

June 3, 1941.

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2,243,979

PRODUCTION OF ALUMINUM-COATED IRON OR STEEL

Original Filed Dec. 17, 1935

Fig. 1.

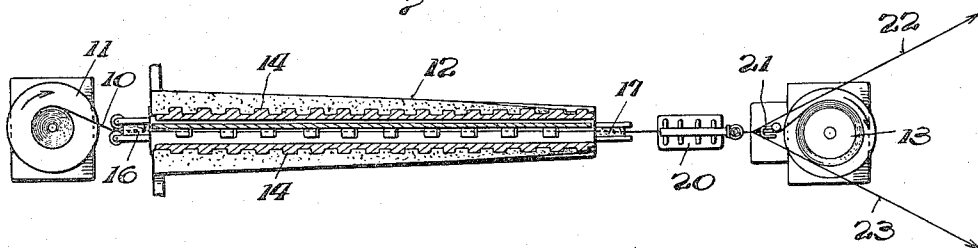


Fig. 2.

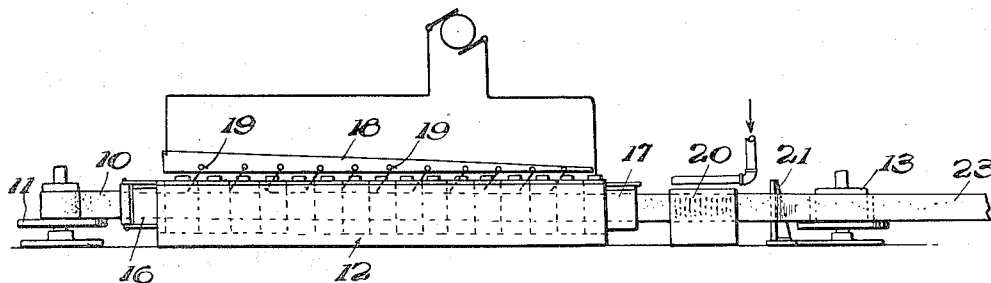
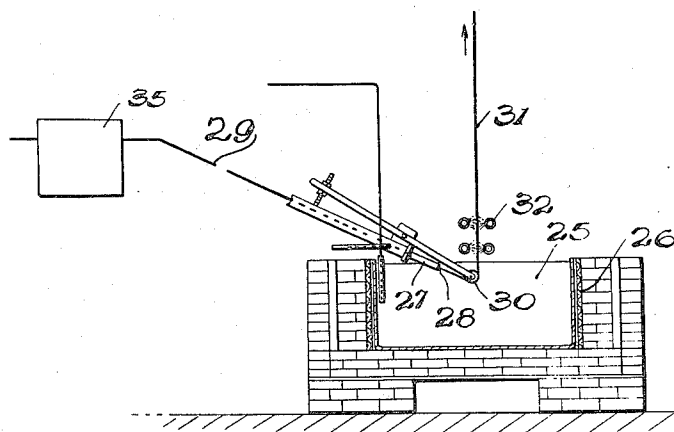


Fig. 3.



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Patented June 3, 1941

2,243,979

# UNITED STATES PATENT OFFICE

2,243,979

## PRODUCTION OF ALUMINUM-COATED IRON OR STEEL

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Original application December 17, 1935, Serial No. 54,890. Divided and this application February 15, 1939, Serial No. 256,543

7 Claims. (Cl. 29—188)

This invention relates to the production of aluminum-coated iron or steel, and more particularly to a method of producing sheets, wires, tubes and other elongated or continuous strips of iron or steel having thereon a substantially impervious aluminum coating that is united thereto by a substantially uniform alloy bond so formed that the composite product is ductile and malleable.

This application is a division of my application Serial No. 54,890, filed December 17, 1935, and entitled Method of producing electrodeposited iron and coated metal products.

