

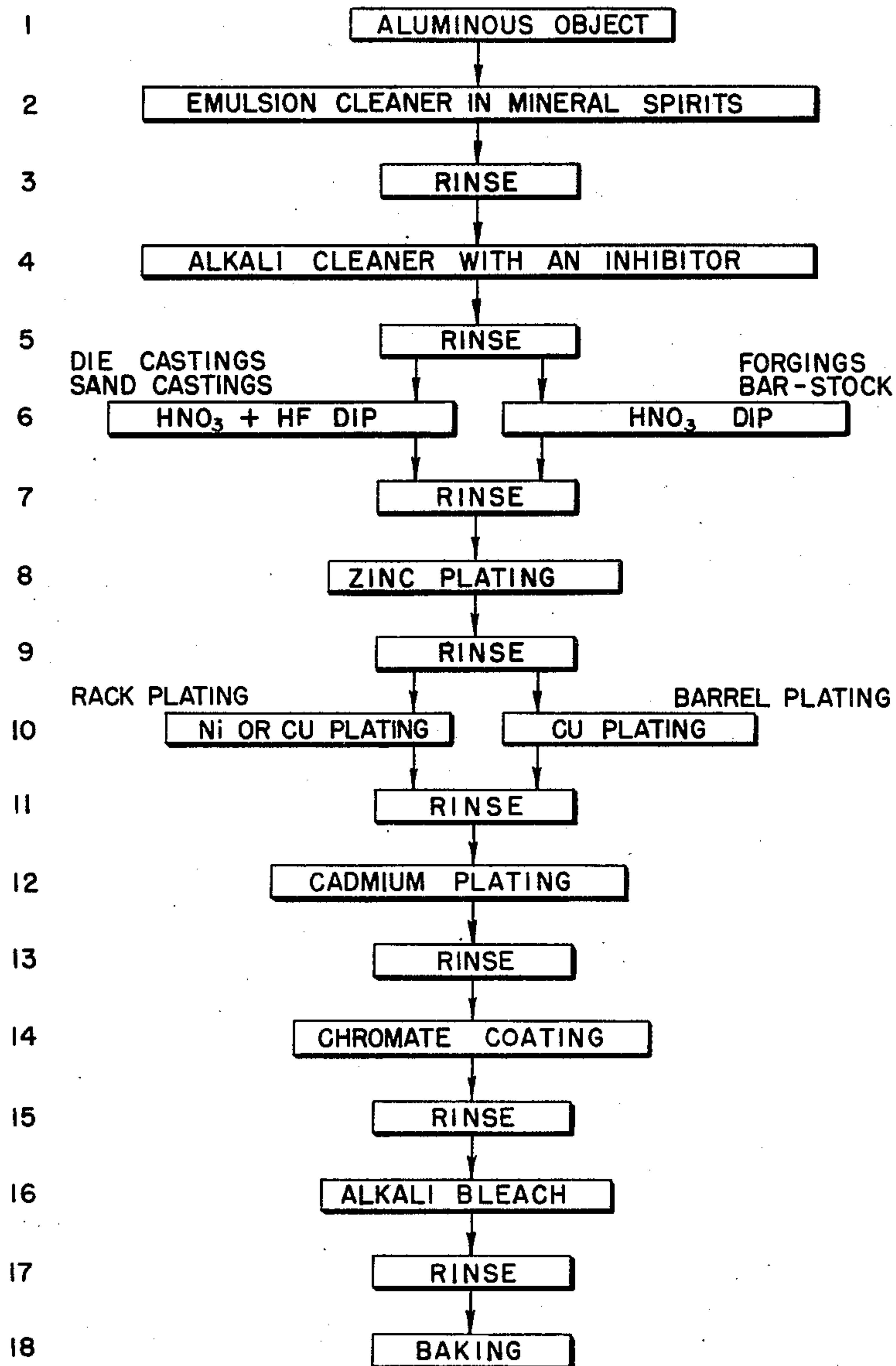
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CADMIUM PLATED ALUMINUM AND THE METHOD OF MAKING THE SAME

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## CADMIUM PLATED ALUMINUM AND THE METHOD OF MAKING THE SAME

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This invention relates to the plating of aluminous metals. It particularly refers to the use of a protective plating of cadmium of aluminum. The invention involves a process by which cadmium plating can be made an effective protection for an aluminous body.

