United States Patent [19]

Kruper et al.

[11] **3,909,209**

[45] **Sept. 30, 1975**

[54] **METHOD OF TREATING ALUMINUM AND ALUMINUM ALLOYS AND ARTICLE PRODUCED THEREBY**

[75] Inventors: **Wayne A. Kruper**, Willowick; **George R. Kingsbury**, Mayfield, both of Ohio

[73] Assignee: **Gould Inc.**, Chicago, Ill.

[22] Filed: **Nov. 5, 1973**

[21] Appl. No.: **412,579**

[52] **U.S. Cl.** ..... **29/183.5;** 29/195 T; 29/197; 117/50; 117/62; 117/71 M; 204/33; 204/35 R; 204/38 B; 204/40; 204/49; 204/52 Y; 204/55 R

[51] **Int. Cl.²** .. **B23P 3/00;** C23F 17/00; C25D 5/44; C25D 5/48

[58] **Field of Search** ..... 29/197, 195 T, 183.5; 204/40, 33, 35 R, 42, 38 A, 38 B, 28; 117/71 M, 62, 47 R, 49, 50

[56] **References Cited**

UNITED STATES PATENTS

2,035,380	3/1936	Wilhelm	29/195 T X
2,142,564	1/1939	Korpiun	204/33
2,490,700	12/1949	Nachtman	204/40 X
2,543,545	2/1951	Faust et al.	204/55 R
2,654,701	10/1953	Calderon et al.	204/33
2,709,847	6/1955	Ihrie et al.	204/33 X
3,515,650	6/1970	Asada	204/33 X
3,629,078	12/1971	Okada et al.	204/35 R
3,636,242	1/1972	Hansson	29/197 X

FOREIGN PATENTS OR APPLICATIONS

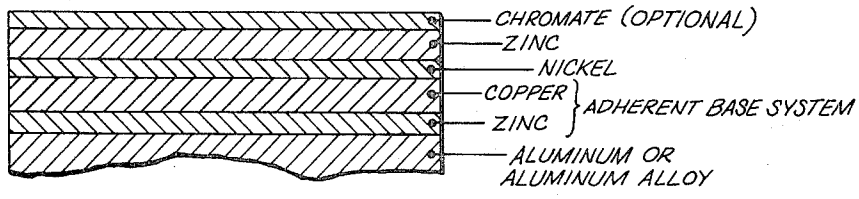
593,763	10/1947	United Kingdom	204/40

Primary Examiner—G. L. Kaplan
Attorney, Agent, or Firm—Edward E. Sachs

[57] **ABSTRACT**

Aluminum and aluminum alloys are rendered solderable and protected against galvanic corrosion by the application successively of an adherent base system followed by plates of nickel and zinc. Further protection against tarnishing and atmospheric corrosion in storage is achieved by the application of a chromate coating.