Various methods have heretofore been proposed for coating iron or steel with another metal to protect the same from corrosion, contact with food stuffs, chemicals, etc., and which involve the passage of the metal to be coated through a bath of coating metal. Among the processes so proposed is one for coating iron or steel with aluminum or the like which pretreats the iron or steel to be coated with a suitable reducing gas such as hydrogen so that the latter, released in the coating bath, may react with and reduce any oxide of the coating metal such as aluminum that might otherwise interfere with the intimate adhesion or alloying of the aluminum to the iron or steel being coated, such pretreatment of the iron or steel involving subjection of the latter for a time and at a temperature such that the desired charge of reducing gas is carried by the ferric base metal to the coating bath.

One of the objects of the present invention is to provide a method of coating ferric metal with aluminum which takes advantage of hydrogen present in the metal to be coated without need for such preliminary treatment of the metal to be coated.

It has heretofore been proposed to form sheets and other elongated articles of iron by electrodeposition, and as the electrodeposition procedure is known to release a relatively large quantity of hydrogen at the cathode, various procedures have been proposed to free the hydrogen from the iron either during or subsequent to the electrodeposition procedure.

One of the objects of the present invention is to take advantage of the hydrogen present in iron formed by electrodeposition to facilitate and improve the coating of said iron with aluminum.

Another object of this invention is to provide a method of producing aluminum-coated electrodeposited iron which will have the desired tensile strength and ductility and malleability to enable its fabrication into articles that require such operations as cupping, drawing, bending, crimping, etc., without injury to the protective coating thereon.

Another object of this invention is to provide a continuous process by which aluminum-coated

iron or steel may be formed, starting with the formation of the electrodeposited iron and ending with aluminum-clad iron that is malleable and ductile.

Another object of this invention is to provide a method of treating aluminum-coated ferric metal to render the coating thereof substantially impervious without unduly increasing the thickness of the coating.

When a coated metal is examined under the microscope, although the coating is apparently continuous so far as the unaided eye is concerned, numerous microscopic interruptions in the coating are found to exist unless the coating is made relatively thick. Established standards specify the maximum number of such interruptions that may exist in unit area when microscopically examined under a predetermined magnification. Such interruptions in the coating surface may be eventual centers of chemical or electrochemical action, and therefore are a limitation on or source of difficulty with respect to the use of coated iron as containers for certain food stuffs, chemicals, etc.

It is an object of this invention to provide a method of treating coated ferric metal, whether formed by electrodeposition or not, so as to minimize if not entirely avoid such microscopic interruptions in the coating, and thereby fully protect the material in contact with the coated metal from the effects of such chemical or electrochemical action.

Other objects will appear as the description of the invention proceeds.

The accompanying drawing illustrates diagrammatically in the form of a flow sheet a preferred procedure for practicing the present invention, but it is to be expressly understood that the drawing is for purposes of illustration only and is not to be construed as a definition of the invention, reference being had to the appended claims for that purpose. In said drawing,

Figs. 1 and 2 are diagrammatic illustrations, in plan and elevation, of apparatus that may be used in the formation of a continuous strip of electrodeposited iron, whether in the form of a sheet, wire, or other elongated form, the term "strip" being herein used as generic to a sheet, wire, tube or other elongated article.

Fig. 3 is a diagrammatic illustration of a suitable apparatus that may be used in the coating of the electrodeposited iron.

Assuming, for example, that the electrodeposited iron is to take the form of a sheet, which may be continuous or which may be formed in discontinuous sections to be subsequently united in any suitable way, suitable electrodeposition apparatus is provided wherein may be formed a strip of electrodeposited iron of any suitable width, length and thickness. Referring to Figs.

1 and 2 wherein such apparatus is indicated diagrammatically, the cathode 10 takes the form of a band of suitable material having the desired width and length and suitably treated, as by oxidizing, chromium plating, etc., so that the electrodeposited iron may be stripped therefrom. As shown, the cathode is designed to receive a deposit of iron at both of its faces, but if preferred one face of the cathode may be so treated as to prevent electrodeposition thereon. As illustrated, cathode 10 passes from a reel or drum 11, and after passing through the cell 12, goes to a reel or drum 13. If preferred, however, the cathode 10 may be continuous and may be led from the receiving roll 13 back to the roll 11, after passage if necessary through any suitable apparatus for treating its surface to facilitate stripping of the electrodeposited iron therefrom.