It has always been difficult to secure a good plating of some other metals on aluminum. It was proposed to plate aluminum with various other metals as early as the latter part of the 19th century but all new processes, even those which offered the greatest promise during development, have been shown by time to have some material imperfections. The difficulty has been enhanced whenever aluminum is present in appreciable quantities in an alloy, particularly when silicon is present in the same alloy, so that while the plating of aluminum is sufficiently difficult, the plating of some of its alloys is even more difficult. Among the more difficult of such plating processes is the cadmium plating process. Cadmium is a metal having many theoretically desirable properties as a surface coat, but which has been most disappointing in the results achieved. Among the difficulties which appear in cadmium coating of aluminum are a tendency to degradation on standing or in use, a degradation which may be quite rapid in its effects, having a non-set shortly after the plating is completed. Another difficulty, and a very bad one, arises from the blistering of the cadmium coat during or after its application. Even the best known processes produce blisters on a very large proportion of all bodies that are cadmium plated. This makes the process extremely expensive because the only practical method of dealing with the situation is to strip the plating from the blistered parts and re-plate them again.

An object of the invention is to cadmium plate electrical connectors used in the military arts, which are subject to the most rigorous service conditions, and which consequently have a high rate of plating failure. Certain of the properties of cadmium are highly desirable for plating, but although there are many known processes for applying cadmium plate to aluminum, the products of such processes have been shown to have material imperfection when subject to the rigid tests required by the military, and a low output of perfect parts. Their imperfections have been mainly functional but there is another problem which involves the appearance of the articles; as users of such parts require not only a serviceable article but an article of good appearance it is necessary to produce a cadmium plate which has a uniform luster and excellent appearance. There are other functional problems but they have been discussed at length in other places and their nature will not be set forth in detail here.

Among the multitude of processes that have been proposed to remedy the known difficulties of this situation, most have been directed to some particular step of the process, usually to the application of the cadmium itself. It is our discovery that any such detailed improvement is insufficient, and that the problem must be considered as an entirety, beginning with the consideration

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of the material that is to be plated and its composition, continuing with the preparation of and the maintenance of the surface during the process, and the plating itself, and involving a number of steps which are used in sequence and in essential combination to produce a product having an aluminous body, that is, a body containing aluminum as a major and essential constituent, and bearing a coating an essential protective layer of which is cadmium.

It is not possible to condense the statement of this new process into any few words but an understanding of the process should be gained by a consideration of the specification as a whole, and it should be understood that some of the steps of the process which are brief and simple have been found to be of very great importance in the production of an excellent coated piece.

The accompanying drawing includes a flow sheet of the process, the various steps of which are included in numbered boxes, arrows indicating the progress of the aluminous body that is being coated through the various steps.

A particular object of the invention is to clean the body more thoroughly than has been possible heretofore, a difficult thing because some aluminous bodies have foreign adhesions burned into the surface by prior treatment.

Another object is to improve the coating after application and to determine which plated bodies have hidden defects, prior to use.

At various places in the specification, reference is made to proprietary names and products, which have been particularly included because, while they generally refer to a particular type of operation which is elsewhere described in general terms, the particular product is on the market, has been found to be satisfactory, and furnishes a ready source of the necessary ingredients.

The steps of the process as shown on the flow sheet have been numbered and those numbers will be employed from time to time in the specification for ready reference and correlation.

The process starts with an aluminous metal body which is to be plated. Such bodies contain aluminum in large or small percent but aluminum is always present in substantial amounts. Thus pure aluminum bodies, commercial aluminum bodies containing various degrees of impurities, and aluminum alloys containing other materials may alike be treated by this process. The plating may be applied to aluminous bodies of all shapes and regardless of the process by which made. For instance, sand castings, die castings, forgings and wrought stock may be satisfactorily plated by this method. The constitution of the body affects the nature of the treatment as shown on the flow sheet and as described hereinafter. In particular, bodies containing silicon as a part of an aluminium alloy, or to which silicon or silicious materials have become attached due to their presence in some stage of the manufacture, require a special treatment at some stage of this process. Similarly, there may be a separate type of treatment which is best applied for different types of plating technique. Such major differences will be discussed in some detail herein. As to minor variants in the process, enough information is given to permit persons skilled in the art to adapt the process to particular requirements arising from the type of their apparatus and the nature of the product which is being plated.

The various treatments to which the body is applied before it is subjected to plating, such as casting, forging and the like, frequently involve treatments which coat the body with an undesirable layer which may adhere to or even be actually burned into and incorporated in the outer layer of the body. It is an object of this



invention to remove oxides and other adhesions, including smut, without changing the form or size of the body. This is important because the surface of a body is frequently harder than the interior, and any severe attack on the surface impairs the hard surface layer.

