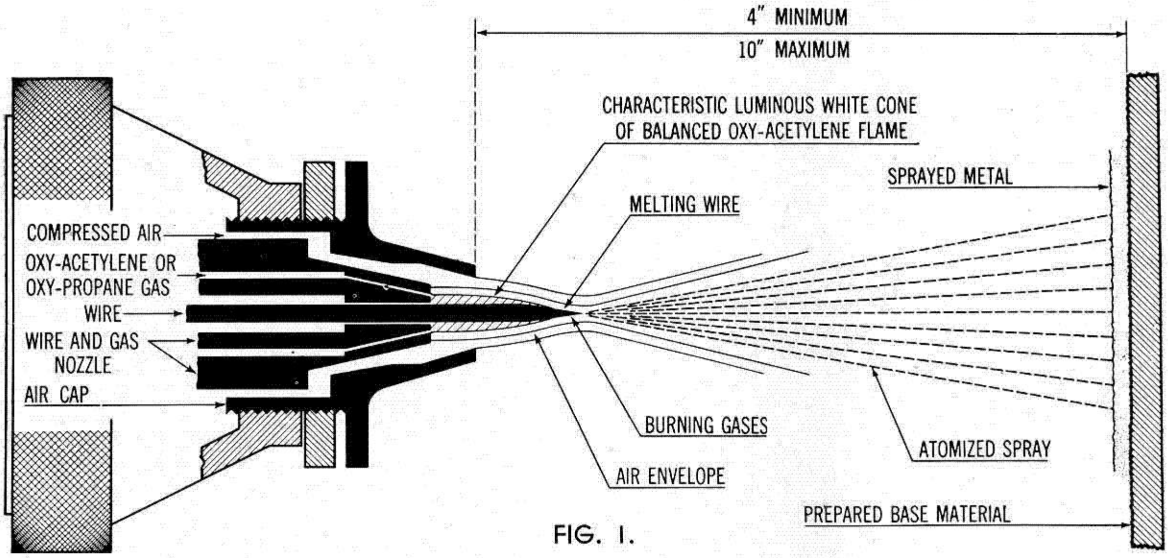


FIG. 1.

THE METALLIZING PROCESS

By HERBERT S. INGHAM

THE metallizing process has reached its maturity as an established industry. Fortunately, there was a long period of industrial development before the present war, so that well-established metallizing methods were available for the tooling up period in industry's war effort. Now, in the second phase of the war, metallizing is particularly active in maintaining the tools of war.

The metallizing process was invented by Schoop before the last war, and introduced into this country about 1920. In the last 24 years, it has become so interwoven with our national industrial life that it deserves the attention of engineers in almost every field. This is particularly true at the present time, as it gives to the engineering profession a new tool and a new material for the construction of postwar products.

The metallizing gun is being used today predominantly as a maintenance tool for repair and rebuilding of machinery. It is also being used to a greater extent than ever in the manufacture of new products, particularly as a means of producing new corrosion resistant materials. There are so many uses already developed for metallizing in the production of new products, that the handwriting on the wall of postwar activity is quite evident.

DESCRIPTION OF THE PROCESS

Metallizing is the process of melting metal and propelling it in finely divided form against an object to be coated. A number of different types of equipment have been developed to perform this process. According to the equipment used, the metal may be supplied in the form of either wire or powder, and may be melted by either an electric arc or any oxy-acetylene flame. The most practical metallizing guns today use metal supplied in the form of wire and utilize a flame for melting the metal. The flame is usually an oxy-acetylene flame, but other gases may be used in place of acetylene, such as propane, hydrogen, coal gas, etc.

Metallizing guns of this type consist of two major parts. The body of the gun constitutes the wire feeding mechanism which conveys the wire to the melting zone. The power is supplied by a high-speed air turbine which drives the wire feed rolls through a train of gears. The most modern equipment of this type has a variable speed governor built into the housing with the turbine. This type of equipment will provide a speed regulation of closer than five per cent from no load to full load over a wire speed range of from two and one-half to 12 and one-half feet per minute.