The cell 12 may be of any suitable size, character and construction and supplied with any suitable electrolyte. As indicated, the cell at its opposite sides is provided throughout its length with suitable anodes 14 as a source of iron, and suitable bus bars are provided for the anodes and connected with any suitable source of electric current. The cathode 10 passes into and out of the cell 12 through suitable stuffing boxes 16 and 17. A cathode bus bar is indicated at 18 and preferably has a plurality of contact strips 19 which bear on the edge of the cathode 10, the number of such strips being suitably selected to obtain the desired voltage drop through the strip and the desired relative uniform current distribution. It is to be understood that any suitable means may be provided for replenishing or circulating the electrolyte in the cell, for supplying iron to the anodes 14 when they are not in the form of iron plates, etc., and it is also to be understood that the cathode 10 is moved through the cell at such a rate as to obtain the desired thickness of deposited metal before the strip leaves the cell through the stuffing box 17, or if preferred the electrodeposited strip may be given its desired thickness by passage through a plurality of cells or by repassage one or more times through the same cell.

After leaving the cell 12 the cathode with its electrodeposited strips thereon may be passed through any suitable washing or other cleaning apparatus 20, so as to clean the electrolyte adhering to the surface thereof, for example, and then said cathode with its electrodeposited strips is passed to a suitable stripping apparatus 21 wherein the electrodeposited strips, here shown as two in number, 22 and 23, are suitably stripped from the faces of the cathode. The plane of the cathode as it passes through the cell is preferably vertical so as to avoid the formation of pin holes due to the presence of foreign matter or gas collected on the cathode during its passage through the cell.

As the present invention is preferably embodied in a continuous process, the strip is preferably passed continuously from the cell 12 through intermediate treating apparatus for preconditioning the electrodeposited iron hereinafter referred to, and then to and through a coating bath. Referring to Fig. 3, the coating bath is shown as taking the form of a tank 25 provided with any suitable means 26 for heating the same and maintaining the contained metal suitably fluid. The coating metal may be aluminum or any suitable alloy of aluminum, the term "aluminum" being used herein as generic to both. Projecting downwardly into said bath is a nozzle

27 having a restricted outlet opening 28 generally conforming in size and contour to the size and contour of the electrodeposited iron and preferably opening beneath the surface of the aluminum so that the strip enters the aluminum with minimum contact with any oxide film existing at the surface of the molten metal. The electrodeposited metal 29, as shown, is led from said nozzle 27 to and around a drum or roll 30 and thence out of the bath as indicated at 31. After leaving the bath the coated metal may be led to any suitable apparatus for quenching, tempering, cold working, or otherwise treating the coated metal as hereinafter referred to.

As the quantity of hydrogen contained in the strip as it leaves the cell 12 depends upon the particular electrodeposition procedure and apparatus used, said strip may, if necessary or desirable, be subjected to an atmosphere of reducing gas before its introduction into the coating bath, and it may be heated prior to or during its passage through such reducing atmosphere, or it may be heated without passage through such reducing atmosphere, so as to increase or decrease the quantity of reducing gas carried along therewith or to raise the temperature of the strip more nearly to the temperature of the coating bath, etc.

By passing the electrodeposited iron directly from the electrodeposition bath to the coating bath, the hydrogen therein, whether in the form of atomic hydrogen or in the form of a hydride, is available to be freed in the coating bath where it may combine actively with any oxide present, such for example as may exist in solution in the metal of the coating bath or may otherwise occur at the surface of the contacting metals, where it is likely to interfere with the desired intimate adhesion or uniform alloying of the aluminum to the ferric base.

