NASF SURFACE TECHNOLOGY WHITE PAPERS
86 (3), 9-14 (December 2021)

Military Applications of Electroplating

by
*Dr. William Blum**

Technical Editor's Note: *The paper begins with introductory remarks by Chairman Maurice R. Caldwell.*

Chairman Caldwell: We will follow right through and have Dr. Blum's paper. Dr. Blum, I am sure, needs no introduction . . . Dr. Blum.

Dr. William Blum (U. S. Department of Commerce, National Bureau of Standards, Washington, D. C.) : Mr. Chairman, Members of the American Electroplaters' Society:

My speech was also censored, but I cannot read a paper. I am not sure whether I know how to read. What I have to say officially is in the record that Miss Marquardt has, and anything else you hear, I did not say.

I. Introduction

The purpose of this paper is to summarize typical important military applications of electroplating. It is based largely upon a list compiled by W.W. McCord and the author, and published in the *A.E.S. Review* for March, 1942. However, since the preparation of that list, the situation has changed with respect to certain metals, especially nickel and tin.

No effort will be made to discuss all the items on that list or to give detailed specifications. Many of these uses are still in the experimental stage, and subject to the restrictions of military developments and metal shortages. It is hoped that the compilation and distribution of this information will be advantageous to the military departments and to the electroplating industry. The unprecedented scale of the present war has brought about shortages of many metals normally employed in the construction and coating of articles for both civilian and military use. The consequent curtailment of many industries has caused a great reduction in the use of electroplating. Efforts are being made by the War Production Board to foster the application of existing plating facilities and personnel to meet essential military needs.

II. The Metal Situation

The present shortage of metals affects their military as well as their civilian uses. The supplies of nickel, copper, tin, lead, zinc, cadmium and chromium are so limited that for each metal it is necessary to meet in sequence, (a) the most critical military uses, (b) the less critical military needs, (c) essential civilian requirements, and finally, if any metal remains, (d) the normal civilian uses. As was predicted in my address last year (published in the *AES Review* for July 1941), the necessary changes in the base metals have brought about certain increased uses of plating. Plain carbon steel has been extensively substituted for aluminum, brass, nickel-brass (nickel-silver), zinc-base die-castings and stainless steel. In practically all these applications, the steel must be protected against corrosion. For such protection, plated metal coatings have certain advantages. For example, their thickness can usually be controlled more closely than by hot-dipping, and strategic coating metals can thereby be conserved. A good illustration is the increased use of tin plated steel as a substitute for hot-dipped tin-plate.

At present, almost the only metals used in plating that are not abnormally scarce are silver and gold. The supplies of chromium, zinc and lead are less critical than those of nickel and copper, but are subject to restrictions. From certain examples to be cited, it is evident that for the less critical military requirements, expediency demands that plated products be used that may not be entirely satisfactory. In each case it is necessary to select the best products that can be made from the available materials, in the hope that they will prove fairly serviceable. The specifications are subject to frequent revision in the light of experience. Persons who expect to engage in this type of plating, usually through primary military contractors, must therefore be sure to obtain the latest pertinent specifications.

* Chemist, National Bureau of Standards.

III. Ordnance

1. Guns

(a) Gun barrels
Chromium plating has been used for years to increase the wear resistance of the rifling on gun barrels. It is now being applied successfully to the interior of large-caliber guns, but has not thus far found much application to small-caliber guns such as machine-guns.

In certain cases, chromium is being plated on the outside of water-jacketed guns to protect them against corrosion. Nickel would probably be equally effective but is less available and less easily applied than chromium.

(b) Gun mounts
Chromium plating has proved very satisfactory on rollers and circles of gun mounts to protect them against both corrosion and wear.

(c) Building-up
A minor but often very important use of plating on guns is to bring up to dimensions some part of a large casting or forging. When the latter is of such shape or size that it can be conveniently handled, chromium, nickel or iron may be applied. Practically, it is often more convenient to deposit copper from a cyanide bath, which has a cleaning action on the steel, and does not corrode the latter where it may be splashed.