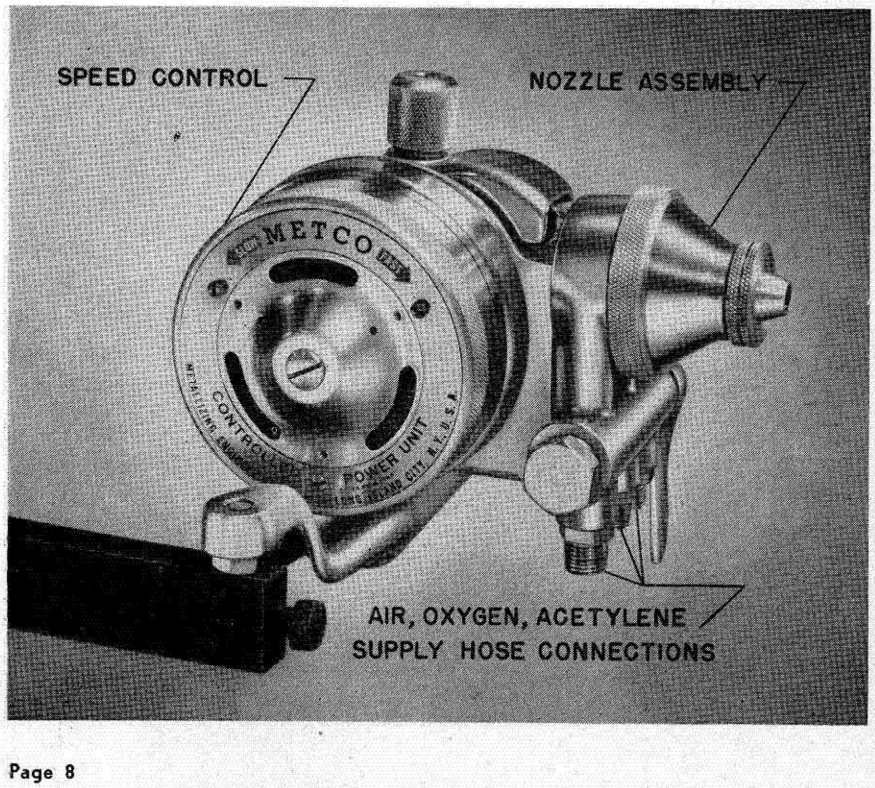


FIG. 2. Production type metallizing gun.

The melting and atomizing of the metal takes place in front of the nozzles, which are mounted on the gas head. *Fig. 1* shows the nozzle and air cap construction in cross-section. The wire is fed through the central hole of the wire nozzle. The combustible gas mixture emerges from a series of holes around the wire, producing a cone of hot, relatively inert, gases extending beyond the tip of the wire. Compressed air emerges from the space between the wire nozzle and the air cap, compressing the hot gases onto the wire tip at a high velocity so as to finely divide the molten metal and propel it from the gun.

Modern guns of this type spray any metal at high capacity and run in production, giving good continuous service. Many such guns, equipped with the governor speed control, are in operation today on automatic machines operating 24 hours per day. These guns will melt some steels at rates as high as 12 pounds per hour, and zinc at approximately 30 pounds per hour.

Fig. 2 illustrates a production type metallizing gun. A complete installation for metallizing must include, in addition to the gun, air compression equipment, suitable air cleaning and regulating equipment, accurate oxygen and gas regulators, and suitable wire handling equipment for coiled metal wire.