In accordance with the preferred procedure of the present application the electrodeposited iron after leaving the cell 12 and before entering the coating bath is passed through means 35 for working the electrodeposited iron, said means preferably being pressure rolls in the case of a sheet, or it may be a reducing die in the case of wires, etc. This has the advantage of compacting or densifying the electrodeposited iron which otherwise tends to be in a relatively porous condition with the result that the aluminum tends to diffuse thereinto to an undesirable extent during passage through the coating bath and before sufficient quenching is possible. Deep penetration of the aluminum into the iron is undesirable if the resulting product is to be ductile or malleable because of the relative hardness and brittleness of the aluminum iron alloy and the consequent difficulty of working the composite metal without injury to the coating if the alloy layer is permitted to become too thick.

After the coating has been effected the metal may be passed to and through any suitable apparatus for cold working the composite metal, to modify or improve its characteristics, to reduce its cross section, etc. Where, as preferred, the electrodeposited iron is so treated in advance of the coating operation as to compact its surface and limit the tendency of the aluminum to penetrate thereinto, and then as preferred the coated metal is quenched, as diagrammatically indicated in Fig. 3 at 32, as soon as it leaves the coating bath so as to promptly discontinue the tendency of the metals to diffuse into each other, the alloy layer may be relatively thin, and

the composite metal may also be subjected to various forming, drawing, bending and other operations without separating the coating from the core or injuring the coated metal.

Coated metal so formed, when examined under a microscope may show the existence of a certain number of discontinuances, per unit of area, in the metal coating. As before noted, the present practice permits a certain number of such discontinuances in the coating, when microscopically examined at a predetermined magnification, but the presence of these discontinuances in some instances, particularly in the storage of food stuffs which may have an acid or alkaline reaction with the iron, is disadvantageous. In accordance with the present invention these discontinuances may be substantially if not entirely eliminated by integrating with the aluminum-coated ferric metal one or more additional sheets of the coating metal by subjecting the coated metal and a thin sheet of the coating metal, preferably in the form of a relatively thin foil, to a relatively high pressure, preferably by passing the same between pressure rolls. Thereby the foil facing sheet is caused to flow under the pressure of said rolls so as not only to become homogeneously integrated with the coating already formed on the ferric base but to fill up the before mentioned discontinuances in the surface of the latter. The coating sheet is preferably of foil-like thickness so that the total thickness of the sheet after it is subjected to the rolling pressure is not materially greater than that prior to such treatment. In fact the rolling operation may be accompanied by some thinning of the composite sheet. Thus the coating may be given the desired thickness and be made substantially impervious, and yet owing to the prompt quenching after coating, and also to the treatment prior to coating of the base metal when electrodeposited iron is used therefor, the bonding layer of alloy may be kept relatively thin so that the product is ductile and malleable.

While the sheet of metal so united to the coated iron would ordinarily be of the same metal as the coating on the ferric core, the present invention also provides for applying a thin facing of a different metal than the coating metal, if desired, provided that the coating metal is one to which the aluminum facing may be made to adhere intimately and permanently by the procedure herein explained. Thus, for example, the coating metal may be tin and the facing foil applied thereto may be of aluminum so that the aluminum surface is thus provided by its adhesion to the intermediate tin coating formed on the ferric base. The foil-like facing metal so applied to the coated metal will in itself ordinarily have discontinuances, but these discontinuances will rarely coincide with the discontinuances in the coating, and even where such coincidence occurs the flow of the applied facing sheet or of the existing coating or both under the pressure existing during the application of the facing sheet to the coated metal will tend to fill such coinciding discontinuances which until filled are regions of relatively low pressure under the application of the rolling pressure. Thus the resulting product will be substantially free of exposures of the ferric core through discontinuances in the coating.