2. Ammunition

(a) Steel cartridge cases
The present shortage of copper and zinc arises largely from the enormous consumption of brass in the manufacture of cartridge cases. Steel cartridge cases were made by U. S. arsenals during the last war, but were not manufactured in quantity till 1941 . In the large-scale tests now in progress in this country on the production and use of steel cartridge cases, two applications of electroplating are involved. Copper is usually plated on the steel blanks to furnish "lubrication" of the drawing dies. To protect the outside against corrosion, plated coatings of copper, zinc, or brass may be used. If any of these plated coatings proves satisfactory for this purpose it will result in very extensive demands upon existing plating equipment and personnel. The amounts of copper or zinc thereby used in plating represent a very small proportion of what would otherwise be used to manufacture the cases from brass.

(b) Deposited copper driving-bands
Experiments are now in progress upon the deposition of copper driving bands on steel shells, instead of using the swaged bands made from copper tubing. The latter type of band involves grooving and possible weakening of the steel shell. Electrodeposition of the copper without grooving would reduce the consumption of copper and possibly strengthen the shell. Because the copper band may have to be as thick as 0.035 inch, high current densities will be very desirable in order to reduce the time of deposition. If this method of producing driving bands is adopted, it will also demand very extensive plating facilities.

(c) Fuse parts
Practically all the steel parts of fuses must be plated to protect them against corrosion. Cadmium plating is most commonly specified, because of its good protection against marine exposure, and because the cadmium coatings are usually very smooth and therefore more readily meet the close dimensional tolerances. Because the present and prospective supplies of cadmium are not adequate for all military requirements, it is probable that zinc plating may be accepted for the less critical fuse parts.

(d) Ammunition containers
A large proportion of the loaded ammunition must be shipped in sealed metallic containers to exclude moisture. For this purpose, steel sheets preplated with zinc, copper or lead may be used. The zinc furnishes the best protection against corrosion, the copper is most easily soldered, and the lead most easily painted. Bonderized painted steel may also be used.

3. Tanks

Because of the sturdy construction of armored tanks, little application is made of protective metallic coatings. When rubber treads were employed, the steel tracks were usually brass plated to increase the adhesion of the rubber.

IV. Aeronautics

Because of the weight economy and consequent low factors of safety on aircraft, prevention of corrosion is very important. Resistance to wear of moving parts is also essential. Electroplated coatings have found many applications for both purposes.

1. The Power Plant

(a) Engine parts
The extreme hardness of deposited chromium naturally led to many efforts to use it to reduce wear on moving parts. It was then found that under certain conditions the chromium coating reduced the fatigue resistance of the steel and caused structural cracks and failures of stressed parts. While this adverse effect of chromium is somewhat reduced by the use of relatively low current densities of deposition, it is not desirable to apply chromium coatings to engine parts that are highly stressed. There are therefore not many present applications of chromium on the aircraft engines.

It has been reported that nickel plating is used abroad on certain parts of aircraft engines to insure close fit of stationary members. The moderate hardness and ductility of nickel probably account for this use.

On those aircraft parts that are to be selectively hardened, copper plating is used to protect against case-hardening and tin plating against nitriding.

One of the most interesting applications of plating is upon aircraft bearings. In certain cases, a relatively thick silver coating is applied, followed by a layer of lead and a very thin film of indium. When the composite coating is heated, the indium alloys with the lead to form a surface layer that resists attack by the lubricants. For certain bearings, lead plating alone is applied, which is especially useful during the run-in period.

Many of the manifolds are now made of heat-resistant alloys containing nickel and chromium. Use of plain steel with thick nickel coatings has been suggested as a means of conserving nickel. Nickel, chromium and iron plating are sometimes used to salvage worn or undersized parts of aircraft.

(b) Propellers
When chromium was applied to steel propeller blades to protect them against abrasion, some failures were attributed to the embrittling effect of the chromium, especially on the edges, where the current density is highest during the plating. Nickel plating may prove more effective, even though it is not as hard as the chromium.

2. Aircraft Fittings

(a) Brass and steel parts
In order to prevent accelerated corrosion of aluminum that may come into contact with brass or steel parts, the latter are usually plated with cadmium. A zinc coating would furnish even more protection to the aluminum, but is itself more subject to corrosion in such a combination, and hence does not last as long as the cadmium.

