, since its coefficient of expansion is less than that of most metals (it is about the same as glass), flaking of plate might be experienced at the elevated temperatures. Chromium plate on cast iron forms a useful combination and is employed for glass molds.

Chromium has approximately the same heat conductivity and electrical conductivity as aluminium and approximately half that of copper and silver. It is nonmagnetic, which opens a new field in making nonferrous electrical parts longer wearing.

Some features of practical plating follow: When the base metal has been properly cleaned and prepared, the plate will have excellent adherence. Of the common materials gray cast iron and the tungsten steels, with high-speed steel outstanding, offer the greatest difficulties. A surface passivity presumably caused by graphite in the cast iron and tungstides in the tungsten steels often becomes manifest, and that part either will not plate at all, or else the plate will peel owing to poor adherence. It is essential that prime metal be exposed for plate deposition. A sandblast finish on these two types of metals ordinarily helps considerably.

It is generally known that antimonial lead anodes are employed for chromium plating. The chromium metal is taken from the electrolyte, and at regular intervals additions are made to the bath in order to maintain the proper metal content. The anodes are insoluble and may be used over and over again. When dealing with wear-resisting plate, it becomes necessary to have the anodes shaped so that they properly distribute the plate on the part being plated. This is made necessary because of the extremely low cathode efficiency and throwing power of the plating solution. A very small percentage of the electrical energy is used in the deposition of the chromium, the energy being mostly consumed in the electrolysis of the water with the accompanying evolution of large quantities of hydrogen at the cathode and oxygen at the anode.

Porous Chrome Plating.—An important development in chromium plating is the deposition of a porous plate. The process is said to reduce cylinder wear, ring wear and ring-groove wear and, in general, to produce a more reliable engine. It is employed to reclaim worn aircraft cylinders. The chrome deposit must be porous to hold the oil for lubrication purposes, because ordinary dense chrome does not wet with oil.

Extensive investigations have been made to reduce cylinder wear, chiefly in the direction of alloyed cast iron but also by using nitrided cast iron and nitrided steel for cylinder material. These methods have reduced the wear to some extent, but the engine designers have created fresh problems by designing engines of much higher power, in which wear is much more serious. For that reason, chromium plating of engine cylinders was investigated.

Of course, there were difficulties: plated high-speed engines scuffed readily. Several engine blocks for automobile engines were plated, and in every instance scuffing of the cylinder bore and of the piston rings was noticeable, and always of the same character, namely, at the lower end of the bore at the thrust and antithrust sides. The cylinder bores were plated with ordinary hard chromium to the right size of the bore and then finish honed, giving a finish that closely resembled a polished decorative chromium. The reason for these failures was found to be the lack of lubrication.

A piece of chrome-plated cylinder was taken to a gathering of lubricating experts who tried all sorts of oils and concluded that none of them would work. Smooth dense chrome does not wet with oil. To platers with experience, this was not surprising.

There was, however, one small high-speed engine running with chromium bores that performed very well. The reason was that the cylinder of this engine had been plated and stripped more than once; and, after each stripping, the cast-iron bores had to be honed; finally, the coating of chromium had become very thick and rough. The subsequent honing had not given an entirely smooth bore but had left pits and depressions. Here, then, was the answer to the difficulty. It is essential that chromium be porous or provided with a multitude of pits and depressions that will serve as oil reservoirs.

The best method found to obtain a porous-chromium deposit was to plate on a smooth surface, to obtain a workable and machinable coating of chromium. The coating should be about 0.002 to 0.003 in. or more on the diameter than is necessary for bore size. The cylinders are then put in another tank containing another solution with the same anodes and the same setup, but the current is reversed for a few minutes. In other words, the chromium is stripped. This results, however, in the removal of metal in depth, unevenly, and not in layers, leaving a coat with a large number of pits for oil reservoirs.

Special Anodes.—The building of suitable conforming anodes is extremely important. Suitable "thieves" to prevent plate build-up must be provided. Fixtures must be rigid so that the spacing between the anode and cathode is constant at all times. The work must be set up so as to eliminate gas pockets. Stop-off materials that are not easily decomposed also are essential. Since the rate of deposition is about 0.0004 in. per hr., the work must remain in the tanks for extended periods for the heavier plates. Ordinary stop-off materials will break down and allow plating to take place through the leaks.

Chromium-plating Tools.—An outstanding application of chromium plate in connection with tools is on the cylindrical plug gage. Records of five to ten times the life in service obtained from gages made of the best grades of alloy tool steels are obtained. When cost and performance are considered, this application places chromium plate in an outstanding position. It is no exaggeration to predict that this type of tool eventually will be almost exclusively furnished with a chromium-plated surface. It is customary to grind the gage 0.003 to 0.004 in. under size on diameter before plating. Sufficient plate is added to include a

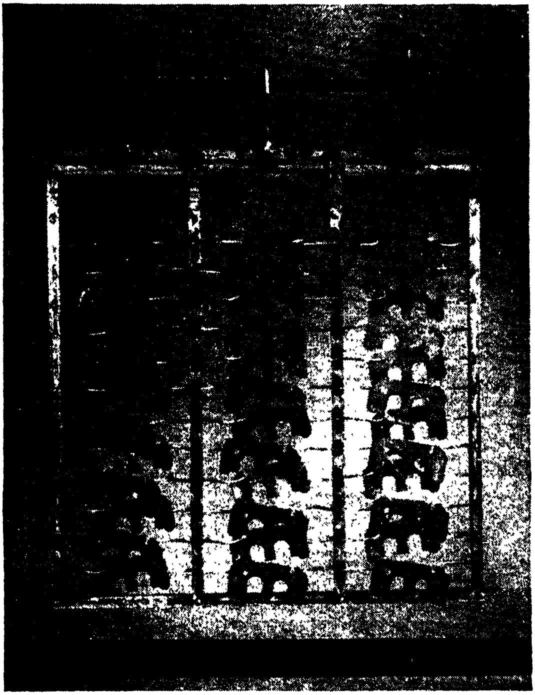


FIG. 84b.—Typical setup for light plating of flat steel railroad gages. These pieces have been carburized, hardened, ground and then plated to a depth of 0.0003 in.

grinding allowance. The finish might be ground or ground and lapped, depending on the mechanical tolerance and finish desired. The residual plate depth of 0.0015 to 0.002 in. will withstand the normal abuse given a tool of this sort throughout its life. When worn undersize, the gage can be stripped and replated. A liberal radius should be ground on the entering end of the gage before plating. This radius should be ground as large as is permissible after plating in order to eliminate the tendency to chip. Flat, snap and cylindrical ring gages also are being plated to excellent advantage.

Special Uses.—Reamers for use on nonferrous alloys, cast iron and many ferrous applications have given excellent service. For this type of tool, the plate is allowed to remain in the flutes only. This is accomplished by plating the reamers when they are oversize on the outside diameter. After plating, they are ground to size. Thus the cutting actually takes place against a chromium

FIG. 85.—Buffing a chromium-plated concave break-down roll made for the brass industry, using a Kellerflex flexible-shaft machine designed for this purpose.

edge that offers maximum wear resistance against the soft abrasive materials such as aluminum alloys, brass and the copper and nickel alloys. In addition, the plate in the flute ensures rapid chip disposal. A plate depth of 0.0002 to 0.0003 in. ordinarily is employed. Whenever cutting conditions permit, a carbon-steel reamer should be used in preference to one of high-speed steel.

Taps and drills for machining abrasive materials such as asbestos sheet and for soft metals will show decidedly improved performance after plating.

Drawing dies, forming dies and rolls for working soft metals such as copper, brass, nickel, gold, silver, palladium and platinum are greatly aided by chromium plate. Metals of this type adhere to the dies, causing short tool life and a poor finish on the metal being worked. Chromium plate entirely eliminates this tendency to stick and thereby yields added tool life and a better finish to the metal. Drawing and forming dies for steel also

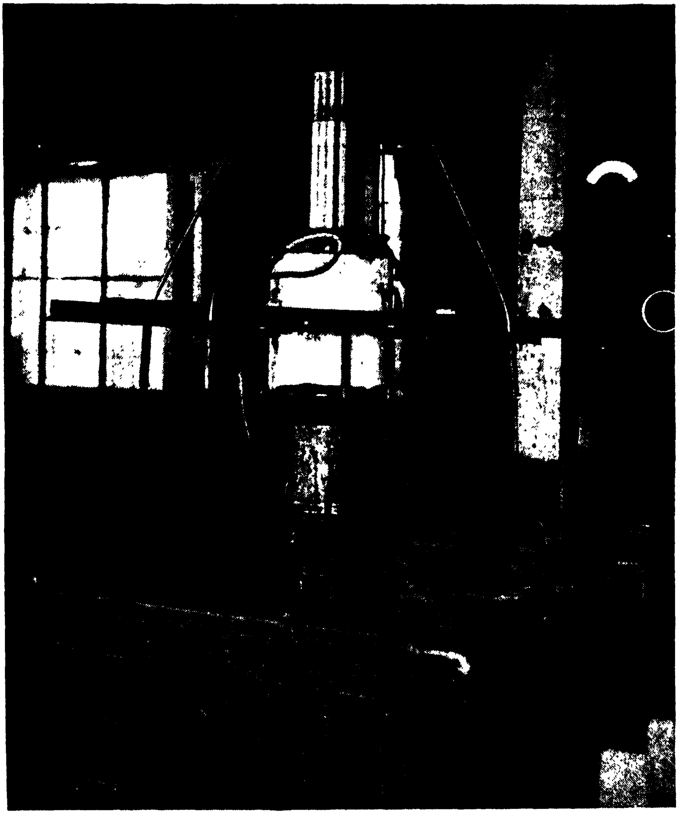


FIG. 86.—Salvaging the worn bearings on a heavy steel roll by building up with chromium plate and then refinishing to size. The cylindrical anode around the bearing surface is in position ready for plating.

have been plated successfully, particularly for the working of the softer steels. A plate depth of 0.0015 to 0.002 in. is satisfactory when applied to the fully hardened drawing die or forming tool. If the mechanical tolerance is not too close, the die is lapped after plating. Otherwise sufficient plate must be added to allow for grinding. The residual plate depth of the rolls is usually held between 0.005 and 0.008 in. Grinding is resorted to for properly maintaining mechanical accuracy.

Despite the rapid expansion in the use of chromium plating during recent years, the art may be said to be in its early infancy, especially in the utility fields. For salvaging gears and small machine-tool parts, for protection against sandblast and against wear of thread fibers in textile mills, and for an almost endless list of other uses chromium plating seems to have a bright future.

CHAPTER XXII

COPPER PLATING

There are two standard solutions used for the deposition of copper—the cyanide and the sulfate baths. The acid copper sulfate bath is characterized by very high current efficiency, simple composition, ease in maintenance and permanence. Although this solution is hardly ever used to plate copper directly on steel, owing to the high solution pressure of the iron in sulfuric acid baths, a wide application of this solution is found in electrorefining of copper, and also it may be used to advantage on steel after a cyanide bath.

The bath most commonly used for copper plating steel is the cyanide copper bath. It has a considerably lower current efficiency than the sulfate bath, owing to the greater resistivity and polarization and to the tendency to carbonate. Considerable care must be exercised, because of the toxic nature of this solution, and more control is necessary to maintain the constituents in the proper proportions.

The cyanide copper solution is used almost exclusively for plating iron and steel to prepare it for ornamental finishes or for further plating with nickel or with copper from the sulfate bath.

Another bath recently developed to replace the cyanide bath utilizes a double salt with copper sodium oxalate as its main constituent, doing away completely with the hazard connected with the use of cyanide. The efficiency, at low current densities, that is, 10 amp. per sq. ft., is higher than that obtained with the cyanide copper solution However, when the current density is raised to 30 amp. per sq. ft., the reverse is true. With the double-salt bath, good adherent copper deposits are obtained, suitable for further deposition from the acid sulfate bath or for other finishes. A practical scheme, in other words, is first to apply a thin coat of copper with the double-salt process, and then to transfer the work to the acid sulfate bath for building up the plate to the required thickness.

A modern development in copper plating is the Rochelle salt—copper cyanide bath, made up as follows:[1]

	Average composition, oz. per gal.	Approximate limits, oz. per gal.
Copper cyanide	3.5	3–6
Sodium cyanide	4.6	4–7
Rochelle salt	4.0	3–8
Sodium carbonate	4.0	2–8
pH	12.6	12.2–12.8

Conditions

Metallic copper, oz. per gal	2.5
Free cyanide, oz. per gal	0.75
Temperature	140°–160°F.
Current density, amp. per sq. ft.	20–60
Voltage	2–3
Cathode efficiency, per cent	40–70
Anodes	Rolled annealed copper
Anode area	Two times cathode area
Anode efficiency, per cent	50–70
Time to deposit 0.0001 in. at 140°F.:	
At 20 amp. per sq. ft., min	Approximately 3.6
At 60 amp. per sq. ft., min	Approximately 2.2

The conditions given cover the range within which bright deposits may be obtained. The higher the temperature, the higher the efficiencies are. The Rochelle salt solution deposits copper at a much faster rate than the conventional cyanide copper solution.

The proper preparation of the surface to be plated is of the greatest importance in this type of work. In fact, upon this hinges, to a very large extent, the porosity of the plate. Cleaning, which is a well-developed phase of the art, has been covered in previous chapters. In general, alkaline electrolytic cleaning, following buffing, constitutes the main cleaning method.

Corrosion Resistance.—The position of copper in the electromotive series is to its advantage when used solid but constitutes a serious disadvantage when it is applied as a thin coating over metals less noble than it, such as nickel, iron, chromium and

[1] From the "Platers Guidebook," 1944.

zinc, owing to the strong voltaic action exerted when the base metal is laid bare by a pinhole or scratch. This is reflected in the reports of various authorities when they advise a coating

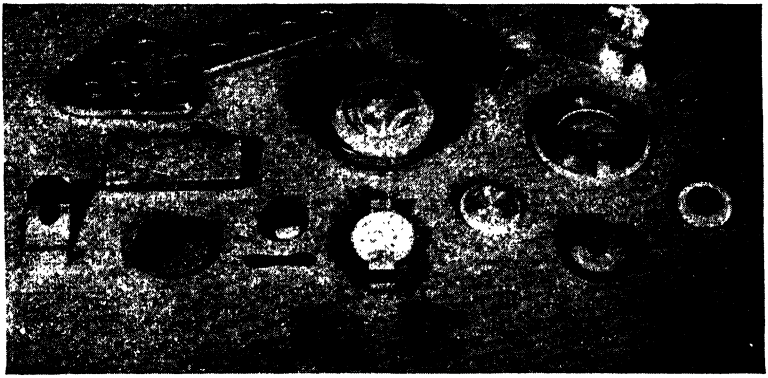


FIG. 87.—This shows a miscellaneous assortment of small highly finished metal parts where copper plating in one form or another contributes to the permanence of the finish. (*Courtesy of American Nickeloid Co.*)

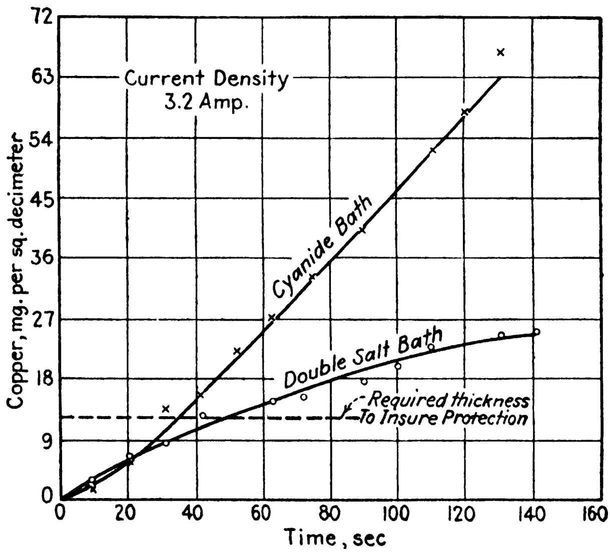


FIG. 88.—The weight of copper deposited with a current density of 3.2 amp. per sq. dm. is here shown.

thickness of copper of approximately 0.001 in. for outdoor exposure and state that less than 0.0005 in. gives very little protection even when used in conjunction with nickel and chromium. Since copper is only moderately resistant to abrasion, a substantial coating is necessary to minimize exposure of the base metal in forming or handling. This is particularly true if the base metal is steel or iron.

In view of the above relations, the importance of pinhole-free coatings is apparent. Anyone acquainted with the difficulties encountered in tin plate due to porosity will realize what that would mean for copper, which is more noble even than tin. Fortunately, however, copper deposits from both acid and basic solutions are relatively dense and, if applied in reasonable thicknesses, over 0.0005 in., reduce defects due to porosity to a mini-

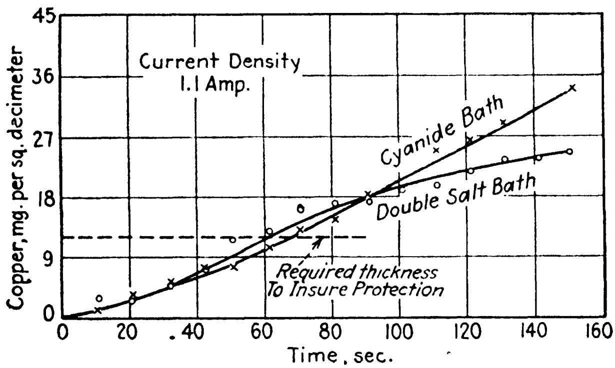


FIG. 89.—This shows the weight of copper deposited during plating with a current density of 1.1 amp. per sq. dm.

mum. Heat-treating heavy copper-plated sheet in a reducing atmosphere greatly increases its corrosion resistance.

Of vital importance, as stated above, is the proper preparation of the base. Slag specks and other surface inclusions will vary with the lot or shipment of steel and therefore require constant inspection and special care in cleaning.

If the current density is raised unduly in an effort to speed up the plating time, the coating becomes more porous, requiring a heavier coating for protection.

Resistance to Specific Mediums.—As is commonly known, solid copper and brass piping and sheet-copper roofing are widely used for permanent installations. Although there is some solution or corrosion of the copper exposed to the atmosphere or to water, it is not appreciable except in acid waters or salty or acid atmospheres. Copper-plated steel will have to be rather heavy to give a reasonable life in such an application. In fact, for any article that is to be kept outdoors, having a steel base, a copper deposit 0.001 in. thick should be considered a minimum.

On many bright-finish steel and die-cast parts, in the automobile industry and other fields, copper plating is widely used as an undercoating to reduce buffing costs or to ensure bright deposits serving as a base for further plating operations, either nickel or nickel and chromium. It is much easier in some cases to obtain a mirror finish on a thin copper coat than to produce the same on the original steel-base material, and, as is well known, the surface condition of the base plate is reflected in the final finish obtained.

Copper plating is used extensively in electrotyping. The familiar rotogravure supplement of Sunday newspapers is a copper product. Copper plating is also used in selective case-hardening and as templates for color effects.

One of the latest uses for copper-plated steel is in the canned-motor-oil field. While a relatively thin coating of copper is applied (0.00025 in. average), the chances for perforation or rusting are very small, especially so since the cans are stored indoors.

Comparison with Other Coatings.—A summary of the characteristics of various electrodeposited metals as regards protective value, appearance and abrasion resistance is given in other chapters. A like comparison with other types of coatings on steel should be valuable, with emphasis on the coat and method of production and the advantages of each.

There have been numerous developments and refinements in regard to both new and old coatings, particularly as applied to steel. Tin plate and hot galvanizing, which were for years recognized as the two major cheap coatings to be used for protection of steel, are being crowded hard at the present time by electrodeposited finishes and rolled composite or duplex coatings. Some have greater corrosion resistance; others have better physical characteristics. Some are cheaper, and one or two combine all or most of these points of superiority.

Sheets produced by rolling down compound billets of stainless steel and ordinary steel have not been produced commercially in the thinner gages demanded by can manufacturers, and their price is still high compared with other can stock. Furthermore, tests have shown that rolling composite sheets down to competitive thicknesses ruins the corrosion resistance.

Within recent years hot-dip zinc has been improved considerably as regards ductility in both wire and sheet. Its corrosion resistance is excellent when carrying between 0.5 and 2 oz. of zinc per square foot, especially in the case of the unwiped coatings. Electroplated zinc is pressing forward in competition

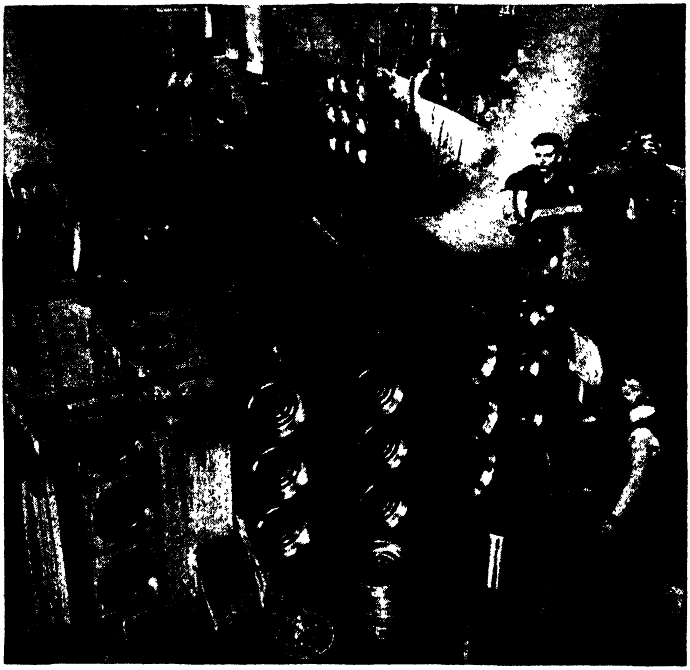


FIG. 90.—View of typical plating department in a large manufacturing plant. (*Courtesy of The International Nickel Co., Inc.*)

continually. Wire carrying both medium and heavy coatings (range 0.5 to 2.7 oz. of zinc per square foot) is very ductile and is at least equal to the hot product as regards corrosion. It is interesting to note that, when a very thin coating of copper is plated over galvanized zinc, the life of the product in the salt spray is cut to almost half. This is a rather striking example of electrocouple action and should serve as a warning in the application of coatings of inadequate thickness. The protection obtained from a galvanized product is directly proportional to the thickness of zinc coating, and it is well that the metal price accommodates a heavy coat.

Tin plate carrying 1.5 to 5 lb. of tin per base box, or per 31,360 sq. in., is the old standby for most of the containers and closures produced today. It is resistant to attack by a large number of substances, especially when augmented by lacquers. Probably close to half the cans used for foodstuffs today are lacquered, the cost of the lacquer protection equaling or exceeding that of the metal coating in a number of cases. The average grade of tin plate is rather porous. Average 1.5-lb. tin plate carries 82 pinholes per square inch. Solid aluminum cans, in spite of a higher cost, have been adopted in Norway and also by a tuna-fish packer in this country.

In the oil industry, where special conditions prevail, the copper-plated steel can has today met the competition of the tin-plated can, the galvanized iron can and others. The copper plate is very ductile, and operations such as drawing and bending are carried out easily and with great precision, owing to the "lubricating" effect of the copper coat, a phenomenon familiar to many steel-wire drawers.

CHAPTER XXIII

NICKEL, ZINC AND OTHER METALLIC COATINGS

Nickel plate is one of the best known finishes for metal. It is relatively inexpensive and simple to apply, yet many manufacturers do not appreciate its full possibilities.

When an authority was asked about nickel plating, he said that the secret of good nickel plating was good copper plating.

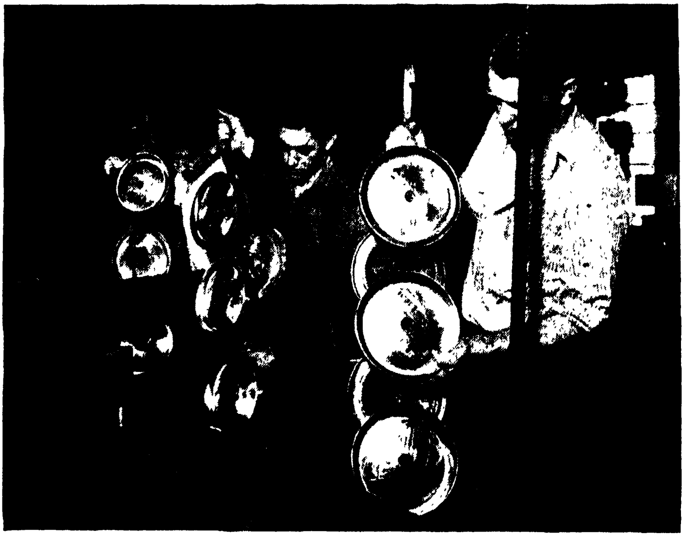


Fig. 91.—Applying a flash of nickel to lawn-mower parts. (*Courtesy of The International Nickel Co., Inc.*)

Similarly it may be supposed that a question on copper plating would bring forth the importance of preparation of the base metal for receiving the electrodeposited coating. Copper is used as an undercoat partly because of its good corrosion protection on steel, but partly also because it is much easier to burnish copper than to burnish steel, and, where a high polish on the nickel-plated surface is desired, it is important to have a similar high polish on the parts before plating. As stated, this is easier to secure on copper than it is on steel.

Much has already been said in this book about the cleaning and preparation of metal for subsequent finish, and in considering the subject of nickel plating it is only necessary here to stress again the importance of proper preparation for the actual depositing of the nickel plate. A good idea of the whole process may be had from the following detailed specifications:

Nickel Plating Steel

General

This specification shall cover the nickel plating of steel parts, such as winterfronts and window ventilator frames.

Individual specifications for each operation are a part of this specification and must be carried out in the following order:

1. Polish.
2. Clean.
3. Copper plate and wash.
4. Clean and copper strike.
5. Nickel-plate and wash.
6. Buff.

Polishing

Surface Condition

All parts, as received, shall be free from die marks, dents, wrinkles, bad welding scale and other surface defects.

Material

Cloth wheel.
No. 70 Borolon emery.
No. 120 natural emery.
No. 150 artificial emery.
No. 220 artificial emery.
Tripoli metal polish.
Glue B-2—Special joint hide glue.

Preparation of Material

Brush working surface of cloth wheel with a coat of glue. Dry 1 hr. Recoat with glue and immediately roll in desired emery. Dry 12 hr. Recoat with glue and roll in desired emery. Dry 24 hr.

Application of Material

Polishing wheels shall revolve at approximately 2000 r.p.m., and each succeeding polishing operation shall completely remove the marks of the preceding polishing wheel.

The direction of the polish shall be:

No. 70 Wheel—Approximately 30-deg. angle with horizontal plane.
No. 120 Wheel—At right angles to the above.

No. 150 Wheel—Approximately 30-deg. angle with horizontal plane.
No. 220 Wheel—At right angles to the above.

Remarks

At this point the part shall be free from deep scratches or welding scale and any defects that would show on the finished part.

Cleaning

Surface Condition

The part shall be free from deep polishing scratches, dents, welding scale and any defects that would show on the finished part.

Material

Plater's cleaner, Specification No. 8-K.
Muriatic acid (commercial).
Sodium cyanide (commercial).
Trisodium phosphate (commercial).
Iron plates (3 ft. by 6 in. by ¼ in. anodes).
Munning automatic electroplating equipment.

Preparation of Material

Mix 2 oz. of trisodium phosphate to 1 gal. of water in the 400-gal. power spray tank. Dissolve 6 oz. per gal. of Plater's cleaner in the 2080-gal. and also in the 1350-gal. steel cleaning tanks. Keep at temperature of 180° to 200°F. The part being cleaned shall act as cathode in the first cleaning tank and as anode in the second cleaning operation. Current density shall be 25 amp. per sq. ft. minimum.

Mix 1 part of muriatic acid to 9 parts of water in the 685-gal. acid dip tank. Keep at room temperature.

Mix 3 oz. of sodium cyanide to 1 gal. of water in the 2320-gal. steel tank. Keep at room temperature.

The strength of the above solutions shall be maintained by the addition of materials as required.

Application of Material

The part shall be hung on the Munning conveyor. It moves to the power spray for 1 min., is kept in the first alkali cleaning tank for 3 min. and in the second alkali cleaning tank for 1½ min. It is dipped in cold running water, then in 10 per cent muriatic acid, then in cold running water. It is dipped in the cyanide solution and conveyed to the copper-plating bath. All rinsing tanks are equipped with sprays so that the work is thoroughly rinsed as it leaves the tank.