17 Claims, 2 Drawing Figures



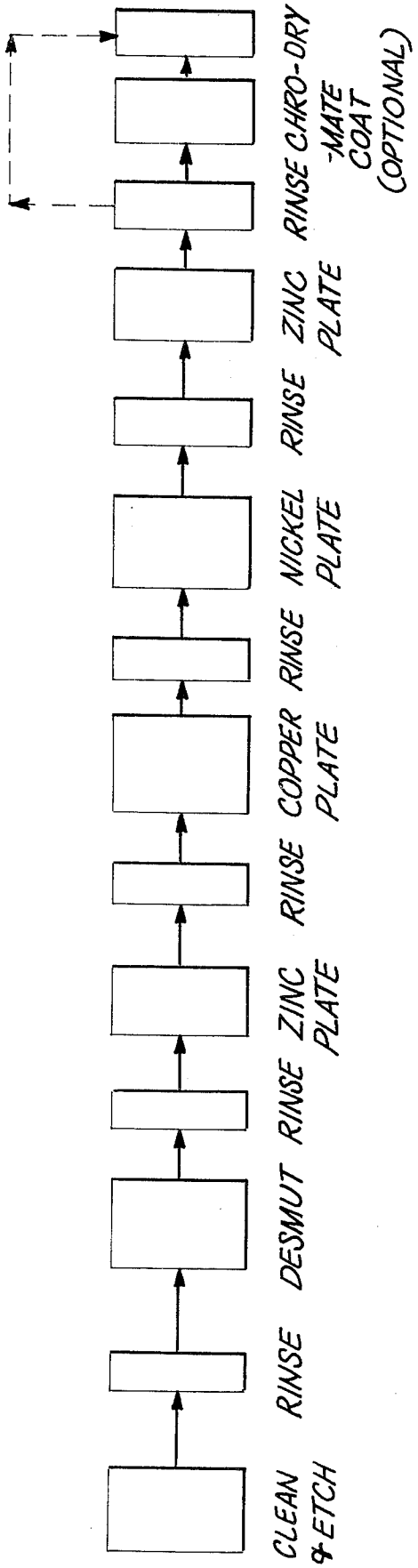

CLEAN & ETCH
RINSE
DESMUT
RINSE
ZINC PLATE
RINSE
COPPER PLATE
RINSE
NICKEL PLATE
RINSE
ZINC PLATE
RINSE CHRO-MATE COAT (OPTIONAL)
DRY

FIG. 1

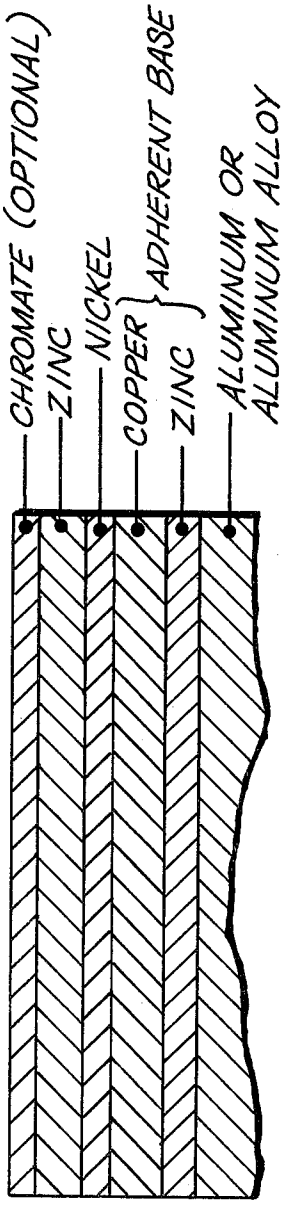

CHROMATE (OPTIONAL)
ZINC
NICKEL
COPPER
ADHERENT BASE SYSTEM
ZINC
ALUMINUM OR ALUMINUM ALLOY

FIG. 2

METHOD OF TREATING ALUMINUM AND ALUMINUM ALLOYS AND ARTICLE PRODUCED THEREBY

This invention relates to the metal treating art, and more particularly, to a method of treating aluminum and aluminum alloys and the article produced thereby.

BACKGROUND OF THE INVENTION

It is generally recognized that aluminum and aluminum alloys are not readily solderable with conventional lead-tin, silver-lead, tin-silver, and other standard, commercial solders. It is believed that the oxide normally present on surfaces of aluminum and aluminum alloys inhibits solderability by preventing the metal from being wetted by the solder.

It is also well known that aluminum corrodes quite readily in aqueous electrolytes if it is in contact with or coated with tin, copper, iron or other metals more "noble" than aluminum; as have been used previously to render the aluminum solderable.

Because of these drawbacks, aluminum has not replaced copper in many applications where aluminum would otherwise be the preferred material because of its lighter weight and lower cost. Automobile radiators, heater cores and automatic transmission fluid coolers are specific examples of pieces of equipment in which the use of copper dominates because of the aforementioned drawbacks of aluminum.

The present invention is addressed to the matter of treating aluminum and aluminum alloys to render these materials solderable with commercial solders and protected against galvanic corrosion. The invention is also concerned with protecting the treated aluminum and aluminum alloys against tarnish and corrosion during storage.