The prior art has proposed to acid etch or otherwise etch the surface of the aluminum body to a depth such that an actual removal of material occurs, leaving a somewhat roughened surface to which the plating may key itself mechanically, but we have found that this is a source of difficulties as it may open up pores in castings, cause increased blistering and black spotting and may cause leaks that admit air to the aluminum body. It also requires the building up of the body to its original size by plating, which may result in faulty dimensions because plating operations are not machining operations. A plate builds up faster on small thread than large, that is a source of grave trouble when one piece has two sizes of thread. This invention removes the undesirable adhesions from the piece by a controlled and calculated process which leaves the body in its original size and shape, or substantially so, and while there may be a slight attack upon the surface of the body the attack is carefully controlled and does not materially change the dimensions of the piece or degrade the surface which has been so carefully prepared in precise dimensions.

The first step of the cleaning portion of the process is to subject the body to an emulsion cleaner dip. In dealing with small parts such as connectors, the parts are put in baskets which are resistant to chemical attack and the baskets are immersed successively in the various solutions or baths. These baths may be made up in tanks of appropriate size and shape conveniently arranged in the plating room. The emulsion cleaner dip that is preferred contains mineral spirits in a ratio of about 5 to 1. The Stoddard solvents are satisfactory mineral spirits. An emulsion cleaner of general usefulness is Oakite No. 8. Where only a light cleaning is necessary this cleaner may be dissolved in water and, when employed in such solution, gives fairly satisfactory results. The basket containing the body to be plated is dipped in the emulsion cleaner for a minimum of 2 minutes, but when a die casting lubricant has been burned into the surface the dip should continue for at least a half hour. This part of the treatment need not remove the oxides, smut or discoloration but needs only to degrade, soften and loosen it, or break its surface tension. Much of the actual removal takes place at a later time in the process.

Another emulsion cleaner dip for the second step includes a solvent such as Stoddard, or other hydrocarbon solvents, a soap made from KOH or NaOH and fats or oils, or sulfonated oils, water soluble soaps being superior, a solvent or diluent for both the soap and the hydrocarbon such as pine oil, cresylic acid, or lower aliphatic alcohols, and a little water. The Stoddard solvent should be present in preponderance, on the order of roughly 90%. Some caustic soda or potash may be added, if any saponifiable matter such as excess oil or cresylic acid be present, to take up the excess.

This first step of the process, numbered 2 on the chart, is followed by a rinse in water at room temperature or in cold water. The rinsing bath may be a tank full of running water, an overflow being provided at the top. The basket containing the parts is lowered into this cold water rinse, agitated a little, and is removed and allowed to drain briefly, and is ready for the fourth step of the process.

Step 4 of the process involves the use of a light alloys cleaner with a buffer or inhibitor for the protection of the aluminum. This is an alkali cleaner but it is not strong enough to constitute a caustic dip that removes part of the aluminum. An inhibitor is present in the

solution to prevent an attack on the aluminum by the bath.

Mild sodium hydroxide solutions buffered with trisodium phosphate or sodium silicates, are preferred and constitute an excellent cleaner for this stage of the cleaning process. The sodium silicates not only buffer the aluminum and protect it against the NaOH but are excellent detergents themselves. Water glass, and sodium ortho, meta and sesqui silicates are useful but the ortho silicate is the best detergent. Those silicates with high  $\text{SiO}_2/\text{Na}_2\text{O}$  ratio have the best preventive action against corrosion. The NaOH can be omitted and replaced by alkali silicates. A typical such formula includes 33% by weight  $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$ , 66%  $\text{Na}_2\text{SiO}_3 \cdot 5\text{H}_2\text{O}$ ; wetting agent 1%. Concentration 6 ounces per gallon of water.

$\text{Na}_2\text{CO}_3$  is somewhat inferior to other alkalis. A list of useful alkalis includes alkali silicates, phosphates including complex phosphates, and borates. Borax and sodium meta borate are exemplary of the borates. If alkali hydroxides are used they should be used in a concentration that will not attack the aluminum rapidly and should be well buffered with a silicate, phosphate, or borate.

Wyandotte light alloys cleaner contains an inhibitor or buffer and has been used satisfactorily in this portion of the process, in a concentration of about 12 ounces of cleaner by weight per gallon of water. This gives a specific gravity of 1.04 to 1.06 at 180° F. by the hydrometer test. The immersion in this cleaning solution is for a minimum of about a minute. The temperature of the bath should be maintained between 160° and 200° F.