Remarks

The surface of the part shall be chemically clean, free from all traces of dirt and grease and must not show any break in the water film after the last dip.

Copper Plating

Surface Condition

The part must be free from dents, dirt and grease marks and must not show any break in the water film after the last cyanide dip.

Material

Copper cyanide.
Sodium cyanide.
Sodium carbonate.
Copper anodes and hooks (36 in. length), 99 per cent copper, minimum.

Preparation of Material

One thousand seven hundred twenty pounds of sodium cyanide shall be dissolved in hot water in a steel tank (capacity 4930 gal.); 1509 lb. of copper cyanide is added slowly and the solution stirred until the copper is dissolved; 925 lb. of sodium carbonate is added to the tank and the solution diluted to 4930 gal. The bath is held at a temperature of 120° to 130°F. during plating operation.

Application of Material

The part hung on copper hooks shall be conveyed and suspended in the copper bath 13 in. from the anode. The part, suspended from the conveyor, shall revolve slowly in the tank for a period of 10 min. A current density of not less than 25 amp. per sq. ft. shall be used for the plating operation.

Remarks

Immediately after the part is removed from the plating solution, it passes through a cold-running-water rinsing tank, then in hot water and is air dried. The copper deposit must not chip, peel or curl and must be free from runs and blisters.

The copper-plating bath shall at all times contain:
3.0 to 4.0 oz. of copper (metal) per gallon.
2.5 to 3.5 oz. of free sodium cyanide per gallon.
2.0 to 4.0 oz. of sodium carbonate per gallon.

Nickel Plating

Surface Condition

The part must be entirely free from grease and dirt and must not show any break in the water film after the final cold-water spray.

Material

Single nickel salt (nickel sulfate).
Sodium chloride.
Boric acid.
Nickel anodes (36 in. length), 99 plus hot rolled-bright annealed-depolarized.

Copper hooks.
Hydrogen peroxide (100 volume).
Steel tank (rubber-lined).

Preparation of Material

The 15,600-gal. tank shall be half filled with tap water. Then 39,000 lb. of nickel sulfate and 2432 lb. of sodium chloride shall be dissolved in the

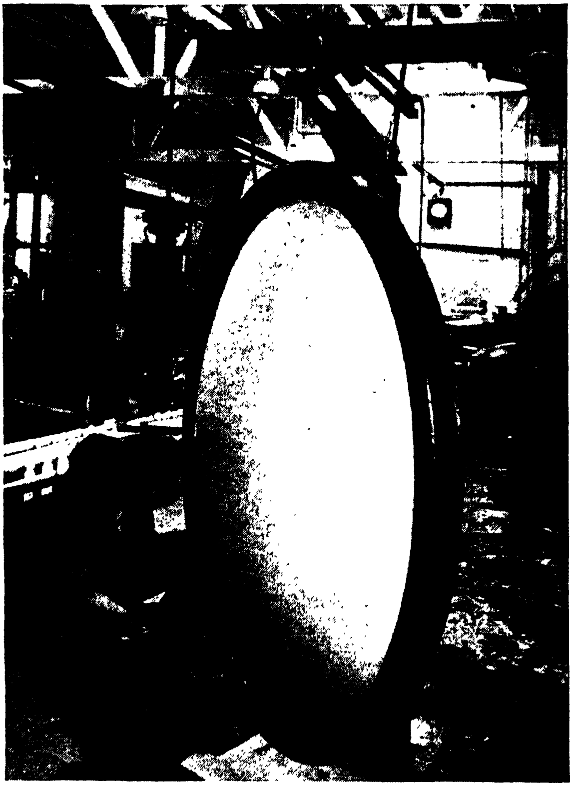


FIG. 92.—Large metal reflector before plating with rhodium. (*Courtesy of the International Nickel Co., Inc.*)

tank. The tank shall be filled with tap water (15,600 gal.) and 2,432 lb. of boric acid added. The bath shall be kept at a temperature of 110° to 120°F. The strength of the solution shall be constantly maintained to the limits shown below by the addition of the salts as required. In making additions, the salts shall be placed in a bag and suspended in the plating bath.

Application of Material

The part to be plated shall be suspended from the conveyor into the plating bath, the face of the part facing the anodes. The distance from the anodes shall be 13 in. The current density shall not be less than 25 amp. per sq. ft., and the part, attached to the automatic conveyor, shall be slowly revolved in the plating bath for a period of 30 min.

Remarks

Immediately after the plating operation, the part shall be dipped in cold running water, then in hot water and air dried. The acidity of the bath

FIG. 93.—Large metal reflector shown in Fig. 92 after plating with rhodium.

should be between pH 5.5 to 5.9. The acidity may be controlled by adding ammonia or sulfuric acid in small quantities as the case may require. The nickel anodes shall be scrubbed each time the tank is filtered, which shall be at regular intervals. Any tendency of the nickel to pit can be controlled by the addition of hydrogen peroxide (100 volume) in small quantities ($\frac{1}{32}$ oz. per gal.).

The bath at all times shall contain:

35.0 to 45.0 oz. of nickel sulfate per gallon.

2.0 to 3.0 oz. of sodium chloride per gallon.

2.0 to 3.0 oz. of boric acid per gallon.
7.0 to 9.0 oz. of nickel (metal) per gallon.

Cleaning—Copper Strike

Surface Condition

The part at this point must have a good copper deposit that does not chip, peel or curl and must be free from runs and blisters.

Material

Plater's cleaner (Oakite—Rex or Northwest).
Sodium cyanide (commercial).
Muriatic acid (commercial).
Copper cyanide (96 to 98 per cent).
Trisodium phosphate (commercial).
Sodium carbonate (commercial).
Iron plates (3 ft. by 6 in. by ¼ in.).

Preparation of Material

Two ounces per gallon of trisodium phosphate shall be dissolved in the power-spray tank. Six ounces per gallon of Plater's cleaner shall be dissolved in each of the steel-cleaning tanks. The temperature shall be 180° to 200°F. The parts being cleaned shall act as cathode in the first cleaning tank and as anode in the second tank. The minimum current density shall be 200 amp. per sq. ft. in each tank.

Add 1 part of muriatic acid to 9 parts of water in the 685-gal. rubber-lined acid tank. Keep at room temperature.

Dissolve 3 oz. of sodium cyanide to 1 gal. of water in the 730-gal. steel tank. Keep at room temperature. The strength of the above solutions shall be maintained by the regular addition of the materials required.

Four hundred fifty pounds of sodium cyanide shall be dissolved in the 2080-gal. steel-copper strike tank; 390 lb. of copper cyanide shall be added and the solution stirred until the copper is dissolved; 325 lb. of sodium carbonate shall also be dissolved in this solution. The temperature of this solution shall be 100° to 120°F.

Application of Material

The part, hung on the conveyor, shall pass through the power spray for 1 min.; it then goes to the first electric clean for 3 min. and to the second electric clean for 30 sec. It is rinsed in cold running water, then dipped in the muriatic acid and rinsed in cold running water. It is dipped in the cyanide bath and plated in the copper bath for 3 min. at a current density of 10 amp. per sq. ft. It is then given two successive cold-water rinses and then nickel plated. All rinsing tanks in this lineup shall be equipped with sprays.

Remarks

The surface of the part must be chemically clean, free from all traces of dirt and grease and must not show any break in the water film after the last rinse.

The copper strike bath at all times shall contain:
3.0 to 3.5 oz. of copper cyanide
1.0 to 0.5 oz. of sodium cyanide
2.0 to 3.0 oz. of sodium carbonate

BUFFING—COLORING

Surface Condition

The nickel deposit shall be of a fine texture, free from pits, must not chip or peel and shall show no indication of having a dark or yellowish cast.

Material

Cloth buffing wheel.
Nickel coloring compound.

Preparation of Material

The cloth buffing wheel shall be coated as necessary with the polish specified above.

Application of Material

Buffed with cloth wheel and nickel polish.

Remarks

The finished part must be free from pits, dark spots, scratches and grease marks and must show no indication of having been burned or buffed through.

Advances in Nickel Plating.—Much progress has been made in nickel plating during the past few years. In addition to the standard so-called "dull nickel" solution using single nickel salts, a rapid-plating warm nickel solution, Watts type, is now available, permitting high current densities. Hard nickel plates have been developed by W. A. Wesley of the International Nickel Co. The Wesley solutions yield deposits with hardnesses up to 480 Vickers.

On the whole, for most purposes, the standard dull-white nickel solution is generally useful. It yields good ductile deposits at thicknesses up to about 0.001 in. and has a good color and excellent throwing power. Its one drawback is its limited current density range and consequent low speed of deposition.

For higher speeds and heavy deposits, the Watts type warm nickel solution is preferable. Its current density range is from 15 to 50 amp. per sq. ft., but the deposit is not so ductile as the dull-white nickel, nor has the solution such good throwing power.

Harder nickel deposits are useful mainly for wear-resistant heavy coatings and for building up worn or mismachined parts.

Such plates can be produced in thickness and quality suited to industrial and engineering applications by the use of electrolytes containing ammonium salts. It has been shown experimentally by Wesley that the soundness and structure of such deposits are markedly influenced by the composition of the plating bath in respect to other ingredients. Important improvement in the quality of the product can be accomplished, for example, by replacing the old hard baths with one of the following composition: nickel sulfate, 180 grams per liter; ammonium chloride, 25 grams per liter; boric acid, 30 grams per liter.

This electrolyte is well buffered and contains sufficient chloride to ensure high anode efficiency; hence it can easily be maintained at a constant pH. The hardness of deposits made from it varies only a little with change in thickness and can easily be maintained by control of the plating conditions. Heavy deposits can be made that are free from laminations, sound in structure and of a high degree of hardness and tensile strength coupled with measurable ductility. Typical tensile properties of this hard nickel are an ultimate tensile strength of 157,000 lb. per sq. in. and an elongation of 6 per cent in 2 in.

Bright nickel plating has made enormous strides. It has been known for many years that some metal baths were affected by the addition of materials that were called "addition agents." These compounds were generally organic in nature and had a high molecular weight. Nickel is very sensitive to the presence of many such compounds. A very bright deposit can be obtained, for instance, by the addition of small amounts of gelatin, glue, gum tragacanth, gum arabic, etc. Trouble is encountered usually because of lack of control and the decomposition of the material. The plates obtained are bright, fine-grained, hard and somewhat brittle. All such addition agents are introduced into the bath in very small quantities.

At present, six companies of national importance have developed bright nickel-plating solutions based on the use of complex organic addition agents: Pyrene Manufacturing Co., Seymour Manufacturing Co., Harshaw Chemical Co., McGean Chemical Co., Udylite Corp., and Hanson-Van Winkle-Munning Co. All these solutions are in successful operation in many plants.

A group of special nickel-plating processes developed by Hanson-Van Winkle-Munning Co. are based for their brightness on their cobalt content and the use of organic addition agents such as formaldehyde. These processes give deposits of varying cobalt content, from a maximum of 18 per cent to a minimum of 1 per cent. The high cobalt deposit gives the highest luster, whitest color and greatest hardness; the low cobalt deposit is relatively soft and of lower luster, but it is said to be flexible and capable of meeting varied demands. The company has also developed a rapid nickel-plating process for high-speed ductile

FIG. 94.—A steam fitter is pleased because he has a wrench with a new type of colored finish.

deposits especially designed for use in plating steel billets that are to be clad, for electroforming (stereotypes, for example) and for plating special equipment where heavy deposits are required.

Galvanizing.—Although electrolytic galvanizing is gaining rapidly in importance in industry, the great bulk of the work of coating metal with zinc is done by the hot-dip process. This is exceedingly simple and involves merely the careful cleaning of parts and the immersion in a tank of molten zinc kept at regulated temperature. This temperature varies from 835° to 925°F., the exact level in each case depending upon the quality of the zinc used, the possible addition of other metals, such as lead, antimony and aluminum, and the size and nature of the material treated.

For most products there is the problem of removing excess zinc after the dipping. This is especially a problem when several parts in contact are dipped, as, for instance, bolts in a basket container. If the excess zinc is not removed, such products tend to freeze into a solid mass. The common method of removing the excess is in a centrifugal machine. Sometimes agitators are used. It is important to keep the bath at a uniform temperature in order to secure uniform coatings. Usually gas or oil-fired furnaces are used for heating the tanks.

One of the disadvantages of hot-dip as against electrodeposited zinc is the fact that the bath must remain hot throughout the night, for otherwise it becomes a solid mass that may crack the tank and in any case is difficult to remelt. The actual coating differs somewhat from that which is electrodeposited. Small cracks tend to be covered up by the dipping process, and these same cracks would show up after electrogalvanizing. Thus electrogalvanizing in some cases facilitates inspection. When open tubes are hot galvanized, care must be taken to see that one end enters the bath before the other. Otherwise the metal seals a pocket of air and an explosion may result.

Sherardizing, which is another method of applying a zinc coating to metal parts, consists essentially of tumbling the products in a mixture of zinc dust, the whole mass being heated from 725° to 825°F. The common method is to throw small parts such as bolts and nuts into a tumbling barrel and to shovel in an ample quantity of zinc dust and revolve the barrel for some 4 to 8 hr. while the contents are held at the desired temperature. In this process the zinc dust does not melt but adheres closely to the surface by a kind of amalgamation process.

In **electrogalvanizing,** parts are immersed in an electrolyte and a current is passed through from the sides of the tank, or from electrodes, to the work. Two types of electrolyte are used, an alkali and an acid. The alkali generally consists of a cyanide zinc bath, and the acid is a sulfate of zinc. Many different proportions are used for both acid and alkali processes.

One company is now electrogalvanizing 27,000 steel sheets a day, each 24 by 30 in. These are used for the manufacture of small cans and containers to compete with the tin can. The galvanized can is not used for food products, however. One of the the chief outlets is for individually canned oil for dispensing at gas stations. Here electrogalvanizing is used in preference to hot dip, because in the process of manufacture the sheets are crimped at the joints and hot galvanizing is apt to crack under this severe process. In electrogalvanizing the temperature is frequently room temperature.

One of the most important stages in electrogalvanizing is cleaning, and here many methods and many solutions are offered. At one large plant, flat strip for BX conduit manufacture is electrogalvanized in a continuous automatic process. The strip from reels passes through the cleaning, galvanizing and drying stages and then on to reels again at the far end.

In Europe some companies spread aluminum powder over the zinc bath in galvanizing. It is claimed that this prevents oxidizing of the zinc and that it creates a silvery finish on the galvanized products.

Galvanizing Bolts and Nuts.—At one plant bolts and nuts are cadmium plated, parkerized or galvanized, and the various processes involved have been standardized and placed on a production basis.

At the washing machine a hoist picks up the containers and dumps them into a hopper from which they are fed into the machine and thoroughly washed in an alkaline solution held at 222°F. This solution is heated in vats in the basement below the machine and is circulated by pumps.

From this first cleaning stage the parts pass automatically into a rotating drying drum which is heated by an oil-fired furnace. They travel gradually through this drum and are automatically dumped into containers which, when filled, are removed by electric lift trucks. The capacity of this cleaning machine is about 2000 lb. of small parts per hour. The parts usually are 1½ in. or smaller.

Larger parts are put through a belt-type washing machine which consists of a long belt loaded at one end and unloaded at the other and traversing at its central portion a cabinet in which the parts receive a pressure shower of cleaning solution. In this case the solution is of a slightly different character and is held at 200°F. instead of 222°F. Drying in this case is a separate operation.

After preliminary washing, the bolts are inspected, and then they usually pass directly to one of the three typical finishing operations. The following cadmium sequence is included here because the cleaning and handling are practically the same as for galvanizing.

Bolts from the standard-sized containers are dumped into perforated aluminum-alloy baskets in which they are immersed, first into an acid tank, then into an alkali tank, then into cold water and finally into a cadmium-plating barrel of horizontal type. This barrel is made of bakelite and revolves in a cyanide solution which carries the plating metal from cadmium anodes to the work.

The capacity of barrels used in this process is about 250 lb., and the coating of one load takes about 20 min. This is for the usual depth of cadmium plate, which is 0.0002 in. thick. Tests under the standard salt spray show this coating to stand 60 to 100 hr. Where heavier coatings are desired, a thickness of 0.0004 in. is used, and with this the life under the salt spray ranges from 200 to 300 hr. After coming from the cadmium-plating tank, the parts are washed in cold water, then dried, and then delivered to small containers from which they pass through inspection to the packing and shipping room.

For hot galvanizing, after the acid dip and the washing, the bolts must be thoroughly dried to avoid spattering when submerged in the zinc. A 10-ton steel tank heated by an underfired oil furnace is used for holding the zinc bath, which consists of pure zinc kept to a designated level by frequent additions. The parts to be galvanized are placed in perforated steel baskets containing about 30 lb. each and are handled to and from the tank by an overhead trolley conveyor. The temperature of the bath is 850°F., and the baskets are left submerged about 30 sec., after which they are lifted up, one at a time, and set into a Watrous centrifugal machine that throws off the excess zinc. At this point the parts are sprinkled with a sal ammoniac solution, after which they pass through a shaker to a cold-water bath, the purpose of the shaker being to distribute the solution.

Experimental Work.—Some new uses for aluminum plate or for solid aluminum appear possible. One of these is the anodic treatment for the production of a mirror surface. On this subject

Dr. Harlow Shapley stated that the mirrors of the Crossley reflector at the Lick Observatory were aluminized.

New alloy coatings and new combinations of two or more metals plated simultaneously have shown certain advantages. The codeposition of cadmium and zinc may have advantage in the protection of steel. The codeposition of cobalt and nickel has been used extensively as an undercoat for rhodium in the manufacture of large reflectors. The cobalt-nickel alloy containing

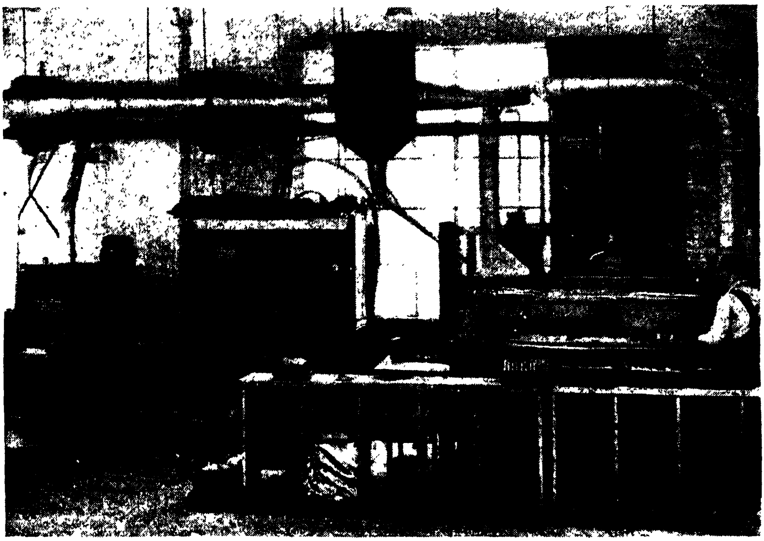


FIG. 95.—A series of different sizes and types of blast cleaning machines gives an efficient and flexible method of preparing all sizes of drills for the final finish.

25 to 40 per cent cobalt is claimed as the whitest alloy known. Rhodium reflectors are used for airplane-course markers.

SPECIAL METAL COATING PROCESSES

Cementation.—Cementation is a method of coating in which the article is immersed in a heated powder of the metal that is to form the coating. The process results in an alloying action between the heated metal powder and the surface of the article to be coated.

The commercial applications of cementation have in general been limited to "sherardizing"[1] with zinc powder, "calorizing" with aluminum powder and "chromizing" with chromium powder. Cementation by cadmium has been carried out successfully, however, and cementation coatings on steel may also be produced with tungsten, vanadium, cobalt, uranium, titanium, silicon, zirconium, molybdenum, tantalum, boron, manganese and beryllium. Many of these coatings show high resistance to corrosion and may in time be used on a commercial scale for the protection of ferrous metals. Their application to other metals is clearly possible.

The cementation process is especially adaptable to small pieces, but it cannot be operated on a small scale. The work is packed in the metal powder in large containers, made gastight and rotated so as to tumble the cementing powder over the surfaces of the work to be coated. It is heated for several hours by gas or electric heating coils. In calorizing, for example, the process is generally carried on in a hydrogen atmosphere.

Metal Cladding.—Veneering base metals with noble metals is an old art. Sheffield plate is produced by the simultaneous rolling of silver and a copper alloy like jeweler's gold-filled ware, which is a gold or gold-alloy shell "filled" with a base metal. Bimetal strip composed of sheets or bars employing two base metals is a later development. A "duplex" ingot may be made of two metals having a central portion of one metal but surrounded by a thick layer of the other. It is then possible to roll the duplex ingot or billet into coated plate, bar, sheet, wire, etc. The finished product, for example, may have a coating of copper alloyed to a steel base. Aluminum alloys are also regularly coated with pure aluminum by casting an ingot of the alloy in a steel mold lined with sheet aluminum and rolling the duplex ingot to the required dimensions.

Nickel-clad steel is made on a broad commercial scale. Heavy layers of steel and nickel are put in close contact, heated to alloying temperature and rolled to the desired size of finished plate.

Cathode Sputtering.—If a high voltage is applied between two electrodes in a partial vacuum, a glow discharge takes place and the cathode disintegrates. The cathode metal removed is deposited as a thin film on near-by objects within the chamber. This process, "cathode sputtering," has many special applications, such as metallization of electrically nonconducting materials, fabrics and phonographic recording waxes and the deposition of small amounts of silver in surgical gauzes. Cathode sputtering has been successfully used in producing gold deposits 0.001 mm. thick and of very high quality.

Coating from Vapor Phase.—A process akin to cathode sputtering is the condensation of metal vapors by thermal rather than electrical means. The material to be evaporated is heated to evaporation in a high vacuum, for example, 10^{-4} mm. of mercury. The process has been applied to a wide variety of metals, and it shows considerable promise for the future.

Vapor coating may also be done on metals. In vapor coating with tin, for example, a volatilized tin salt is brought into contact with the metal to be coated. The temperature is sufficiently high for the tin to be molten and to alloy with the metal being coated. In coating copper by this method, the coating is a very hard tightly bonded copper-tin alloy. This process is called "stannizing."

Rhodium Coatings.—Rhodium is electrodeposited, forming a pinkish-white coating that does not tarnish in air. It does not dissolve in hot aqua regia. Its principal uses are in jewelry and reflectors, where tarnish resistance and high reflectivity are important properties.

Platinum and Palladium Coatings.—Platinum and palladium coating are used for protective coatings and for electrical contacts. The coatings are bright. Coatings of the platinum metals, especially palladium, may be fabricated mechanically.

Indium Coatings.—Electrodeposited indium is silver-white and satiny. It remains bright in air and is fairly resistant to tarnish. The coating is soft. An outstanding contribution of this comparatively rare metal is its applicability to airplane bearings as a coating on silver-backed steel. Such bearings have been shown to withstand very heavy loads at elevated temperatures.

Rhenium Coatings.—Rhenium has been successfully electrodeposited but has little if any commercial application yet. Its most important property is its resistance to hydrochloric acid solutions.

PLATING ON PLASTICS

Recent years have witnessed a tremendous rise in the electrodeposition of metals on all types of nonmetallics. The war has further advanced this trend with increased uses.

Briefly, some of the advantages obtained by metallizing plastics are:

1. Preventing the absorption of moisture and oil and consequent warping and swelling.
2. Protection against corrosion by alkalies, solvents, etc.
3. Sales appeal, with bright and satin finishes (chromium, gold, silver, etc.). Colored, inexpensive, or even waste materials may be given the appearance of jewelry.
4. Use of coated plastics for electrical conductors or to act as shields or condensers.
5. Increasing longevity. A surface such as chromium provides a longer life by resistance to friction and wear.
6. Combining the good features of both the plastic and the metal: the light weight of the plastic and the appearance of the metal.
7. Increasing the resistance to heat and impact and also the stability and rigidity of the plastic.

There are several methods of applying a metal to a nonmetallic surface:

1. A bond and a conducting coat combination.
2. Sprayed molten metal.
3. Cathode sputtering.
4. Evaporated metal or vacuum deposition.
5. Silvering by chemical reduction (spraying or precipitation).

The oldest of these is the bonding and conducting coat combination. This process calls for (1) the application of a bonding coat, (2) an electrolytically conductive film and (3) electrodeposition of a metal (generally copper) to the desired thickness after which any other plate or finish may be applied.

This method is applicable over a wide range of products and materials. However, it has definite disadvantages in that it requires great care and the skill of an experienced metallizer. Its deposit is nonuniform—it is heaviest on those points where the bronze powder, for example, is thickest. It also has a tendency to show an orange-peel effect.

Spraying molten metal, a relatively simple process, calls only for the thorough cleaning of the work and a roughened surface (by sand blasting) to provide proper anchorage for the molten metal. The metal is fed in wire form (or powder) to a heated air gun and then atomized and sprayed on the work. This process, too, has limitations and disadvantages but is generally applicable to large or structural installations for protection against weathering and other deteriorating influences. It can also be used on small work where the granular effect of the sprayed metal surface is not objectionable.

Cathode sputtering is an excellent process for depositing metals, but expensive. The work is placed in a vacuumtight chamber or vessel such as a bell jar fitted on a heavy ground-glass plate. A relatively high voltage (up to 2000) is applied between an anode and a metal coating material, which is the cathode, in a partial vacuum, approximately, 0.01 to 0.1 mm. mercury pressure. A slow discharge is induced causing the disintegration of the cathode from which the metal is removed and deposited as a thin film on the work that is placed between the anode and cathode. The three phases of this process are (1) generation of the metal gas, (2) transportation of the gas and (3) condensation of the gas as a film on the work. The metallic deposit is very fine grained and crystalline in character and its porosity decreases with the thickness of the coating.

Commercial uses for this process are in the preparation of fine mirrors, metallizing fabrics, deposition on acetate phonograph recording disks and silver on surgical gauze for the treatment of wounds.

Metal vapor has been deposited by thermal means. The metal is heated to evaporation in a very high vacuum (0.0001 mm. pressure) in a magnesium, alumina or graphite crucible or by coating a tungsten resistance wire. Obviously, the high vacuum required limits the commercial use of this process although it holds some promise for special applications, such as optical mirrors, rayon coated with aluminum, etc.

Silvering by chemical reduction is an old process and has been widely used in the manufacture of mirrors. This process has made tremendous strides in the application of silver to newer materials. Its efficiency has been increased to such an extent that it is now one of the most widely applicable means of applying a metal coat on nonmetallics.

In principle the process consists of the precipitation of a thin film of silver on a clean, pretreated surface by reducing the silver from one of its compounds by the addition of a chemical reducer. For example, mixing of ammoniacal silver nitrate with formaldehyde results in the deposition of metallic silver. This can be done by means of a spray in which a jet of an ammoniacal silver nitrate solution and a jet of a reducer are mixed in a chamber or by precipitation in trays, tanks or barrels.

PREPARATION OF THE PLASTIC

In the plating of plastics it is extremely important to become familiar with each group and class of plastics and their proper pretreatment. This step is necessary to remove the "molding flash" of the plastic since a dull, sandy surface takes an easier bond. Pretreatment of this kind can be efficiently done in bulk.

In the cases of cast phenolics, urea resins, celluloid, polystyrene and methacrylate wet tumbling with pumice or light depolishing is effective. Rubber requires pretreatment with either benzol or acetone. Cellulose acetate, before being treated with the formaldehyde-ammoniacal silver nitrate solution, requires an additional priming operation. For casein plastics, a 3 to 4 per cent solution of hydroquinone or *p*-amino phenol is used as a reducer. Hydroquinone, pyrocatechin and acetone are used for a few minutes on phenol formaldehydes, which are then dried and placed into silver nitrate solution and heated to 176°F. Acrylic plastics utilize boiling hydroquinone and are then bonded by reduction with cane sugar, nitric acid, alcohol, water and a silver nitrate solution. For urea and thiourea formaldehyde resins, boiling hydroquinone is also used for reduction. The importance of the pretreatment of plastics cannot be overemphasized.

Lacquering.—In some difficult cases it may be more desirable to coat the plastic with a clear lacquer or synthetic that can take an easy bond than to go through a lengthy system of operations or to go into extensive research on a new plastic product.

In spraying the lacquer or synthetic, the handling of the gun is extremely important. It must be held at a proper distance to avoid flooding the article with lacquer and causing running. Care should be taken in drying to prevent dust or any other foreign materials from coming in contact with the surface, which would cause pitting later on. A dustproof room is extremely useful here. The lacquer should, of course, be thoroughly dried before treatment for bonding.