STRUCTURE OF SPRAYMETAL

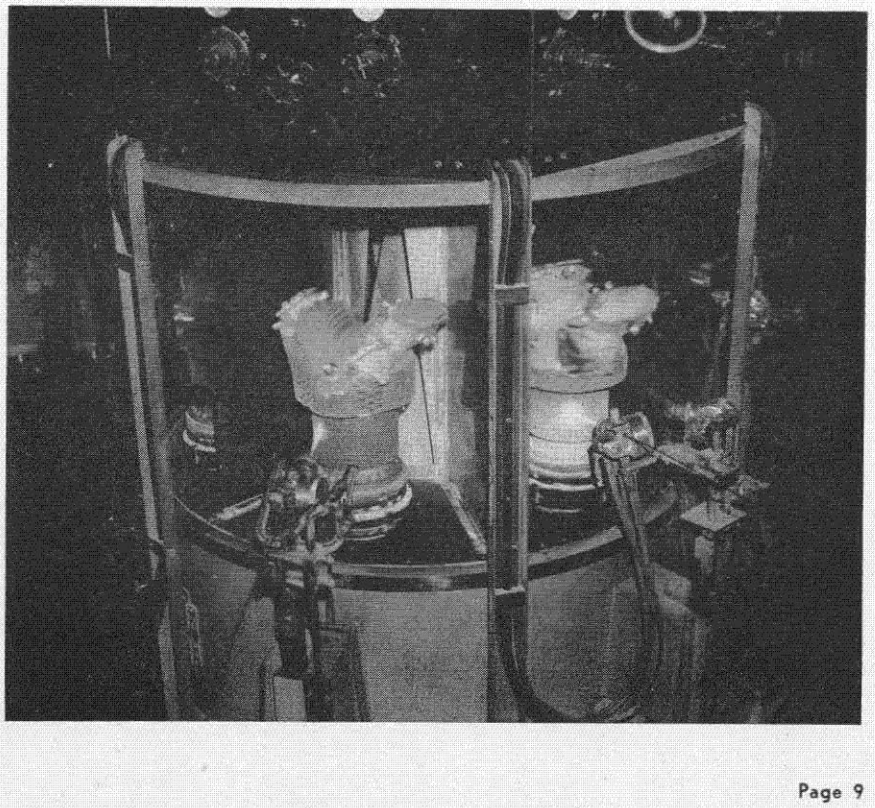
Spraymetal is the metal produced as the result of the metal spraying operation. It is chemically and physically different from the original wire sprayed. Considerable emphasis is required on this point, as spraymetal is a new engineering material. A good many mistakes in the past have been due to the misconception that spraymetal will have physical characteristics corresponding to the metal sprayed. This has led to the specification of wire analysis, for instance, which would have been suitable in the original state, but which, when sprayed, produced a spraymetal that proved unsuitable. Conversely, many of the desirable characteristics of spraymetal that do not exist in the original metal in wire form have been overlooked.

The conditions under which the metal is sprayed with modern equipment are subject to complete control. Therefore, spraymetal can be controlled and standardized. Entirely different structures can be obtained, using the same wire under different or abnormal spraying conditions.

The structure of normal spraymetal results from spraying under normal conditions such as would be normally obtained in a manufacturing or repair shop. This normal spraying, for instance, is thought of as a cold process because the work sprayed does not normally become appreciably heated. Also, for instance, normal spraying uses air as an atomizing medium. Therefore, normal spraying is the practical operation as it is carried out in the present practice of the process industrially. There are some theoretical refinements which can produce far different results in the laboratory, but which, at the present time, defeat the general purpose and utility in commercial metallizing.

AT RIGHT:

FIG. 4 Automatic metallizing machine for aircraft engine cylinders.



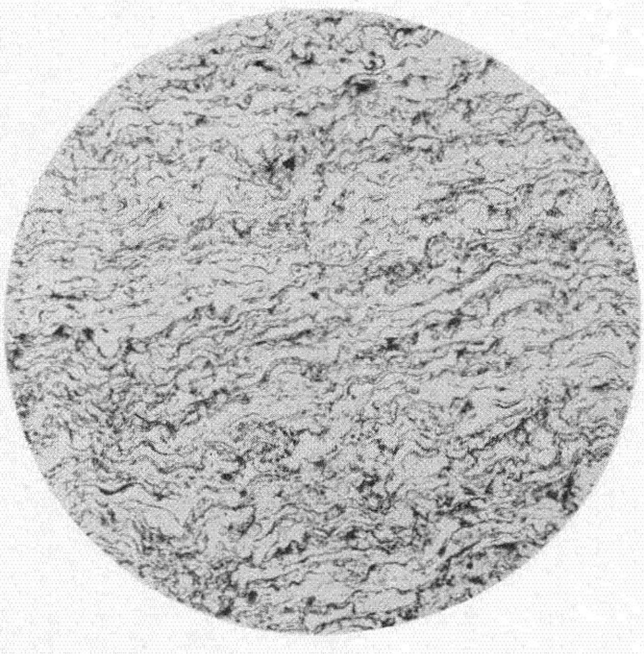


FIG. 3. Photomicrograph of normal spraymetal (100X).

Normal spraymetal has a structure made up of a great many layers of small scale-like particles which overlap and interlock with each other. These scales generally are parallel to the surface sprayed, although they are very irregular. A typical spraymetal structure is shown in *Fig. 3*. This is a photomicrograph, at a magnification of 100X, of a cross-section of stainless steel syraymetal polished and etched. The structure is dependent for its strength largely upon a mechanical interlock of the particles, but in addition to the mechanical interlock, there is a certain amount of localized fusing or welding between particles.

The physical properties of spraymetal follow the same general pattern as the physical properties of the wire

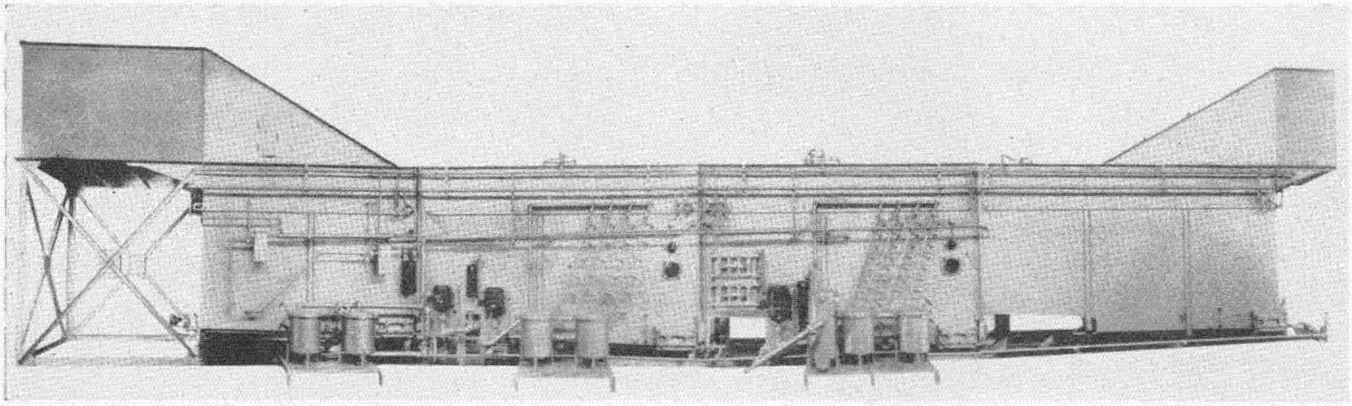


FIG. 5. Vapor spray-type degreaser metallized for corrosion resistance.

sprayed but certain general changes take place. The tensile strength and elongation are considerably reduced. The hardness of such soft metals as tin and babbitt increases considerably. The hardness of steels corresponds roughly to the hardness that would be produced in the same steel by rapid quenching. This hardness results in the spraying operation without requiring a separate treatment. However, as the structure is porous, ordinary hardness testing methods will indicate lower hardnesses. The actual hardness of the particles can be checked either by wear tests or by the micro-hardness testing method. As the structure is somewhat porous, the density is reduced by about 10 per cent. All normal sprayed metal has a certain oxide content. This oxide content tends to increase the brittleness, increase the hardness, and in some cases, as in sprayed aluminum, to increase the corrosion resistance.

It is, therefore, evident that the properties of each spraymetal must be evaluated in terms of its particular use. For instance, coatings for corrosion resistance generally are improved by their oxide content, but being porous, metals which are anodic to the base metal generally are used. For withstanding wear on a machine element, the porosity of the spraymetal structure becomes very important because of the ability of spraymetal to absorb oil. There are special uses for spraymetal, as in the manufacture of electrolytic condensers, where the peculiar porous structure is particularly important since it is responsible for the very large total area of effective condenser surface.

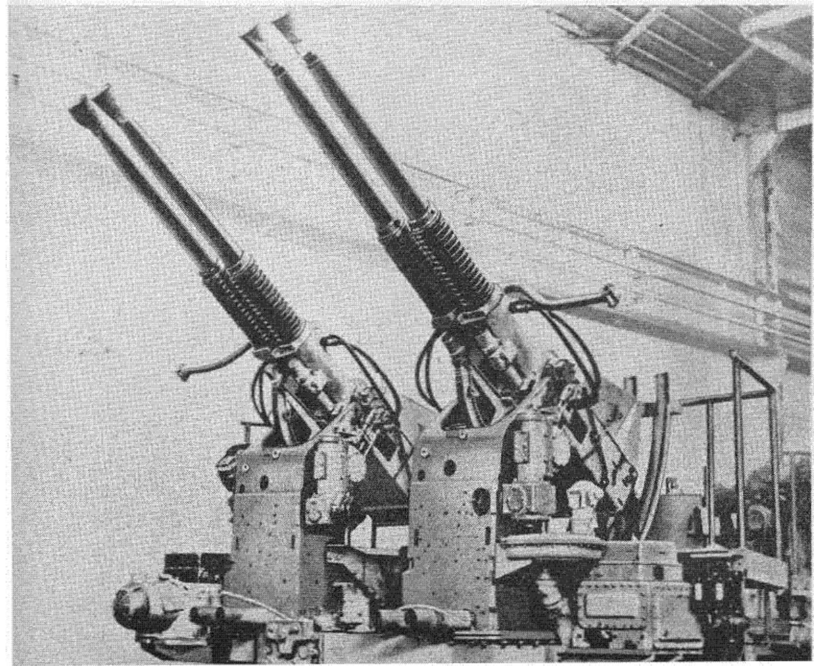
Abnormal spraymetal structures are too varied and not sufficiently important for much discussion here. The gas, oxygen and air pressures, the air cap adjustment and wire speed adjustment affect the resulting spraymetal. These factors are not too critical for average shop practice. One very interesting factor that affects the structure of spraymetal is the mechanical method by which it is formed. In this respect, it differs from all other metals. The structure will vary considerably, for instance, if the metal is sprayed from the gun at a work piece at too oblique an angle. By spraying very nearly parallel to the surface being coated, a very rough and porous structure can be produced. This is due to what is known as the shadow effect. The first particles striking form shadows behind them, which result in large open pores. As in all new materials and processes, an understanding of such fundamentals helps in the application.