The fifth step of the process is a rinse in cold water or water at room temperature and the same type of rinsing apparatus may be employed.

The water rinse is followed by an acid cleansing employing either nitric acid or a mixture of nitric and hydrofluoric acids depending upon the constitution of the piece and the treatment to which it has been subjected. When sand castings, forgings or die castings are used, or when the aluminum body contains silicon, the dip should include both nitric and hydrofluoric acid. On the other hand, when wrought stock is being cleaned a nitric acid dip alone is sufficient. When a nitric acid bath alone is used it may be constituted of ordinary commercial nitric acid, which has about 40 to 66%  $\text{HNO}_3$  by volume; 56% acid has been very satisfactory. It is employed at room temperature. The time of immersion of the body is about 15 seconds regardless of the nature of the material and regardless of the bath employed. This produces a white etch. It removes oxides from the surface and makes a slight, controlled attack upon the aluminum itself without materially or noticeably changing its actual dimensions and without injuring the hard outer coat. When hydrofluoric acid is added to the nitric acid bath 20% HF is added directly to commercial nitric acid in the proportion of 1 to 1¼. This mixed cleaner and oxide remover is particularly satisfactory with sand cast articles because silica tends to adhere to the outside of such castings and the HF readily removes it.

The body has now been subjected to cleaning with an emulsion cleaner, with an alkali cleaner in the presence of a buffer, and with  $\text{HNO}_3$  with or without HF. It is rinsed in water, a single rinse at room temperature ordinarily being sufficient.

Step 8 of the process calls for immersion zinc plating from a basic zincate solution. Simple immersion in a bath of this sort is sufficient to apply this plating. The basic ingredients of a particular bath are zinc oxide, caustic soda, and water. The plating is carried out at a temperature about 50° F. as a minimum, only because below that temperature the reaction begins to slow up and to require unnecessary time. A general upper limit of 70° is preferred but the process can be carried out as



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high as 90° F. in some cases. However, the 90° is a fairly firm upper limit as the coating tends to become spongy if the temperature rises beyond that degree. The time required to carry out this plating is related to the actual temperature which is employed in the plating bath. It varies from ½ to 2 minutes generally speaking. To exceed these limits of ½ to 2 minutes in either direction is generally undesirable as producing an insufficient coat below the lower limit and as producing too thick and a somewhat unsatisfactory coat above that limit. The concentration of this bath should be maintained at its initial strength throughout the coating process by suitable additions of salts, and it should not be allowed to become thin.

In the immersion zinc plating process of this eighth step the alumon salts of Enthone Inc. have given satisfactory results, the bath being made up to 40° to 42° Bé. using alumon salts and water, the ratio of salts to water being 4.5 pounds per gallon.

It has been thought in the past that this zinc undercoating would be sufficient for the application of a fine coat of cadmium, but we have discovered that this is not so, and that yet another undercoat should be applied before the cadmium. This is applied as the tenth step of the process, but before the body can be subjected to that plating step it must be most thoroughly rinsed. This is accomplished by transferring the basket containing the parts to a tank having an overflow and filled with running cold water. The parts are washed in this tank and are then transferred to a similar second tank which also has running cold water. After the second rinse is completed it is again transferred to a third tank having running cold water. When it is removed from this triple rinse the body may be immediately subjected to the necessary second undercoating over the zinc, and it is transferred to an electrolytic plating rack or to a plating barrel.

The plating of step 10 is with nickel or copper.

Among the solutions satisfactorily employed are "white nickel" solution, cobalt nickel solution, and Watt nickel solution. White nickel solution is made up in a proportion of nickel salts such as nickel sulfate, 16 ounces by weight, ammonium chloride 3 ounces by weight, boric acid 4 ounces by weight, and enough water to make up a gallon. This solution is used in whatever quantity is necessary for the plating of the particular objects. The plating bath when thus made up analyzes 2 to 4 ounces per gallon of nickel, ammonium chloride 2 to 3 ounces per gallon, sodium chloride 2 to 3½ ounces per gallon, nickel chloride 4 to 7 ounces per gallon and it has a pH of 5.0 to 6, that is to say, it is operated at about neutrality or slightly on the acid side. The temperature of the bath should be maintained at 75° to 100° F. The voltage employed is 1.5 to 3, a current density of 5 to 15 amps per square foot is employed and the plating requires 5 to 15 minutes depending upon the articles and various conditions. One current used as a primary source has been 60 cycles, 220 volts three phase rectified by a selenium rectifier. Adjustment of the plating bath is by voltage alone, when such a source is employed. The plating bath contains nickel anodes, the object being cut into the bath as cathodes. Mild agitation, and uniformity of the coat, may be achieved by moving the objects slowly through the bath on a closed path while the plating continues.