Cleaning.—The plastic must be thoroughly cleaned. Grease, oil or any other foreign material will give rise to an uneven plate and must be removed. Cleaning with dilute alkalies, nitric acid or mild soap and water, or the use of sodium hypochlorite solution have proved practical. In some cases the tinning solution (tin protochloride) acts as a cleaner.

Tinning.—Plastics can seldom be bonded without first being tinned. This process (patented) consists of treatment in a solution of stannous chloride, by dip, brush or swabbing with cotton and then thoroughly washing to prevent any of the solution from remaining on the surface.

Bonding.—By bonding is meant the reduction and deposition of a fine, thin conductive coat of silver. This can be done by immersion or by spraying.

Experience has shown that there are simple methods of bonding as in the case of Bakelite, which can be boiled for about ½ hr. in

Silver oxide	1 oz.
Ammonia	155 cc.
Water	1 gal.

Here, the formaldehyde in the Bakelite acts as a reducer making the use of a reducing solution unnecessary. However, a variety of reducers can be used with the ammoniacal silver nitrate solution.

A recent innovation is to spray the plastic with the ammoniacal silver nitrate solution and a reducer, premixed in a special gun. The silver is reduced directly from the nitrate to metallic silver in midair or inside the gun and is then deposited on the plastic.

After bonding, the article should be rinsed well and permitted to dry either in air or under mild heat. At this point a protective finish may be applied by lacquering. If greater thickness of deposit is required, a copper plate is deposited in a sulfate solution.

One acid copper plating solution, which has been used successfully, consists of

Copper sulfate	26 oz.
Sulfuric acid	5 oz.
Ammonia alum	2 oz.
Water	1 gal.

Shor recommends the addition of 1 quart of corn molasses per 1000 gal. of the above solution, as a brightener.

The solution may be air agitated, thus permitting higher current densities, and obtaining a smoother, more even deposit. At the beginning of the plating operation, 1 volt may be used and continued for about 3 hr., after which the voltage may be stepped up. At 20 amp. per sq. ft. the copper will be deposited at the rate of 0.001 in. per hr.

The copper plate can be bright dipped and tumbled, or polished by hand if the pieces are large, and plated or finished in any desired manner.

There are many methods for the chemical deposition of metallic films other than silver. Copper films are made by reduction with hydrazine or formaldehyde using a chloride or sulfate solution. Films of gold have been produced from aqueous solutions of gold chloride using invert sugar, alcohol, citric acid or formaldehyde. Lead films have been made using lead acetate with thiourea as the chemical reducer and nickel films have been deposited by the long-established method for the production of nickel by decomposition of nickel carbonyl.

Considerable information on this subject will be found in "Plastics and Plating on Plastics" by Harold Narcus, Chief Chemist, Plating Processes Corp., Holyoke, Mass., a paper read at the meeting of the American Electrochemical Society of Cleveland, June, 1944; also, Silver Coatings on Non-metallic Surfaces, by J. R. I. Hepburn, *Metal Finishing*, November, 1941.

A new and highly original aid to the electroplater is made by the Hanson-Van Winkle-Munning Co. It is an instrument called the Jernstedt electroplating computer. It does for the plater what the slide rule accomplishes for the engineer—makes use of logarithmic scales to eliminate lengthy calculations for the following:

1. Computes the chemical additions required in a plating bath of any gallonage, including cyanide additions.

2. Indicates the weight of metal deposited on unit area, given the thickness. Metal costs can be quickly determined.

3. Lists the usual cathode efficiencies of all modern electroplating solutions.

4. Gives the plating time required to deposit a given thickness of any metal.

5. Computes the current density required to produce a deposit of given thickness.

6. Indicates the thickness of deposit resulting from an established plating time at a known current density.
7. Space is provided for recording the standard composition of 20 different plating solutions. The normal temperature of operation and gallonage of each solution can also be recorded.
8. Lists the component parts, in per cent by weight, of salts commonly used in electroplating.
9. Lists the commonly used metric conversion equivalents.

CHAPTER XXIV

SPRAY COATING

If a metal part wears down in service, it is possible to build it up by applying a new coating of metal with a spray pistol. In a similar way, a coating of a hard metal may be successfully applied to a soft metal on production work, or a metal subject to corrosion may be coated with zinc, cadmium or aluminum so that it will resist corrosion under different conditions. This process of metal spraying is relatively new in this country, and the possibilities of the method as a fabricating means in industry are just becoming apparent.

If molten metal is blown, under proper conditions, onto a solid metal surface, it will adhere to that surface with a tenacity that for many purposes is as satisfactory as if it were actually part of the surface metal. This fact is the basis of a development in metal finishing known as metal spraying and apparently destined to become an important industrial process.

Powder spraying, or the atomizing of metals for decorative purposes such as gilding, is a very old art—older in fact than the Christian era—but in that art the tiny particles used invariably were made from the solid metal. The modern sprayed molten-metal coating process, which M. U. Schoop, a Swiss engineer, is given credit for originating, may be described as follows: metal in the form of wire is fed automatically into an oxy-gas flame where it is melted. The thin stream of molten metal is broken up into a finely divided condition by means of a powerful jet of compressed air and finally carried or projected onto a prepared metal surface.

During this operation, metal is transformed from wire into a sheet of metal which, in many applications, as mentioned, may be considered an integral part of the base metal. The metal thus applied is made up of a multiplicity of semimolten or plastic particles, which are flattened out by impact and interlocked first with the base metal and subsequently with each other.

The apparatus for processing is an ingenious instrument called a "spraying pistol" which uses oxyacetylene, oxyhydrogen or oxygen and city gas for melting the wire. In the experience of The Arthur Tickle Engineering Works, Inc., the wire ranges in size from No. 13 to 20 B. & S. gage and is pushed into the nozzle of the pistol at a uniform rate so that, as the end of the wire is melted and atomized, the position of the end with respect to the flame remains unchanged. The best size of wire to use has been determined by careful tests and varies for the different

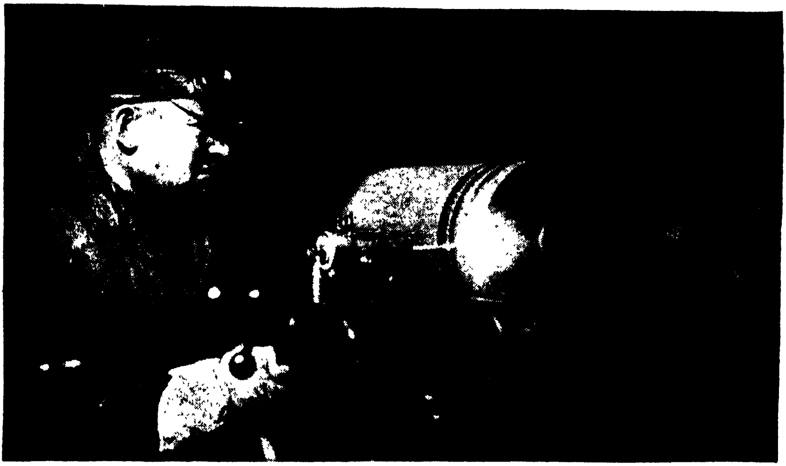


Fig. 96.—The metal-spraying pistol may be mounted on the tool rest of an ordinary lathe. Revolutions of work about 20 per minute. Feed about $\frac{1}{32}$ in.

metals sprayed. Different-sized tips are used to correspond to the different wire sizes.

The process of metal spraying at present is most extensively used in building up worn parts such as crankshaft bearings, valve stems and guide rods. One of the routine jobs handled at the Tickle plant is the building up of printing-press cylinders, and a description of this more or less standardized process will serve to explain the nature of metal spraying. The cylinders are 36 in. long and 13 in. in diameter, made of a fine-grain gray iron casting with no blowholes. These cylinders develop hollows in service. This is possibly due to corrosion from the acid cleaner used to remove ink. The job in repairing such a cylinder is twofold: (1) to build it up to the original diameter of 13 in., and (2) to apply a coating of stainless steel that will protect it against subsequent corrosion of a similar character.

The cylinders, after reaching the Tickle plant, are first calipered and then turned down to a uniform diameter. They are then sandblasted and placed in the spray machine for coating. The spray machine is essentially a lathe with two or more spray-pistol attachments mounted on the tool slides. If two spray pistols are used, one is placed at the end of the cylinder and the other at the center, and the feed is then arranged so that the entire surface is covered by moving both pistols through half the length of the cylinder.

FIG. 97.—Irregular containers used in the food industry are easily coated with protective metal by spraying.

The pistols are so set that the point where the wire melts is about 5 in. from the surface of the cylinder. The cylinder itself is revolved at approximately 20 r.p.m., and the feed of the pistols across the surface is about $\frac{1}{32}$ in. per revolution. By this means a uniform layer of stainless steel to the depth of $\frac{1}{32}$ in. will be applied in about 8 hr.

Comparatively little work has been done on the microscopic structure of the coating applied by spraying. When the tiny molten-metal particles are hurled through the air at great force, they come to rest as they splash against the rough metal surface, and in so doing they flatten out and interlock with the surface irregularities and with each other. Each tiny particle is flattened into a microscopically thin scale, and, when it is realized that the structure of the sprayed coating consists of mechanically interlocked scales, it becomes obvious that there will be a loss of tensile strength and an increase in porosity as compared with the original solid metal of the wire.

Despite this, a properly applied sprayed coating will exhibit some remarkable qualities. Valve stems used in marine engines are repaired after packing wear by spraying high-carbon steel on the worn mild-steel shaft, and these repaired shafts have never been known to wear down again, although the work has been going on for several years. It is the opinion of the Tickle company that the sprayed coating of high-carbon steel is of such a nature as to resist wear better in this particular service than would an ordinary rolled steel shaft with a case equal in hardness to that of the sprayed metal coating. The theory is that the slightly porous nature of the sprayed coating aids self-lubrication after oil has been applied, because the oil sinks deep into the pores of the coating.

The individual particles of the sprayed coating must be exceedingly minute because they do not interfere with accurate grinding and polishing. Printing-press cylinders, after spray surfacing, are ground to a tolerance within 0.0002 in.

Technique of Spraying.—The preparation of the surface to be sprayed is of great importance. It determines in a large measure the degree of adherence of the coating. A good method is to blast the surface with steel shot at high pressure. This cleans and roughens the surface and leaves small elevations and depressions, or keys. In actual practice the Tickle company never allows an uncoated surface to remain more than 1 hr. without applying metal. This minimizes oxidation of the surface and the gathering of moisture or dust on the surface.

Every effort should be made to control the melting of the wire evenly to obtain a fine-grain metal structure. This is important for two reasons. (1) If the metal is lumpy or not uniform in its application, the tiny particles will be too large to fit the crevices made by blasting the base-metal surface, and an insecure bond will be the result. (2) The applied metal will not have adequate density and will therefore permit access of moisture. Also, the metal structure will be weak or "powdery." It must be remembered that the mechanical bond of the process depends upon a properly roughened surface and upon a properly melted and atomized sprayed-metal coating.

A wide range of metals may be successfully applied by spraying, among which are high-carbon steel, aluminum, lead, zinc, tin, copper, bronze, brass, nickel, monel, stainless steel, silver, gold, molybdenum, tantalum and nichrome. In fact any metal can be sprayed that can be obtained in wire form and that has a melting point within the range of the heating mechanism of the pistol.

One of the variables in spraying that must be watched carefully is the distance from the pistol to the work. About 5 in. is the usual distance. Other variables are

1. Speed of work in r.p.m.
2. Feed or travel of pistols.
3. Air pressure.
4. Temperature.

Spraying Pistols.—A diagrammatic cross section of a typical American spraying pistol is shown in Fig. 98. The nozzle may

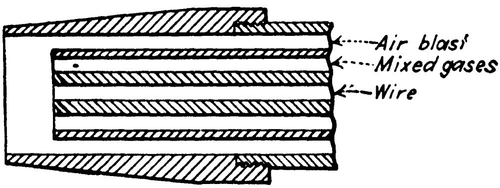


Fig. 98.—This is a section through the nozzle of the American-type spray pistol. There are three concentric spaces, one for the wire, one for the melting gases and one for the air blast.

be considered as consisting of three concentric tubes. The wire to be sprayed is advanced through the central one, the gaseous mixture (acetylene with oxygen) through the next, and the compressed air through the third or outer annular space. The gaseous mixture burning at the orifice melts the wire in the inner part of the conical flame, and the compressed air accomplishes the atomizing and spraying of the metal as it is melted.

A wire-feed mechanism in the pistol is employed to draw the wire from a coil and feed it through the oxyacetylene flame where it is melted as fast at it emerges. The driving mechanism for feeding the wire is a small air turbine driven by the compressed air used for spraying the metal. The oxygen and acetylene pressures range from 14 to 28 lb. The compressed air pressure ranges from 40 to 60 lb.

The English method is somewhat different from that described above, as the following quotation from Mellowes & Co., Ltd. will indicate:

All metal work must be sandblasted before spraying, to remove any rust or scale, and to provide a suitable surface to which the metal spray can adhere. With other materials it is only necessary for the surface to be dry and free from grease.

The metal to be sprayed is first melted in a small gas-heated crucible, from which the container of the pistol is filled about every 20 min. A bunsen-type flame under the container, the gas for which is obtained by connecting the pistol to the ordinary gas mains by means of a rubber hose, keeps the metal in a molten condition while spraying. The pistol is also connected by a rubber hose to a compressed-air supply of 60 to 75 lb. per sq. in., and when the molten metal flows to the nozzle it meets the preheated compressed air which very finely atomizes it, so that the minute particles of metal are blown against the surface to be covered at a tremendous velocity and adhere firmly, forming a continuous metallic coating with a fine matte finish.

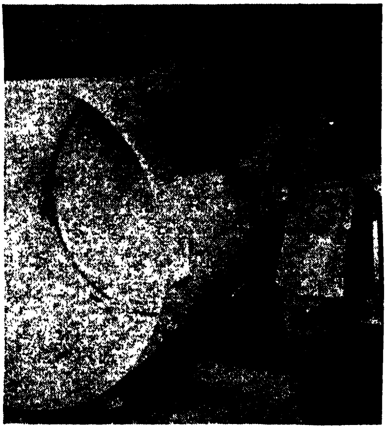


FIG. 99.—After a little practice, an operator is able to apply metal to tanks about as simply as he would spray paint.

The thickness of this coating is approximately 0.004 in. and the speed of application 8 to 10 sq. ft. per min., but this coating can be increased to any desired thickness by allowing the pistol to travel at a slower rate across the surface to be sprayed.

A special type of pistol has been developed in America for coating the inside of long tubes and pipes with soft metals. This pistol has a tiny revolving nozzle at its tip, which throws the metal particles laterally against the walls of the pipe. With this special pistol, pipes 1¼ in. inside diameter and 14 ft. long have been spray coated.

Applications.—A description of a few actual metal-spraying jobs will serve to illustrate some of the practical details of the process. Two Medart rolls, one approximately 8 in. in diameter and 12 in. long, and the other, an hourglass, 8 in. at the largest diameter and 12 in. long, were successfully repaired. These rolls are used for straightening brass and bronze rounds 2 in. in diameter. The bronze bars, after extrusion, are pushed through the rolls which polish and straighten them for finished stock. The rolls are subjected to terrific wear and heavy pressure at the same time.

When these rolls were received for coating, they were worn about $\frac{1}{16}$ in. They were built up with high-carbon steel and ground to original size and are now in service where the new coating is expected to show better wearing qualities than the base metal.

A tail shaft for a yacht, 18 ft. long and 6 in. in diameter, with two bronze bearings, was received for repair. Between the two bearings the steel shaft was badly pitted and corroded. Adjacent to the bearings on the steel shaft, the condition of the shaft was particularly bad. The stern gland liner was worn. It was repaired as follows:

The two low badly corroded areas adjacent to the bronze areas were filled in with low-carbon iron, bringing the shaft back to size. The steel shaft, for a distance of 8 ft. between the two bearings, was then sprayed with cadmium to resist salt-water corrosion and the reoccurrence of this condition. The tail end bearing was built up with phosphor bronze and turned to original size. This job was done at a great saving in time and expense, with the repaired shaft better than a new one.

A closing machine valve and seat, which are the main parts of a vacuum-pack machine, were worn and were giving inefficient service. The valve was 21 in. in diameter with a 12-in. face. It was built up with high-carbon steel and ground to size. The seat had developed several low areas. These areas were filled in separately with an alloy metal and machined to suit the temperature of the valve. The machine is now running with the efficiency of a new machine, at a saving of 50 per cent.

In the automobile industry many parts are reclaimed to advantage by metal spraying. Crankshafts are built up on the journals and ground to original size. Rear axles and king pins are similarly prepared, using a hard-wearing metal for spraying. Leaky cylinder blocks may be filled in with an alloy metal where hair-line cracks develop between the valve seat and the cylinder. Wear-resistant metal, such as an alloy steel, has been successfully used to coat brake-drum lining faces.

Another application that is gaining favor in repair of automobiles is the spraying of aluminum in the combustion chambers of high-pressure motors. This retards carbon and aids complete combustion of the gasoline. The development of applying high-speed babbitt for bearings bids fair to be of importance in industry. A thickness of $\frac{1}{64}$ to $\frac{1}{16}$ in. may be applied, and such

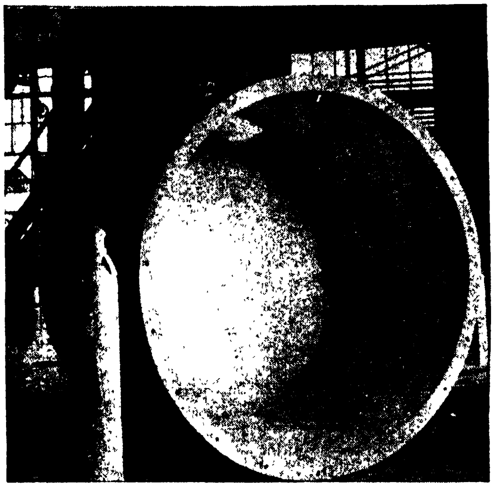


Fig. 100.—Storage tanks in the chemical industry are spray coated with aluminum.

a coating is used where it was only practical to use bronze in the past. Apparently babbitt, when sprayed, is free from blowholes or defects in the finished layer, and the bond, when the base metal is prepared by blasting, is better than in most cases where the babbitt is poured hot into place.

Another valuable feature of the spray-applied babbitt is the control of the composition. Not only may coatings of the purest metals be applied, but two metals may be applied simultaneously or successively by merely altering the mechanical features of the spray pistol. A combination of zinc and aluminum has been found excellent for resisting the corrosive attack of atmospheres high in sulfur dioxide.

An example of the practical application of aluminum to iron is illustrated by the coating of a drum used for extracting caffeine from coffee. The drum in question is 6 ft. in diameter and 21 ft. long and is subject to great changes in temperature in use and also to the action of solvents used in the process. As originally made, the drum had a coating of enamel on its interior. Constant expanding and contracting under temperature changes caused this to chip off. The aluminum as applied is 0.015 in. thick, and it has been successful as a protective layer.

Advantages.—Since no preheating is done during the spray coating of a part, some objectionable features of welding are eliminated. It is unnecessary to dismantle equipment in order to facilitate a repair by spray coating. The worn or mismachined section can be treated without interfering in any way with the rest of the equipment. After the coatings are applied, they may be used in their unfinished state, which is a matte or sanded surface. They can be filed, ground or polished just the same as ordinary metals. To sum up, any metal can be applied to the same metal or to any other commercial metal, and to any base surfaces such as wood, plaster, stone, glass, concrete, rubber or molded compositions.

Sprayed metal coatings may be used in many cases for protecting ferrous metals against corrosion, but the process is not so simple as just applying any noncorroding metal to steel. The electrochemical theory of corrosion must be followed through closely in the application of sprayed metal for protection. Zinc is anodic toward iron and close in the electrochemical series.

One of the most practical and economical methods of producing a protective coating of aluminum on steel is by metal spraying. Aluminum is anodic to iron and resistant to much chemical action. For the protection of steel, which is exposed to high temperatures, sprayed aluminum has been found to (1) retard oxidation, (2) prevent clinkers from adhering to surface, and (3) increase the life of the object four to ten times.

In extreme cases a heat-treatment is applied to the coated piece, the aluminum thereby penetrating to a considerable depth and consequently raising the resistance to a still higher temperature range.

CHAPTER XXV

METAL COLORING

Basically there are three metal-coloring processes: chemical, heat and electrocoloring.

In coloring as well as in other metal-finishing work, the surface of the base metal must be properly prepared. If a good reflective surface is needed, a high polish is necessary. If a certain density of color is needed, as in copper bronzing with copper nitrate, a satin or scratch brushed surface is required. For matte finishes, sandblasting or matte dipping should precede the coloring operation.

Hundreds of formulas are in existence, but only a small percentage are in general use, the rest being designed for a particular article or color and not adaptable for wide commercial application. A few representative formulas are given in this chapter.

CHEMICAL COLORING

Until recently, chemical dipping or brushing was the only means of coloring metals. Although this type of work deals mainly with the older and longer known metals, new processes have been developed, including the dipping of the newer light alloys.

Copper Alloys.—For browns of any shade on copper or brass, a boiling saturated solution of copper nitrate will give excellent results. If the article is too bulky for dipping, a solution made of equal quantities of a cold saturated solution of copper nitrate and wood alcohol can be applied either by brushing or with a rag. The copper nitrate must be absolutely free of sulfate.

A black color on brass may be obtained by applying this solution at half strength and heating the article until the solution evaporates. The heating is continued until the nitrate turns black. Excess copper oxide is removed, and if necessary the article is rebronzed.

Ammonium sulfide may also be used on copper and silver. To prevent the smoky black color, which often occurs, a weak solution should be used, which will give a brown to copper color. Barium sulfide or antimony sulfide mixed with ammonium hydrate will give similar results.

Still popular for their appearance as well as for good protection against corrosion are the greens on copper and brass, such as the following:

Antique Green	
Copper sulfate	12 oz.
Ammonium chloride	2 oz.
Water	1 gal.
Verde Antique	
Copper nitrate	4 oz.
Ammonium chloride	4 oz.
Calcium chloride	4 oz.
Water	1 gal.
Green Patina on Copper (Cabra Process)	
Copper sulfate	3 oz.
Ammonium sulfate (technical)	6 lb.
Concentrated ammonia	1⅓ fl. oz.
Water	6½ gal.

The above quantity will color 1000 sq. ft. of copper.

Brown on Copper	
Potassium sulfide	2 oz.
Caustic soda	3 oz.
Water	1 gal.
Temperature, 180°F.	

An excellent black is the ammoniocopper carbonate black on brass. This is made by dissolving copper carbonate in ammonium hydroxide, with a slight excess of carbonate, diluting the solution with nine times its volume of water. The cold solution gives the brightest blacks. At 100°F. the black is dull, and ammonia must be added frequently to replace losses by evaporation.

Another mixture is

Copper carbonate	1 lb.
Ammonium hydroxide	1 qt.
Water	3 qt.
Temperature, 175°F.	

To deepen this black the work should be treated with a dip of 2 oz. of sulfuric acid in 1 gal. of water.

Steel.—Rustproofing methods such as parkerizing and bonderizing have been used for many years. They are gray protective coatings of phosphate on the surface of the iron or steel. Today, however, there are new solutions, which are primarily decorative blacks, rather than protective in character. These are mainly saturated solutions of caustic soda and an oxidizing agent worked at 250° to 320°F. depending upon the concentration of the caustic used. They must be handled carefully for fear of spurting when water or wet articles come in contact with the solution.

Caustic soda	5 lb.
Sodium nitrate	3 lb.
Water	1 gal.

Temperature, 285°F.
Time, 10 min.

Such solutions can be made to give consistent results with careful handling, but occasional additions of the oxidizing agent (sodium nitrate) are necessary. Some iron is dissolved since the base metal is attacked in the process. This blacking is not rustproof, but a coating of lanolin dissolved in mineral naphtha is extremely helpful in preserving the color.

Two old methods, still in use today for producing a black color on steel, are (1) oil blacking, in which the steel is heated to red heat and plunged into sperm oil; (2) tumbling the steel articles in charred sawdust.

Other Metals.—The lead acetate-thiosulfate solution may be used on copper, brass, nickel, steel and tin, giving a variety of colors ranging from yellow, red and purple to peacock blue.

Lead acetate	3 oz.
Sodium thiosulfate	3 oz.
Water	1 gal

Temperature, 180°F.

Gray colors are obtainable on many metals by the use of

Arsenic oxide	20 oz.
Copper sulfate	10 oz.
Ammonium chloride	2 oz.
Muriatic acid	1 gal.

For tin, zinc and cadmium, the above solution is diluted to one-fifteenth of the above concentration. It will yield a fine black surface on cadmium without impairing its rust-resisting qualities.

Other blacks on cadmium:

(1)	Potassium chlorate	4/5 oz.
	Copper chloride	1 oz.
	Water	1 gal.
	Temperature, 250°F.	
(2)	Sodium chlorate	7 oz.
	Copper nitrate	5.5 oz.
	Water	1 gal.

For brown tones on cadmium:*

(3)	Potassium dichromate	1 oz.
	Nitric acid, 36°Bé	0.5 oz.
	Water	1 gal.
	Temperature, 140°–160°F.	
	Time, 6–8 min.	

A comparatively new development is the coloring of cadmium with potassium permanganate, adding cadmium nitrate, potassium chlorate and copper nitrate. This oxidized surface has resistance to both corrosion and abrasion.

1. Light yellow to deep browns:

Potassium permanganate	21 oz.
Cadmium nitrate	8–32 oz.
Ferrous sulfate	2⅓–1⅓ oz.
Water	1 gal.

2. Deep red:

Potassium permanganate	43 oz.
Cadmium nitrate	13.5 oz.
Ferrous chloride	2.75 oz.
Nitric acid	¼ fl. oz.
Water	1 gal.

Molybdate coloring has recently been applied to the light metals. Aluminum can be blackened with a neutral solution of sodium molybdate at 120°F. in 15 min., and with the addition of sodium chloride colors can also be on zinc with sodium molybdate.

For a beige color on aluminum and brown on zinc, the following immersion solution is used:

Sodium molybdate	¾ oz.
Sodium fluoride	½ oz.
Zinc sulfate	1½ oz.
Water	1 gal.
Temperature, 160°F.	

* Erskine, W. J., *Metal Finishing*, March, 1939.

A black color on zinc will be produced by ammonium molybdate at a pH of 5.6, also various intermediate shades.

Silver.—Grays and blacks (Butler finish) are produced on silver by sulfides: sodium, potassium, calcium or ammonium, ½ to 1 oz. per gal. of water at 180°F. For a black, scratch brush the deposit; for gray, use a rag or tampico wheel with pumice and water.

Another gray is obtained with

Potassium sulfide	½ to 2 oz.
Water—enough to make	1 gal.

Temperature, 150°F.

HEAT COLORING

Iron and Steel.—The simplest process is the dip in sodium nitrate held at 575°F.; another mixture contains equal parts of sodium nitrate and sodium nitrite; a third consists of sodium and potassium nitrates, with a little manganese dioxide.

A good brown on iron or steel is quite difficult to achieve. One method is to bury the articles in silver sand held at a temperature of 480°F. This operation requires experience, however.

Chromium.—Chromium plate also responds to heat-treatment, yielding a good black color in the molten mixture of

Sodium cyanide	45 per cent
Sodium carbonate	35 per cent
Sodium chloride	20 per cent

A beautiful green is obtained by heating chromium plate at 1200°F. in a controlled oxidizing atmosphere.

Copper-tin alloys (bronze) heated to 350°F. give a beautiful brown with iridescent greens, blues and reds.

Electrocoloring.—Anodic black coloring was developed on tin and tin alloys by Kerr and MacNaughton. The solution consists of

Sodium phosphate	1⅓ oz.
Phosphoric acid (sp. gr. 1.75)	2.5 fl. oz.
Water	1 gal.

Temperature, 140°–195°F.
Current density, 40 amp. per sq. ft.

This gives a fine lustrous black deposit that takes a high polish and affords some resistance against abrasion. The best results are obtained on pewter, but it can be applied to electrodeposited tin or tin plate. Colorless films that will absorb dyes may be deposited at low current densities. Tin may also be colored black with a weak chromic acid solution, under careful control.

Magnesium Alloys.—An anodic black finish for magnesium alloys was developed by C. B. F. Young, consisting of

Chromic acid	$1\frac{1}{3}$–$2\frac{2}{3}$ oz.
Trisodium phosphate	$1\frac{1}{3}$–$3\frac{1}{3}$ oz.
Water	1 gal.