To some extent, the problems to which the present invention is addressed are discussed in U.S. Pat. Nos. 1,147,718, 3,274,021, 3,454,374 and 3,622,470.

SUMMARY OF THE INVENTION

The present invention has for its principal object the treatment of aluminum and aluminum alloys to render them both solderable and protected against galvanic corrosion.

In accordance with this aspect of the present invention, there is provided a method of treating a material selected from a group consisting of aluminum and aluminum alloys comprising the steps of applying to such materials, successively, coatings of an adherent base system, nickel and zinc. Aluminum and aluminum alloys treated in accordance with the present invention are readily wet by commercial solders, in fact more readily wet than copper is, and are far more resistant to galvanic corrosion than is aluminum which has been treated for solderability by prior art methods.

A further object of the invention is to post-treat the solderable, corrosion resistant aluminum and aluminum alloy materials with a coating which renders the materials resistant to tarnish and atmospheric corrosion during storage.

In accordance with this further aspect of the invention, the solderable, corrosion resistant aluminum and aluminum alloy materials are treated with an acidic solution containing at least one hexavalent chromium compound whereby a chromate coating is formed on the outer surface of the material.

Other objects and advantages of the present invention will become apparent from a reading of the following detailed description of the invention and accompanying drawing, which includes a description of the best mode presently contemplated for practicing the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, it will be seen that:

FIG. **1** is a highly schematic flow chart of the various steps conducted in the practice of a preferred embodiment of the present invention; and

FIG. **2** is a highly schematic cross-sectional view, drawn grossly out of proportion for purposes of clarity, illustrating an aluminum or aluminum alloy bearing the successive coatings defining the article produced in accordance with a preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **2**, it will be seen that an article of manufacture produced in accordance with the present invention comprises a body formed of a material selected from the group consisting of aluminum and aluminum alloys, the body having at least one surface on which are disposed successively an adherent base system which, according to the preferred embodiment, consists of a plate of zinc followed by a plate of copper; and plates of nickel and zinc.

For purposes of this disclosure, an adherent base system is any system which promotes adhesion between the aluminum base and the nickel plate. Other adherent base systems which may be used in the practice of the present invention consist of brass alloys, zinc followed by brass alloys, zinc followed by electroless nickel, zinc followed by chromium and tin followed by bronze alloys. Two commercially available adherent base systems which may be substituted for our preferred system, though not necessarily with identical results, are M & T Chemical's Alstan 70 Process, believed to consist of tin followed by bronze, and a DuPont system, believed to consist of white brass.

Turning again to our preferred zinc-copper adherent base system followed by nickel and zinc plate, the thickness of the first applied zinc plate will generally fall within the range of about 0.5 to 5.0, and preferably 1.0 to 3.0 in.$\times 10^{-6}$; the copper plate will generally have a thickness within the range of about 5.0 to about 200, and preferably within the range of 14.0 to 16.0 in.$\times 10^{-6}$; the nickel plate will generally have a thickness within the range of about 2 to about 200, and preferably from about 9 to about 11 in.$\times 10^{-6}$; and the last applied zinc plate will generally have a thickness within the range of about 1.0 to about 200, and preferably from about 18.0 to about 22.0 in.$\times 10^{-19-6}$.

The application of these four successive plates renders the body of aluminum or aluminum alloy both solderable and resistant to galvanic corrosion.

Where tarnish and atmospheric corrosion resistance during storage is desired, an optional chromate coat may be applied to the second zinc plate, also as illustrated in FIG. **2**. The thickness of this coat will generally be within the range of about 0.1 to about 2, and preferably from about 0.3 to about 0.7 milligrams of chromium per square foot surface.

Referring to FIG. 1, it will be seen that the method of the present invention involves two pretreatment steps, a cleaning and etching step and a desmutting step, each followed by a rinse step. These are followed by four successive plating steps of zinc, copper, nickel, and zinc, respectively, each followed by a rinse step. Following the last of these four rinse steps, the article under treatment is either dried directly or chromated and then dried, depending on whether or not it is desired to protect the article against tarnish and atmospheric corrosion during storage. Where the chromating step is omitted, the dotted line in FIG. 1 shows the flow path followed.