When copper is employed for plating, a Rochelle salt type of solution is employed in preference to other types, and pure copper anodes are immersed in the bath. It is well employed at a temperature on the order of 140° to 150° F. at a voltage of 4 to 12 for 5 to 15 minutes when barrel plating, or 1 to 3 volts for the same periods of time when still tank plating. In both the nickel and copper plating steps, the current should be imposed on the article that is to be plated, as soon as it enters the bath. Any delay will result in an attack on the zinc.

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In making up a salt bath of this type, copper cyanide is employed at about 3.5 ounces per gallon, sodium cyanide at about 4.6 ounces per gallon and sodium carbonate at about 4 ounces per gallon. In addition, the bath should contain some Rochelle salt or other addition agent designed to keep the cyanide concentration from dropping. Analysis shows a suitable copper plating bath includes copper cyanide 3.5 to 4.5 ounces per gallon, free cyanide .75 to 1.5 ounces per gallon, and Rocheltex 6 to 8%. This copper plating process may be used with equal success for either rack plating or barrel plating. It is preferred whenever barrel plating is to be employed. Consequently, the flow sheet shows only the use of the copper plating when barrel plating is used.

After the rack plating the body is subjected to two rinses in cold running water before cadmium plating. After barrel plating a single rinse in cold running water is usually sufficient.

Cadmium plating is carried out immediately from cadmium cyanide solution, preferably of the still tank type. The makeup of a particular cadmium cyanide solution includes 3 ounces cadmium oxide, 1 ounce of sodium hydroxide and 12 ounces of sodium cyanide per gallon of water. It analyzes cadmium 2 to 4 ounces per gallon, total cyanide 10 to 24 ounces per gallon and it has a relation of cyanide to cadmium of 4 to 1 to 6 to 1. It also contains of sodium carbonate less than 9 ounces per gallon, 3 to 5 ounces per gallon being considered to be very good, and to produce excellent plating conditions. The temperature of the bath is 70° to 100° F. and 1 to 3 volts are applied with a current density of 5 to 25 amps per square foot. Plating takes 15 to 35 minutes depending upon the type of parts. There is a faster build up on smaller parts. The flow of current is from cadmium electrodes acting as anodes to the body acting as a cathode.

When barrel plating is to be employed the constitution or make up of the cadmium cyanide solution is similar to the above except that 6 ounces of cadmium oxide, 24 ounces of sodium cyanide and 1 ounce of sodium hydroxide are employed in place of the figures given above. 4 to 12 volts of E. M. F. are employed. Current density is impractical to figure on this type of plating.

The object has now been triple plated, has a working layer of cadmium, and is immediately subjected to rinsing in cold water. It is then subjected to chromate coating as indicated in step 14 of the flow sheet. The coating bath contains chromic and relatively minor amounts of sulfuric and acetic acids. The temperature of the bath is maintained at 80° to 100° F. and the dip is for 2 to 10 seconds. The proper concentration of the bath is obtained by titration. A 5 cc. sample is taken and is titrated with IN. sodium hydroxide solution, the proper concentration being attained when 22 to 25 cc. of this sodium hydroxide solution produce neutralization of a phenolphthalein indicator. A satisfactory bath is made of 1 part of Iridite BR4 to 3 parts of water.

The 14th step of the process is followed by a double rinse in cold water, rinsing being carried out in successive tanks of running water, and by baking. This is an important addition to the process, not to be minimized. Baking at about 250° F. for about 15 minutes is satisfactory but a more prolonged baking is frequently helpful. Baking times and temperatures may be varied to suit the particular product.

The baking has not only an apparent effect of improving the coating but an additional effect of disclosing hidden imperfections which would otherwise remain concealed and lead to premature failure. In this it is invaluable.

The baking step may be preceded by a sodium hydroxide bleach which is useful in producing an improved appearance. The application of the chromate plating produces an iridescent coating, particularly on grooved or threaded portions of the body, and may create the illusion that the plating job has not been uniformly done



and is consequently inferior. Although this may not be the case, it is advantageous to subject the article at room temperature to a 5 to 10 second exposure to a solution of sodium hydroxide containing 2 ounces per gallon of NaOH. The rinse that follows the bleach in sodium hydroxide solution is followed by the baking without waiting for the body to dry. This step is No. 16 on the chart.