Current density, 15–30 amp. per sq. ft.

Buzzard & Wilson recommend a solution to give a black on magnesium:

10 per cent solution of sodium dichromate
5 per cent of sodium hydrogen phosphate
5–10 amp. per sq. ft.

Aluminum.—Usually anodic oxidation and coloring are associated with aluminum. The condition of the oxide film and its properties are extremely important for the subsequent dyeing operations. The current density, time, temperature and the composition of the alloy must be consistently maintained. There must be complete neutralization (of the sulfuric acid) in the film so as not to affect or be affected by the coloring operations. Dyeing solutions must also be closely controlled. For further discussion of aluminum coloring, see Chap. I.

The aniline and alizarine series in acid solutions give good results with some modification. Dyeing can be done to almost any shade; gold, blues, greens, reds and blacks are quite dependable, although intermediate shades begin to fade after 18 months.

The dye solution should be used at boiling point; or "sealed," by dipping the dyed article in boiling water to prevent "bleeding."

If the pH of the dye is markedly different from the water, the colored film should be sealed with a 1 to 2 per cent solution of a metal acetate at 75°F.[1] For outdoor decoration it is definitely advantageous to reseal in boiling water.

Green Patina on Copper.—A good protective green patina on copper was developed by Vernon, consisting of the following:

[1] Covered by British and American patents.

Magnesium sulfate	10 per cent in water
Magnesium hydroxide	2 per cent in water
Potassium bromate	2 per cent in water

Temperature, 200°F.
Current density, 25–30 amp. per sq. ft. using 5 volts and a carbon cathode

Molybdate Solutions.—Black coating of molybdenum sesquioxide on zinc, cadmium, iron, lead and tin from solutions of ammonium molybdate, with additions of ammonia and sodium thiosulfate, was developed by H. Krause.

Color Plating.—Great progress has been made in the cathodic deposition of thin metal oxide films. These films have varying interference colors that are highly lustrous. Commercial examples of such colors are Electrocolor and Patternplate in a variety of colors, developed by United Chromium, Inc. The practice is to use alkaline solutions of oxidizable metal such as copper with an organic substance (lactic, tartaric and glycollic acids or sodium tartrate, Rochelle salts, sodium silicate or cane sugar). Careful control of all the factors involved is imperative.

A representative formula is

Copper sulfate	12 oz.
Caustic soda	12 oz.
Commercial lactic acid	1 pt.
Water	1 gal.

The colors develop in a cycle. With a pressure of ¼ vlot and a current density of ¼ amp. per sq. ft. a bright yellow color appears first. With continued operation it changes to orange, red, purple, blue, green, silver, rose, violet green and back to yellow. The cycle then starts anew.

Iron and nickel solutions also produce good results. There is said to be a wide field for this type of decoration, even though the solutions are extremely sensitive and the deposits fragile unless protected by clear organic coatings.

Chromium.—Chromium plate has been colored by electrodeposition using an ordinary chromium plating electrolyte, with the sulfate radical replaced by an organic acid radical, such as acetate, propionate or tartrate. The colors vary from light brown to black. Also some interference colors may appear.

Aluminum.—Aluminum can be colored black in a nigrosine bath which should be slightly acid (sulfuric acid), using carbon anodes. Current density is 0.25 amp. per sq. ft., 2 volts.

Arsenic on Steel.—An excellent gray on steel can be obtained by the deposition of arsenic from the following:

Sodium hydroxide	12 oz.
Arsenious oxide	12 oz.
Copper cyanide	1 oz.
Sodium cyanide	1 oz.
Water	1 gal.
1 volt	

Black Nickel.—The use of black nickel has spread widely, for example, on optical instruments, novelties, etc. A simple bath used is

Nickel ammonium sulfate	9 oz.
Zinc sulfate	1.25 oz.
Sodium sulfocyanide	1.25 oz.
Water	1 gal.
Correct density, 1 amp. per sq. ft.	
1 volt	

Periodic additions of zinc sulfate and sulfocyanide are necessary.

The growth of the metal-coloring field is evidenced by the large number of proprietary mixtures and processes now available for producing all imaginable colors.

CHAPTER XXVI

ELECTROPLATING COSTS AND ESTIMATING

Many manufacturers are still treating their finishing departments as a necessary evil and know little about the details of their operations, sometimes even leaving their financial control to men unfamiliar with the intricacies of this type of work.

Electroplaters have attacked, time and time again, the problem of devising a method both simple and practical for estimating metal-finishing costs, and, at the same time, one accurate enough to allow them to estimate safely, with reasonable allowance for the unforeseen (which in metal finishing almost always happens).

In order to obtain a true picture of costs in the electroplating field, a number of platers pooled the figures from their annual profit-and-loss statements. These were combined and reduced to percentages to show the "normal" expenditure for each dollar of sales of still plating. The results, in round numbers, for simplicity, are shown in Table VII.

TABLE VII.—EXPENDITURES PER DOLLAR OF SALES

Items of Expenditure	Percentages of Sales Dollar
Direct labor:	
Polishers, platers, tank operators, general help, etc.	40
Indirect labor:	
Receiving, office, delivery, etc	10
Executives and salesmen	10
Materials (excluding precious metals)	10
Rent	3.5
Power	3.5
Fuel and water	1.5
Insurance (compensation, fire, liability, etc.)	2
Taxes (unemployment, social security, etc.)	3
Repairs depreciation	3.5
Discounts and bad debts	2
Telephone, office supplies, etc	1
Total	90
Profit	10
Grand total	100

From Table VII, certain conclusions were drawn:

1. Prices for still electroplating work should be at least 2½ times the total direct labor in order to show the moderate margin of profit, 10 per cent.

2. In order to be accurate, an estimate must include *total direct labor—for every operation.*

TABLE VIII.—JOB CARD

Factory Order No. 1298. Date ______________

Name of Customer Doe & Co. Finish—Copper, nickel, chrome

Article—Holder No. pieces—1,000

Time Promised ________ Instruc.—Spec.

Name of operator, operation performed and quantity done	Time	
Mike Jones—cut down 200	Start Finish	Mon. 8 Mon. 5
Mike Jones—cut down 230	Start Finish	Tues. 8 Tues. 5
	Start Finish	
	Start Finish	

The 2½ to 1 factor for total direct labor could be used for all "still" plated decorative work on base metals. It was not applicable to barrel plating, hard or industrial chromium, hard or industrial nickel or precious-metal plating. Barrel plating requires very little labor but has long "dwells" in the barrel. Hard chromium work spends so much time in the tank, uses so much power and so often calls for special preparatory work, racks, jigs, etc., that special provision must be made for the additional power and the metal deposited. Prices for precious-metal work must include special allowances for the high-priced metals.

It must also be remembered that the 2½ to 1 ratio will not hold in all instances; in fact it is probably a minimum. Local conditions, special machinery and layout, and other factors may change it radically. It will serve here, however, as a general guide.

A simple job card can be utilized for any single class of work, as shown in Table VIII, which will keep the record with reasonable accuracy, if the operations are simple, clear-cut and continued for a reasonable length of time, such as polishing, for example.

From such a card the time of all such types of labor put in on a job can be totaled. It is also possible, of course, to make up a job card that will include every item of cost, materials, rate per hour of each individual, etc.

This is quite satisfactory for steady, continuous operation. However, it is generally recognized that it is difficult to keep close track of plating labor since the work so often overlaps and is divided among many individuals having various rates of pay. The plater, for example, is the highest priced man, but his work is largely supervisory, making it hard to estimate his time on any one job. The manual laborer will move rapidly from job to job and back, spending only a few minutes on each. Keeping close records of such work is not practical.

Estimating Labor Costs.—Estimating labor costs should be kept equally simple. For most still-plated decorative work, the estimate would be divided into two main parts, polishing and plating.

Taking as an average the figure of $1 per hour for skilled polishing labor, the polishing price may be figured at two and one-half times $1, or $2.50 per hour. In the plating shop, labor rates range from the skilled plater down to the unskilled boy or girl, but a fair average might be 75 cents per hour. The plating price may therefore be estimated at two and one-half times 75 cents per hour times the total number of man-hours a job will take, without attempting to itemize in detail the specific rate for the time each employee puts on each piece.

Again it must be pointed out that these figures are general, subject to change for the rates of pay and other special conditions in the specific plant in which the work is done.

The elements of this method of cost estimating, however, are simple, being confined to the following factors:

1. An estimate of the polishing labor.
2. An estimate of the plating labor.

3. A fair figure for the average rate of pay per polishing hour (or per hour of wheel time).

4. A fair figure for the average plating-room labor hour.

5. The application of the proper factor, 2½, 3, 3½, etc., to the total direct labor costs involved.

6. Additions for special items, such as expensive materials and precious metals, and for excessive power or metal consumed by industrial work that spends a long time in any plating tank.

In principle, this method can be applied to any metal-finishing plant or department. A full automatic plating machine will reduce the plating labor to much lower figures, just as automatic polishing machines will cut polishing costs deeply. Consideration of such equipment must, of course, be included in the overhead items, such as interest on investment and depreciation, but the factor, under such conditions, may therefore be raised from 2.5 to 3, 3½ or more. Once determined for the particular plant, however, it can be used steadily with a good degree of accuracy.

Barrel Plating.—Among the hazards in estimating barrel-plating costs is the variation in the condition in which the material reaches the plating department, the variety of finishes applicable and, also in some cases, the varied sequences of operations.

Barrel plating may be divided into two broad classes.

1. Bright plating—requiring four principal operations: (*a*) tumbling, (*b*) plating, (*c*) barrel burnishing and (*d*) sawdust tumbling.

2. White nickel and cadmium—requiring two operations: (*a*) plating and (*b*) sawdust tumbling.

"Intermediate" plating, which calls for tumbling, plating and sawdust tumbling could be considered another class of work. Generally its cost falls between classes 1 and 2.

Cleaning, although a necessary step, is omitted from detailed consideration here because the time involved is small compared with that for other operations.

It has been shown that a plant operating a total of 25 barrels including tumbling, plating, ball burnishing and sawdust tumbling (the barrels holding 75 to 100 lb. of work) requires three employees for its operation, one man and two boys.

The output of a barrel-plating plant varies with both the type of work and equipment. Considerable progress has been made in the handling of materials—automatic hoppers, fillers and emptiers, mechanical trolley arrangements, etc.—which have reduced labor cost greatly.

Below is a description of the operations, using simple, hand-operated barrels, in a typical job shop in the East.

	Minutes
Loading tumbling barrel	4
Unloading tumbling barrel	8
Loading plating barrel	8
Unloading plating barrel	12
Loading ball-burnishing barrel	4
Unloading ball-burnishing barrel	12
Loading sawdust barrel	4
Unloading sawdust barrel	8
Total handling time	60 min. = 1 hr.

The above represents the equivalent of handling four barrel loads per hour or one barrel of bright-plated work per hour.

In a typical case, four men working 8 hr. (total 32 hr.) loaded and unloaded

48	tumbling and burnishing barrel loads (before and after plating)
38	plating barrel loads
42	sawdust barrel loads
128	barrel loads of all kinds

The complete bright-plating process takes four barrel operations, as listed.

Therefore, four men can turn out $^{128}\!/_{4}$ = 32 barrels of bright-plated work per 8-hr. day.

Three men will turn out, proportionally, 24 barrels of bright-plated work per 8-hr. day or one finished bright-plated barrel load per hour per man (actually handling four barrel loads per hour per man).

With the use of modern equipment, it is possible to obtain nine barrel loads per hour per man. For the calculations to follow, therefore, the figure of six barrel loads per man per hour is chosen as a fair rate under average conditions. The plant has 24 barrels in all, plating, tumbling and burnishing, and drying.

Costs Per Man-hour

1. Labor:

1 lead man........................	\$1.00 per hr.
2 boys at 60 cents per hr...........	1.20 per hr.
Total...........................	\$2.20 per hr.

$$\frac{2.20}{3} = 73 \text{ cents per man-hour average}$$

2. Supplies:

a. Balls are used up at the rate of about 45 lb. per month at 50 cents per pound = about \$22.50 per month.

Three men work 8 hr. 5 days per week and 4⅓ weeks per month = about 520 working hour per month.

$$\frac{22.50}{520} = \text{about 4.3 per man-hour cost of balls.}$$

b. Soap is used up at the rate of about \$25 per month.

$$\frac{25.00}{520} = \text{about 4.8 per man-hour cost for soap.}$$

c. Sawdust cost is about \$10 per month.

$$\frac{10.00}{520} = \text{about 1.9 cents per man-hour cost for sawdust.}$$

d. Cleaners, potash and cyanide, cost about \$35 per month.

$$\frac{35.00}{520} = \text{6.3 cents per man-hour cost for cleaners.}$$

e. Anodes. Annual consumption was about 1000 lb. of nickel and 1000 lb. of cadmium. Total cost at this time was about \$1450 per year, or about \$120 per month.

$$\frac{\$120.00}{520} = \text{23.1 cents per man-hour cost of anodes.}$$

f. Salts. Annual consumption about 1 barrel of nickel salts of 450 lb.; total cost about \$60 per year, or \$5 per month.

$$\frac{\$5.00}{520} = \text{about 1 cent per man-hour cost of salts.}$$

g. Linings for barrels. Cost of new linings required, about \$75 per month.

$$\frac{\$75.00}{520} = 14.4 \text{ cents per man-hour cost of barrel linings.}$$

3. Power:

This particular plant uses about 4000 kwh. per month, which at rates obtaining in the district, about 4 cents per kilowatt-hour amounted to \$160 per month.

$$\frac{\$160}{520} = \text{about } 30.8 \text{ cents per man-hour of power.}$$

4. Depreciation, interest on investment and repairs:

This plant cost about \$15,000 to buy and install complete.
Depreciation at 10 per cent is \$1500 per year.
Upkeep and repairs at 5 per cent is \$750 per year.
Interest on investment at 6 per cent is \$900 per year.
Total = \$3150

$$\frac{\$3150}{12} = \text{about } \$262.50 \text{ per month.}$$

$$\frac{\$262.50}{520} = \text{about } 50.5 \text{ cents per man-hour cost of depreciation.}$$

5. Insurance, taxes, etc.

Compensation insurance, fire insurance, pay-roll taxes, etc., total in this district about 6 per cent of pay roll.

6 per cent of 73 cents = 4.4 cents per man-hour cost of insurance taxes, etc.

6. Rent:

Should be about \$125 per month.

$$\frac{\$125}{520} = 24.3 \text{ cents per man-hour cost of rent.}$$

7. Trucking and shipping:

Cost of operating a truck, driver, depreciation, upkeep, gas, oil, tires, etc., is about \$300 per month.

$$\frac{\$300}{520} = 57.8 \text{ cents per man-hour cost of trucking and shipping.}$$

8. Office supplies, telephone, etc.

Total cost is about $25 per month.

$\frac{\$25}{520} = 4.8$ cents per man-hour cost of office supplies and telephone.

9. Office help:

This plant may be operating as a part of a larger organization, in which case it will use only a part of the time of an office worker. If it is operating independently, it can also manage with a part-time girl.

Cost, about $60 per month.

$\frac{\$60}{520} = 11.6$ cents per man-hour cost of office help.

10. Executive:

Salary allowed, $300 per month.

$\frac{\$300}{520} = 57.8$ cents per man-hour executive's salary.

11. Miscellaneous and emergency:

Allowance is made for unforeseeables, emergencies, rejects, miscellaneous, etc., of $75 per month.

$\frac{\$75}{520} = 14.4$ cents per man-hour cost of unforeseeables, etc.

A recapitulation of all these costs is shown in Table IX.

Estimating that one man will load and unload, on the average, 6 barrels per hour and figuring that each completed barrel of bright-nickel plated work represents $\frac{6}{4}$ barrel operations, the result is $\frac{6}{4} = 1\frac{1}{2}$ barrels of completed bright-nickel work per man-hour.

The cost therefore is 3.85 cents per pound for $1\frac{1}{2}$ barrels, or $2.56 per barrel load, if the barrel holds 100 lb.

A point that must not be overlooked is that this figure of $2.56 represents the cost when the barrels are loaded up to their full capacity of 100 lb. Lots of less than 100 lb. will vary in cost, per pound inversely with their weight. Also, work that is bulky and does not permit loading in the barrel up to 100 lb. will be proportionally more expensive per pound. Odd-weight shipments such as 340 lb. or 570 lb., for example, may result in one short barrel load. For strict accuracy, the short-weight barrel must be charged for at a proportionally higher rate per pound.

TABLE IX.—RECAPITULATION OF COSTS PER MAN-HOUR

Item	Cost per Man-hour
Labor	$0.730
Supplies:	
Balls	0.043
Soap	0.048
Sawdust	0.019
Cleaners	0.063
Anodes	0.231
Salts	0.010
Linings	0.144
Power	0.308
Depreciation interest on investment and repairs	0.505
Insurance, taxes, etc	0.044
Rent	0.243
Trucking and shipping	0.578
Office supplies, etc	0.048
Office help	0.116
Executive's salary	0.578
Miscellaneous	0.144
	$3.852

It will be interesting to note the sales-to-direct-labor ratio in the above plant. It is, according to the above figures, briefly as follows:

Labor	$0.730	per man-hour
Supplies	0.866	
Overhead	2.255	
Total	3.851	
Profit at 1/9	0.426	
Grand total	$4.277	

$$\frac{4.28}{0.73} = 5.86$$

This figure, 5.86, at the same rate of profit (10 per cent) compares with 2.5 for still plating, showing that the two types of plating, still and barrel, differ substantially.

In actual practice, it has been found that estimates are often based on the *plating barrel hour*, at rates varying from \$3 to \$6 and even higher, depending upon the type of work and the finish required.

WHITE NICKEL OR CADMIUM

This type of work requires about one-half the labor time of bright-plating, calling for only two barrel operations, plating and sawdust tumbling. Roughly, therefore, the cost per labor hour will be \$2.56/2 = \$1.28 per barrel load.

The complexities of plating are not generally known to those without experience in the field. The work calls for skilled and experienced help, and technical control must always be maintained. For a company that is having its metal-finishing work done on contract outside of its plant, to install its own plating plant simply because floor space is available might be a mistake. Under only the most special circumstances should a company put in its own plating plant if it has less than \$25,000 worth of finishing work to be done annually.

PART V

ORGANIC COATING

CHAPTER XXVII

PREPARATION FOR PAINT

The preparation of a metal surface on which a paint or enamel is to be applied is a vital factor in the life and service of the coating, and the quality of the paint itself may often be of less importance in the final result than the quality of the surface preparation. Improved technique in prepainting treatment has extended the use of the corrodible metals as well as the use of paint in the metalworking industry.

Gradually the buying public has become rust-conscious, until now, as never before, rustproofing is a strong selling factor in the steel-products industry, even though the process frequently is hidden under a coating of paint or enamel. Rustproofing and preparing for paint in the treatment of steel surfaces are often identical processes, for almost always a good rustproofing treatment produces an etched surface that affords an excellent base for paint.

The proper application of paint to any metal product involves as a fundamental process preparation of the metal surface to receive the paint. In the public mind, first consideration is given to the quality of the coating material itself, but manufacturing experience demonstrates that paint failure on metal products is more frequently caused by improper preparation of the surface than by the use of inferior coating materials.

Plain polished sheet steel is not of itself an ideal paint base. Unlike wood, it lacks porosity to permit penetration, and so, when untreated, paint for the most part will simply lie on the smooth glasslike surface and, no matter how adherent it may seem when applied, the bond is not secure.

In addition to this lack of bond, the smooth steel surface presents another disadvantage as a base for painting, because with the admission of moisture to the metal through any cause, either through porosity of the paint film or abrasion of the coating, a condition favorable to corrosion develops and, once started, tends to spread. The outward sign may be a tiny spot of rust, but a pernicious activity may set up under the paint and, if allowed to progress, whole sections of the coating will become detached.

Alkaline Reaction.—Whatever theory of corrosion is accepted, laboratory research has established the fact that, in addition to the visible growth of rust at the point of actual abrasion, the surrounding area develops an alkaline reaction which creeps back between the metal and the applied finish, neutralizing the adhesion over an ever-widening surface.

When a piece of steel is strained, certain parts of it become electropositive and other parts electronegative. This condition may be demonstrated by tests, for the surface area in some parts will give a strong ferrous-iron reaction, and in other parts, an equally strong hydroxyl-ion or alkaline reaction.

When these respective areas are immersed in agar-agar jell, to which has been added potassium ferrocyanide and phenolphthalein, a blue color develops where the ferrous iron dissolves, and a pink develops where the surface is alkaline. This relatively simple test indicates several things. (1) It proves that there is a condition favorable to corrosion, and (2) it indicates a method of cleaning steel for paint which should be avoided. When a bare steel sheet is treated with almost any kind of acid before subjecting it to this test, the concentration of alkali is greater than for a similar sheet untreated with acid.

This seems strange at first, but when it is realized that any pickling effect tends to cause iron to dissolve more rapidly, the increased concentration referred to seems more logical. It is well known that most pickling, without subsequent treatment, leaves iron in a favorable state for corrosion. When a steel sheet is dipped in a 5 per cent phosphoric acid solution and then placed in agar-agar jell, a blue color appears almost immediately, indicating solution of the iron. Under such a condition it usually takes longer for the pink color to show up on the sheet because the hydroxyl ion must first neutralize the hydrogen ion from the acid remaining on the surface of the sheet. When this neutralization has once taken place, the phenolphthalein indicator turns decidedly red.

In Fig. 101, *A* and *B* indicate two small pieces of sheet steel connected by a wire and immersed in a water solution of any salt that will give the solution a slight conductivity. This is to illustrate the electrochemical theory of corrosion.

If we assume that both *A* and *B* are neutral, then, if corrosion is to take place, some iron must dissolve, which means that hydrogen gas is liberated at the metal surface. If such corrosion takes place on *B*, for instance, the iron that dissolves takes into

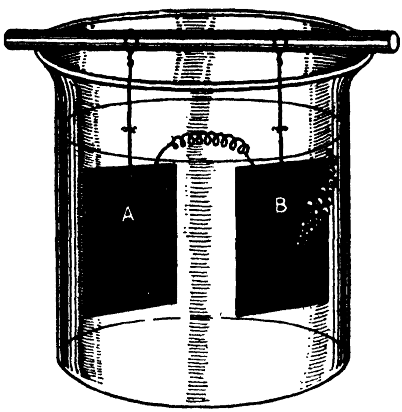


Fig. 101.—Electrochemical theory of corrosion.

solution with it two positive charges for each iron ion, and this leaves a negative with respect to *A*, owing to the fact that it is left with more negative charges than positive, and, since the two pieces are connected by a conducting wire, a circuit is formed through the wire, with its return through the solution.

Since *A* is now a positive electrode, any hydroxyl ions migrate to this electrode and a fairly high concentration of alkali is established. If the connecting wire is severed between *A* and *B*, the current cannot flow, of course, and corrosion from this source ceases.

This illustrates one of the important features to be developed in preparing a metal surface for paint. If by some means the positive and negative areas on the surface can be insulated, one from the other, the effect will be like severing the wire in the illustration shown in Fig. 101 and the tendency to corrode will have been retarded.

Two Important Factors.—There are then two important qualities to be sought in preparing for paint:

1. Etching or roughing, to provide a foothold for the paint.
2. Surface insulating, to prevent electrochemical development of alkali.

Both these objectives may be attained in a single operation between the cleaning and finishing of metal. One method is to

FIG. 102.—Plain carbon steel with baked enamel coating after salt spray test.

create a phosphate coating that gives greater adhesion and at the same time arrests the flow of a electrical current from one point to another on the surface.

Tests show that such treatment before painting will stop the spread of rust underneath the paint film, even when the paint is scratched sufficiently to allow local corrosion to take place. If such a treated specimen is placed in the agar-agar jell, there will be practically no color to indicate either ferrous iron or alkali.

Even though rust itself tends to loosen a paint film, the alkali formed as the result of the corrosion of metal is more pernicious and causes more pronounced loosening of the paint than does the rust itself.

Figures 102 and 103 illustrate another test. Here two identical pieces of steel were taken. Both were cleaned. The one in Fig. 102 was untreated, and the one in Fig. 103 was given a bonderizing treatment. Both pieces were then covered with two coats of baked enamel, and afterward each was pricked at the center to expose the metal. Both were then subjected to 228 hr. in a salt spray. The light area in Fig. 102 shows where alkali has destroyed the paint film surrounding the abraded spot. In Fig. 103 slight rust appears at the point of abrasion, but no spread of corrosion or alkali in the surrounding area is apparent.

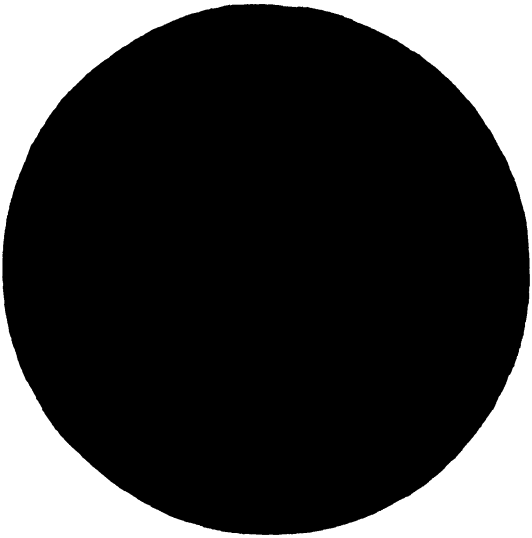


FIG. 103.—Same steel as shown in Fig. 102, coated in the same way and subjected to the same test but rustproofed before enameling.

The process of bonderizing, as with some other phosphate coatings, consists of a chemical action on the metal itself, in which a microscopically thin portion of the surface is converted to a minute crystalline structure. In the subsequent application of paint, the fluid permeates the crystals and, when dry, is securely keyed to the metal.

Figures 104 and 105 show two shallow receptacles containing the agar-agar jell referred to above. In the one in Fig. 104 a small piece of untreated steel is placed, and in Fig. 105 is placed a similar piece of identical steel but provided with a phosphate coating. The dark spots in Fig. 104 indicate the blue development where iron has dissolved. The gray portion of the piece was actually a decided pink, indicating alkali. No dark spots are visible in Fig. 105, and the small piece of steel showed no blue or pink areas, indicating that no corrosion had set up on the surface.

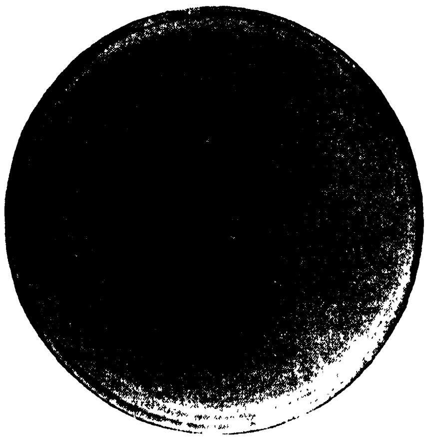


FIG. 104.—The agar-agar test—untreated sample.

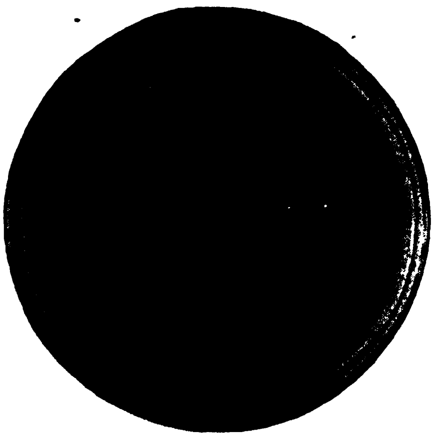


FIG. 105.—The agar-agar test—rustproofed sample.

Rustproofing.—Rustproofing is so closely identified with painting and enameling that it may in general be considered as a means of preparing metal for paint, and some of its chief characteristics will be considereed here. For many years the rusting of iron and steel was ignored as far as possible. The steel manufacturers themselves certainly did not want to call attention to it, and fabricators of metal products realized that any aroused public sentiment on the subject of rusting might have the effect of increasing the cost of production by forcing them to turn to some nonrusting materials.