The cleaning and etching step is designed to remove soil such as dirt, grease, oil, finger prints and the like from the surface of the aluminum or aluminum alloy, and to remove the surface film of aluminum oxide which is invariably present on aluminum alloys which have been exposed to air.

Any one of the many commercially available cleaning agents for aluminum and aluminum alloys may be used. One commercially available material which has been successfully employed is MacDermid S449 cleaner. This cleaner is fortified with a suitable etchant such as sodium hydroxide.

Following cleaning and etching, the material being treated is rinsed with water, preferably demineralized or distilled water. The same applies to all of the rinses used throughout the method of the invention.

The aluminum or aluminum alloy is then immersed in a desmutting solution to remove scale, slime and undesirable byproducts of the cleaning and etching step. An aqueous solution of nitric acid is satisfactory for this purpose. The desmutted aluminum or aluminum alloy is then rinsed with water.

The first zinc plate may be deposited by immersion in an alkaline zincate solution, or by electrolytic methods. The zincate solution is preferred, and will generally comprise an aqueous solution of sodium hydroxide and zinc oxide, to which other ingredients such as ferric chloride, sodium nitrate and Rochelle salt may be added. A suitable range of compositions and operating parameters are as follows:

Sodium Hydroxide	500–550 gm/L
Zinc Oxide	95–100 gm/L
Immersion Time	10–20 seconds
Temperature	70–80°F

Reference may also be had to ASTM B253-53 for a recommended practice for the preparation for electroplating of aluminum alloys by the zincate process. The zinc plated aluminum or aluminum alloy is then washed thoroughly with water.

The copper plate is deposited electrolytically, preferably from a cyanide bath, using copper as the anode. The bath will generally contain copper cyanide, sodium cyanide and sodium tartrate. The sodium salts may be replaced in part or in toto by the corresponding potassium salts provided suitable proportional adjustments are made to maintain the cyanide and tartrate ion concentrations at constant levels. Suitable compositions and operating parameters are as follows:

Copper Cyanide	65–75 gm/L
Sodium Cyanide (Total)	70–90 gm/L
Sodium Cyanide (Free)	3–5 gm/L
Sodium Tartrate	20–120 gm/L
Temperature	115–125°F
Cathode Current Density	55–75 amp/ft.²
pH	9.7–10.0
Anode	Copper

The copper plated aluminum or aluminum alloy is then thoroughly washed in water.

The nickel plate may be deposited by electrolytic or electroless methods, with the former preferred. Suitable nickel salts which may be used in the electrolyte include nickel fluoborate, nickel sulfamate, nickel chloride, nickel sulfate, or mixtures of nickel chloride and nickel sulfate. A preferred range of compositions and operating parameters for nickel sulfate-nickel chloride electrolytes are as follows:

Nickel Sulfate	225–275 gm/L
Nickel Chloride	50–60 gm/L
Boric Acid	27–33 gm/L
pH	2.0–2.5
Temperature	130–150°F
Cathode Current Density	20–500 amp/ft.²
Anode	Nickel

Following the deposit of the nickel plate, the aluminum or aluminum alloy is again thoroughly washed with water.

The second zinc plate is deposited electrolytically. Suitable zinc salts which may be used in the electrolyte include zinc fluoborate, zinc sulfate, zinc chloride, and mixtures of zinc sulfate and zinc chloride. A zinc sulfate system is preferred. Suitable ranges of compositions and operating parameters for the preferred electrolytic system are as follows:

Zinc Sulfate	270–330 gm/L
Aluminum Sulfate	27–33 gm/L
Sodium Sulfate	20–25 gm/L
Temperature	120–130°F
pH	3.0–4.5
Cathode Current Density	20–500 amp/ft.²
Anode	Zinc

The zinc plated aluminum or aluminum alloy is then thoroughly washed with water. The plated article may then be dried, formed to the desired shape, and soldered.