The process that has been described hereinabove is superior to any other process known to the inventors. It produces a cadmium plating which is freer of defects of all sorts, and particularly of blistering, than any other cadmium process. It produces a higher yield of perfect parts. It will be realized that this is not a simple cadmium plating but that it involves a plating with several layers of different material, and that while the process is called a cadmium plating process that name is an over-simplification of the fact, because the object produced is actually a body of aluminum, or containing aluminum as its major and essential ingredient, bearing a first coat of zinc, a second coat of copper or nickel, a third coat of cadmium, and an outer coat of cadmium chromate. The cadmium plating is superior, but this plated body, with all its coatings, is of the highest quality and is preferred. The cadmium plate is better because of the relationship to the other things to which it stands and its desirable properties are thus more perfectly made available.

Some of the articles which are plated by this process still show blistering. Nevertheless, the amount of blistering is less than with any prior process and the number of pieces which have to be rejected is fewer. The advantages of cadmium plating are obtained and the disadvantages of its known poor adhesion are avoided. The plated article has a better appearance than known cadmium platings of the best sort and the durability of the plating in conditions of use is greater. This is especially important in military uses where the articles are subjected to the most rigorous conditions.

#### EXAMPLE I

##### *Plating of a die cast connector shell*

This shell contained about 10% silicon, about 85% aluminum, and the balance various other metals, the nature of which was disregarded as they offered no problem in plating comparable to that which is presented by the aluminum and silicon.

An emulsion cleaner dip was made up from Oakite No. 8 and Stoddard solvent in a proportion of 5 parts of Stoddard solvent to one of Oakite. The aluminum part was put in a basket comprised of inert plastic and was submerged in the cleaner at room temperature for ½ hour. The scale, oxides, and smut were not removed but their appearance was changed and they had obviously been degraded.

The part was subjected to a rinsing in a tank of running cold water.

A light alloys cleaner was made up, being an alkali cleaner with a buffer or inhibitor to prevent attack of the alkali on the aluminum, the cleaner being present in 12 ounces by weight per gallon of water. The hydrometer showed a specific gravity of 1.05. Wyandotte light alloys cleaner was employed. The bath was at a temperature of 180° F. and immersion was for one minute.

The body was rinsed as before and introduced into a dip having a composition of 1 part by volume of 20% HF to 1½ parts by volume of commercial HNO<sub>3</sub> analyzing 40 to 66% HNO<sub>3</sub> by volume. Immersion was at room temperature for 15 seconds. The oxides were obviously removed from the surface and the body was given a white etch which was not, however, deep enough to materially change the size of the body or to harmfully attack its surface. Nevertheless, there was a slight and controlled attack on the metal itself.

After the acid dip the body was given another single

water rinse under similar conditions and was transferred to a rack and subjected to zinc plating by immersion in a basic zincate solution containing zinc oxide and caustic soda. In making up the bath Enthone Alumin salts were employed in water in the ratio of 4.5 pounds per gallon and a correct concentration was determined when a 40° to 42° Bé. reading was obtained. The bath was carried at 60° F. during the period of this test. Immersion was for one minute. The concentration of the bath was maintained throughout by the addition of salts.

When the zinc plating had been completed the body was subjected to three successive rinses in three successive tanks of running cold water.

The part was admitted to a nickel plating bath of electrolytic potential which was already applied, and which needed only the admission of the rack to complete the electrolytic circuit through the body. Consequently, the imposition of the current upon the piece was simultaneous with its admission to the bath. The nickel plating solution was called dull white nickel solution containing 16 ounces by weight of nickel sulfate, 3 ounces by weight of ammonium chloride and 4 ounces by weight of boric acid in each gallon. Its pH was 6, its temperature 85° F., potential was impressed upon the bath prior to the admission of the racked body so that the flow of current and electrolysis began immediately. Plating continued for 10 minutes. The current density was 10 amps. per square foot. There was thus applied upon the immersion zinc a layer of electrolytic nickel.