So, ignoring as much as possible the fact that untreated steel might rust, paint was used in ample fashion. This was something like the popular fiction of the ostrich burying its head when in danger and thinking all would be well. As soon as scratches

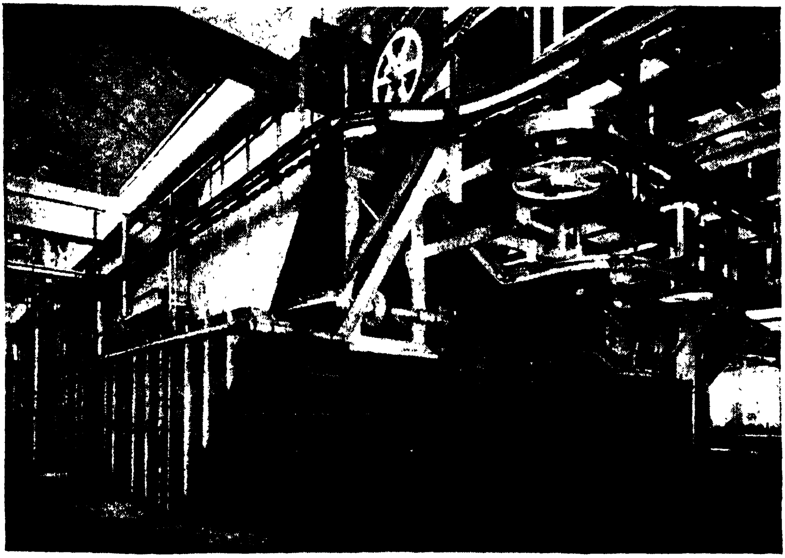


FIG. 106.—This typical modern equipment, used for preparing steel products for enameling, shows the extensive auxiliary equipment in this field of manufacturing.

appeared in the paint, there was an opening for rust to start, and corrosion then spread under the paint coat. Even high-class automobiles previous to 1915 were subject to spreading corrosion if the surface was scratched or bruised. One result of the stocktaking period just after the war was the directing of public attention to the tremendous losses due to rust. Figures were published widely, giving the estimated yearly loss in dollars, and most of these estimates ran upward from $100,000,000. As a result of this, several things happened.

1. The use of copper and other nonferrous and nonrusting materials increased.

2. A movement toward the development of rustless and stainless steel was started.

3. The attention of all users of steel and steel products was turned to the question of rustproofing methods and of better painting practice.

In most cases better painting practice meant more thorough cleaning before painting and greater care in creating a bond between the paint and the metal. A quotation from government specifications of some years ago will serve to illustrate the character of a good rustproofing process.

> The steel shall be processed after fabrication by some commercial method of rustproofing which will coat equally all surfaces, so that samples of the fabricated sections shall show no rust after 72 hr. continuous exposure at room temperature to the spray of 20 per cent salt solution. When painted and subsequently scratched to the bare metal, there shall be no creeping of rust under the paint away from the scratch at the end of the salt spray test.

Three Methods.—Three commercial methods of rustproofing came into early prominence. These were galvanizing, sherardizing and parkerizing.. Which is the best?

There can be no simple answer to this questión, because different articles and different uses call for different processes. Take, for instance, cleaning. For some products, alkali cleaning is the cheapest. For others, acid pickling may be necessary. And in still other cases, the sandblast may be the most efficient method.

In the case of some products, cleaning and rustproofing must be done after assembling. This is the experience with a steel casement window for which specific item the following advantages and disadvantages of some rustproofing processes are given:

Galvanizing—warps; hard to paint.

Sherardizing—difficult to do after assembling.

Zinc plating—not uniform on irregular surfaces.

Cadmium plating—good, but paint does not adhere well.

Parkerizing—good; paint holds well.

The Parker Rust-Proof Co. sponsors three main processes for metal treatment:

Parkerizing is a process of rustproofing iron and steel articles by immersing them in a hot solution that converts the surface to an insoluble phosphate coating. The coating is produced partly at the expense of the article coated, but no material change in the dimensions of articles results from the coating, and it thus lends itself to the rustproofing of small articles such as machine screws, bolts and nuts. The time of treatment varies, depending on the composition of the steel, and is usually 30 to 45 min.

Bonderizing is a process that produces on metal surfaces a phosphate coating especially adapted to inhibiting corrosion and increasing the adherence of any paint film applied thereon. The treatment is applied by immersing the articles in a bath prepared from the bonderizing chemical or spraying the bonderite solution

FIG. 107.—Automobile parts are here being conveyed to bonderizing tanks in a continuous preparation and painting process.

onto an article in equipment similar to an ordinary washing machine. The time of treatment varies from 1 to 5 min., depending on whether it is applied by spray or by immersion application.

Parco Lubrizing is a chemical treatment that produces a phosphate coating on iron and steel surfaces for the prevention of wear. The treatment is carried out by immersing the properly cleaned articles in a solution of Parco Lubrite that is maintained at near boiling for approximately 15 min. The Parco Lubrite coating thus produced absorbs oil and retains oil on bearing surfaces so effectively that it permits rapid break-in of wearing parts and also retards subsequent wear and corrosion.

Some of the advantages claimed for parkerizing are that it does not impair the elasticity of fine springs, does not alter the magnetic properties of iron and steel, and frequently makes possible the substitution of these metals for brass or copper. The characteristic finish of a parkerized product is matte black, and, while this, as stated, is in itself rustproof under many circumstances, it frequently is used as a base for paint or enamel.

After all that has been said about rust under paint, it perhaps is only fair to quote from a letter from Inland Products Co.: "We are using with satisfaction, directly over rusty surfaces, an elastic metal coating which penetrates through the pores of rust, neutralizing the rust stimulants and putting the entire surface in a passive condition."

Among the methods used for preparing metal surfaces for paint should be mentioned metal spraying, described in the preceding chapter. One of several companies working in this particular field is Mellowes & Co., Ltd., which has developed a method of depositing a thin coating of one metal on the surface of another by means of a metal-spraying gun which consists essentially of a torch for melting the metal to be sprayed and of a jet of compressed air that blows the molten metal onto the surface that is to be covered.

Zinc and cadmium are sometimes spoken of as the "greasy" metals and normally form a poor base for paint. However, the Mellowes company claims that, when a zinc-cadmium coating is applied by the spray gun to steel, it not only protects against corrosion but forms a porous surface which is a good base for paint or enamel. In the painting of cadmium in the past, lacquers and enamels have not adhered well to cadmium surfaces, but this difficulty has been overcome by the development of special coating materials that adhere well and will stand severe bending without cracking or peeling. In addition to this, a treatment for cadmium surfaces has been developed that creates a good base for ordinary paints.

One method of rustproofing is merely to etch or roughen the metal surface by some means and then apply certain penetrating oils. In this case it is the oil and not the roughening action that constitutes the rustproofing agent.

Cleaning Nonferrous Metals.—One of the chief causes of failure of paint on any metal is dirt or impurities between the metal and the paint coating. Previous chapters have dealt extensively with cleaning and descaling, but certain cleaning processes on copper and brass and other nonferrous metals, intended especially to prepare such metals for receiving paint, come logically under the heading of preparing metals for paint. In cleaning nonferrous metals oil, graphite, grease, alkalies and the miscellaneous materials commercially classified as dirt are all causes of paint failure.

All must be removed from copper and brass and stainless steel if a smooth unbroken finish in the subsequent coating of paint is to be obtained. Oil is one of the commonest materials found on sheet metal, for it forms part of the process at the mill

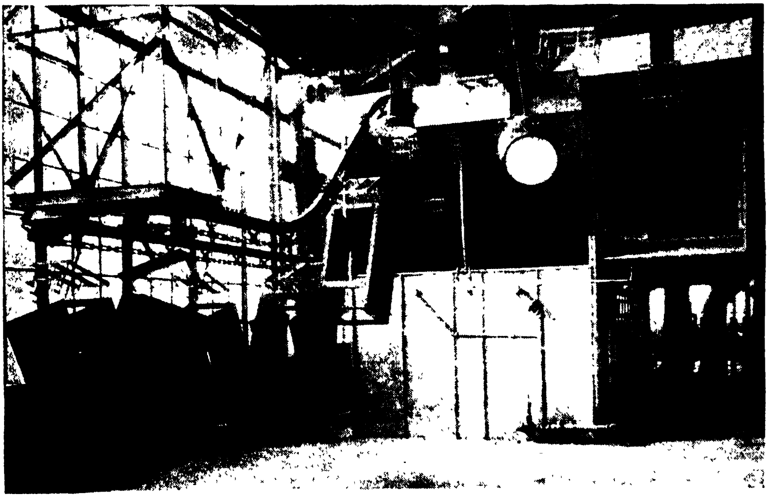


FIG. 108.—Refrigerator cabinets are bonderized before enameling. This shows part of a continuous process.

and is frequently left on for its preservative property. In the past, a thin coating of oil was not regarded seriously by metal painters, but now, with the quick-drying undercoats that are looked upon with increasing favor, thorough removal of oil is of increased importance.

Petroleum fractions and various solvents are frequently used for removing oils and lubricants. Others use alkaline baths, but here the danger lies in a residual coating of alkali on the surface. The presence of even a trace of alkali is highly objectionable on surfaces that are to be enameled. The usual run of dirt is frequently removed successfully by washing with warm soap solutions under pressure, but since all classes of impurities exist at one time it is an advantage to have a single cleaner designed to remove all. A cleaner of nonferrous metals, therefore, should be one that will remove oil and grease, will not leave an alkali residue and will produce a surface to which a prime coat will adhere tightly. Several such universal cleaners have been developed by different companies. For large parts the solution is applied by so-called dopers with large brushes. Parts

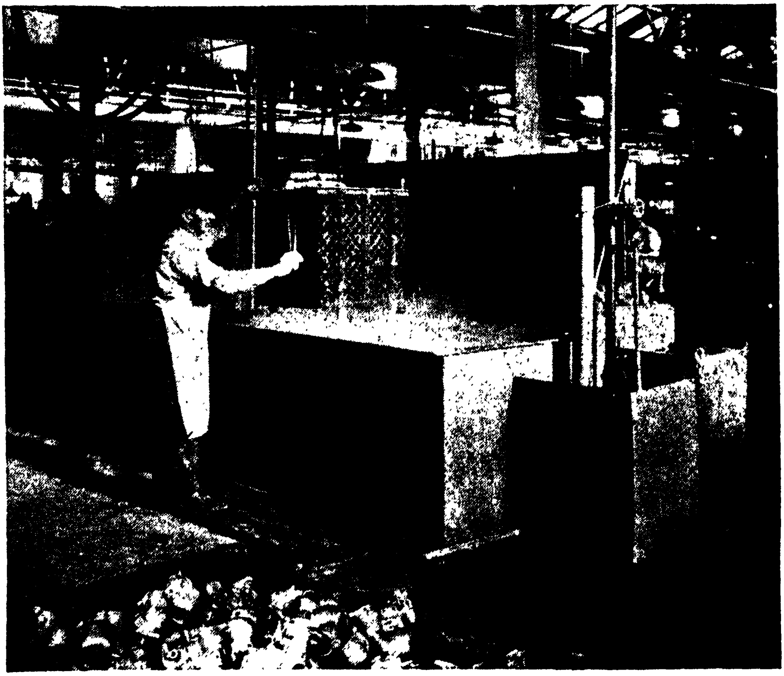


FIG. 109.—Carburetors and other similar parts are frequently rustproofed by immersion in still tanks. This shows a load of carburetors about to enter a process tank for parkerizing.

to be cleaned rest on a deck or floor provided with a V groove underneath for collecting the draining liquid. In some cases the deck is movable and the parts are cleaned in a continuous process. While the solution is still wet, the surfaces are handscrubbed with steel wool, after which the parts are washed with a hose, first with cold water and then with hot water.

Preliminary drying is with an air hose, and this is followed by oven drying, ordinarily at a temperature of 150°F. Frequently parts, particularly aluminum parts, are wiped with a rag dipped in alcohol after they come out of the drying oven. This operation is partly for the purpose of inspection to ensure that a thorough cleaning job has been done. When assembled automobile bodies are cleaned by the above method, the unit cost averages about 60 cents. Small parts on a production basis follow a similar sequence except that immersion tanks replace the brush application. Cadmium and zinc, whether applied by the electrolytic or the fused-powder method, as stated, may offer difficulties to the painter for the reason that these methods cause an alkaline reaction with most paint oils, tending to change the oils slowly into soap and thus destroy the adhesion of the paint coat. The well-known flaking of paint from zinc and cadmium results from this cause. To prepare these metals for painting, therefore, requires some radical change in their surface characteristics. One of the best methods is to create a thin phosphate film by chemical treatment. This corrects the alkalinity and leaves the surface in a slightly acid condition, which is satisfactory for painting. Among the different processes available is granodizing. Parts free from oil are immersed in a heated solution for 1 to 2 min. A variation of the process, known as electrogranodizing, coats clean metal surfaces with a thin film that forms an excellent foundation for paint and which at the same time is said to be corrosionproof.

CHAPTER XXVIII

THE COATING INDUSTRY

The ships of our costly Navy and Merchant Marine, as well as a multiplicity of other important metal applications, attain their great life in service by being painted or otherwise coated for protection against corrosion. In fact, without an organic coating of some sort, steel bridges and most other metal structures could not be maintained, from which it follows that the process of coating metal is essential to satisfactory service under normal conditions of use.

As explained in the last chapter, the fight against corrosion of metal assumes tremendous proportions, and the principal weapon in this fight is paint. In the years immediately preceding the war, the value of paint and lacquer manufactured in America was well over $250,000,000.

The steel, light metal and allied industries consume a fairly large proportion of all manufactured paint products, and there is a close bond of mutual advantage between these commodities. Paint finds a good market as a coating for metal, and metal finds a good market in the paint industry. Lead, zinc, antimony, aluminum, titanium and other metals are used in paint production both directly and as pigments. Steel and tin are used for paint containers, and a heavy tonnage of steel and other metal is used each year for such painting equipment as sprays, drying rooms, spray booths, exhaust and blower systems, material-handling apparatus, dip tanks, bake ovens and sandblast machines.

The application of organic coatings for protective purposes was an important war requirement. Colored coatings were restricted to identification and camouflage.

Organic finishes and coatings are made from hundreds of raw materials, such as synthetic resins, natural resins, drying and nondrying oils, plasticizers, cellulose derivatives, chlorinated rubber, pigments, driers and solvents. The synthetic resins draw upon such chemicals as urea formaldehyde, mallic anhydride, phenols and their derivatives, polyhydric alcohols, modifying oils, sebacic acid and many others. Most of these materials were needed for war products, and the WPB consequently placed practically all of them under Conservation and Allocations Orders, seriously limiting their availability to the manufacturers of coatings for civilian use.

New materials of considerable merit were developed to substitute for the restricted materials, but as rapidly as they showed promise of having valuable coating characteristics, they in turn were allocated to war uses, or the materials from which they were derived became critical. The value of the substitutes will not cease in peacetime, but much of the value was held in abeyance.

Instances of finishes that were developed as wartime replacements are numerous. Pearl essence is used to substitute for metal powder finishes on everything from women's compacts and cosmetic containers to heavy industrial equipment and machinery. Fine results have been obtained, with both one- and two-coat systems. Brass, copper, gold and other plates have been simulated by spraying, air drying or baking transparent lacquers and synthetic finishes over highly polished steel and other metals. There have even been requests to simulate brass over wood and black iron, a very difficult performance because it is the brilliance of the base metal that is directly responsible for the brilliance of the finished product.

A material currently of great importance is the zinc chromate primer for its moisture-resistant and protective qualities.

The great advance in range, altitude, speed and power of our aircraft has called for finishes that would stand the steaming heat of the tropics and, equally well, the clear dry cold of the stratosphere. Radios and equipment require insulating varnishes and coatings that would insulate and remain flexible at low temperatures. The problems set by these extraordinary conditions are gradually being solved and suitable finishes and new products developed.

The first requirement is a primer that will inhibit corrosion and at the same time act as a bond between the bonderized or anodized metal and subsequent coatings. For this, as previously noted, both Army and Navy use zinc chromate primer. The chromate primer is followed by one or two coats of lacquer or synthetic enamel, generally cellulose nitrate lacquers fortified with glyceryl phthalate resins. Both Army and Navy specifications include glossy and nonspecular or lusterless lacquers and enamels.

Besides corrosion resistance, the government required finishing materials that could be used for camouflage. These call for certain other properties in addition to those of corrosion resistance. Low visibility to the human eye, of course, is a primary requirement. Under some circumstances, invisibility to the infrared films used in aerial cameras is also requisite. Moreover, this is no static requirement, for with the seasons, this infrared reflectance changes and the paints and lacquers must meet these changes.

For the camouflage of tanks, trucks, large guns and automobiles for the Army, olive-drab enamel is used, lusterless, of low visibility and nonspecular reflection. It retains these properties and does not polish when rubbed. It is applied over a zinc chromate and red oxide combination.

Sometimes trucks and tanks, as well, need to be concealed for short periods only. An airplane on landing, for instance, may require over a regular finish, a quick coat of paint, which can then readily be washed off with a garden-hose spray of cheap solvents.

For the concealment of equipment, roads, bridges, installations, landing fields and buildings, the requirements call for a paint that can be applied easily, can be transported readily and can be thinned with water. Also, the material has to be fungusproof and fadeproof and have good coverage. This combination of properties has been met by the paint manufacturers with emulsion paints.

Luminous paints were another wartime requirement. There are two main groups, the radioactive materials emitting shortwave emanations through slowly disintegrating fluorescence, and phosphorescent pigments.

The fluorescent pigments are commonly used on the dials in the cockpit of a plane. They must be activated by ultraviolet or "black light" and are visible only when so activated. It is the "black light" that the pilot switches on and so renders the dial visible. It is immediately invisible when the "black light" is turned off.

Phosphorescent paints were useful on the subways, buildings and street curbings of "blackout" London. These paints will glow in the dark without fading for several hours, if they have previously been subjected to bright light for a short time. They are available in several colors. Activated strontium sulfide glows bluish white and is the best and most popular. Activated zinc sulfide glows greenish yellow; activated calcium sulfide produces a purple glow.

Various other types of blackout paints and lacquers were used on our own Atlantic seaboard to meet the dimout regulations that prevailed there. These ranged from cheap water paints and cold cut asphaltums to expensive shatterproof lacquers both pigmented and unpigmented, which are capable of preventing injury from breaking glass in case of bombing.

As noteworthy as the mere recounting of examples in which electroplated and nonmetallic finishes have contributed to war production was the readiness and adaptability that the metal-finishing industry showed in meeting critical conditions of shortages, its resourcefulness and versatility in developing new methods and techniques at every turn with the new and increased demands of the war. On the evidence, the promise is good for the part that metal finishing will play in our peacetime economy.

Unfortunately, there is no simple term covering the various types of organic coatings. The term paint is sometimes loosely used in this sense. The different terms such as enamel, lacquer and lithographic coatings are difficult to define clearly, but the trade usage of the principal terms enables us to list the somewhat overlapping definitions:

1. Paint.—Paint is a mixture of opaque pigment with nonvolatile oil or resin, with or without the addition of volatile thinner. It is applied in the form of a liquid in thin films and after application dries to form hard, tough, elastic coatings. The nonvolatile liquid portion of paint is one or more of the vegetable drying oils or the various synthetic resins that dry and harden by absorbing oxygen from the air; thus paint films dry substantially by oxidation.

In the metal industries, paints have many important uses such as the protection and decoration of steel bridges, buildings, ships, ornamental sheet-metal and iron work, and many manufactured metal products.

Paints may be classified in different ways: for instance, based on the structures or products on which they are to be used; based on whether they are designed to dry with a gloss or flat finish; or based on whether they are intended for exterior or interior exposure. The nonvolatile vehicle of most paints is linseed oil, although other drying oils are used to some extent.

Under one classification, paints may be divided into white and light tints, in another, into dark colors. Light paints are made with a white base, and for durable exterior exposure the white pigments used are white lead, titanium-barium pigment, titanium

Fig. 110.—The right kind of paint job would have protected these steel tie rods.

oxide, zinc oxide and basic lead sulfate. For interior use, where the exposure is less severe, light paints may be made with a white base containing titanium-calcium pigment or lithopone, as well as the other white pigments. For exterior exposure the light paints are usually the finishing coats used to obtain decorative finishes.

The priming coats that are required to prevent rusting and corrosion of metal are usually red lead paints containing no white pigments. Blue basic lead sulfate is sometimes used in priming coats for metal surfaces.

Paints that are so dark in color that they cannot contain any white base include not only red-lead-paint priming coats but also many finishing-coat paints where such strong dark colors as yellow, green and black are required. Such dark-colored paints are made with the pigments needed to give the desired color, in which case the nonvolatile vehicle is linseed oil. Some of these paints contain varnish and have enamel or semienamel characteristics.

Aluminum paint contains no white base but has a light gray color and might be considered in a special class. Aluminum

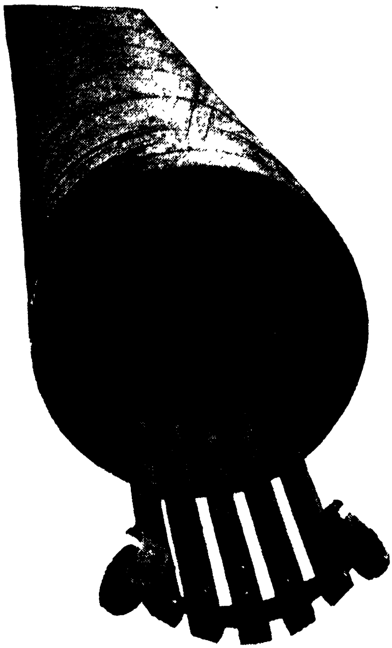


FIG. 111.—Many long steel pipe lines are painted on the inside to protect them against the effect of gas or chemicals. This shows a special type of buggy used in painting the inside of a long line 3 ft. in diameter.

paint is sometimes used for a finishing coat where its particular color and surface sheen are wanted.

In the classification of paints according to their surface finish, there may be gloss or flat paint or an intermediate semigloss frequently known as eggshell paint. The essential difference between gloss and flat paint is the proportional amount of pigment as compared with the nonvolatile vehicle. If the paint contains a high proportion of oil or nonvolatile vehicle by volume, the oil will flood the pigment, allowing the pigment particles to recede from the surface, and the paint will dry with a smooth, even, plain surface with high gloss.

If the paint contains a small proportion of oil with volatile thinner added to give brushing consistency, the rapid evaporation of the volatile thinner will leave a coating with insufficient oil to flood the particles of pigment, and the pigment particles will pile up on each other and extend through the surface of the paint in a broken manner resulting in more or less complete diffusion of light reflected from the surface and giving what is known as a flat finish.

In addition to the above classification, paints should be selected according to the structures or products on which they are to be applied and may vary in composition, color and surface finish according to requirements. Since the nonvolatile vehicles of paints consist principally of linseed oil and other vegetable drying oils, drying takes place almost entirely by oxidation, and contact with the air is necessary.

2. Enamel.—An enamel is similar to paint, as it is a mixture of opaque with nonvolatile vehicle and volatile thinner, but it must dry to a full high-gloss film. This requires a limitation on

TABLE X.—DEFINITION OF TERMS

	Vehicle	Color agent	Thinner	Drying
Paint......	Nonvolatile drying oils	Opaque pigment	Volatile (mineral spirits, small amount)	By oxidation
Enamel....	Solution of resins and drying oils (varnish)	Opaque pigment	Volatile solvent (large proportion)	By evaporation, oxidation and polymerization (usually baked)
Lacquer...	Solution of nitrocellulose and/or synthetic resin	None (clear) or opaque pigment	Nonvolatile plasticizer plus volatile solvent	By evaporation
Varnish ...	Resins (natural or synthetic) usually combined with drying oils	Clear	Volatile (large proportion)	By evaporation, oxidation and polymerization

the pigment-vehicle ratio and the use of synthetic resin or varnish as a vehicle. This type of vehicle dries by a combination of oxidation and polymerization. The evaporation of the nonvolatile content produces a fast initial set that makes the film dust-free in a short time.

Industrial enamels are extensively used on virtually all kinds of manufactured metal products, such as machine tools and other machinery, railroad equipment, sheet-metal containers of different kinds and innumerable smaller metal products.

What has been said about paints applies almost equally to enamels, for they vary widely in composition, color and character of finish. The popular conception is that enamels dry with a high-gloss finish, and this is true of most enamel products, although there are some enamels that dry flat or with an eggshell finish. It might be said that the principal use for paints is for the exterior or interior surfaces of large permanent structures, whereas the principal use for enamels is for finishing manufactured metal products, although there are exceptions in both cases. Technically speaking, enamels are made with gum or resin-varnish vehicles containing some linseed oil or other vegetable drying oils. For this reason enamels dry partly by oxidation and partly by evaporation of the volatile thinner which causes a "set" of the nonvolatile portion of the varnish. Enamels are made to dry either by exposure to the air or by baking, depending on the requirements in each individual case.

3. Lacquer.—At the present time the term "lacquer" is properly used to designate a solution of nitrocellulose with various resins and plasticizers in a volatile solvent with or without opaque pigment. Prior to the introduction of nitrocellulose lacquer, the term lacquer was loosely used to describe oriental lacquers.

An important use for lacquer is for finishing automobiles, but it is also used on motorcycles, bicycles, metal furniture and on many specialty metal products.

Lacquers are essentially solutions of nitrocellulose in certain organic solvents that dissolve the hard nitrocellulose material to form a liquid that may be applied in thin coatings. If nitrocellulose alone were used, evaporation of the volatile solvent would leave a hard brittle coating, and for this reason small amounts of other nonvolatile materials known as **softeners** and

plasticizers are added. Lacquers may be used in the form of clear coatings or with the desired pigments to make opaque coatings of different colors. They dry entirely by evaporation of the volatile solvents, leaving the nonvolatile portion in the form of a hard film.

4. Varnish.—Varnish is a clear solution obtained by various cooking procedures, of resins in vegetable drying oils, thinned to liquid consistency with volatile solvents. Varnish dries by both oxidation of the oil and evaporation of the volatile thinner.

FIG. 112.—For adequate protection and continuing good appearance, steel must be properly prepared and the right kind of paint must be used. This shows what happens after less than a year's weathering of a poor paint job.

Clear varnishes are not so important in the metal industries as paint, enamel and lacquer, but they are used to some extent where clear finishes are desired.

Varnishes are clear liquids consisting of solutions of gums or resins in one or more of the vegetable drying oils thinned with suitable volatile liquids so that the thick, viscous, nonvolatile combinations of oil and gum or resin will have the proper liquid consistency for application. Linseed oil and china-wood oil are the principal drying oils used in making varnish, although some other oils are utilized to some extent. A generation ago varnishes were largely made with natural fossil gums and resin, but today varnishes are made almost entirely with modified resin compounds such as ester gum and synthetics such as phenol-formaldehyde and glyptal resins. Because the nonvolatile portion of varnishes consists of both drying oils and gums or resins, varnishes dry both by oxidation and by evaporation of the volatile thinners. Varnishes are designed to dry either by exposure to the air or by baking, as conditions require.

5. Lithographic Coatings.—Lithographic coatings vary greatly in composition and use. Generally speaking, they are enamels that are baked after application and, technically speaking, are any of several coatings applied by printing processes.

Lithographic coatings are used on sheet-metal containers of different kinds such as cans and tubes and wherever small sheet-metal articles can be economically handled by printing processes.

They are similar to paints and enamels in composition, and from the point of view of composition they probably should not be considered as in a separate class, but they are generally applied by some printing process, and it is this method of application which has resulted in their designation as lithographic coatings. After application, the coatings are usually baked.

CHAPTER XXIX

SYNTHETIC AND NOVELTY FINISHES[1]

The automobile industry had hardly settled down in its adoption of nitrocellulose lacquers popularized under the name Duco, with their great advantages of timesaving and improved durability, when along came synthetic enamels, with greater fullness and depth. They required baking treatment to bring out their full possibilities of toughness, hardness and weather resistance, but this was a difficulty easily surmounted. At first these synthetics were of the alkyd type, made by combining glycerin, phthalic anhydride, fatty acids and oils, with occasionally some phenol-formaldehyde resins. But it was not long before a great variety of other synthetic resins began to appear: chlorinated rubber, the polyvinyl family, polystyrene, pentaerythritol and hexitol esters, olefinic and ketonic condensates and the condensates of formaldehyde with urea and malamine. Infinite modifications and blends of these, together with new and improved pigments such as rutile titanium dioxide, phthalocyanine blue, molybdate, tungstate and benzidine yellows and cadmium reds, have been fashioned into clear coatings and enamels.

More spectacular than most other branches of metal finishing has been the development of novelty coatings in the lacquer and enamel industry. Purposely roughened and crinkly surfaces of uniform character have been devised by reversing research procedure. That is, instead of refining materials, investigators have devised means of systematically increasing impurities to produce novelty effects.