It will therefore be perceived that by the present invention a process of producing aluminum-coated electrodeposited iron has been provided which may provide continuous sheets, wires,

tubes, etc., and whereby the advantage is taken of the strength and ductility of electrodeposited iron while providing an aluminum coating therefor which is intimately adhered thereto under such conditions that the coated metal is ductile and malleable and may therefore be subjected to various manufacturing operations without disrupting or injuring the coating or its adhesion to the ferric base. Thus the coated metal may be cupped, drawn into tubes, stamped, crimped, corrugated and subjected to a wide variety of fabricating operations. The electrodeposited iron comes clean from the electrodeposition cell, and to the extent that the hydrogen in a highly active state is present as a result of the electrodeposition procedure, it is present as a reducing gas at the coating bath, for release under the temperature thereof, to reduce any oxide that might otherwise interfere with the uniform and intimate adhesion of the aluminum to the ferric base.

The present invention also provides a process whereby the discontinuances ordinarily occurring in coated metal may be largely if not entirely eliminated so as to greatly reduce the tendency to corrosion or chemical and electrochemical reaction with materials in contact therewith, whereby many of the difficulties heretofore encountered in the use of coated iron for the storage of food stuffs, chemicals, etc., have been avoided. Furthermore, while the described procedure for improving the imperviousness of the coating may be used where the coating is formed upon an electrodeposited core as herein explained in detail, it is apparent that as a sub-combination thereunder this procedure for improving the character of the coating is of wide utility and may be used in the formation of aluminum-coated iron or steel wherein the ferric core has been otherwise formed than by electrodeposition.

While the present invention has been described with considerable detail, it will now be apparent to those skilled in the art that various modifications and combinations of the various features disclosed may be made, and certain procedures described as illustrative may be replaced by equivalent procedures, and certain features used without other features, without departing from the spirit of this invention. While the invention has been described more particularly with respect to the formation of aluminum-clad iron or steel in sheet form, it will be apparent as hereinbefore pointed out that the invention may also be equally well applied to the formation of aluminum-coated iron wires, tubes and other forms, and whether the cathode is separated from the electrodeposited metal or left as a permanent part of the aluminum-coated structure. Reference is therefore to be had to the appended claims for a definition of this invention.

What is claimed is:

1. The method of forming in a continuous operation a ductile or malleable aluminum-coated iron strip including the steps of depositing iron on a cathode under conditions favoring the absorption of hydrogen by the iron, stripping the electrodeposited iron from its cathode, reducing the tendency of aluminum to disperse rapidly into the electrodeposited iron by reducing the porosity of the electrodeposited iron at its surface by densifying the surface thereof without substantial loss of the included hydrogen, and then continuously passing said iron while retaining therein hydrogen released at the cathode in the electrodeposition cell into a bath of molten alu-

minum and releasing said included hydrogen from the iron under the heat of said bath to overcome interference with a substantially uniform adhesion of the aluminum to the iron by the reducing action of the included hydrogen on the oxides existing at said bath.

2. The method of forming in a continuous operation a ductile or malleable aluminum-coated iron strip including the steps of depositing iron on a cathode under conditions favoring the absorption of hydrogen by the iron, stripping the electrodeposited iron from its cathode, reducing the tendency of aluminum to disperse rapidly into the electrodeposited iron by reducing the porosity of the electrodeposited iron at its surface by densifying the surface thereof without substantial loss of the included hydrogen, then continuously passing said iron while retaining therein hydrogen released at the cathode in the electrodeposition cell into a bath of molten aluminum and releasing said included hydrogen from the iron under the heat of said bath to overcome interference with a substantially uniform adhesion of the aluminum to the iron by the reducing action of the included hydrogen on the oxides existing at said bath, and then quickly discontinuing the diffusion of the aluminum into the iron by immediately quenching the coated iron after it leaves the bath of molten aluminum.