After the nickel plating the body was rinsed twice in successive tanks of cold running water and was then subjected to electro plating with cadmium. The plating bath contained 3 ounces of cadmium oxide, 1 ounce of sodium hydroxide, and 12 ounces of sodium cyanide per gallon. It also contained 4 ounces per gallon of sodium carbonate. It was operated at a temperature of 85° F., at 2 volts and it had a current density of 15 amps. per square foot. Plating was for 20 minutes. A longer time would have been used for larger parts. After the cadmium plating the body was rinsed in cold running water and subjected to an Iridite dip which applied a chromate film over the cadmium. A chromate bath was made up from 1 part Iridite BR<sub>4</sub> to 3 parts of water and maintained at a temperature of 90° F. Immersion in the chromate bath was for 8 seconds, then the body was subjected to successive rinses in successive tanks of cold running water and was immersed in a sodium hydroxide bleach which was continued only long enough to remove the iridescence from the threads on the body. The bleach contained 2 ounces per gallon of sodium hydroxide and was used at room temperature. Immersion was for 10 seconds only. The body was subsequently rinsed in cold running water and then immediately, while still wet, transferred to a tray and taken to an oven heated at 250° F. wherein it was baked for 20 minutes.

The final product had the appearance of cadmium plating, was without blemish, of uniform appearance and luster and did not blister or show evidence of other degradation after standing. In prior art processes, some of which approximate individual steps of this process, there has been a tendency for blisters to appear after the body has been aged. This tendency has been corrected by this process.

#### EXAMPLE II

In this case the aluminum article was pure aluminum bar (wrought) stock. The process was carried out identically in steps 1 to 5. In step 6 the dip was composed of straight commercial nitric acid. Thereafter, the body was handled identically in steps 7, 8 and 9 of Example I, but in step 10 it was decided to plate by barrel plating and a solution of Rochelle copper was made up containing of copper cyanide 3.5 ounces per gallon, of sodium cyanide 4.6 ounces per gallon, and of sodium carbonate 4.0 ounces per gallon. 7% of Rocheltex based on the volume of the solution was also included. Rocheltex is



a Rochelle salt containing added cyanides to keep the concentration of the cyanide from dropping. The temperature was kept at 145° F. and 8 volts were imposed upon the bath. Plating was for 10 minutes. The current was imposed on the article instantly in order to prevent stripping the article of zinc. A single rinse sufficed after the copper plating. Cadmium plating was carried out as above described and a single rinse and Iridite bath followed. The process thereafter was carried out identically as in Example I. The finished object had an aluminum body, a first coat of zinc, a second coat of copper, a third coat of cadmium and a fourth coat of chromate.

### EXAMPLE III

The process was carried out as exactly as in Example II except that the sodium hydroxide bleach at the end was omitted. The product had a different appearance, showing iridescence, but appeared to be of high quality and comparable in usefulness to that produced in Examples I and II.

There are a number of emulsion cleaners which may be used to produce the degradation of the oxide and smut on the surface of the body. Similarly there are several light alloys cleaners on the commercial market and they may be employed with some difference in effect but it is advisable to incorporate with them a buffer to prevent their attack upon the aluminum body itself. The concentration of caustic soda in such cleaners should not be sufficient to actively attack the aluminum and the attack should be further inhibited by the presence of the buffer.

When barrel plating is to be employed a difference in the composition of the plating solution is indicated as hereinabove set forth. It is impractical to figure current density under such conditions as the articles, while in the barrel, are continually in motion and it is quite difficult to know what proportion of the mass is actually being plated at any one moment.

The advantages of this invention are so material that they can be recognized instantly by inspection by persons skilled in the art who are familiar with the type of plating which is achieved by prior art processes. These material advantages may also be demonstrated by the usual tests for plating, durability, etc.

These advantages are not obtained by the use of any one of the individual steps which are included in the process but, on the contrary, the advantages are the result of the process as a whole, as defined in the claims. However, certain phases of the process are themselves believed to be new and they are claimed alone as well as in combination.

The only steps which can be omitted without harmfully affecting the result are numbers 16 and 17 and even the omission of these steps produces an article which, if not inferior, is at least different in appearance.

As many apparently widely different embodiments of the present invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments.

What is claimed is:

1. The method of plating a body, having aluminum as a major and essential ingredient, with a plating having cadmium as the essential protective coat for the body, that comprises cleaning and etching the body, plating the body with zinc from a basic zincate solution, at a temperature between 50 and 90° F. for ½ to 2 minutes, plating the body electrolytically with one of a group consisting of nickel and copper from basic salt solution at a temperature circa 75 to 150° F., at a voltage of circa 4 to 12, electrolytically plating the body with cadmium from a basic salt solution at a temperature circa 70° to 100° F. at circa 1 to 12 volts and for 15 to 35 minutes, coating the body by immersion in a chromic acid bath, and drying the body at baking temperature.