On the other hand, specialty finishes have called for great refinement in quality and character of the coating material, and this has led to increased scope and use of synthetic enamels.

Research workers engaged in the arduous task of producing for metal parts enamel coatings that would remain smooth and flawless through the baking process found that impurities in the

[1] Prepared in cooperation with C. R. Bragdon.

materials, or even in the atmosphere of the baking oven, had a habit of causing wrinkles, bubbles or cracks in the surface. Little did they think that these annoying impurities would be turned to profit. But that is just what has been done by the originators of some of the present-day novelty finishes. The processes of refinement that developed the smooth-surface

FIG. 113.—A variety of articles with Alumilite finishes. (*Courtesy of Aluminum Company of America.*)

enamels have been reversed by definitely seeking to increase impurities.

Certain crystalline enamels when baked 10 to 20 min. in a foul oven, that is, an oven in which the gases of combustion are retained, have the property of developing a uniform wrinkly texture or stipple finish as they dry. This finish has become popular for metal panels on scientific instruments and on such equipment as adding machines and cash registers.

Scarcely any other finish available will so readily and effectively cover defects in the base metal, and besides this important advantage some of the "krinkle" enamels, as they are called, are surprisingly durable and resistant to abrasion.

A further type of novelty finish is created by adding ingredients that make the lacquer stringy or fibrous before it is used and then applying this stringy substance by means of an air gun. The result gives a peculiar air-line tracery, which, independent of the operator who is applying it, forms an interesting and varied design which nevertheless gives a fairly uniform effect over a large surface. This is known as a veiling lacquer.

Further unusual effects are secured in novelty finishes by spraying dry materials onto freshly coated surfaces and also by introducing foreign materials into the enamel just as it is being sprayed. One surface effect of this nature is known as izarine, which is produced by spraying finely ground suede over a special size coating. This gives a warm soft finish of an unusual nature.

Several other ways have been devised for producing unusual finishes. One is the silk-screen process, which is actually a modification of the use of stencils. A piece of silk stretched on a frame is prepared so as to leave open parts through which lacquer is brushed. Different colors may be successively used to create varying effects. In fact it is possible in this way, by using several different screens for the same design, to produce multicolor art work resembling printing or lithographing. Other experimenters have used copper stencils to create startling effects in applying lacquer to metal.

Methods of Application.—A rapid increase in the use of lacquers and enamels in industry has created a demand for improved methods of application. At first, parts were dipped in tanks of enamel and then allowed to drain back into the tank before passing on to the baking oven. This method is still extensively used and for some work seems to have advantages. The most widely used method today is spraying, and by carefully regulating the air pressure and using special nozzles it is possible to conform to well-defined simple patterns in multicolor work either by hand or automatically. Thus barrels or other metal containers may be revolved under a row of three spray nozzles, each supplied with a different colored lacquer, and the result will be clearly defined bands of color.

Conforming to the trend toward increased finishing of raw material at the mill, large coating machines have been developed to apply lacquer and enamel to sheets and strip metal in continuous operation. These machines consist essentially of two or more rolls between which the sheets are passed. One roll carries a thin film of lacquer onto the sheet, and the other usually is uncoated and kept clean by means of a scraper. One advantage of a coating machine is a saving in the amount of material. A gallon of lacquer, for instance, will cover 800 to 1000 sq. ft. of

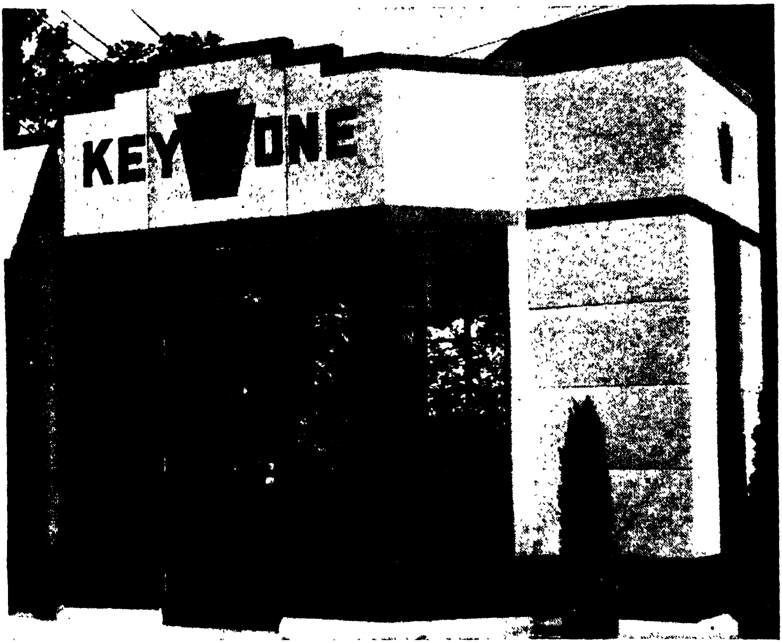


FIG. 114.—Service station built with enameled steel panels.

metal surface on a coating machine as against 300 to 400 sq. ft. with the lacquer spray.

Most spraying lacquers are about 40 per cent solid, and in some large shops a more or less successful attempt has been made to recover some of the volatile material that escapes in the spray booth. The solid material that collects around the booth is usually considered waste.

Modifications in design of a coating-machine roll may be made to give patterns or stripings on the sheets or strip being finished. Thus by merely cutting out a small band around the applying roller, an uncoated strip will be left on the metal. Also a roller may be made up with several separated sections. Then, by applying different colors to the different sections, it is possible to apply multicolor band designs to strip.

One of the important prewar developments was a finish called Polymerin, which was widely used on bicycles, washing machines and stoves. It combined a baking schedule that might, by raising the temperature, be shortened to as little as 3 min. with color retention, luster, hardness and superior toughness.

The recent use of infrared lamps for heating has led to the development of enamels, of this quick-baking type, in which the pigment composition was so designed, by study of the physical principles involved, as to assure the maximum absorption of the infrared rays and avoid the losses by reflection that would ensue in the use of enamels not so designed. The great advantage is that the rays penetrate to, and heat, the surface beneath the finish, and the baking proceeds outward rather than inward, giving a thorough polymerizing action throughout the coat, at a saving usually of at least half the time. Knowledge gained from studies of this infrared effect became of immediate value for camouflage purposes, when the converse principle was employed, using paints of high infrared reflecting power to simulate the chlorophyl of leaves and fool the infrared camera. Paints thus developed have been used on gasoline storage tanks, to minimize absorption of solar heat and save evaporation losses. High-frequency heating is a newer development that is beginning to be utilized for drying finishes, following its success in the curing of thick or intricate plastics or rubber forms. This technique also requires an understanding of the physical reaction of pigment and vehicle compositions in electric fields.

The need to assure adequate protection, or concealment or some other special service, almost regardless of cost, during wartime stimulated research along lines that would ordinarily not have been attempted at all, and hundreds of new compositions, or new combinations of old ones, are now ready to be put into civilian consumption as soon as materials become available. The war demands coincided with the shortage of certain former important raw materials, such as tung and perilla oils, natural resins and rubber. In learning to use new materials to replace these, the coating technologist learned the intrinsic value of many of the newer synthetic resins which thus acquired a permanent place in his repertory.

One war-stimulated type of finish is the luminescent class which shine in the dark receiving illumination for a period (used for air-raid shelter signs). Another group is the so-called fluorescent type which give out visible rays when illuminated by invisible ultraviolet light. These came into considerable use for lining fluorescent lamps. Better and cheaper fluorescent and luminescent pigments have been developed, and there will be much wider use of such coatings in the future.

Flameproofing has also been thoroughly investigated for military purposes, and there will be flameproof paints for metals, as well as for wood and textiles. Fire hazards, which have been particularly feared on ships, will be greatly reduced. Another "war baby" was the strippable protective film applied either in molten form by dipping or coating, or from solution; such a film forms an impervious seal over a surface that must receive temporary protection while in transit, or while manufacturing operations are being performed on it, but can be readily peeled off later, by loosening a corner and pulling off like a banana peel. And still another type is the metal impregnating group of coatings which seals the pores and minute blowholes in light metal castings. These pores had run the rejection rate up to a high percentage before the coatings were adopted. These coatings build up a smooth impervious wall nearly as strong and resistant as the metal itself and cut rejections to below 5 per cent. This use requires rather elaborate equipment for exhausting air by vacuum from the hot castings and then forcing the compound in by pressure, but it has been found well worth while by a number of users.

Emulsion paints, containing an oleoresinous or synthetic resin binder, first came into prominence as a finishing material at the New York World's Fair. They can be shipped in heavy paste form and require only water for thinning and thus were well suited for army field use and for camouflage. Through cooperative work done by committees of the Federation of Paint & Varnish Production Clubs, as well as by many individual organizations, they have been greatly improved. Although they are more specifically adapted for application on wood, plaster and wall board, they have also been satisfactorily used on metal, particularly over suitable priming coats. They dry with a flat or eggshell finish but are easily applied and are free from the usual paint odor.

The wartime scarcity of tin would have left manufacturers in a much worse way for containers for many materials if there had not been developed a variety of can and drum-lining finishes which made bonderized black iron sheet acceptable. Although some foods cannot safely be packed in black iron, even with the best coatings so far developed, many foods and a great variety of solvents, chemicals and other necessary war supplies are handled safely in lacquered iron cans. Much progress has been made in coating sheet and strip metal continuously—passing it through a bonderizing bath, drying, applying the finishing materials, baking at high temperature for a short period and rewinding, all in one operation. The metal is provided on one side with a resistant lining, on the other with an attractive colored outer finish.

Cable and wire coatings and motor insulation form another specialized type of finish eminent for war duty, having taken on new attributes of resistance to high temperatures and to subzero cold. Not only have the conventional types been greatly improved, but fundamental research has produced an entirely new kind of resin, the silicones, which, used with fiberglas in motor insulation, have permitted safe high-temperature operation. As a result motors rated at 3 hp. can now deliver 10 hp. Thus many pounds of excess weight can be saved on airplanes. More will be heard of these silicones as time goes on. Another new resin, polyethylene, has found important uses in cable insulation but so far has not proved adaptable for general metal finishing.

In one of its minor by-products, war has served as a gigantic accelerated weathering machine for testing the finishes used on ships, tanks, jeeps, airplanes, railway rolling stock and other automotive objects, and from this have come better, faster drying, more durable paints and enamels for all the means of transportation. One finish of unique type is that used on airplane propeller blades to prevent ice from forming on and clinging to them—a highly specialized function that serves here to signalize how American technical skill has met problems of most diverse types.

Finishes duplicating the appearance of wood grain on metal have been somewhat in eclipse for the past 5 years but are being resumed as civilian goods again come upon the market and have now the aid of new machine technique to assist in the reproduction, as well as improved types of ground coat, graining ink and finish coat. Popular for office furniture, these finishes are becoming more rich and realistic. Wrinkle and crystalline finishes, which were almost universally employed on scientific instruments and business machines, and which in the prewar period were made mostly from tung oil imported from China, are again available from domestic and synthetic sources. Their popularity is threatened, however, by new "hammered" and "Krakolyn" enamels which in either one spray coat or two spray applications a few minutes apart, with a single baking, produce a most pleasing two-tone patterned effect of the nitrocellulose type. Nitrocellulose enamels that depend upon the strong shrinking tendency of the upper color coat to open up cracks and expose the undercolor are still available though less frequently seen.

Elastic Coatings.—One of the outstanding achievements in coating steel sheets is the elastic finish produced by certain varnishes and lacquers. Because of the necessity of keeping cost to a minimum for such items as small metal containers, the manufacturers of enamels have been asked to produce a material which when applied in one coat directly on the metal will be of a character to resist subsequent deep drawing. This task, which would have seemed almost impossible some years ago, has now been accomplished.

A good example of such a finish is that used on catsup-bottle tops. One of the most successful enamels of this character contains an excess of wax which comes to the surface during baking to leave a very thin film that serves as a lubricant under the action of forming dies. Lithograph work using the new elastic coatings has greatly extended the scope of forming and processing subsequent to surface finishing. The most important feature in this case is to have a flexible ground coating. The lithographing process consists first of applying a color coat, usually white, and then of printing the design in color over this ground coat. This is done in metal-printing presses using printing ink which, as stated, is usually a combination of pigment and linseed oil. Elaborate automatic continuous printing and drying operations have been developed to produce in several colors repeated small designs to cover the large flat surfaces. The small designs are later blanked out and formed into final shape. The original elastic coating on the sheet adjusts itself to the new contours and without further processing becomes the final finish of the metal part.

An interesting example of special decorative finishes is the so-called "hammered-effect" finish covered by U. S. patent

Fig. 115.—A boon to the architect engaged in modernizing old buildings is the enameled steel panel.

2,326,623. This finish is made up according to the following formula:

	Parts
Ultramarine-blue pigment	4.1
Lithol-red pigment	0.4
Bone-black pigment	0.1
Aluminum-flake pigment paste	2.9
Alkyd resin A (solids)	3.0
Alkyd resin B (solids)	30.3
Urea-formaldehyde-monohydric alcohol resin (solids)	0.9
Driers (*e.g.*, cobalt naphthenate)	0.2
Hydrocarbon solvents (*e.g.*, petroleum hydrocarbons)	57.1
Raw rubber	1.0
	100.0

Research on Synthetics.—Research in the field of synthetic enamels has been so extensive during the last few years that it may be said that almost every available source of complex molecular structure has been investigated and a resin made from it. One of the picturesque sources is the oil of the cashew shell, from which a successful coating for metal exposed to severe acid conditions has been derived. Petroleum, corncobs, and sludges from many industrial processes also have yielded resinous

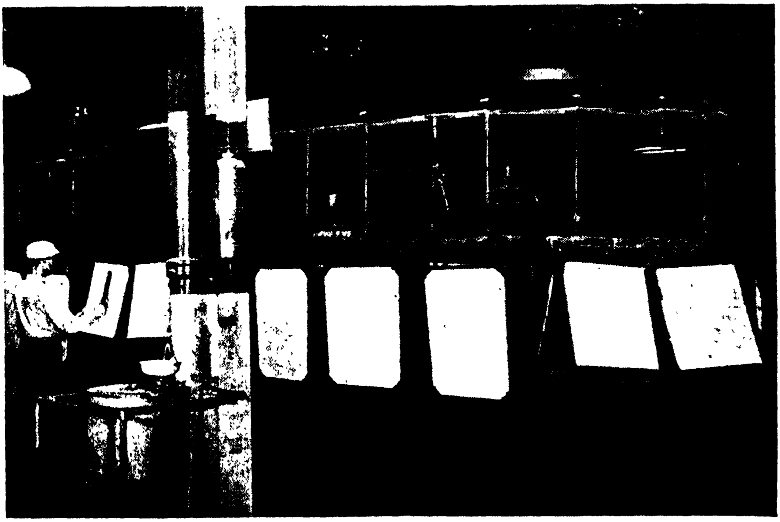


FIG. 116.—Enameled parts are carried by conveyor into a gas-fired enameling furnace.

materials that have been made into coatings, many of which have not yet reached commercial application.

The question is often asked, why do synthetic enamels dry faster and harder than the old oil-base enamels? No simple answer is possible, but in general synthetic materials dry largely by evaporation and by molecular rearrangement, both of which processes can take place quickly, especially when aided by heat. Unlike the old oil-base enamels, they do not have to go through the slow process of absorbing from the air about one-fifth as much oxygen by weight as there is oil in the base. The forces that hold the minute particles together in the case of the synthetic product are stronger and less subject to attack by alkalies, and the fact that a practically completely saturated compound is formed at once, leaving the molecules no appetite for further absorption of oxygen or for further condensation with each other, prevents the embrittlement so common with the usual drying oils.

Price Not Paramount.—In any problem of selection it must be borne in mind that the price of the enamel itself is only a partial element of the over-all cost. Coverage, ease of application, ease of repair or touch-up and freedom from after-troubles, such as printing, marring, and discoloration, are often of far more importance economically. Lack or high cost of baking facilities, size of the metal itself, or fire hazard due to location of the finishing department are other factors that may limit the choice in some cases.

A still further factor is that of desired color. Some of the enamels are receptive to certain dyes and not to others, and where it is important to get an exact shade or to maintain certain color standards an enamel must be selected accordingly. For specialty work such as wood graining and marble effects, special drying or baking conditions may be called for. For a smooth surface the condition of the metal before painting is important, although in some cases a few extra coats of enamel may be less expensive than machining or otherwise preparing the metal surface.

CHAPTER XXX

PAINTING FOR PROTECTION

Paint that will give the greatest satisfaction and lowest upkeep cost on a steel bridge usually is equally satisfactory on a viaduct, elevated railway structure, water tank, standpipe, metal cornice or any one of innumerable other metal surfaces directly exposed to similar weather conditions. The great similarity in the painting of such structures is in the priming coat, which is equally suitable for all of them, and in many cases there is no difference in the body and finishing coats, although the finishes may show wide variations, depending upon the color and effect desired, because it must be remembered that paint is used for both protection and appearance. Metal structures and metal products may be broadly divided into a few major classes where the paint materials used and the methods of application are more or less the same throughout each class. Here we are considering principally the painting of iron and steel, which are the products used for a vast majority of metal structures and products.

Steel Bridges.—This class includes fabricated steel structures such as railroad and highway bridges, viaducts and elevated railway systems. The first and most important painting problem is the priming coat on the bare metal, which must be relied on to protect the metal against corrosion and to furnish a suitable foundation for the subsequent coatings of paint. It is generally considered standard practice by the large railroads, highway departments and fabricators of steel structures to use red lead paint for the priming coat next to the metal. This is made with pure red-lead pigment and linseed oil with a small amount of drier and with or without a small amount of volatile thinner. It would seem that this is a simple formula, but many variations are possible in the kind and character of red lead used and in the proportions of red lead and linseed oil. Some kinds of red lead are better than others, and the proportions of red lead and linseed oil must be kept within fairly narrow limits if the best results are to be obtained.

Red lead is made by a furnace treatment of litharge, which is the lower oxide of lead, and in this treatment the litharge is further oxidized to the higher oxide form, and the red color is developed. The extent to which this further oxidation takes

Fig. 117.—In the face of rapid strides toward laborsaving operation in most fields, painting of bridges is today practically the same operation it was 50 years ago. There has been a remarkable improvement in materials but practically none in method of applying them. This shows the maintenance painting of Brooklyn Bridge, a process which has been going ahead almost constantly during half a century.

place in the manufacture of red lead determines the character and usefulness of the red lead to a marked degree. There are really three distinct grades of red lead used for paint purposes which are classified in accordance with their degree of oxidation and are designated as 85, 95 and 97 per cent red lead, which means that they contain these percentages of true red lead; in other words, the litharge has been oxidized to an extent corresponding to these percentages. The 85 per cent grade is usually coarser than the more highly oxidized material and contains a considerable amount of unoxidized litharge which is not desirable for the best red lead paint.

FIG. 118.—All steel bridges are carefully painted, first in the shops and then in the field. More than 10,000 lb. of red-lead paint was used for the field coats of this railroad bridge. For the field work of the George Washington Bridge more than 36,000 gal. of red-lead paint was used.

The most satisfactory red-lead pigment for iron and steel paint is the 97 per cent grade with uniformly fine particles. Many scientific tests and long practical experience have demonstrated that this highly oxidized red lead produces paint films on iron and steel that have durability and that protect the metal against corrosion for a great length of time. Even if the best grade of red lead is used, the most satisfactory paint will not result unless the red lead and oil are properly proportioned.

A satisfactory red-lead paint for the priming coat on iron and steel is a mixture consisting of 33 lb. of red lead to 1 gal. of linseed oil. If raw linseed oil is used, a small amount of drier must be added, but if boiled linseed oil or a mixture of boiled linseed oil and raw linseed oil is used, a drier is not required because sufficient drier is contained in properly made boiled linseed oil. Considerable red-lead paint of somewhat lighter formula than 33 lb. to 1 gal. of linseed oil is used on steel structures, but for the best results the paint should contain not less than 28 lb. of red lead to 1 gal. of linseed oil.

At least three coats of paint should be applied on a new steel structure, and the second or body coat should be the same red-lead paint as the priming coat except that a very small amount of lampback or carbon black is added to produce a variation in color so that, when each successive coat is applied, there will be sufficient difference to ensure complete covering by the second coat without leaving any unpainted or thin spots. Red-lead paint with its natural red color is seldom used for the finishing coat where durability and decorative effect are both important, but one of the most satisfactory and durable finishes is obtained with red-lead paint by adding sufficient carbon black to produce a dark-brown color or by adding carbon black and Prussian blue to give a black color. A light-brown second coat may be obtained by the use of about 0.2 per cent of black pigment, and the dark-brown finishing coat contains about 1.3 per cent of black pigment, the remainder of the pigment being red lead.

A black finishing coat is made with a pigment mixture consisting of about 80.5 per cent of red lead, 11.5 per cent of black pigment and 8 per cent of Prussian blue. Other black finishing coats, some of which contain graphite, are sometimes used. Frequently light colors such as white and light or medium gray are desired for the finishing coat, particularly for highway structures where high reflection of light is required to make such structures readily visible both in the daytime and under automobile headlight illumination at night. Such white and light-colored finishing coats are made with white-base pigments which, as mentioned, include white lead, titanium-barium pigment, titanium oxide, zinc oxide and basic lead sulfate. The addition of the tinting colors gives the desired shade.

A standard formula for light-colored finishing coats of this kind is made with white lead and consists of 100 lb. of heavy-paste white lead in oil thinned with 3 gal. of raw linseed oil, 1 qt. of turpentine and 1 pt. of drier, or 100 lb. of all-purpose soft-paste white lead in oil, thinned with 3 gal. of raw linseed oil and 1 pt. of drier with the necessary tinting materials.

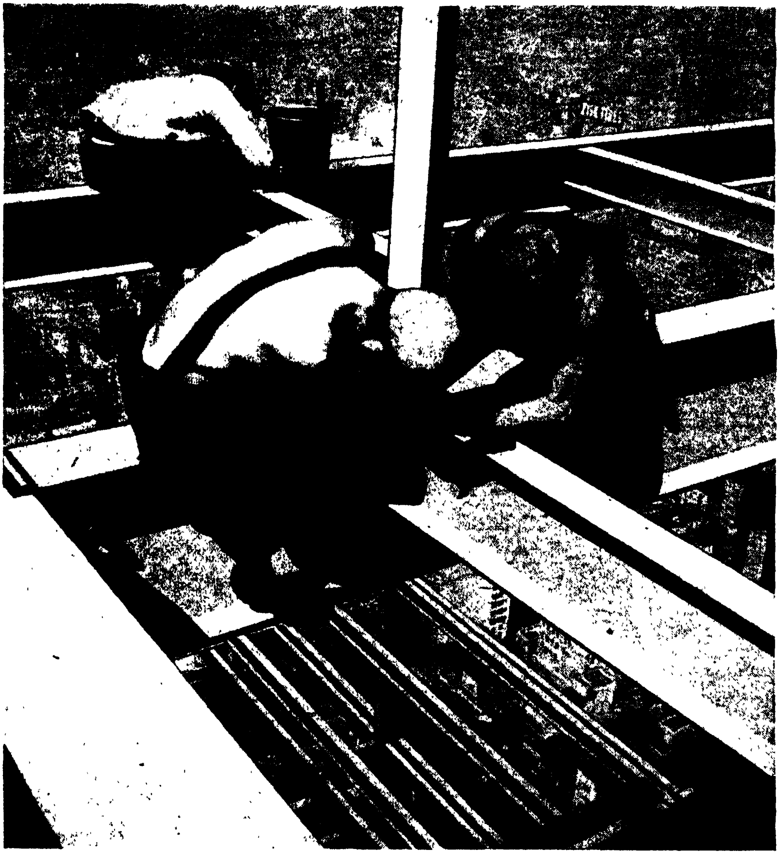


Fig. 119.—Painting of structural steel is a vital process in its erection. It is hazardous work and calls for well-trained men. Good practice in this field is to use the best available materials, because usually the steel is not painted again after the building has been completed.

Nearly all the structural steel used in building construction today is either surrounded by brick or stone or encased in concrete. It is important that this steel be well painted at the time of erection, because after the building has been completed it is usually impossible to get at the steel surface again for repainting or repair. Although brick and concrete afford considerable protection against the elements, neither is waterproof. Brick is porous and may absorb much moisture during wet weather. Concrete lacks uniformity, and vibration weakens its internal structure so that moisture is allowed to penetrate. Steel encased in brick, stone or concrete must therefore be painted with special care to prevent its later corrosion and destruction.

The steel frames of buildings should receive at least three coats of the best paint, and, since there is no question of decorative finish involved, it is generally considered good practice to apply three coats of red-lead paint, adding slightly increasing amounts of lampblack or carbon black for the second and third coats so as to ensure complete covering of the preceding coat. A standard red-lead paint, as described for bridges, is generally used for the frames of steel buildings, and all coats should be made in accordance with the full weight formula using 33 lb. of red lead to 1 gal. of linseed oil with a small amount of drier. Three coats of such paint will give the greatest protection against corrosion, and every precaution should be taken in selecting and applying the paint because the painting is done only once, and its cost is very small in comparison with the cost of the building it must protect.

Steel Ships.—The painting of steel ships for protection consists first in work done while the vessel is building. This involves thorough painting of the steel frames, followed by the painting of the steel plates that form the outer shell and the later painting of the various tanks and other minor metal parts.

In the better class of such work two full coats of red-lead paint are applied, generally with a month's interval between coats for drying, and then two coats of white or light-gray paint are put on before the final varnishing and other finishing. Steel ships have a very long life, and the first paint applied on new ships is of the greatest importance. The priming coat on steel ships is similar to the priming coat for other steel structures, and the practice described for bridges is equally applicable to ships.

The main difference between ships and other steel structures is that the hulls of ships are immersed in water after launching, and for this reason the paint should be applied sufficiently far in advance so that it will be completely dry and hard before it comes in contact with the water. For the exterior of the hull below the water line, special antifouling paints containing toxic ingredients to prevent marine growth are applied over the red-lead paint. The portion along the water line is frequently finished with special "boot-topping" paint, and the upper portions of the hull and superstructure are finished with white or light-gray paint similar to the finishing coats for bridges. The interior surfaces may be primed with red-lead paint and finished with light-colored interior paints and enamels to give the desired decorative appearance. Salt-water ships, and bridges located near the seashore, are particularly subject to corrosion, and therefore frequent inspection and repainting are advised.

Automobiles.—The finishing of modern automobiles has become an exceedingly technical operation in which coating materials and methods of application are highly specialized. Automobile bodies consist almost entirely of sheet steel, so that automobile finishing is really an important matter in the steel industry. Modified alkyl lacquers and other plastics-type coatings are the prevailing finishes in the automotive industry today. This type of coating has been described in other chapters. The priming coats for automobile bodies most frequently are special enamels that adhere to the steel and dry with a semigloss hard finish that can be rubbed and polished to an exceedingly smooth surface, suitable for receiving the lacquer finishing coats.

In high-grade automobile finishes a number of coats of nitrocellulose lacquer are applied over the special primers with the necessary colored pigments added to the lacquer to give the color desired in each particular case. The priming coats may be applied by spraying, and the lacquer coats are always sprayed on because the lacquer solutions dry rapidly and it is not possible to brush them.

Tanks.—Steel tanks and similar equipment such as standpipes, penstocks and pipe lines are used for many different purposes. Where such equipment is used for holding water, the painting of the exterior does not differ from the painting of other steel structures, and the same general procedure may be followed as described for painting bridges. The painting of the interior of tanks containing water is a special problem because after the paint comes in contact with the water, the air drying can no longer take place, and the paint should be thoroughly dry and hard before the water is admitted.

The interior of all industrial tanks and pipe lines that are to contain water should receive three coats of full-weight red-lead paint containing 33 lb. of red lead to 1 gal. of oil, with the necessary drier with or without a small amount of volatile thinner. To hasten the hardening of the paint 2 lb. of finely pulverized litharge should be added to each gallon of paint just before it is applied. Litharge reacts quickly with linseed oil, and paint containing a small amount of litharge forms a hard elastic film which matures more rapidly than paint to which litharge has not been added. It is well to use highly oxidized red lead when adding powdered litharge, because the litharge is then more completely reactive.