3. The method of forming in a continuous operation a ductile or malleable aluminum-coated iron strip including the steps of depositing iron on a cathode under conditions favoring the absorption of hydrogen by the iron, stripping the electrodeposited iron from its cathode, reducing the tendency of aluminum to disperse rapidly into the electrodeposited iron by reducing the porosity of the electrodeposited iron at its surface by densifying the surface thereof without substantial loss of the included hydrogen, then continuously passing said iron while retaining therein hydrogen released at the cathode in the electrodeposition cell into a bath of molten aluminum and releasing said included hydrogen from the iron under the heat of said bath to overcome interference with a substantially uniform adhesion of the aluminum to the iron by the reducing action of the included hydrogen on the oxides existing at said bath, quickly discontinuing the diffusion of the aluminum into the iron by immediately quenching the coated iron after it leaves the bath of molten aluminum, and then filling in discontinuities in the aluminum coating by applying under pressure an aluminum foil to the aluminum-coated face of the iron.

4. The method of forming ductile or malleable aluminum-coated iron which includes the steps of depositing iron on a cathode under conditions favoring the absorption of hydrogen by the iron, stripping the electrodeposited iron from said cathode, reducing the tendency of the aluminum to disperse rapidly into the iron by reducing the porosity of its electrodeposited surface by compacting said surface without substantial loss of the included hydrogen, and then passing the electrodeposited iron while retaining therein hydrogen released at the cathode in the electrodeposition cell into a bath of molten aluminum and releasing said included hydrogen from the iron under the heat of said bath to overcome interference with a substantially uniform adhesion of the aluminum to the iron by

the reducing action of the included hydrogen on the oxides existing at said bath.

5. The method of forming ductile or malleable aluminum-coated iron which includes the steps of depositing iron on a cathode under conditions favoring the absorption of hydrogen by the iron, stripping the electrodeposited iron from said cathode, reducing the tendency of aluminum to disperse rapidly into the iron by reducing the porosity of its electrodeposited surface by compacting said surface without substantial loss of the included hydrogen, then passing the electrodeposited iron while retaining therein hydrogen released at the cathode in the electrodeposition cell into a bath of molten aluminum and releasing said included hydrogen from the iron under the heat of said bath to overcome interference with a substantially uniform adhesion of the aluminum to the iron by the reducing action of the included hydrogen on the oxides existing at said bath, and then quickly discontinuing diffusion of the aluminum into the iron by quenching the aluminum-coated iron immediately after it leaves the aluminum coating bath.

6. The method of forming ductile and malleable aluminum-coated iron which includes the steps of depositing iron on a cathode under conditions favoring the absorption of hydrogen by the iron, stripping the electrodeposited iron from said cathode, reducing the tendency of aluminum to disperse rapidly into the iron by reducing the porosity of its electrodeposited surface by compacting said surface without substantial loss of the included hydrogen, passing the electrodeposited iron while retaining therein hydrogen released at the cathode in the electrodeposition cell into a bath of molten aluminum and releasing said included hydrogen from the iron under the heat of said bath to overcome interference with a substantially uniform and intimate adhesion of the aluminum to the iron by the reducing action of the included hydrogen on the oxides existing at said bath, then quickly discontinuing diffusion of the aluminum into the iron by quenching the aluminum-coated iron immediately after it leaves the aluminum coating bath, and then filling in the discontinuities in the aluminum coating by rolling under pressure a foil-like sheet of aluminum into intimate adhesion with said aluminum coating.

7. The method of forming ductile or malleable aluminum-coated iron which includes the steps of depositing iron on a cathode under conditions favoring the absorption of hydrogen by the iron, stripping the electrodeposited iron from said cathode, reducing the tendency of aluminum to disperse rapidly into the iron by reducing the porosity of its electrodeposited surface by compacting said surface without substantial loss of the included hydrogen, then passing the electrodeposited iron while retaining therein hydrogen released at the cathode in the electrodeposition cell into a bath of molten aluminum and releasing said included hydrogen from the iron under the heat of said bath to overcome interference with a substantially uniform adhesion of the aluminum to the iron by the reducing action of the included hydrogen on the oxides existing at said bath, and then filling in the discontinuities in the aluminum coating by rolling under pressure a foil-like sheet of aluminum into intimate adhesion with said aluminum coating.

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