2. The method of plating a body, having aluminum

as a major and essential ingredient, with a plating having cadmium as the essential protective coat for the body that comprises cleaning and etching the body, plating the body by immersion in a basic zincate solution at a temperature between 50 and 90° F. for ½ to 2 minutes, thoroughly rinsing the zinc plated body, plating the body electrolytically with copper with imposition of the plating current as soon as the body has entered into the plating bath, rinsing the body, electrolytically plating the body with cadmium from a basic cadmium cyanide solution, at a temperature circa 70 to 100° F. at circa 1 to 3 volts, a current density circa 5 to 25 amps. per square foot for 15 to 35 minutes, rinsing the body, coating the body in a chromate bath, rinsing the body, and heating the body at baking temperature for a minimum of 15 minutes with imposition of the heat before the body dries.

3. A plated metal body having aluminum as a major and essential constituent, the plating thereof consisting essentially of a base coat of zinc, a second coat, applied to the zinc, from a group consisting of copper and nickel, a third coat applied to the second consisting essentially of cadmium, and a fourth coat applied to the cadmium of chromate.

4. A plated metal body having aluminum as its major and essential constituent, the plating thereof comprised essentially of a base coat of zinc, a second coat of one of the group consisting of copper and nickel, a third coat of cadmium, and a chromate overcoat.

5. A plated body having a metal base comprising aluminum, a plating of zinc upon the metal base, a plating of one of a group consisting of copper and nickel upon the zinc, a plating of cadmium thereupon, and a coating comprising chromate upon the cadmium.

6. The method of plating a body, having aluminum as its major and essential ingredient, with a plating having cadmium as the essential protective coat for the body that comprises cleaning the body with an emulsion cleaner comprising mineral spirits, rinsing the body, cleaning the body by immersion in an alkali cleaner comprising a buffer for aluminum at a temperature circa 160 to 200° F., rinsing the body, cleaning the body by immersion in a bath containing at least nitric acid from a group of acids consisting of nitric and hydrofluoric at room temperature for about 15 seconds, rinsing the body, plating the body by immersion in a basic zincate solution at a temperature between 50 and 90° F. for ½ to 2 minutes, thoroughly rinsing the zinc plated body, plating the body electrolytically with copper with imposition of the plating current as soon as the body has entered into the plating bath, rinsing the body, electrolytically plating the body with cadmium from a basic cadmium cyanide solution containing about 6 ounces cadmium oxide, 24 ounces sodium cyanide, and 1 ounce of NaOH per gallon, at 4 to 12 volts, rinsing the body, coating the body in a chromate bath, rinsing the body, and heating the body at baking temperature for a minimum of 15 minutes with imposition of the heat before the body dries.

7. The method of plating a body, having aluminum as its major and essential ingredient, with a plating having cadmium as the essential protective coat for the body that comprises cleaning the body successively in an emulsion cleaner, a buffered alkali cleaner, and an acid cleaner from the group consisting of nitric and hydrofluoric acids, plating the body with zinc, plating the body electrolytically with nickel from basic salt solution, electrolytically plating the body with cadmium from a basic cadmium salt solution, coating the body by immersion in a chromate coating bath, bleaching the body in sodium hydroxide solution and baking the body while still wet.

8. The method of plating a body, having aluminum as its major and essential ingredient, with a plating having cadmium as the essential protective coat for the body that comprises cleaning the body successively in an emulsion cleaner, a buffered alkali cleaner, and an acid



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cleaner from the group consisting of nitric and hydrofluoric acids, plating the body with zinc, plating the body electrolytically with copper from basic salt solution, electrolytically plating the body with cadmium from a basic cadmium salt solution, coating the body by immersion in a chromate coating bath, bleaching the body in sodium hydroxide solution and baking the body while still wet.

9. The method of plating a cleaned and etched body having aluminum as its major and essential constituent that comprises plating it with zinc by immersion, plating it with one of a group consisting of copper and nickel by electrolysis, and plating it electrolytically with cadmium.

10. The method of plating a cleaned and etched body having aluminum as its major and essential constituent that comprises plating it with zinc by immersion, plating it with one of a group consisting of copper and nickel by electrolysis, plating it electrolytically with cadmium from a cyanide bath, and coating it with chromate.

11. The method of plating a cleaned and etched body having aluminum as its major and essential constituent that comprises plating it with zinc by immersion, plating it with one of a group consisting of copper and nickel by electrolysis, plating it electrolytically with cadmium from a cyanide bath, coating it with chromate, and baking it.

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