For tanks that are to be used for the storage of volatile liquids such as gasoline, a special problem is involved because it is essential to coat the exterior of such tanks with paint that reflects the heat of the sun to a maximum degree. White paint has a higher coefficient of heat reflection than any tinted or colored paint, and for this reason white paint is the most efficient coating to use for storage tanks of this kind. It must be remembered, however, that the white paint must remain white, because, if it becomes badly discolored by dirt collection or other causes, it loses its ability to reflect heat. Perhaps the most satisfactory finishing coat for tanks that are to be used for the storage of volatile liquids is white paint, which begins to chalk fairly soon after application and continues to chalk throughout its life, because slow continuous chalking causes dirt to wash off with the loose chalking particles and therefore is the only practical method of keeping such surfaces clean and white. Special finishing-coat white paints are designed for this purpose, using pigment and vehicle formulas that dry with little or no gloss and begin to chalk within a few weeks.

Although much of the tonnage production of iron, steel and other metals is included in the major classes of metal structures and metal products, there are innumerable metal products of different kinds, such as stationary machinery, farm machinery, architectural metalwork, barrels, drums, plain and corrugated sheet steel, galvanized sheet, metal containers of different kinds, and many that are technically and commercially important. Some of the special coatings required for many of these products are considered in a previous chapter. Porcelain enamel has not been mentioned here because it involves a coating well differentiated from coatings of paint and enamel. It is discussed in Chap. XXXIII.

CHAPTER XXXI

ENAMELING AND LACQUERING

The manufacturers of portable metal products that are turned out more or less on a mass basis are interested in coating as a production process. In this group of manufacturing are such diverse items as machine tools, washing machines, cash registers, lawn mowers, and an almost endless variety down to cans, buttons and bottle tops.

This miscellaneous assemblage accounts for products running into billions of dollars annually and affords the chief outlet for enamels and lacquers.

The manufacturer who produces in quantity any metal item is chiefly interested in three fundamental features in his approach to the problem of enameling or lacquering. These features are sales value, durability and cost.

Sales Value.—Sales value, which for many products is the most important feature, is an intangible and elusive quality. In most cases it has to do with color and luster, and in this connection a few generalities may be stated. Bright and pleasing color contrasts, with the avoidance of bizarre effects and with a smooth rich finish, usually have the greatest power of attracting sales. It is important of course to suit the color and the type of finish to the specific product in question. Metal parts for interior architectural use must blend with surroundings. Pastel shades generally are unsuitable for strictly utilitarian parts. For parts that are to be handled frequently, such as tools, the public seems to prefer a dull finish rather than a high polish, and this is fortunate because a high polish would be more difficult to maintain in service.

Another important factor in sales value of a metal product is style. Not many years ago a bright-colored machine tool or machine-tool part would have lacked much of the sales appeal it has today, and it is safe to say that color is more important on metal products now than it has ever been before. Certainly the manufacturer of products sold directly to the public should know something of the relative appeal properties of different colors and different color combinations.

In Chap. IV a good deal was said about color, and many harmonizing combinations were suggested. However, for most small products, the manufacturer who is facing the problem of selecting a finish should consider even the best advice as suggestive rather than conclusive. Having selected several plausible kinds of finish for a metal product, the surest way of determining relative sales value of any one is by experimenting, that is, by actually finishing the same product in several different ways and testing the relative sales volume.

Another point to consider in selecting the finish for a metal product is the technique of application. This subject perhaps more properly comes under the heading of cost, but, independent of cost, the size of the part and the nature of the base metal often limit the selection of enamel or lacquer.

Color Tests.—Even here another difficulty presents itself in that results of tests in different parts of the country vary. In some conservative sections bright colors for useful products sometimes give way to more sedate finishes, yet sales managers are continually being surprised at the so-called whims of the public in relation to color and to product finishes. Few people would have advised bright-colored typewriters before one company had the courage to try them out.

In some cases color may have a practical value. For instance, certain combinations are more legible at a distance, and light colors, such as aluminum, reflect and radiate heat better than dark colors. Thus, other things being equal, a light-colored radiator is more efficient than a dark one.

Durability.—Almost as important as the initial appearance of a product is its ability to withstand normal service and still remain attractive. Certain colors are more durable than others, and this fact often must be taken into account. An article finished in a nonpermanent color will usually fade unevenly, with the result that the product is no longer a credit to its manufacturer. Certain pigments are nearly always fugitive. Paint pigments originally were taken from the earth, and earth pigments now form an important part of enamel coloring. They are noted for durability. The need for new combinations and also the growing scarcity of some of the earth pigments led to the development of coal-tar products and other synthetic pigments. A description of a few of the chief pigments used in paint may be of interest.

Cobalt blue is a compound of oxides of aluminum and cobalt. It is permanent to light, is unaffected by alkali, lime or acids and can be mixed with any other pigment or color. The chief

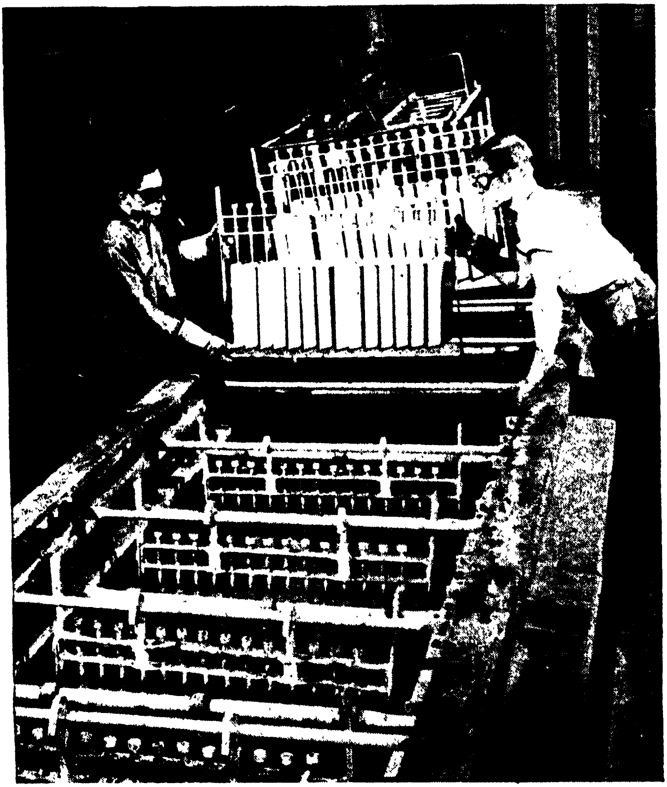


FIG. 120.—Alumilite finishing aluminum ice-cube trays. (*Courtesy of Aluminum Company of America.*)

difficulty is its high price. Because of this, ultramarine blue is frequently substituted.

Prussian blue, sometimes known as steel blue, is formed by precipitating potassium or sodium compounds with ferrous sulfate and oxidizing the resulting pale-bluish precipitate into a dark blue. This pigment has a fair permanence for ordinary use on metal products. It discolors, however, in contact with alkalies. It fades gradually in outdoor exposure. It has a fine texture that prevents its settling in the vehicle in enamel production and is extensively used for dip coating steel products.

The so-called **bronze paints** use finely divided metals as pigments. Thus an aluminum bronze paint usually has as its pigment metallic aluminum.

Several kinds of **brown pigments** are available for paint use. One of these is obtained by roasting iron ores. Another, known as Vandyke brown, is found in the earth, usually near bogs. On metal it is used chiefly in applying imitation wood finishes.

Burnt umber is a rich brown color extensively used for graining on metal.

One of the best greens is known as **iridian green.** It does not fade and mixes readily with other pigments.

Madder lake, which is a sort of bluish red, is now made from coal tar and, although used for enamels and lacquers on metal work, is relatively expensive. One of the best reds, known as toluidine, is a coal-tar product. It is permanent and does not bleed.

Chrome yellow is brilliant, has good hiding power and is fairly permanent.

Most of the above pigments may be mixed to form new colors. Chrome yellow, however, should not be mixed with any pigment, such as ultramarine blue, which contains sulfide, as sulfide tends to change the yellow to black.

The method of applying an enamel or lacquer has much to do with its permanent character. Frequently protective undercoats or priming coats are used, and on iron and steel these priming coats should be of a character to prevent corrosion.

Cost of Lacquering.—Lacquer for commercial use may cost about $3 per gallon, but this is only a small part of the total finishing cost. Some examples of cost given in a previous chapter will afford an indication of general practice. One manufacturer estimates that through the entire metalworking industry the cost of lacquer finishing will average about 3 per cent of the total cost of the product. A modern cash register weighing about 50 lb. is finished at a unit cost of $1.50, which means a cost of 3 cents for each pound of product. An average automobile takes 1 gal. of lacquer, and the entire finishing operation costs upward of $10. Both these examples are of a somewhat specialized character. For small parts that can be automatically coated, the relative cost drops appreciably. Elaborate spray-coating equipment has been developed for lacquering such products as cameras, clock parts, electrical fixtures, lamp shades, builders' hardware, metal trays, radio parts and buttons. The actual cost of lacquering a metal product may be relatively unimportant

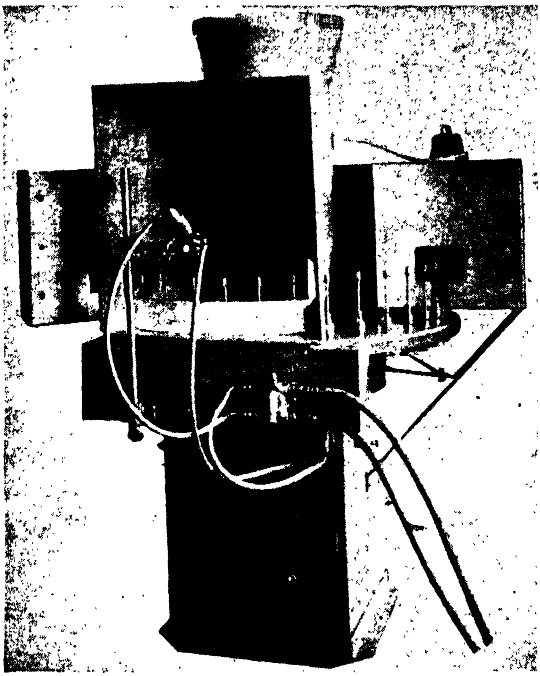


FIG. 121.—Small metal articles, such as thimbles, bottle caps and pencil parts, are usually enameled on automatic machines of which this is one type. (*Courtesy of The DeVilbiss Co.*)

if the nature of the finish has sufficient sales value. Thus, manufacturers of high-grade automobiles take elaborate pains and use much skilled handwork in developing just the right sort of attractive finish.

Enameling vs. Lacquering.—The processes of enameling and lacquering overlap and in many cases are strongly competitive. The chief point of difference is pigmentation; lacquers are clear and enamels are pigmented finishes. These are further classified as air-dried and baked finishes. It was the quick-air-drying feature of lacquers that first introduced them to the automobile industry, and today practically all makes of cars use lacquer and enamels for finishing.

A varnish with a clear gold color is a popular finish for such items as powder-can bottoms, vegetable-can ends, bottle tops and a great number of inexpensive stamped products where the appearance is of secondary consideration. In the tin-products trade, if a lacquer has an opaque color, it is no longer called a lacquer but instead is called a "coating."

Lithographing over Enamel.—A process closely associated with lacquering is lithographing. Strictly speaking, lithographing is not a coating but rather is a method of applying a coating, yet the lithographed finishes are generally known by that term. A lithographed metal tray may be made as follows: A sheet coated with an enamel background in a neutral tint is furnished by a steel company to the lithographer who then prints on this sheet whatever decorative design may be desired. This may be done with lacquers, special enamels or, more commonly, with lithographing ink.

The sheets containing the lithographed design are then sent to the tray fabricator, where without injuring the surface they are pressed into the form of the finished tray and are then ready for shipping. Many of the larger lithographing companies are equipped to do the fabrication as well as the lithographing. Thus lithographing of decorative cans nearly always is a production process in the plant of the can manufacturer. Some such manufacturers buy plain sheets which they lacquer or enamel, and others buy enameled sheets from the steel companies.

Enameling in Steel Plants.—From this it may be seen that steel companies often are in the enameling business. Actually the coating of certain types of sheets in flat stock on the part of steel companies is increasing. This is due primarily to the fact that the paint manufacturers in recent years have been able to produce enamels that are sufficiently elastic and have a strong enough bond when applied to steel sheets to enable the sheets to pass through even severe subsequent drawing and stamping operations without surface injury.

Competition between Lacquer and Enamel Finishes.—Generally speaking, a lacquer does not build up so full a finish with the same number of coats as does enamel. Also lacquer usually does not adhere to bare metal as well as enamel. Thus it is common practice to use a priming coat preceding the application of lacquer. This practice in the automobile industry has already been pointed out. Most manufacturers feel that a lacquer finish on metal provides a more durable surface when exposed to the weather than that developed by the usual oil enamel. Within the last few years certain new synthetic enamels have been developed that are more durable under exposure to the weather and more resistant to abrasion than the best lacquers. Therefore, renewed strenuous competition is sure to come between lacquers and enamels in the metalworking industry and particularly in the automobile branch. In the refrigerator field there is already keen competition between the porcelain enamels and the newer synthetic enamels. One of the largest manufacturers in this field, although using porcelain for its highest priced refrigerators, is now using a highly satisfactory synthetic enamel for all other models.

Metal bathroom tiles are an example of another competitive field between porcelain and the synthetic enamels, and here the lower drying temperatures required for the synthetic enamels gives them an advantage at least as far as unit cost goes.

Uses for Enamel.—Outside of the automobile field, enamels, both oil base and synthetic, constitute by far the most extensive coating in the metalworking industry. Some of the principal outlets for enamels are metal furniture, stoves, cash registers, signs, telephones, electric-fan bases and light fixtures. Other extensive outlets are washing machines, trucks, sewing machines, scales, railway equipment, adding machines, bicycles, machine tools, kitchenware, filing cabinets, clocks and instruments, cameras, decorative packages, metal trays, dishes of many varieties and buttons.

With the exception of agricultural machinery, where standard paint still seems to be preferred, and the automobile, where lacquer is preferred, most metal products that are coated for attractive finish are enameled. Those engaged in research work in this field state that the future for synthetic enamels is most promising. They say that progress so far seems to indicate the development of an enamel that will dry at low temperature, or perhaps may even be air dried and will have at the same time a surface sufficiently elastic for deep drawing and sufficiently hard to withstand abrasion.

The quality of abrasion resistance often becomes an economic problem through the fact that parts coated with enamels having this quality can be shipped in bulk and thus save crating and boxing expense. Recently a manufacturer of parts used in connection with city water hydrants changed the type of enamel used and by this process alone was able to save nearly 10 per cent through boxing and shipping economies. Heretofore rigid municipal inspection made it necessary to box the parts individually, since a scratch was sufficient cause for rejection. With the new finish, the manufacturer was able to load the parts, without boxing or crating, into a truck and drive them to the city warerooms without scratching them.

Selecting the Coating.—Some of the difficulties of selecting the best coating for any specific article have been mentioned. Perhaps the best way to give suggestions to a manufacturer would be to consider the experience of some who have solved the problem. A manufacturer of small flashlights at first bought tin-coated steel sheets with an enameled coating put on by the steel company. At this stage in his experience the cases were made by forming and pressing without soldering, but, in order to produce a more accurate product that would give better service, the manufacturer desired to solder the case. It was found at once that the soldering operation discolored the enamel; consequently plain tinned steel sheets were used. These were made up into cases by soldering, and afterward the completed units were enamel coated. At this point difficulties developed because the temperature required for baking the enamel had a tendency to melt the solder. Therefore a change was made to a lacquer that would dry at a low heat and thus not injure the solder.

This particular finish was fairly satisfactory, and the manufacturer continued to use it for some years, but eventually, partly because of the expense and partly because he had difficulty getting the lacquer to stick to the tin, he changed again. He submitted his problem to a paint manufacturer who developed a new type of synthetic lacquer that had excellent bonding qualities with the tin coat. Now the whole cycle has started over again because the company has discovered a new enameled sheet that is not discolored by the soldering operation.

This lengthy experience indicates the rapidly changing conditions in the metal-finishing field and shows that a problem solved today may be a problem again tomorrow if new materials become available.

When manufacturers of buttons desired to use metal with a lacquer finish, they immediately discovered that ordinary lacquer was adversely affected by the strong solutions used in laundries and also by the severe treatment in pressing. Seeing a possible new outlet slipping because of this difficulty, lacquer manufacturers were quick to cooperate with the steel-button producers and today have developed a special button lacquer that not only withstands all laundry solutions but will not break or crack under mandrel and flatiron pressing. In a similar way enamels have been developed for use in washing machines, to withstand the soaps and washing solutions.

A manufacturer of metal furniture supplies the following procedure for a high-quality finish. The parts are given two priming coats and finishing coats with spray guns in well-ventilated spray booths. Two men work in each booth on opposite sides of certain pieces of furniture. After each coat the parts are dried at 125°F. before proceeding to the next booth. Color combinations are applied by masking or shielding certain parts with paper which is later removed. Final decoration is by hand, and the final coat of lacquer is water sanded with fine sandpaper and then air dried with pressure jets. Slight defects are touched up by hand and later concealed by applying a so-called "mist coat" of lacquer.

For this type of finish and with the usual lacquers 1 gal. of lacquer will cover 400 to 500 sq. ft. of surface with one coat. In order to duplicate the hand-rubbed effect on certain quality pieces of furniture, aluminum or zinc stearate is added to the lacquer.

For bar fixtures and bar furniture that must be coated to withstand alcohol, special enamels and lacquers are available. A manufacturer of cash registers has changed a former popular wood grain to a morocco finish, which has an advantage in that it does not reflect light as much and yet seems to have an equal sales value.

Enameling Steel Sheets.—The manager of a steel-stampings plant describes his enameling process as follows: Sheets containing 4 sq. ft. of surface are fed through a continuous machine at the

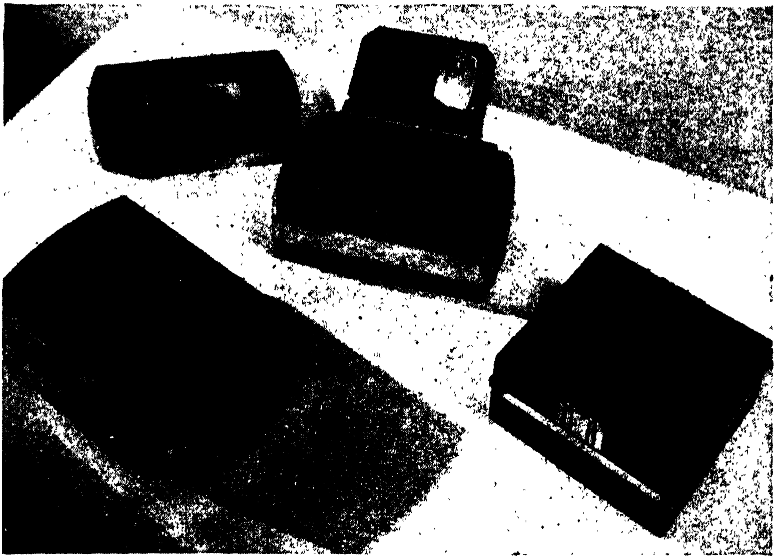


FIG. 122.—Parts of decorative boxes are frequently automatically enameled, leaving other parts plated and polished. This is done with the use of paper masks.

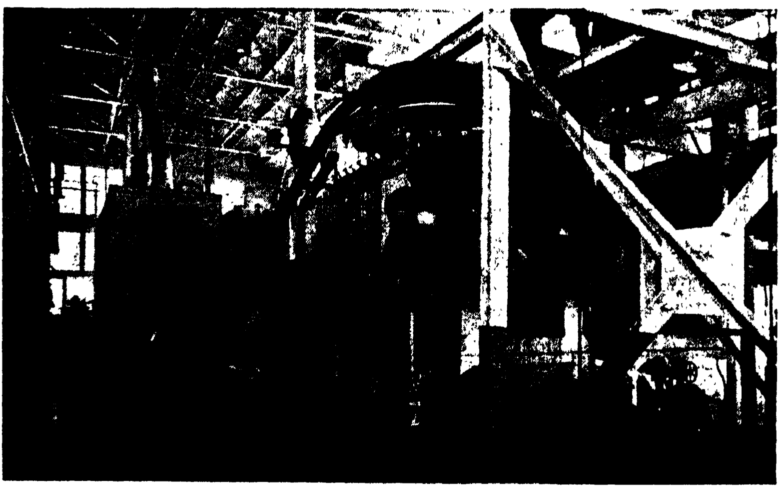


FIG. 123.—Automatic operations are common in the process of enameling automobile-body parts. Here such parts are passing on a continuous overhead conveyor through the bonderizing sequence preparatory to enameling.

rate of 100 sheets per minute. The cycle includes a baking period of about 25 min., and for this operation the sheets are up-ended on a conveyor in order to save space. The oven, in order to accommodate the production of 100 sheets per minute, must have a total capacity in excess of 2500 sheets for its 25-min. period, and, if it were not for this up-ending feature, the length of the oven would be prohibitive.

After the company has decided upon the desired appearance of any one product, an excellent method is to refer the problem of actual selection of coating material to a reputable paint manufacturer. By picking a manufacturer who produces both lacquers and enamels, any objection due to competition between these two coatings will be eliminated. Often the coating material can be purchased by specifying the result rather than specifying the ingredient. Manufacturers generally should be cautioned to pay more attention to the finishing operation and not consider it as merely an added or supplementary process. It often happens that, when a type of finish is given due prominence in the entire sequence, other preceding operations may be changed to advantage. The nature of the metal itself is sometimes changed to accommodate a particular type of enamel or lacquer finish. Some companies make steel sheets with special finishes for receiving enamel.

PART VI

SPECIAL FINISHES

CHAPTER XXXII

COLORING ALUMINUM

Metal parts are now successfully colored for many uses by the application of lacquers and enamels. In the case of aluminum products, an unusual method of color application involves the forming of a dyeable oxide coating on the metal surface. Colored aluminum strip, which is afterward polished and buffed, is now being used for making cigarette cases, automatic pencils, cafeteria trays and even costume jewelry.

The added sales value that may result from the use of colors in metal finishing has already been pointed out. Having decided upon a color, or color combination, the next step is to determine what method to use for securing this color on the particular product in question. Lacquers form one method, and their rapidly growing use in the metal industry indicates the popularity of this means of finishing. Another method is to select alloys which in themselves have the colors desired. An example of this is seen in the architectural use of stainless steels, of bronzes and of many other so-called white and red metals.

The denser metals in natural state are particularly resistant to dyes, but slight modification of the surface, as by oxidizing, may reverse this characteristic and make these metals readily receptive to almost all dyes. Designers and metallurgists are now aware of the great possibilities in the surface treatment of metals.

Oxidizing.—Aluminum and its alloys can be given a unique finish by a process of anodic oxidation. The article to be oxide coated is made the anode in an electrolyte of controlled composition. The time of treatment varies from about 10 min. to 1 hr., depending on the thickness and other properties desired in the coating. The coating consists substantially of aluminum oxide and, depending on the current employed (amperes × minutes), will vary in thickness from about 0.00005 to 0.0006 in. Various electrolytes are employed, such as dilute solutions of chromic acid, sulfuric acid and oxalic acid, depending upon the process in use.

The coating is an integral part of the metal, since it is not deposited from solution but is made by oxidation of the metal itself. It is hard, adherent and resistant to abrasion. Its resistance to wear increases with the thickness of the coating, a characteristic that is under the control of the operator. The coating is also protective and is widely employed as a finish for aluminum that is exposed to weathering and for which appearance is an important consideration. Another important application is on aluminum aircraft parts. Anodic coatings are particularly useful as a base for paint when the aluminum is to be used in corrosive environments.

The coating, as produced in acid electrolytes of the type described, is porous and adsorptive. The pores are too fine to be seen under the light microscope; there may be as many as a billion pores per square inch of surface. These pores, however, will permit the entrance of a dye solution and, by immersion of such a coating in the proper type of dye, the oxide can be colored throughout its depth with almost any color of the rainbow.

These dye-colored coatings show satisfactory permanence indoors, although when exposed to sunlight and weather they will fade in time. More durable colors for outdoor use can be produced by impregnating the coating with mineral pigments. For both plain and colored coatings, the Alumilite process of the Aluminum Company of America is the one most extensively used.

Aluminum oxide itself is colorless, and the anodic coating on most aluminum alloys has a silvery-white appearance. It duplicates in texture the surface on which it is formed, and the oxide coating may therefore have a glossy enamel-like luster or a soft diffusing appearance, depending on whether the aluminum has been polished or etched before anodic coating. The porous adsorptive coating can be sealed without coloring so that it is resistant to staining and offers even better protection.

Fabricating technique involving the use of colored aluminum varies with different manufacturers. Some of them stamp and form articles from the plain aluminum sheets, then surface in the usual way with polishing wheels and buffs, and finally put the parts through the oxide-surfacing process. This surfacing does not appreciably change the polish of the original metal, so that a mirror surface, for example, will come through the oxide process with but slightly altered gloss. On the other hand, if the surface has been given a special texture, as by wire brushing or etching, the oxide coating will have a light-diffusing surface.

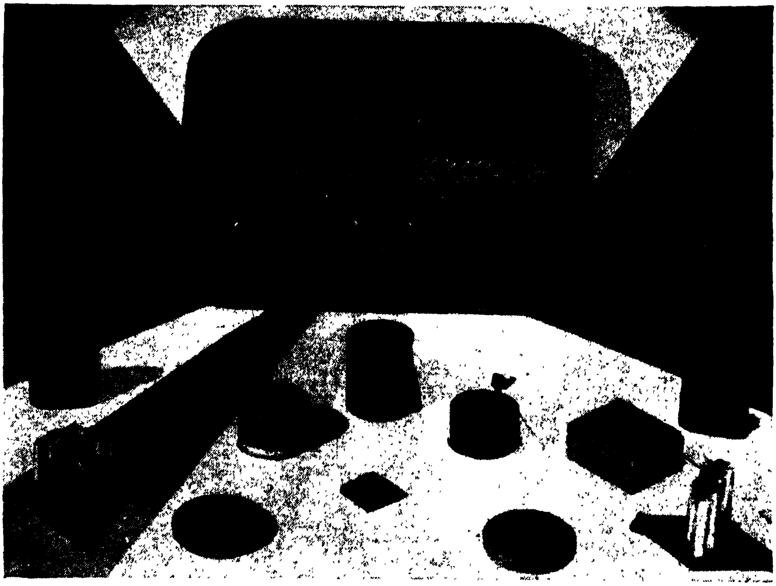


FIG. 124.—The use of aluminum inlays in micarta opens up many new fields for the designer.

The abrasive-resistance properties of the oxide coating have been determined in a comparative way by a series of tests, as shown in Table XI.

In order to obtain at least a rough comparison of this abrasion resistance with that of some enamel finishes, similar tests with enamel were made. A typical coating consisting of primer, two brown coats, draining coat and three coats of finishing varnish, with a total thickness of 3 mils, gave an abrasion resistance of 1095 revolutions. For equivalent thicknesses, therefore, the oxide coat is substantially harder than the baked enamel which was tested.

TABLE XI.—COMPARATIVE RESISTANCE TO ABRASION OF OXIDE COATINGS ON ALUMINUM

Thickness of Coating, Inch	Revolutions of an Abrasive Wheel Required to Destroy the Surface
0.00011	15
0.00019	95
0.00031	268
0.00037	365
0.00074	2563
0.00148	7061

Since the dyes penetrate through the entire depth of the oxide coating, the color thus produced resists the wear incident to hard usage. Dyes are available that are quite permanent indoors, although they show some fading when exposed to sunlight and weather. If a more permanent color is desired, certain pigments may be precipitated in the pores of the coating by a special process. Several so-called sealing treatments are also available, which render the oxide coating quite impervious and seal it against further staining in case it should come in contact with coloring materials such as ink. When the oxide coating is applied to aluminum alloys, its properties may differ through quite a wide range. Duralumin, for instance, when oxide coated, becomes highly resistant to salt-spray corrosion, but, where the maximum protection is required, some further special treatment is necessary.

Oxide Coating for Textile-machine Parts.—As different finishes are developed for different metals, a change in application takes place. Thus a new noncorrosive coating for steel may cause the introduction of steel into many fields formerly occupied by nonferrous material, and, in a similar way, a hard coating on such a material as aluminum has the effect of introducing aluminum into such fields as require resistance to abrasion, without excessive demands on strength. The textile industry is one such field, and oxide-coated aluminum is now meeting with success for many textile-machine parts.