However, if the treated aluminum or aluminum alloy is to be stored for substantial periods of time and/or if tarnish or atmospheric corrosion in storage is considered to be a potential problem, the plated aluminum or aluminum alloy may be chromated by contact with an aqueous solution of chromic acid, and then dried.

A wide variety of commercially available aluminum alloys may be used as the base material in practicing the present invention. The preferred alloys are wrought alloy grades containing less than about 1.5% magnesium. These include the following, which are identified by their commercial Aluminum Association designations:

EC	3030	6063
1050	3004	6066
1060	3005	6070
1100	3105	6101
1145	5005	6151
1175	5457	6201
1200	5657	6253
1230	6003	6262
1235	6053	6463
1345	6061	6951

Where high thermal and electrical conductivity are important characteristics, alloys 1100 and 3003 are particularly preferred. These alloys have the following nominal composition:

	1100	3003
Copper	0.12%	0.12%
Manganese	—	1.20%
Aluminum	Remainder	Remainder

EXAMPLE I

Panels of 3003 "O" temper aluminum alloy sheets 12 inches square and 0.012 inches thick were treated as follows:

The panels were immersed for 10 seconds in an etching and cleaning composition containing 60 gm/L MacDermid S449 cleaner and 60 gm/L sodium hydroxide for a period of 10 seconds. The panels were then washed thoroughly with demineralized water.

The panels were then immersed in a nitric acid desmutting bath formed by diluting concentrated nitric acid on a 1:1 volume basis with water. The treatment was conducted at room temperature for 10 seconds. Following this treatment, the panels were thoroughly washed with demineralized water.

The panels were then immersed in a zinc plating bath containing 525 gm/L sodium hydroxide, and 100 gm/L of zinc oxide for 15 seconds. The bath temperature was maintained at 70°F. The thickness of the resulting zinc plate was approximately 2 in.$\times 10^{-6}$. The zinc plated panels were then thoroughly washed with demineralized water.

The panels were then immersed in an electrolytic copper plating bath containing the following ingredients in the proportions indicated:

Copper Cyanide	70 gm/L
Sodium Cyanide (Total)	80 gm/L
Sodium Cyanide (Free)	3 gm/L
Sodium Tartrate	60 gm/L

Other operating parameters of the cell included a bath temperature of 120°F, a pH of 9.7, and a cathode current density of 70 amps/ft.^{2}. The panels were maintained in the bath for a period of 10 seconds, which produced a copper plate thickness of 15 in.$\times 10^{-6}$. The copper plated panels were then thoroughly washed with demineralized water.

The panels were then immersed in an electrolytic nickel plating bath containing 250 gm/L of nickel sulfate, 50 gm/L of nickel chloride, and 30 gm/L of boric acid. The bath had a pH of 2.0 and was maintained at a temperature of 140°F. The cathode current density was maintained at 75 amps/ft.^{2}. The panels remained immersed in the plating bath for 10 seconds, producing a nickel plate deposit 10 in.$\times 10^{-6}$. The nickel plated panels were then thoroughly washed with demineralized water.

The panels were then immersed in an electrolytic zinc plating bath containing 315 gm/L zinc sulfate, 27 gm/L aluminum sulfate, and 25 gm/L sodium sulfate. The bath had a pH of 3.5 and was maintained at a temperature of 120°F. The cathode current density was maintained at 115 amps/ft.^{2}. The panels remained immersed in the plating bath for 10 seconds, producing a zinc plate deposit of 20 in.$\times 10^{-6}$. The zinc plated panels were then thoroughly washed with demineralized water.

Finally, the panels were immersed in a room temperature chromate dip containing 0.25 gm/L chromic acid. After 10 seconds, the panels were removed and dried with radiant heaters.