When the only requirement is the protection of steel against corrosion, cadmium coatings are preferred, especially for marine exposure. Here again, scarcity of cadmium may necessitate the use of zinc coatings (which in a marine climate are fully equal to cadmium) or of phosphate-treated and painted coatings on less critical steel parts.

(b) Aluminum parts
Electroplating has not been applied to any appreciable extent upon aluminum aircraft parts. These are commonly anodized in either chromic acid or sulfuric acid. The latter process may be carried out with plating equipment, including the 12-vo!t generators.

(c) Magnesium alloys
While it is possible to plate nickel upon magnesium, the coatings do not furnish good protection against corrosion. Both chemical and electrochemical treatments are employed to produce protective coatings on magnesium alloys.

V. Marine Construction

1. Marine Fittings

The widespread use of hot galvanized coatings on iron and steel parts of ships is based on the good protection furnished by zinc against salt-water corrosion of steel. The necessity of substituting steel for brass on many marine fittings has increased the use of zinc coatings. In certain cases, where very thick coatings are not required, zinc plating has been substituted for hot galvanizing in order to save zinc.

2. Marine Engines

Chromium plating the cylinder liners on marine engines has been found advantageous. The process in which the surface of the chromium is anodically etched to produce a porous surface is reported to be especially suitable for this purpose.

VI. Illumination

Preparation of reflecting surfaces by electroplating permits the application of various metals with the desired optical and chemical properties. Silver has the highest reflectivity (about 95%) in the range of visible light, but is subject to tarnish, especially in an atmosphere containing sulfur compounds. Its use is therefore limited to sealed reflectors or protected reflecting surfaces. The use of baked synthetic lacquers to protect the silver against tarnish is being investigated.

Rhodium has a reflectivity of about 75% and is resistant to sulfur tarnish. In spite of its high cost (about $125 per troy oz.) thin rhodium coatings are extensively applied to searchlight reflectors.

Chromium, with a reflectivity of about 65%, is sometimes used on floodlight reflectors. To obtain adequate protection of the underlying steel against corrosion, it would be desirable to apply nickel under the chromium. As the present nickel shortage prevents this use, the steel reflectors are likely to be plated with copper, and then with either silver or chromium.

Preplated steel or brass sheets may be used as flat mirrors, for example, in camps and ward rooms, or for rear-vision on airplanes. Chromium coatings are usually satisfactory.
One very important application of electrodeposition is the electroforming of large searchlight reflectors. This process was devised in 1898 by Sherard Cowper-Coles, and has been developed in recent years by the Bart Reflector Co. By this method, 60-inch reflectors are reproduced, largely by copper deposition, and are finally plated with rhodium. Production of such reflectors by iron deposition is under investigation.

VII. Communications

The military applications of radio, telephone and other signaling equipment involve the use of the same types of plated coating as are employed on similar civilian equipment. The shortages of nickel and cadmium have necessitated substitutions of copper and zinc coatings on many of these parts.

VIII. Attire and Personnel Equipment

With normal metal supplies, brass was always used for buttons, buckles and insignia on uniforms, and for gas-mask fittings. The "coloring" of the brass, *e.g.*, by black nickel plating, usually followed by lacquering, was done chiefly for appearance, because brass is resistant to corrosion. The necessary substitution of steel for such parts has involved the use of coatings which will furnish protection against corrosion under severe conditions, including the laundering and sterilization of the clothing. Chemical treatments are used to produce phosphate or oxide coatings which increase the adherence of the lacquer coatings. Thus far, plated coatings have not been extensively applied to this type of equipment.

IX. Mess Equipment

Aluminum and stainless steel are the preferred metals for cooking utensils and tableware but are not available for this purpose. The efforts to replace these metals with plated steel have been handicapped not only by the shortage of certain metals (especially nickel), but also by the rapid changes in their availability. Specifications have been changed to meet new conditions before there was an opportunity to thoroughly test the preceding requirements, much less the new proposals. Many of the latter involve untried combinations, or procedures that are admittedly inferior but are the best available at the time.

1. Tableware

The use of plain-carbon steel instead of the customary nickel-silver for flatware introduced many new problems of corrosion. Experience with plated steel auto parts showed that good protection can be obtained with about 0.001 inch of copper plus nickel, followed by a thin chromium coating. Some tableware of this type was produced for military use until the shortage of nickel prevented.