Aluminum in Decorative Arts.—Gradually, and with slight changes scarcely noticeable at the time, the metals have moved into the field of decorative arts during the past 10 years. One authority states that the renaissance of metals in art and architecture started with the Paris Exposition in 1925. Impetus to the new movement was given by the public which, tired of the conventional forms, sought something that would approach the permanence of the classic periods of design.

As soon as this general desire was apparent, metallurgists got busy in an attempt to keep up with the many demands the new movement placed on metal. One line of activity concerned

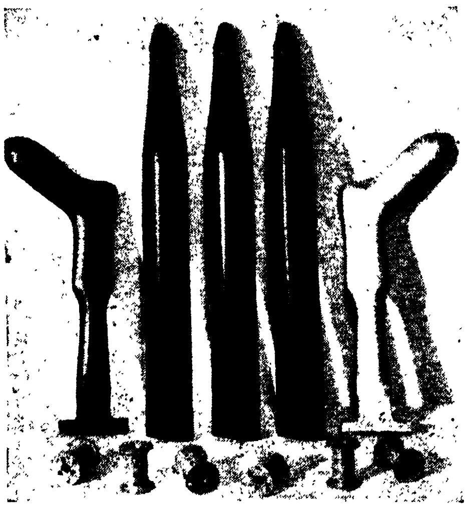


FIG. 125.—The oxide coating on aluminum, when polished, forms an excellent smooth and wear-resistant material for use in the textile industries. This shows two styles of form for stocking inspection and aluminum spools for textile treatment.

itself with the finishing of aluminum, and the dyeable oxide coating described is a prominent result.

The introduction of this metallurgical achievement into modern life may be illustrated by the all-aluminum room completed in Pittsburgh after the design of Harold M. Schwartz. Mr. Schwartz took sheets of aluminum dyed a rich brownish red and laid them end to end along the walls until he had covered the surface from floor to ceiling. This rich dark color was enlivened by a trim made of sheet aluminum in its natural color. Pewter-colored aluminum fire dogs were placed in the aluminum-trimmed fireplace. Even the curtains were made of aluminum lace. The upholstery was in yellows, and a hand-woven straw-yellow rug gave an added touch of life to the room.

Possibilities of Color.—Following the development of the oxide coating, and of dyes suitable for this coating, there have been many processes of refinement. A stop-off method has been discovered, by means of which more than one color can be applied to an article in one operation. The development in methods of oxide coating and dyeing has made it possible for at

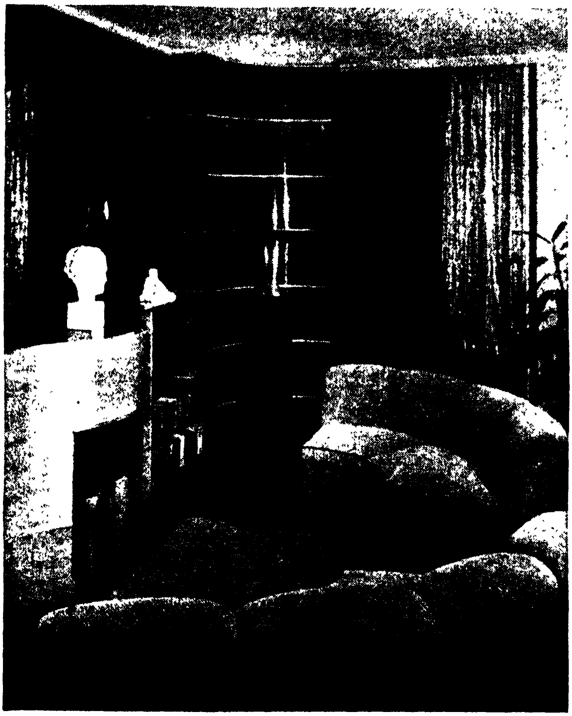


FIG. 126.—The walls of this attractive room are entirely covered with aluminum. Even the curtain is made of aluminum foil. Note the streamlining of the fireplace in aluminum of natural color.

least one company to introduce a continuous process for oxide coating and coloring aluminum strip in coils. This continuous process has brought the material within the scope of such manufacturing as decorative buttons, caps, tags and name plates, all of which are now successfully stamped from colored strip aluminum without chipping or harming the coating.

Colored aluminum may be joined with other metals or other material to produce new effects in the complete assembled unit. Because of the oxide coating, manufacturers have found some difficulty in joining the colored strip to metals such as stainless steel. However, in most cases, a solution has been found. One method is to spin a disk of colored aluminum over the projecting edge of a sheet-steel frame. Other methods reported as practical for fabricating colored aluminum are spot welding and riveting.

In the case of decorative panels, colored aluminum sheets are available in sizes which, for most purposes, eliminate the necessity of mid-panel joining. On production panelwork, as for

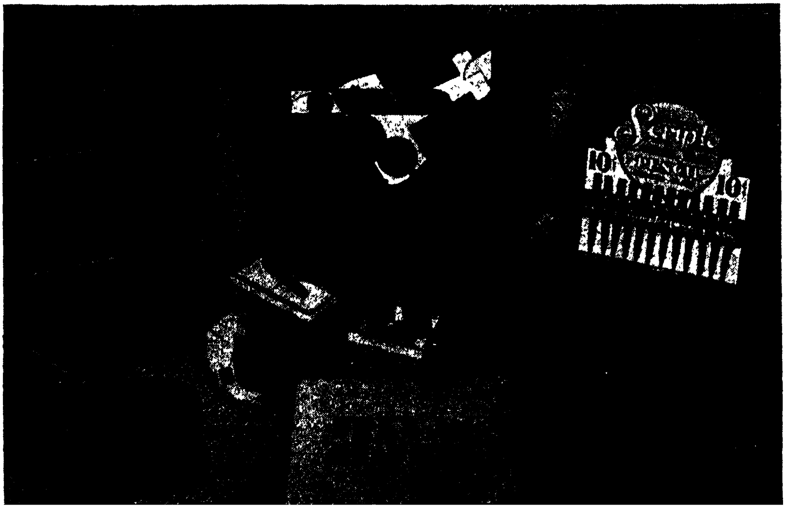


FIG. 127.—Pencils, fountain pens, signs and plaques are made of colored aluminum or of plastics material inlaid with aluminum.

bulletin boards and signs, the edges of the sheets are turned at right angles to facilitate fastening to framework members.

Colored aluminum parts may be joined with plastics by molding without affecting the surface characteristics, and this makes it possible to create some unusual inlay effects. The process is quite simple. A decorative design, for instance, may be stamped from the colored aluminum strip. The stamping is then placed in the bottom of the mold used for forming, say, a plastic tray. The colored surface of the aluminum part is placed directly against the mold, which is then filled with the plastic compound and pressed to form in the usual way. When the mold is opened, the plastic tray appears with a colored metal inlay, flush with the tray surface.

Modifications of this same process are used for making switchboard panels, and, going a step further, colored aluminum foil, instead of strip, is obtainable for inlay work. An extension of this principle of inlay is used by some architects for wall coverings for halls and restaurants and, in the home, as covering for kitchen tables and bathroom walls.

Many unusual surface effects may be secured through polishing and sandblasting colored aluminum sheets. In sandblasting, various effects result from changing the air pressure, the grit size, the distance of nozzle to the work and the angle of impact, and decorative designs are made with paper shields. In polishing, changing the direction of the rotation of the wheel with respect to the travel of the work gives a surprising difference in the "color" or light-reflecting properties of the surface.

CHAPTER XXXIII

PORCELAIN ENAMEL

Porcelain-enameled steel is essentially steel with a coating of glass, and the importance of this finish in industry has developed rapidly during the last few years.

Porcelain enamel is a broad term and in the metalworking field usually includes any vitreous or glasslike coatings. In simplest terms, a compound of various earth ingredients is fused onto a metal base and thus becomes for most practical purposes an integral part of the metal itself.

The metal base is heated to a temperature of 1250° to 1550°F., depending on the nature and thickness of the base metal. The heat fuses the enamel coating, causing it to react with the base metal, giving rise to a physical and chemical bond the effect of which is to key the enamel in place so tightly that it is almost a part of the metal.

Early experiments in applying vitreous coating to metal were tried many years ago in an attempt to close the porous surface of metal for kitchen utensils. Under test these early coatings withstood high temperature, but in service they chipped and were not satisfactory. Then, before the enameling technique could be improved, a new type of attractive aluminum utensil appeared on the market to hold the limelight on the kitchenware stage for some years. During all this time the manufacturers of porcelain enamel carried on extensive research work until finally nearly all the earlier difficulties were overcome, and today porcelain coatings with many varied properties are available. It is possible, for instance, to form and draw steel sheets that are prefinished with a porcelain coat at the mills. An example of this was the manufacture of tiling for the walls of the International Tunnel between Detroit and Windsor. This tiling is formed from porcelain-coated steel, and it was adopted after many rigid tests with a large variety of material.

Another example of forming of precoated sheets is seen in the manufacture of porcelain tile or shingles for roof construction.

One of the earliest examples of the use of porcelain-coated steel for roofs was an installation made by the Porcelain Enamel and Manufacturing Co. on a building in Detroit 25 years ago, and to date there had been no maintenance cost whatever.

Modernizing Old Buildings.—The problem of the old business building confronted architects and real-estate interests more strikingly than ever before during the years of the depression. A large number of buildings, otherwise considered obsolete, are structurally strong. The two principal factors involved in their modernization are better elevator service and better appearance.

FIG. 128.—This cast cooking dish finished in porcelain enamel has a wall thickness less than half the thickness once required. This is due to the development in foundry practice as well as in enameling technique.

Some architects have been successful in making these buildings more attractive from a business standpoint by giving them new faces made of porcelain-enameled steel. Such material is commonly made up in the form of panels at the fabricator's plant and can be had in any of the wide selection of permanent colors. These generally consist of porcelain enamel placed directly on steel, with or without an insulating backing.

A product known as Glasiron macotta is a lightweight concrete slab 1 in. thick, faced with a sheet of steel, the steel finished on its outer surface with porcelain enamel. The concrete gives the panel rigidity and insulating properties, and the enameled surface gives protection combined with the required attractive appearance.

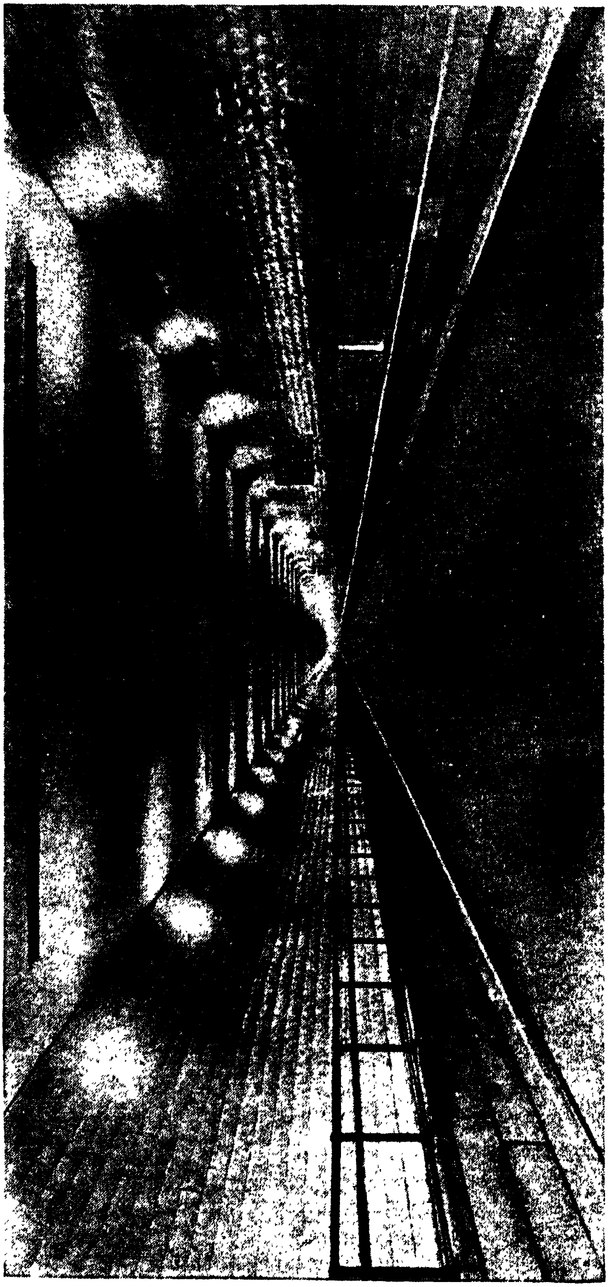


FIG. 129.—The walls of the International Tunnel between Detroit and Windsor, Ont., are covered with porcelain-enameled steel tile.

Engineers who have tested porcelain-enameled steel panels designed for building construction claim that today there is no known finish that will give the permanence in color that these panels afford. It is claimed that a building finished in 1934 in modern high-quality porcelain enamel over steel will look exactly the same in 1960, if it is washed occasionally to remove

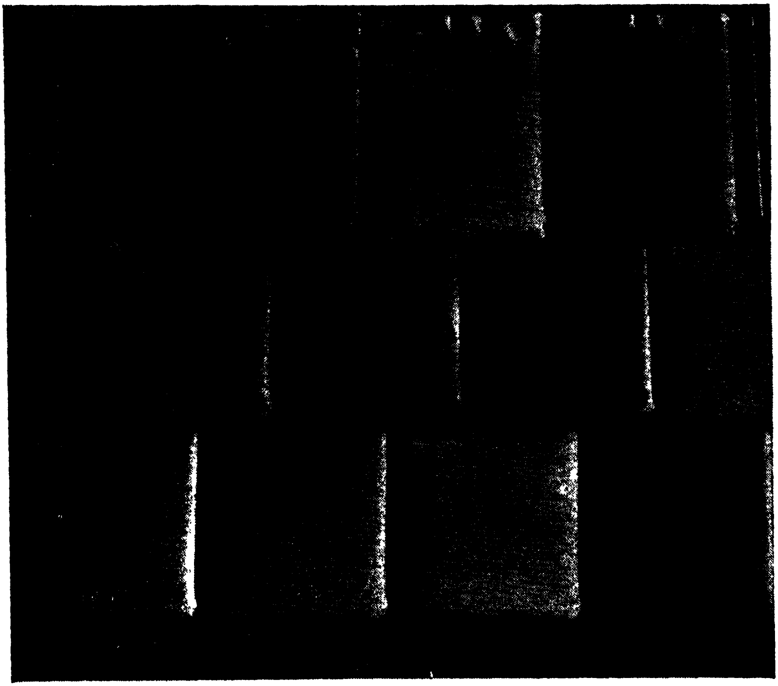


FIG. 130.—Roof tiling made of 22-gage steel sheets pressed to form and then coated with porcelain enamel is said to offer architects a permanent and attractive type of construction with no maintenance cost.

city dirt. Tiles made of steel, coated with porcelain enamel, closely resemble the solid vitrified product. In a similar way, roofing tile may be made up to resemble closely slate or terra cotta.

Metal Roofing Tile.—Metal roof tiling, such as shown in Fig. 130, is pressed from 22-gage Armco ingot iron sheets, and the individual tiles are then covered with two coats of glass enamel, each coat separately fused on at 1600°F. The manufacturers claim for this tile that once properly installed it is practically indestructible. Delicately blended tints are available, thus enabling the architect to produce a roof that will harmonize with the general design and with the environment. An added advantage claimed for deep-pressed steel roof tiling is the fact that the innumerable air pockets thus developed afford both heat insulation and noise insulation.

Of course, in order to have any tile roofing durable, it must be installed with durable nails, and special copper nails with a lead cushion under the head are often specified for installing porcelain-metal shingles.

Extent of the Industry.—The use of porcelain enamel on metal is increasing rapidly in this country. The vitreous coating in general use for sinks, refrigerators and household appliances is a complex mixture. The report of the Porcelain Enamel Institute gives the chief ingredients as nitrate of soda from Chile and Russia, vallendar clay from Germany, cryolite from Greenland, nickel oxide and cobalt from Canada, manganese from Newfoundland, feldspar, quartz, fluorspar, soda ash and borax from the United States. These materials in proper proportions are first ground and thoroughly mixed. The mixture is then smelted at high temperature into a molten glasslike mass. It is held at high temperature for seasoning and then is released into a tank of water where, because of sudden contraction, it breaks up into relatively small fragments. These fragments are the raw material used in producing the enamel, and they are generally known as frit.

The production of frit in this country is probably more than 50,000,000 lb. a year. The enamel itself is usually made up from this frit at the plant of the metal fabricator or of the enameler. Frit is ground with water, clay and the desired color oxides, until it reaches a creamy state ready to be applied to the steel. One method of application is to heat the steel, as already mentioned, to a white-hot temperature and then to spray the creamy enamel onto it. This is the method of producing such familiar items as stoves and ranges, washing machines, table tops and electric-light reflectors.

The large number of advertising and informative signs used in cities and along highways revolutionized the manufacture of such products. First they were boards painted in the field; then sheet steel, also painted after erection; then galvanized, tinned or prepainted sheets; and, finally, finished enameled panels made up at the factory. Sheet-steel porcelain-enameled panels are now produced in a variety of sizes and finishes for use as signs. When permanent lettering or designing is desired, this may be done in different colored enamels. However, where the sign is subject to change, as on advertising panels, a light neutral-tint background is furnished, and this is then painted over in whatever manner may be desired. When the sign is to be changed, paint-removing solutions that do not affect the porcelain base are used, and the process of cleaning off the old sign is almost as simple as washing dirt from an automobile body. After cleaning, the panel is back in its original condition ready for repainting.

Some Principal Uses.—The industrial use of porcelain enamel is expanding, and the new elastic properties secured for the coating itself make it possible for this type of finish to compete with lacquers and enamels in nearly all cases where cost is not a prime consideration. Where high resistance to certain acids is called for, a porcelain coating on metal appears to be a most satisfactory material, for this type of construction is cheaper than solid porcelain and has some other advantages, the most important of which is its greater resistance to shock. The food industry is one of the big outlets for porcelain-enameled steel, and this type of finish on metal is used in the paper, cosmetic, textile and chemical industries.

Porcelain-enameled steel buildings are now an established and practical reality. Both commercial and residential structures of this character are in actual service, and manufacturers state that it merely remains to popularize the style.

Porcelain-enameled steel construction lends itself admirably to prefabricated design and manufacture and thus particularly to lower priced residential building. Many types of construction have been developed, and some of these combine the exterior finish with supporting members. In other designs porcelain-enameled sheets or panels are applied as a finish, just as terra cotta or other materials might be applied. One of the chief architectural advantages claimed for such buildings is the varied treatment possible in color schemes and decorations. In the commercial field, the great appeal of a smooth colored panel is self-evident.

Porcelain enamel can be used successfully in exterior as well as interior construction. For store fronts, construction is relatively simple. Usually a frame of steel or wood studding is built, and the enameled steel panels are then attached with screws or specially designed metal clips. The panels may be insulated with layers of felt or mineral wool and the joints filled with a flexible mastic. Sometimes the joints are covered with battens of

Fig. 131a.—Bathroom in Indianapolis home of James Whitcomb Riley.

aluminum or stainless steel or with chromium-plated steel or copper. One of the most popular uses of porcelain enamel is found in high-grade refrigerators. Porcelain-faced steel shelving and table tops are other important items.

Applications and Plant Procedure.[1]—The compound word "porcelain enamel" was made necessary by the wrong use of the

[1] From comment furnished by Horace R. Whittier, president, Horace R. Whittier Co.

word "enamel" by manufacturers of paints applied to ordinary varnishes and paint finishes. For that reason, many engineers and those responsible for designs are today overlooking a fine and dependable finish for use on small parts, dials, etc., because they

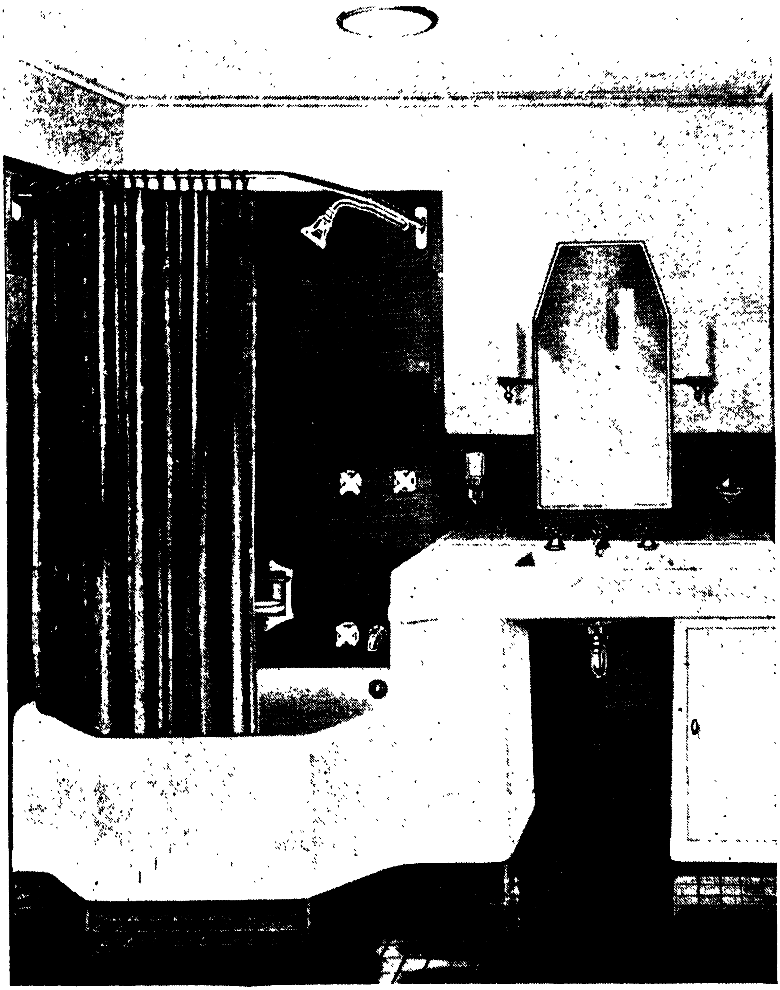


FIG. 131*b*.—Combination tub, shower and lavatory made in enameled cast iron.

lack an appreciation and knowledge of what constitutes porcelain enamel. The very nature of porcelain enamel, a fused glass on metal fired in relatively high heats of 1500°F., results in a product that is impervious to wear, reactions, corrosion, fading by sunlight and other deteriorating effects that attack other mediums of finish or dial materials such as plastics, lithograph and paint finishes.

In oven thermometers, it is necessary to have a dial that will stand high temperatures and will not change color when subjected to heat. Heat indicators on stoves are therefore furnished with procelain-enameled dials. Gas and water meters installed where corrosion is prevalent require porcelain-enameled dials. Copper is used in such applications. Because the reading of such dials must be easy, the light-reflecting qualities of porcelain enamel

FIG. 132.—Ware on continuous conveyor entering furnace.

give an effect that cannot be duplicated by any other medium used for dial purposes. The fine, smooth, glasslike finish of porcelain enamel is recognized as an excellent medium for a finish on those parts used as guides in the manufacture of textile machinery.

Porcelain-enameled signs are used in display advertising and can also be applied to such smaller items as printed plates with messages or instruction, that is, detective signs, house numbers and direction plates. In the preparation of small signs and dials, the same careful procedure is followed as in the enameling of such larger items as store fronts, large signs, sinks and bathtubs.

Special steel is required for porcelain enameling. The blanks are cleaned thoroughly by the known metal-cleaning processes, and then one grip coat and the usual two color coats are applied to give good results. In our factory, we use the spraying method for covering the metal. This method employs spray guns with atomizers that are adjusted for relatively high pressures, and the coat is put on by experts who know the exact thickness required. The dip method is used on some jobs because it is more economical than the spray method. Many of our jobs require additional firing because a thick coat of enamel on steel cannot be applied at one time. Recent research has developed fairly satisfactory one-coat procedures, but the saving is not of great

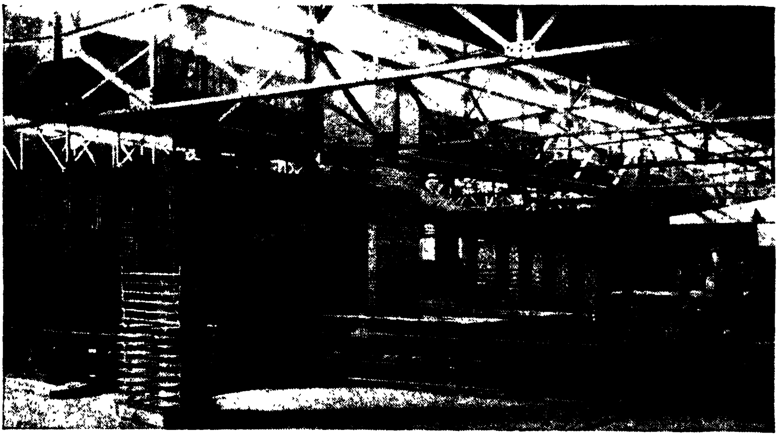


FIG. 133.—Battery of porcelain enamel furnaces showing speed forks for handling ware.

importance in the manufacturing of small parts. This company therefore clings to the conventional three-coat method.

For furnace equipment, we use furnaces with doors on both ends. A few years ago we used the continuous furnace method. While it was in operation, we were under the impression that we were getting favorable volume production; but, because of the excess cost of replacement of belts and the extra heat required for heating the belts, we discovered that the expense was prohibitive. Now we use a simple but nevertheless effective method. We have large-sized flanges approximately 24 by 40 in., which are wheeled up to the furnace door on rubber-tired carriages, and we have a fork of our own design for picking these up. The carriage can be wheeled around to the opposite side for the flange emerging from the other side, giving us a cycle of production equal to if not better than the endless-chain method.

We have three methods of printing or decorating porcelain enamel parts: the offset method, employing small hand presses,

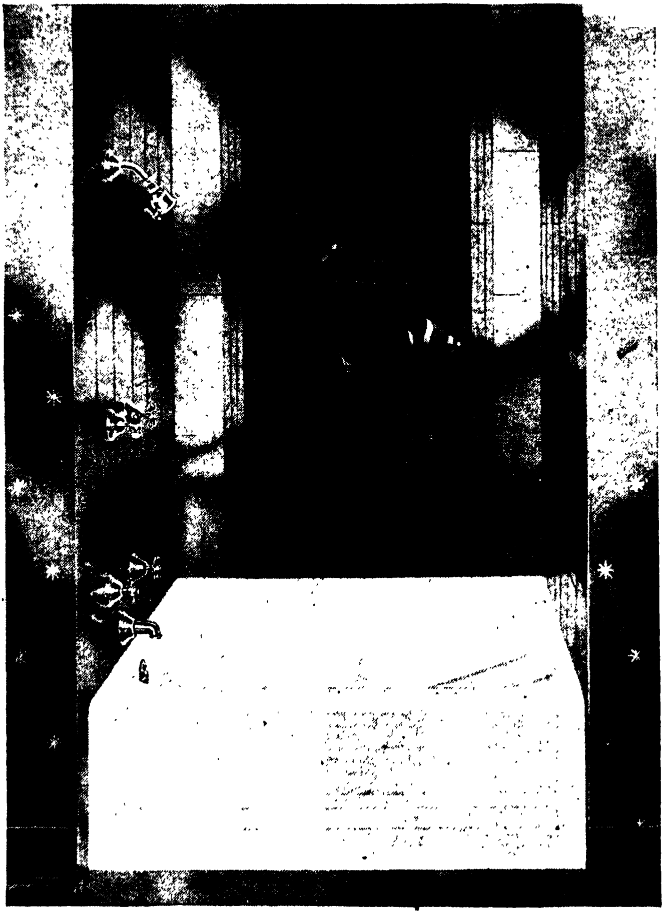


FIG. 134.—Combination bathtub.

the silk-screen process and the stencil process. Because it is not possible to print on a glassy surface by any conventional method, we use the offset method with a printing ink made up of metallic oxides incorporated in a suitable vehicle for printing. In firing, the ink is fused into the enamel and cannot be removed. We can print almost anything on enamel that can be printed on paper.

The printing can be done in any color, but each color must be printed and fired separately. The silk-screen method is the same as in poster work and is excellent for fine detail that cannot be achieved with the stencil method. We use the stencil method for small runs for which the cost of preparation for the silk screen is prohibitive. It can be used, however, only for larger signs for which fineness of detail is not too important.

True craftsmanship is required in these three methods of decorating. We have yet to find a high-speed mechanical means of printing on porcelain enamel that will take their place. In using the offset method of printing, we get approximately 1500 to 1800 pieces per day per operator. The silk-screen method produces somewhat less, and the stencil method is slower.

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