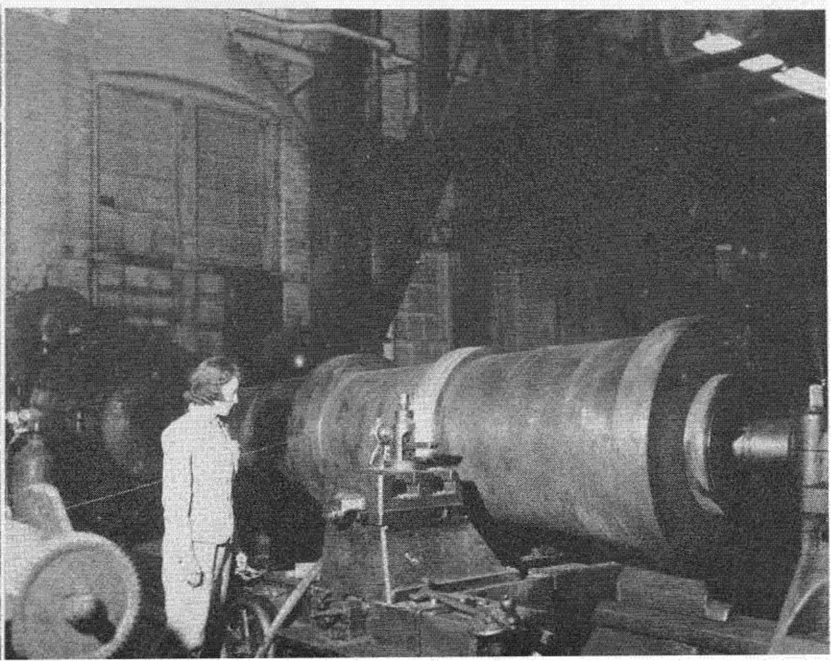
Spraymetal is sometimes heat-treated after application to the base metal. This is quite a common practice in the application of heat corrosion resistant coatings. Where the coatings are heat-treated, the resulting spraymetal structures are changed very considerably. In some cases the coatings alloy with the base or with other coatings, and in some cases the general scale-like structure disappears entirely, leaving coatings that have the pores isolated so that the coatings themselves are impervious to gases.

NATURE OF BOND OF COATINGS

Spraymetal is bonded to the base on which it is sprayed

AT LEFT: FIG. 6. "Bofors Twin" Navy gun which uses metallized cast iron for gear shroud in place of bronze. AT RIGHT: FIG. 7. Salvaging a 60,000-pound chill mold with 50 pounds of spraymetal.





either by mechanical adhesion or by alloying or both. Mechanical adhesion is used for the vast majority of commercial applications. The base metal to be sprayed usually is first prepared by mechanical roughening. The roughness produced must be of a type that has a great many overhanging edges and keyways so as to provide anchorage for the spraymetal. Grit blasting with angular steel grit or with aluminum oxide abrasives is commonly used. Articles such as soft steel shafting may be satisfactorily roughened by tearing a broken thread on the surface in machining. For the strongest bond on machine elements, a method of grooving and treating with a rotary tool has been developed. The tool roughens and spreads the lands between the grooves so that after the metal is sprayed it is locked into the machine element by a true dovetail type of joint.