Sample strips approximately 3 inches × 6 inches were cut from the plated panels and tested by immersing the strips first in a commercial, aqueous zinc chloride soldering flux, and then in a molten 10% tin 90% lead solder at 750°F. The strips were left in the molten solder for varying periods of time ranging from 1 to 15 minutes.

After removal of the strips from the solder, all samples exhibited a clean, uniform coating of the solder alloy. Following cooling of the strips to room temperature, all samples were examined under 10 X magnification. The solder coating was found to be free from holes and nonwet areas, and the heat-affected surface immediately above the solder line showed no blistering, peeling, or other heat-induced defects.

Adherence of the solder layer was tested by "shaving" numerous areas with a scalpel. Examination of the shaved areas under 10 X magnification showed no tendency toward separation of the solder layer or the plated layers.

EXAMPLE II

A continuous coil of 3003 "O" temper aluminum, 6 inches wide × 0.005 inches thick was treated at a speed of 10 feet per minute in a processing line including the following sequence of operations:

The etching and cleaning operation described under Example I was repeated, followed by a thorough rinse in demineralized water.

The nitric acid-desmutting operation described in Example I was repeated, followed by a thorough water rinsing in demineralized water.

The zinc plating operation described in Example I was repeated except that the immersion time was reduced to 10 seconds, providing a zinc plate thickness of approximately 2 in.$\times 10^{-6}$. The zinc plate strip was thoroughly washed with demineralized water.

The strip was then immersed in an electrolytic copper plating bath containing the following ingredients in the proportions indicated:

Copper Cyanide	65 gm/L
Sodium Cyanide (Total)	76 gm/L
Sodium Cyanide (Free)	5 gm/L
Sodium Tartrate	50 gm/L

The temperature of the bath was maintained at 120°F and at a pH of 9.9. The cathode current density was maintained at 70 amps/ft.^{2}. An immersion time of 10 seconds produced a copper plate thickness of 15 in.$\times 10^{-6}$. The copper plated strip was thoroughly washed in demineralized water.

The copper plated strip was then immersed in an electrolytic nickel plating bath containing 270 gm/L of nickel sulfate, 60 gm/L of nickel chloride, and 27 gm/L of boric acid. The bath had a pH of 2.3 and was maintained at a temperature of 140°F. The cathode current density was maintained at 75 amps/ft.^{2}. A 10 second immersion time produced a nickel plate thickness of 10

in.×10^{-6}. The nickel plated strip was thoroughly washed in demineralized water.

The strip was then passed through an electrolytic zinc plating bath containing 300 gm/L of zinc sulfate, 30 gm/L of aluminum sulfate, and 20 gm./L of sodium sulfate. The bath had a pH of 3.0 and was maintained at a temperature of 125°F. Operating at a cathode current density of 115 amps/ft.^{2} and an immersion time of 10 seconds, the strip was provided with a zinc plate thickness of 20 in.×10^{-6}. The zinc plated strip was then thoroughly washed in demineralized water.

The strip was then immersed in a chromate dip comprising an aqueous solution of one-fourth gm/L of chromic acid for a period of 10 seconds at room temperature. The chromate coat which measured 0.4 milligrams of chromium per square foot of surface was then dried by radiant heating.

Sample specimens measuring approximately 6 inches × 12 inches were cut from the coil and tested for solderability in the manner described in Example I. The results were found to be identical, indicating that the process was capable of being carried out by either conventional "batch" plating methods on separate pieces, or continuously on a moving strip of aluminum alloy.

Other sample specimens were subjected to a solder spread test, following the procedures described by C. J. Thwaites at pp. 545–547 of "British Welding Journal" for November, 1965, to which reference may be had for a complete understanding of the test procedure followed.

Briefly, the solder spread test involves a technique in which a fixed volume of solder and flux are placed at the center of a test panel which is then heated to a given temperature for a specified period of time. After cooling the area of spread of solder over the test surface is measured by a suitable means such as a planimeter, or by comparing with standard charts, the magnified image of the solder spread projected on the screen of a microscope. The larger the spread area, the more readily the solder wets the substrate.