Experience with hot-tinned or tin-plated steel tableware shows that the process can be cheaply applied and that the products yield fair service. The present shortage of tin has precluded this use on a large scale.

As previously indicated, silver is one of the few metals now available. Long experience with silver-plated steel knife blades and handles shows that fair service may be obtained, even though corrosion of any exposed steel is accelerated by the silver. Such articles do not usually have a life equal to that of companion pieces consisting of silver-plated nickel-silver. Accelerated tests indicate that even a thin layer of nickel prior to the silver will increase the corrosion resistance, but nickel is not available for this purpose. Present plans therefore call for a relatively thick silver coating directly on the steel, or over a copper flash.

One difficulty in predicting the serviceability of such equipment under severe conditions is the lack of an accelerated test that will yield significant results in a short period. The salt spray test, which is most extensively employed, is a measure of the porosity of noble-metal coatings on steel. If pores are thereby detected, it merely shows that at such points the steel is subject to corrosion, but does not indicate whether such corrosion will occur rapidly in some other environment, or whether the products of corrosion will be extensive or objectionable. Conversely, if pores are absent, it still must be determined whether in service the metal coating will be rapidly attacked or abraded, with consequent exposure of the steel.

Other porosity tests such as the ferroxyl, boiling-water, and moisture-condensation tests are apparently not more conclusive than the salt spray. It is planned at present to eliminate the salt spray and other accelerated tests from the specifications, but to make sufficient tests on delivered equipment to determine whether any correlation exists between these results and those of actual service.

The same considerations apply to the plating of steel mess trays and mess kits, with the additional facts that a silver coating is relatively soft, and its cost would be prohibitive on the large areas involved. To prevent scratching by the cutlery, it is proposed to apply a relatively thick chromium coating (*e.g.*, 0.00015 inch) directly on the steel. Such coatings are somewhat porous and not as protective as if a nickel layer were also present, but they deserve a trial in service.

2. Cooking utensils

It is difficult to produce adequately protective plated coatings on steel cooking utensils without the use of nickel. Available information on chromium coatings directly over steel or over copper on steel indicates that they are unlikely to protect against corrosion by the food constituents, including salt and organic acids. Steel heavily plated with copper and silver may be fairly satisfactory but would be expensive for large vessels. In certain cases, enameled utensils may be used, and in other cases uncoated steel or cast iron, which will be cleaned of rust at intervals.

X. Medical Supplies

Under normal conditions, steel surgical and dental instruments are plated with nickel (about 0.0005 inch) and chromium (about 0.00002 inch). Such instruments usually yield good service under severe conditions, including frequent sterilization, and occasional contact with corrosive compounds.

The shortage of nickel and the W.P.B. order against any civilian nickel plating raised the question as to whether silver-plated surgical instruments might be employed for both military and civilian use. The considerations are similar to those involved in silver-plated tableware, but are complicated by the very severe conditions in using surgical instruments, and the importance of having them at all times in practically perfect condition. Many dental instruments come into contact with amalgams, which are likely to attack silver; and with phosphoric acid (in cements), which will rapidly attack any exposed steel. Tests are now in progress to determine to what extent the nickel plating of surgical instruments is essential to their proper performance. Even with the great demands for nickel it may be found necessary to allocate to this industry at least a part of the small amount of nickel (about 3000 lb. per month) normally used in plating surgical and dental instruments.

XI. Miscellaneous Applications of Plating

To the extent that cantonments, hangars, dwellings and munitions plants are built by or for the government, hardware and plumbing and lighting fixtures will be required. These supplies will be subject to about the same restrictions as those for civilian consumption. In general, steel or cast iron will be used extensively in place of brass. Zinc plating the steel will be adequate for many purposes. The net result will be to utilize at least a small part of the normal plating facilities of the above industries.

It is probable that a fair proportion of the existing plating facilities and personnel can be employed in the production of military supplies, including munitions and other essential equipment. Some of these uses will involve little or no change in plating equipment or methods, while others may require radical conversion. Just as with other industries, the survival of the plating industry will depend upon its ability to meet essential military and civilian needs.