A new method for bonding sprayed metal has recently been developed. This is a patented method known as the "fuse-bond process." It is suitable for preparing hardened smooth surfaces as well as soft surfaces prior to metallizing. A low-voltage, high-amperage source of current is connected to the work piece and to an air-cooled electrode holder which holds about six nickel-alloy electrodes. The electrodes are stroked or brushed across the work piece and the current which flows produces sufficient heat to form a foam or froth of electrode metal fused to the base metal. Viewed with suitable magnification, the deposit appears like frozen soap bubbles or lava. This surface produces a great many craters and interlocks for the sprayed metal so that a uniformly strong bond results.

The use of alloying between the coating and the base for bonding is, at present, restricted commercially almost entirely to coatings for heat corrosion resistance. In this application the grit blasting method is used to obtain sufficient bond for the coating to adhere before heat-treatment.

USE FOR CORROSION RESISTANCE

One of the primary uses for metallizing is to prevent corrosion. As the coatings are generally porous, aluminum, cadmium or zinc usually is used for protecting iron or steel, as these metals are anodic to iron. Occasionally metals such as lead or tin, which are cathodic to iron, are used. In such cases, it is necessary that the coatings either be sufficiently thick that they are impervious to the penetration of liquids, or be made non-porous by other treatment. Lead may be made non-porous by wire brushing between coatings. Other metals may be made non-porous in some cases by the application of lacquers or other finishes.

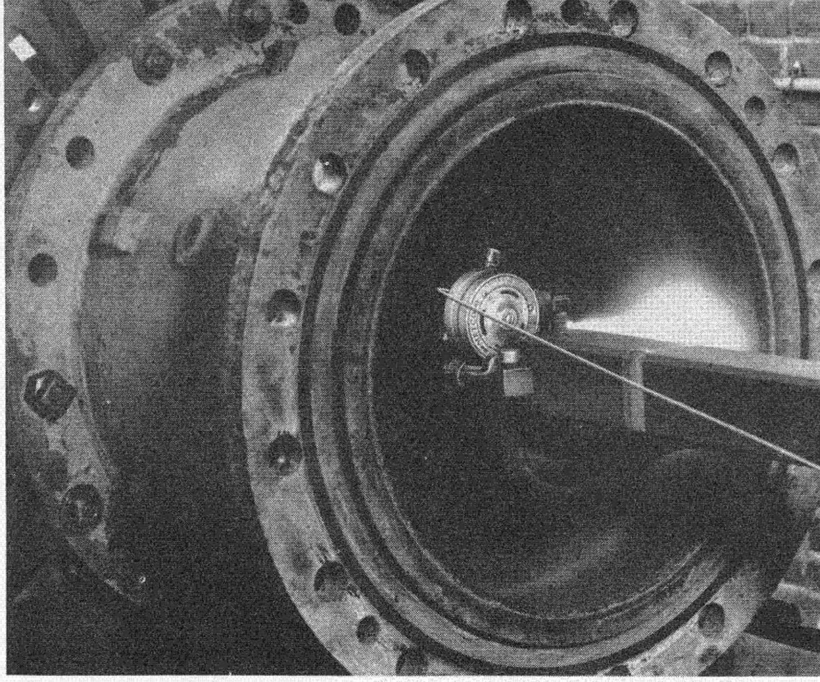


FIG. 8. Rebuilding the bore of a steam cylinder.

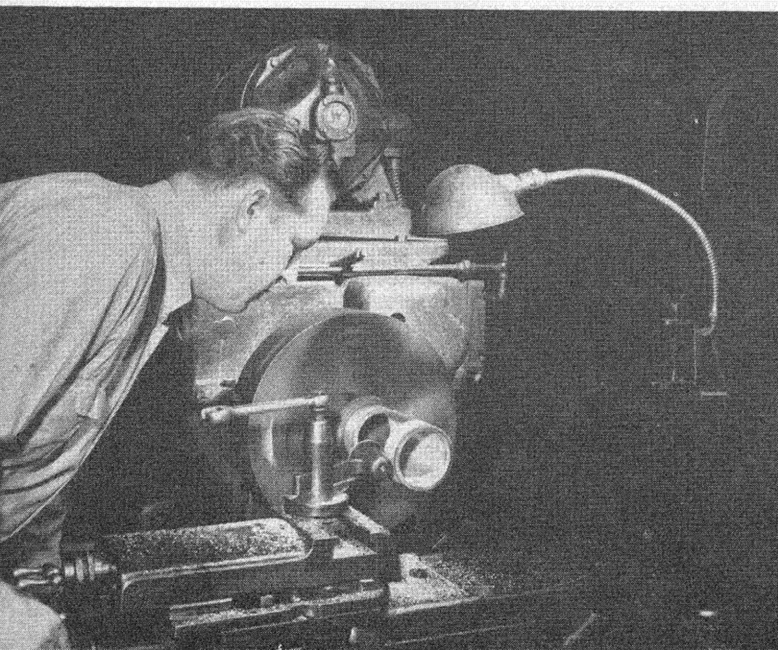
There has been a great increase in the use of metallizing as an undercoat for paint or other organic finishes. Zinc or aluminum is commonly used for this application, and these metals form an excellent base for paint.

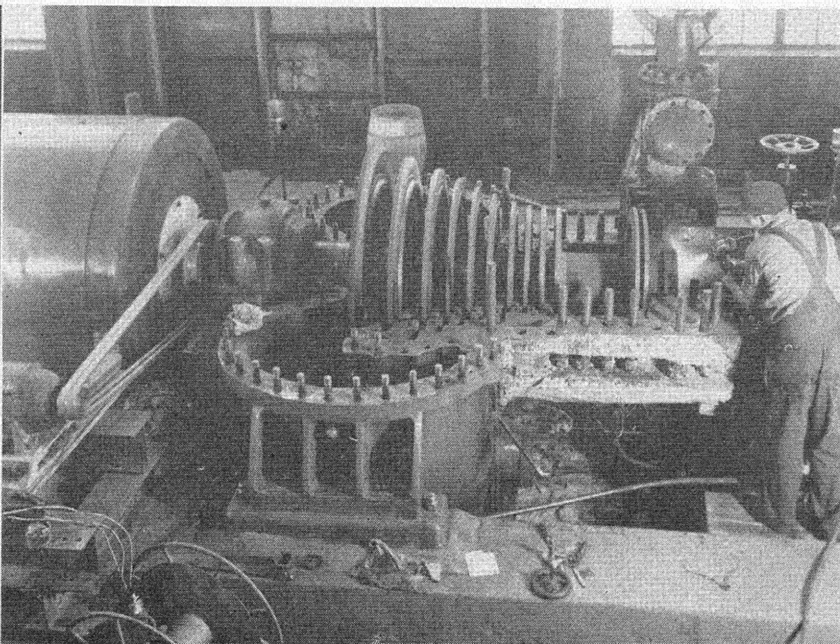
The requirements of the war program have vastly increased the use of metallizing to prevent heat corrosion. A series of new coatings known as "metcolized" coatings has been developed for this purpose. These new processes involve the use of aluminum in combination with nickel-chromium alloys. They have made possible the use in industry of mild steel melting and heat-treating vessels in place of nickel and chrome alloy vessels.

Typical uses of metallizing for corrosion resistance are illustrated in *Figs. 4 to 6*. *Fig. 4* shows an air-cooled aircraft engine cylinder being sprayed with aluminum. This work is done on many automatic machines which employ seven metallizing guns per machine. *Fig. 5* shows a 90-foot long vapor spray type degreaser which has been metallized for corrosion resistance. It is used in an automotive plant where the shop conveyor travels right through the degreaser. *Fig. 6* shows the mighty Bofors Quad. The cast iron gear shroud for the Bofors Twin, formerly made of bronze, is protected against corrosion with sprayed zinc.

(Continued on Page 15)

AT LEFT: FIG. 9. Machine preparation of an armature bearing prior to metallizing. AT RIGHT: FIG. 10. Turbine shaft being built up to size without being removed from the turbine housing.





Metallizing

(Continued from Page 11)

USES FOR MACHINE ELEMENT WORK

The largest single use for metallizing today is for machine element work. This includes maintenance and repair and also includes salvage of mis-machined parts. The metal to be sprayed in each case is selected for the physical properties of the spraymetal which will be produced. Because of the excellent wearing qualities of the spraymetal, it is used most extensively on bearing surfaces. The machine element is first prepared, usually by some form of roughening, and then sprayed to a larger size than the finished size. Spraymetal may then be machined or ground.

Typical uses of metallizing for this type of work are illustrated in *Figs. 7 to 10.* In Fig. 7 is shown the salvaging of a 60,000-pound chill mold with 50 pounds of spraymetal. In *Fig. 8* a steam cylinder is being metallized with iron to restore the bore to its original size. In *Fig. 9* an armature bearing is being prepared for metallizing. After this preparation, spraymetal will be applied, and then finished to size. Many scrap piles are being redeemed in this manner. *Fig. 10* shows how metallizing is being used to make repairs on the job without complete dismantling. The steam turbine shaft is being built up to size at the packing area where it was badly pitted. A portable grinder was installed on a bracket for the final finishing of the journal.

USE FOR NEW PRODUCTS

Spraymetal as a new material offers many new possibilities because of its various and unusual properties. It will be used much more extensively in the future for corrosion resistance on newly manufactured articles. Its recent rapid expansion in the field of tumbling barrel coating of small articles indicates this trend. Its use for inlay of such metals as stainless steel on shaft sections has increased rapidly in recent years. It is being used, for instance, on turbine shafts in several standard makes of steam turbines at the packing ring section. Metallizing will be used very extensively in the future on newly manufactured articles for bearing surfaces, such as crank shafts, because of its superior wear qualities and oil retention feature. Metallizing is being used extensively for the manufacture of carbon brushes and resistors to provide a means of soldering to the carbon. It is being used for the manufacture of electrolytic condensers, the condenser plate being manufactured from cloth tape on automatic metallizing machines. Glass is metallized with copper in production to permit soldering to the glass for sealing purposes, as on gas meter windows. Glass reflectors are being manufactured with reflecting surfaces of sprayed aluminum.

FUTURE OF METALLIZING

The future of the metallizing process lies in two obvious directions. One is the further technical development of the process itself, and the other is the expansion in uses of the process. It is only natural that today the development of the process is ahead of the uses. This is always the case with a relatively new development. Specific applications have brought about the development of metallizing equipment and processes, and this same equipment with the same processes is suitable and available for many other uses that have yet to be found.

It is probably safe to predict, therefore, that the most immediate postwar trend will be the vast expansion of the uses of the present process, while the technical development continues for use in future years.

The biggest increase in use probably will be for bearing surfaces. Another big expansion in use will be for corrosion resistance, particularly on small products produced by production methods, as by tumbling barrel spraying. Metallizing structures such as metal window sash and metal furniture, as an undercoat for paint, will, no doubt, increase very rapidly. The biggest future uses, however, are doubtless among those that have yet to be discovered. New applications are increasing rapidly as the engineering profession appreciates more and more that spraymetal is truly a material with a future.

STATESMANSHIP

By ROBERT A. MILLIKAN*

A YEAR ago a group of some 400 men, quite similar to this group, had completed training in meteorology in U.C.L.A. and C.I.T., just as you now have done, and were then assembled to receive their commissions in the Air Corps.

At that time I chose to address them not in their capacity as soldiers, but rather as citizens of the United States. I shall do the same again to you today, for while we hope that it will be only for a very short time that you will be doing your duty as officers in the United States Army, for the next half century you will be playing a vital role, I hope, in what I expect to be the most critical peacetime period in the history of the world—a period in which we Americans have it in our power largely to determine whether mankind can find a substitute for war and therefore can usher in for the world a period of lasting peace.

That issue will depend, first, upon our will to peace, and, second, upon the kind of statesmanship developed in the United States. That statesmanship will be but a composite of the statesmanship of you voting citizens of this country. You men who are before me today can be vital factors in the determination of the quality of that statesmanship. Your service along side British and other Allied troops will open your own eyes to international situations and to the stupendous need now and in the future of international cooperation, and in particular Anglo-American cooperation.

Let me first try to give you as clear and full an idea as I can of what I mean by statesmanship. Walter Lippmann is generally considered America's foremost political analyst and commentator. According to a recent, and I think a dependable, poll his syndicated column extends its educating influence at its every appearance over some three million American citizens.

One of his recent most penetrating observations was to the effect that the real progressives, the constructive men who alone deserve to be called forward-looking liberals, are in general not found either on the extreme left, which presumes to call itself liberal, or the extreme right, though even Hitler calls himself a democrat, Nazi meaning "National Socialist." Progress actually finds its source and gains its strength in the main not from the left or the right, but from the center.

This is no new discovery. The Greek philosophers knew it when they coined the phrase "the golden mean." The wise men of Rome expressed their approval in the slogan *"Ne Nimium."*

The reason why neither radicals nor reactionaries—extremists on either the left wing or the right—in general are not effective progressive leaders is quite clear. It is because these two groups are very much alike in the

*Address June 5, 1944, at the exercises commissioning Aviation Cadets in Meteorology from the Army Air Forces Base Units at the California Institute of Technology and the University of California at Los Angeles.