For comparative purposes, parallel tests were run on pure copper sheet using pure lead and various tin-lead solders ranging from 2–23% tin. Data generated by the solder spread test are reported below:

Solder Composition	Solder Wet Area - mm²* On Plated Aluminum Substrate (A_1)	On Copper Substrate (A_2)	Al vs Cu Ratio (A_1/A_2)
100% Lead	80	30	2.7
98% Lead, 2% Tin	80	30	2.7
95% Lead, 5% Tin	150	30	5.0
90% Lead, 10% Tin	225	30	7.5
77% Lead, 23% Tin	255	70	3.7

*Solder Volume - 9 mm³

These data show that aluminum alloy treated in accordance with the present invention is more readily wet by conventional solders than is pure copper sheet.

The ability of the method of the present invention to protect aluminum against galvanic corrosion was confirmed in the following manner.

Ribbons of copper plated aluminum and aluminum treated in accordance with the method of the present invention were cut into multiple strips with scissors to expose untreated aluminum edges. The strips were then immersed in sodium chloride and in a commercial, acid zinc chloride flux.

The strips of copper plated aluminum immersed in the flux produced copius gassing at the exposed aluminum edges, while no such gassing was evident along the edges of the aluminum strips treated in accordance with the method of the present invention.

After one hour immersion in sodium chloride, the edges of the copper plated aluminum showed the formation of a white product, while no such product was formed on the edges of the aluminum treated in accordance with the method of the present invention.

The ability of the method of the present invention to protect the treated aluminum against tarnish and atmospheric corrosion was confirmed in the following manner.

Rolls of aluminum, some treated with the chromate step described above and some not, were exposed to the same ambient indoor atmosphere for a period of 6 months. The chromate treated rolls retained their as-plated appearance, whereas the rolls which had not been treated with chromate, stained badly. The staining was taken as an indication of possible surface deterioration. It was deemed that mild fluxing would be required to remove the stain before soldering could be undertaken. The staining also gave an aesthetically displeasing appearance to the rolls which were not chromated.

Aluminum and aluminum alloys treated in accordance with the present invention may be soldered with common, commercially available solders. These include the lead-tin solder alloys in the 5-70% tin range, silver-lead solders, antimonial-tin solders, tin-silver solder, pure lead, and pure tin.

Further, common, commercially available soldering fluxes may also be used, including aqueous zinc chloride type, rosin-base type, and organic liquid types.

Any of the conventional soldering techniques presently employed for soldering copper and copper alloys may be used in the practice of the present invention. These include soldering irons, torches, dipping and furnace methods. The particular technique employed will depend on the size, configuration and heat requirements of the joints to be soldered. By way of specific example, furnace soldering techniques are generally used in the construction of automotive radiators and dip methods are conventionally used in the manufacture of automotive heater cores.

While the present invention has been described with reference to certain specific embodiments, neither the embodiments illustrated nor the terminology employed in describing them is intended to be limiting; rather it is intended that the invention be limited only by the scope of the appended claims.

Having thus described a specific preferred embodiment of the invention, the following is claimed:

1. A method of simultaneously rendering, solderable and protected against galvanic corrosion, a clean aluminum or aluminum base alloy surface to which a nickel coat will not adhere, which method consists essentially of applying to said surface an adherent base system which promotes adhesion between said surface and a subsequently applied nickel coat and then rinsing the treated surface, applying to said adherent base system a nickel coat having a thickness within the range of 2.0–200 in.×10^{-6} and then rinsing the treated surface; and applying to said nickel coat a zinc coat having a thickness within the range of 1.0–100 in.×10^{-6} and then rinsing the treated surface.

2. The method defined in claim 1 wherein said adherent base system comprises a first coating of zinc and a second coating of copper.

3. The method defined in claim 2 wherein said first zinc coating has a thickness within the range of about 0.5 to 5.0 in.$\times 10^{-6}$, and said second copper coating has a thickness within the range of about 5 to 200 in.$\times 10^{-6}$.

4. The method defined in claim 3 wherein said first zinc coating is deposited from an alkaline zincate solution and has a thickness within the range of about 1.0 to about 3.0 in.$\times 10^{-6}$.

5. The method defined in claim 4 wherein said copper coating is deposited electrolytically from a copper cyanide solution and has a thickness within the range of about 14 to about 16 in.$\times 10^{-6}$.

6. The method defined in claim 5 wherein said nickel coating is electrolytically deposited from a nickel chloride-nickel sulfate solution and has a thickness within the range of about 9 to about 11 in.$\times 10^{-6}$.

7. The method defined in claim 6 wherein the second zinc coating is deposited electrolytically from a zinc sulfate solution and has a thickness within the range of about 18 to about 22 in.$\times 10^{-6}$.

8. The method defined in claim 7 comprising the further step of contacting the treated material with an acidic solution containing at least one hexavalent chromium compound whereby said treated material is rendered tarnish and corrosion resistant during storage.

9. The method defined in claim 8 wherein said acidic solution comprises chromic acid.

10. A method of simultaneously rendering solderable and protected against galvanic corrosion at least one surface of a body selected from the group consisting of aluminum and aluminum base alloy bodies, to which a nickel coat will not adhere, comprising the steps of:

a. treating said surface with an alkaline solution to clean and etch it,

b. treating said surface with an acidic solution to desmut it,

c. depositing on said surface an adherent base system, which promotes adhesion between said surface and a subsequently applied nickel coat,

d. depositing on said adherent base system a nickel coat having a thickness within the range of about 2.0 to about 200 in.$\times 10^{-6}$, and

e. depositing on said nickel coat a zinc coat having a thickness within the range of about 1.0 to about 200 in.$\times 10^{-6}$.

11. The method defined in claim 10 wherein said adherent base system comprises a first coat of zinc having a thickness within the range of about 0.5 to 5.0 in.$\times 10^{-6}$, and a second coat of copper having a thickness within the range of about 5 to 200 in.$\times 10^{-6}$.

12. The method defined in claim 11 wherein the thickness of the metal coats deposited in steps (d) and (e) fall within the ranges of about 9.0 to about 11.0 in.$\times 10^{-6}$; and about 18.0 to about 22.0 in.$\times 10^{-6}$, respectively, and the thickness of said first zinc and second copper coats fall within the ranges of about 1.0 to about 3.0 in.$\times 10^{-6}$, and about 14.0 to about 16.0 in.$\times 10^{-6}$, respectively.

13. The method defined in claim 12 further comprising the steps of rinsing the zinc coat deposited in step (e) and then depositing on said zinc plate a chromate coat whereby the treated surface of said aluminum alloy is rendered tarnish and corrosion resistant during storage.

14. The method defined in claim 10 wherein each of steps a-e inclusive is followed by a water rinse.

15. As an article of manufacture, a body formed of a material selected from the group consisting of aluminum and aluminum base alloys to which a nickel coat will not adhere, said body having at least one solderable, galvanic-corrosion resistant surface defined by superposed layers of an adherent base system which promotes adhesion between said surface and a subsequently applied nickel coat, a nickel coat having a thickness within the range of about 9 to about 11 in.$\times 10^{-6}$, and a zinc coat having a thickness within the range of about 18.0 to about 22.0 in.$\times 10^{-6}$.

16. The article defined in claim 15 wherein said adherent base system comprises a first zinc coat and a second copper coat of thicknesses within the ranges of about 1.0 to about 3.0 in.$\times 10^{-6}$ and about 14 to about 16 in.$\times 10^{-6}$, respectively.

17. The article defined in claim 15 wherein said outermost zinc coat has a chromate coat deposited thereon.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,909,209

DATED : September 30, 1975

INVENTOR(S) : Wayne A. Kruper and George R. Kingsbury

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 57 , "x $10^{-19^{-6}}$" should read --10^{-6}--.

Column 4, line 61 , "3030" should read --3003--.

Signed and Sealed this

thirtieth Day of August 1977

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks