

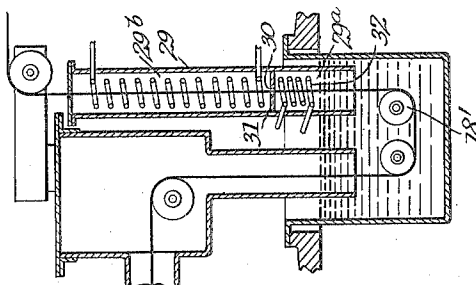
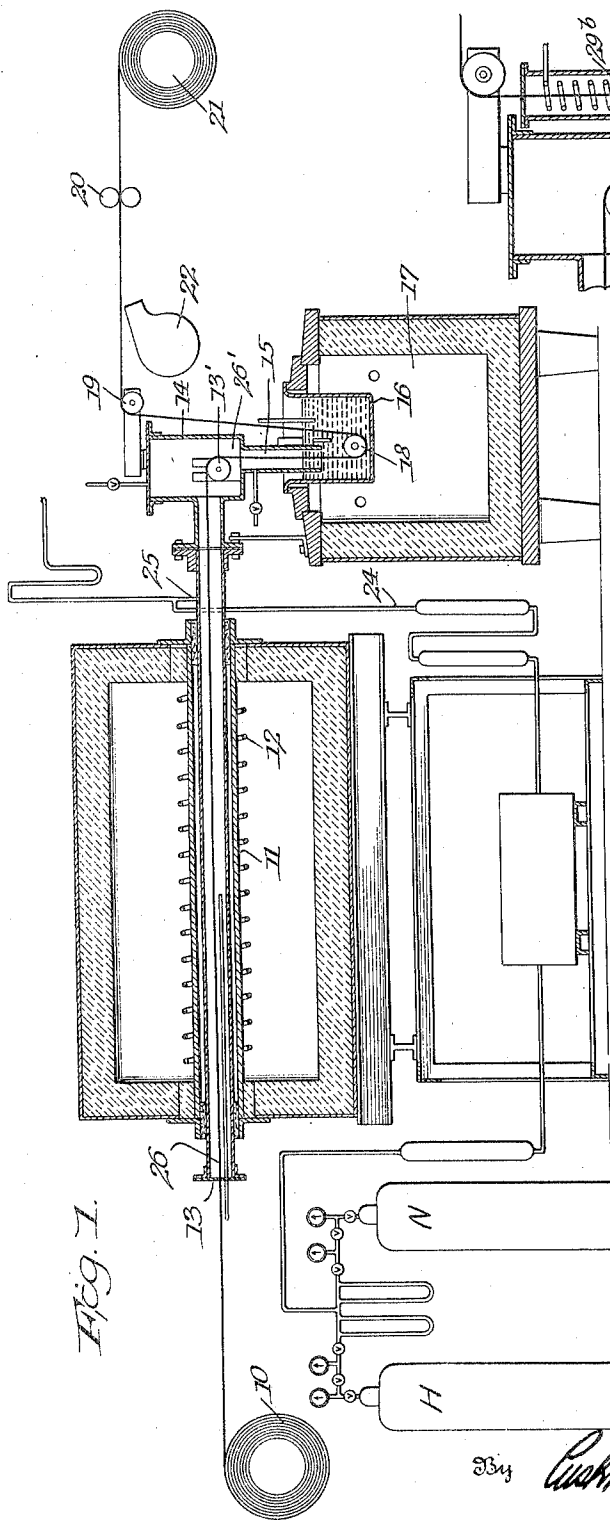
March 18, 1941.

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2,235,729

METHOD OF COATING METAL WITH ALUMINUM

Original Filed Aug. 13, 1936



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UNITED STATES PATENT OFFICE

2,235,729

METHOD OF COATING METAL WITH
ALUMINUM

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Application August 13, 1936, Serial No. 95,940
Renewed July 24, 1940

7 Claims. (Cl. 91—70.3)

The present invention relates to a method of manufacturing a composite metal structure consisting of a metal plate or strip having a coating of aluminum.

It is an object of this invention to provide aluminum coated metal, such as steel sheet or strip, which may be employed in lieu of tin plate now generally used, in the manufacture of various articles, such as container closures and metal containers, such as cans. In the manufacture of these articles there is now generally used a base steel sheet ranging from approximately .005 to .0115 inch thick; these gauges are typical of steel sheet generally used in the container and closure industry.

The present invention seeks to provide sheet steel of this character having an aluminum coating which is superior to the tin coated steel now used and which lacks the defects which have been generally recognized as present in aluminum coated steel as heretofore produced.

It is an object of the invention to provide aluminum coated sheet or strip material which may be annealed, cold rolled to the desired gauge, and subsequently drawn, pressed or stamped for making various articles of the character described without impairing the characteristics of the aluminum coating.

It is an important object of the invention, that the coated metal article has a smooth continuous surface of aluminum highly resistant to corrosion.

A further object of the invention is to provide an aluminum coated sheet or strip in which the aluminum coating has a permanent mirror-like and lustrous appearance.

Another object of the invention is to form a coating which by reason of the control of the iron-aluminum alloy formation will not break down under cold rolling or the high baking temperatures required when using certain types of decorating lacquers and enamels.

Another object is to provide a product relatively free from brittleness which has heretofore characterized aluminum coated steel due to the reaction between the iron and the aluminum, and which may be cold rolled; this iron-aluminum reaction forms an intermediate layer between the coating and the base and sometimes at the surface itself and I have discovered that it must be controlled in the coating process in order that the resulting product may be cold rolled and worked into closures and similar articles. While this reaction cannot be entirely eliminated, it is controlled by this invention and the presence

of the reaction product is so markedly reduced that it is not an objectionable factor where cold rolling, bending and shaping of the coated metal is required, as in the manufacture of containers and closures therefor.

I have discovered that in order to accomplish the foregoing objects it is necessary to maintain a careful control of the sheet or strip to be coated (a) immediately prior to its immersion in a coating bath, (b) during the immersion, and (c) immediately subsequent to removal of the coated strip from the bath.

(a) *Preliminary treatment.*—Numerous attempts have been made to coat steel with aluminum and other metals, and it has been generally recognized that after thoroughly cleaning the metal surfaces, mechanically or otherwise, it is desirable to subject the surfaces to a reducing agent in the form of hydrogen or a hydrogen containing gas; examples of this procedure are to be found in such patents as No. 825,219, Hyde, July 3, 1904; No. 979,931, Cowper-Coles, Dec. 27, 1910; No. 971,136, Monnot, Sept. 27, 1910; British 4,313, of 1907, and British 18,539, of 1907.

I have discovered that in order to obtain a product having the required characteristics, it is necessary to maintain a critical control of the temperature while subjecting the metal to the reducing influence of a reducing gas containing hydrogen, and one feature of this invention resides in the step of maintaining the temperature of the hydrogen or hydrogen containing gas within a definite range hereinafter more specifically described. For coating metal of the character described, I find desirable a temperature not less than approximately 1000° F., and this temperature may run as high as 1600° F. or higher. The strip should be subjected to these temperatures, preferably while traveling, whereby to permit a continuous process, for a sufficient length of time to raise the strip substantially to the temperature selected. It has also been found that by utilizing this temperature it is possible to effect simultaneously a desired heat treatment of annealing of the metal. I find that temperatures in the neighborhood of 1225° F. are satisfactory with a strip speed of 32 feet per minute and this temperature should be increased as the strip speed is increased. It has also been found desirable to maintain an accurate control of the strip temperature between the hydrogen treatment and the immersion in the aluminum to avoid an objectionable drop in the temperature of the metal before immersion; preferably the strip should enter the bath at a

temperature not substantially lower than the bath temperature. I also prefer to avoid such exposure of the strip to the atmosphere as would tend to form an oxide film thereon.

(b) *Immersion step.*—It is well known that the coating of steel by immersion in a bath of hot aluminum forms between the steel and the exposed aluminum surface an iron aluminum alloy (FeAl_3) and the nature of this alloy is discussed in the patent to Ortiz, No. 1,409,017, granted March 6, 1922. I have discovered that in order to obtain a coating of a character which will enable the metal to be cold rolled and formed into articles of the character mentioned, it may be continuously drawn through a bath of aluminum, the temperature of which may range from approximately 1270° F. to 1325° F., provided the speed of travel is regulated to maintain at a desirable minimum thickness the strata of iron aluminum alloy on both metal surfaces, and to prevent the formation of alloy areas or spots at the coating surfaces. To accomplish these results it is desirable that the period of immersion be maintained at a minimum consistent with the formation of a coating of the required thickness. It is also preferred to maintain the surface of the bath, where the strip enters, free of oxide or slag film, and also to prevent the formation of such a film at the area of the bath where the strip makes its exit.

(c) *Post-immersion treatment.*—As the strip leaves the aluminum bath the molten aluminum on its surface has a bright mirror-like reflective surface, and unless the strip is carefully handled immediately after its withdrawal from the bath, its surface becomes dull in appearance. I have discovered that if the metal is rapidly cooled, it retains its bright reflective surface to a marked degree, and that the coated surface thus obtained is much less susceptible to corrosive agents than a relatively dull slowly cooled surface. It is believed that in slow cooling, the iron which is present in all commercial aluminum ingot in the form of FeAl_3 , tends to segregate itself from the aluminum whereas by rapid cooling this iron is maintained well dispersed throughout. I find it desirable to regulate the cooling in such a way as to maintain this desired dispersion and appreciably preserve the reflective surface of the molten aluminum which is apparent on the metal as it leaves the bath. I also prefer to direct the strip as it leaves the bath along a substantially vertical path for a considerable distance whereby to facilitate the flow of excess molten aluminum from the strip back to the bath and to maintain this flow uniform on both surfaces. This post-immersion treatment of the strip may be accomplished by maintaining over the bath a positively cooled chamber through which the strip travels and having therein an inert gaseous medium such as nitrogen. Also, if desired there may be provided immediately over the bath a reducing atmosphere of nitrogen or hydrogen, for example, the temperature of which may be maintained approximately that of the bath, either by positive heating means or by radiation from the bath. The strip or sheet upon chilling of the coating may be continuously wound into coils.

The aluminum coated metal may be further annealed; but it is desirable to maintain the annealing temperature below the melting point of the aluminum, and this will tend to prevent growth of the iron aluminum alloy.

The product may also be cold rolled to the required gauge without objectionably affecting the

aluminum coating, and may be drawn, stamped, or pressed into closures, containers, and similar articles.

The method thus broadly described may be carried out in various ways, and in order that the same may be more clearly understood, I have illustrated in the accompanying drawing a suitable form of apparatus for practicing the method.

Referring to the drawing,

Figure 1 is a diagrammatic view of the apparatus used for carrying out the method of this invention; and

Figure 2 is a fragmentary diagrammatic view of a modification.

In carrying out the invention, by way of illustration, I will describe the method in connection with steel strip or tin plate of varying thicknesses, for example, .005", .010" and .015" and in some cases, strip having a thickness of .0115 is used. This steel strip will usually have a carbon content of from .5 to .10%. The strip is fed from a roll 10 through a reducing atmosphere of hydrogen in the tube 11 and this tube is exteriorly heated, as by a suitable electrical coil 12. The temperature of the tube 11 is maintained above 1000° F., since I find that at this temperature a smooth continuous coating is possible. Temperatures as high as 1600° F. have been satisfactorily employed.

In this preliminary treatment of the metal strip or sheet the temperature factor is critical. I have operated successfully at temperatures from 1000° to 1600° F., but where the temperature is reduced appreciably below 1000° F. the coating has areas which are not properly adhered to the steel and the strip has portions which are not otherwise coated satisfactorily. There does not appear to be any particular time period necessary so long as the strip is raised to the predetermined temperature selected; it has been found that the strip may be travelled at relatively slow speeds through the tube 11; for example, two feet a minute, or even at higher speeds, such as eight or sixteen feet a minute, the speed being largely determined by the period of travel through the aluminum bath through which the strip is continuously fed following this preliminary treatment. I prefer temperatures in the tube 11 of from 1300° F. to 1400° F. since these temperatures permit a desirable heat treatment or annealing of the strip, which enhances the coating.

The entrance end of the tube 11 is closed by a suitable insulated disc 13 having an opening through which the strip passes and the exit end of the tube 11 communicates with a chamber 14 in which is supported a roll 13' over which the strip travels to the bath. The walls of the chamber 14 terminate in a downwardly extending conduit 15 also filled with hydrogen; the lower end of the conduit extends into a pot 16 containing the molten aluminum which constitutes the bath. It will be noted that the strip is maintained out of contact with the air subsequent to the heat treatment and before immersion and enters the aluminum bath in an atmosphere of hydrogen so that at this point no oxide is present on the surface of the bath.

The pot 16 is heated by a suitable furnace 17 so that the aluminum is maintained fluid. Within the bath is disposed a roller 18 which is removable and about which the strip travels downwardly and upwardly through the bath. With respect to the bath, I prefer to arrange the same so that the length and period of travel of the

strip or sheet therethrough are at a minimum since I have found that the period and length of travel have a direct bearing upon the extent of iron-aluminum alloy structure of the product.

5 The bath is preferably maintained at temperatures ranging from approximately 1275° F. to 1325° F., and it has been found that the best results are obtained when the strip is moved at a speed of approximately eight feet a minute, although successful results have been obtained at speeds running from two feet a minute to sixteen feet a minute. Generally a speed is selected which will produce a thin coating with a tendency to form alloy strata on the strip of minimum thickness, it being found that thick alloy strata tend to increase the brittleness of the strip.

10 It is important, also, to control the temperature of the strip entering the bath, and it has been found that best results are obtained if the temperature is not appreciably below 400° F. in the tube above the bath, i. e. at the time of entry; preferably the temperature of the strip between the heat treatment and the chamber 14 above the bath should not drop below from 750° to 900° F.

15 This temperature may be regulated by varying the speed of the strip, and an increase in speed tends to increase the temperature of the strip when it enters the bath. The thickness of the strip is also a factor in determining the temperature, it having been noted that a strip of approximately .0115 has a temperature immediately above the bath, i. e. at the point of entry, of 400° F. with a speed of travel of eight feet per minute, whereas at the same speed a strip having a gauge of .015 has a temperature of approximately 500° F.

20 In order to facilitate determination of the strip temperature, means 26 are located in the tube 11 for controlling the temperature and a thermocouple 26' may be located in the chamber 13.

25 The strip emerges through the bath top surface substantially vertically and is carried over a suitable roller 19. I prefer to have the strip emerge vertically from the bath and travel vertically for a substantial distance, e. g., eighteen inches, since there is less likelihood of lumping, a more uniform coating is produced, and the post-immersion treatment of the coated strip is facilitated.

30 The means for drawing the strip through the tube 11, chamber 14 and bath 16 may be one of several devices, but I prefer a pair of pinch rolls 20 which may be operated to vary the speed of movement of the strip through the tube and bath. After it emerges from the bath, the coated strip is wound by means of a suitable coiler 21. Between the roll 19 and the pinch rolls 20 may be arranged a blower 22 for applying a blast of cool air to the coated strip.

35 The strip as it emerges vertically from the bath has a brilliant molten surface of aluminum which is hardened due to the cooling effect of the atmosphere as well as the roller 19 and blower 22. The roller 19 may be positively cooled, as by internal water circulation, or any suitable cooling means may be disposed in close proximity to the bath so that the coating is hardened by a positive cooling as the strip with molten surfaces leaves the bath. A positive cooling means tends to produce a highly reflective finish and a preferred cooling means is shown in Figure 2.

40 Referring to Figure 2, the strip is led from the bath over a second roller 18' and vertically up through a tube 29, the lower end of which projects into the bath. The tube 29 is in communication with the tube 11 or the line 24 for receiving a supply of hydrogen at elevated temperature therefrom. In this manner, the molten aluminum about the lower end of the tube 29 is also maintained free of oxides so that at no point does the strip in its travel through the bath accumulate any of the usual oxide deposit. On emerging from the bath vertically into the tube 29, the strip enters an inert or reducing atmosphere of hydrogen, nitrogen, or other suitable gas, in the chamber 29a at the lower end of the tube 29; this chamber is at a temperature sufficiently elevated to maintain the aluminum coating molten and free from oxidation. The gas may be heated, for example, by radiation from the coil 32 and the bath. The strip then travels through the opening 30 in a partition 31 in the tube 29 into a chamber 29b which may have a considerably reduced temperature, i. e., a temperature such as will cause instant hardening or freezing of the brilliant mirror-like surface and form a permanent smooth coating of desired lustre. A reducing atmosphere containing nitrogen or hydrogen may be maintained in chamber 29a. In this manner, the strip is given a quick chill, and the cooling temperature will be controlled by the temperature of the cooling medium in a coil 32 positioned in the tube 29 as shown. This quick chill applied to the strip will assure that the same will have a mirror-like lustre and the preliminary travel through a hydrogen atmosphere at increased temperature will avoid formation of a dull or oxide surface. The strip is then led over the roller 19, which may be cooled as previously described, and then if desired, may be subjected to the blower 22 and thereafter wound as at 21.

45 In some cases, the partition 31 is not employed, and the strip travels vertically from the bath through an atmosphere of hydrogen maintained at elevated temperature through the medium of a heating coil 33 and from this zone, the strip then travels into the cooling zone defined by the coil 32 where the cooling and consequent hardening of the molten coating is carried out in a more gradual manner. It is likewise desirable that the strip be travelled through the tube 29 at a rapid rate in order to prevent reaction of the iron and aluminum growth of the alloy strata. In this connection, the temperature of the hydrogen is controlled so as to maintain the coating molten without promoting such reaction or growth of the reaction product. The cooling of the molten strip inhibits the iron-aluminum reaction.

50 In the case of a continuous strip, the speed of the pinch rolls 20 will be adjusted so as to travel the strip through the several instrumentalities at the required speed.

55 I prefer to travel the strip through the aluminum bath at a relatively high speed such as eight feet per minute, since I find that at the higher speeds at which the strip is introduced into the bath, thinner coatings are produced and there is less opportunity for reaction between the iron and aluminum.

60 Referring again to the preliminary treatment, the tube 11 is made of a length and the heating coil surrounds the same for a sufficient distance, such that required temperatures for treating the metal with hydrogen and annealing the metal are possible while passing the sheet through the tube 11 at the desired speed. It will be observed that the strip undergoes a cooling as it passes from the confines of the coil 12 into the chamber 14 and to the bath and the speed of the strip is controlled so that the temperature drop is not

objectionable in order that the advantages above described may be obtained. If desired, the heating means 12 may be extended throughout the length of the tube 11 and about the chamber 14 and tube 15. By having the tube 15 disposed below the level of the bath in the pot 16, no oxide film will form at the surface of the bath where the strip enters. When the construction shown in Figure 2 is not employed, a suitable skimming means may be used to remove or reduce the amount of oxide present at the surface of the bath at the point where the strip emerges. The oxide film as will be appreciated prevents formation of a smooth continuous coating, and it is desirable therefore that its effect be reduced to a minimum.

As one example, tin plate having a thickness of .0115" after cleaning to remove lubricant from the surface is passed into the tube 11 in which the hydrogen is heated to about 1300° F. and the strip is carried through the tube at a speed of about eight feet per minute. The strip at the point of entry into the bath registers by means of the thermo-couple 26 a temperature of about 400° F. In the case of steel strip having a thickness of .015", the strip enters the bath at a temperature of about 500° F.

At this speed, the strip is carried through the bath having a temperature of about 1325° F. and a coating was produced which was less than 0.0012".

The resultant coated sheet treated either in accordance with Figure 1 or Figure 2 may be cold rolled in several passes to reduce its thickness down to, for example, .003" with no breakage of the surface or the bond, the coating remaining perfectly intact.

Where a lustrous or mirror-like surface is desired, the sheet is withdrawn from the bath as shown and described in connection with Figure 2, first through a reducing and non-oxidizing atmosphere, such as hydrogen, at elevated temperatures, and then through a quick cooling zone to harden the molten coating and preserve the lustre. Instead of using hydrogen in the tube 29, any non-oxidizing gas such as nitrogen may be employed.

It is to be noted in connection with Figures 1 and 2 that the strip is maintained out of contact with the atmosphere either until it emerges from the bath or until it emerges from the tube 29.

Thus the heating and cleansing with hydrogen, the annealing step, and the coating and subsequent hardening steps are conducted as a continuous operation. If desired, the process may be carried out with sheets of definite size, and it is to be understood that the thickness of the sheets and the strip material may vary as well as the aluminum coating applied, in accordance with the product desired.

Before operating the apparatus it is desirable that the tube 11 and pot 16 be flushed with nitrogen from tank N, the same being admitted through line 12 and entering the tube by a suitable valve 25. After the apparatus has been flushed with nitrogen, the hydrogen is then run into the tube from the container H, but is first preferably carried through a catalytic chamber 27 for removing oxygen and through the chambers 28 where any moisture is taken out, the hydrogen then entering the tube 11 through valve 25.

As heretofore explained, the product resulting from this method may be further annealed if

desired, and may also be cold rolled. It has been established that this product is capable of taking high rolling reductions without any detrimental effects. I have cold rolled material originally .013" thick in several passes down to .003" without breaking or objectionably affecting the coating. When the thickness of the FeAl₃ alloy is controlled in the manner described, the product may be cold rolled and suitably worked as by drawing or stamping, for the manufacture of closures or metallic containers. The coating is remarkably free of porosity and as compared to tin plate the product is superior. Crown caps, which are typical of closures made from the product, when compared to crown caps made from standard tin plate, show enhanced resistance to corrosion. Also the ductility of the steel after being coated, shows an increase of from 250 to 350%.

Although I have described the method in considerable detail, it will be understood that the apparatus illustrated and the details of the method disclosed are merely illustrative and that such variations in the method and apparatus are within the invention as come within the scope of the appended claims.

What is claimed as new is:

1. In the art of manufacturing aluminum coated sheet steel the method which comprises continuously traveling and heating sheet steel in a reducing atmosphere for a sufficient length of time to raise the temperature of the metal to at least approximately 1300° F., reducing the metal to a point between substantially 400° F. and 900° F. in a non-oxidizing atmosphere and introducing the metal without exposure to oxidizing influences into a bath of aluminum.

2. In the art of manufacturing aluminum coated sheet steel the method which comprises continuously traveling and heating sheet steel in a reducing atmosphere for a sufficient length of time to raise the temperature of the metal to at least 1300° F., continuing the travel of the metal and simultaneously reducing the temperature thereof to a point between substantially 400° F. and 900° F. and maintaining the metal while cooling in its travel from the heating means in a non-oxidizing atmosphere, and introducing the metal continuously from the cooling means to an aluminum bath, while maintaining a non-oxidizing atmosphere about the metal and said bath.

3. In the art of manufacturing aluminum coated sheet steel the method which comprises continuously traveling and heating sheet steel in a reducing atmosphere for a sufficient length of time to raise the temperature of the metal to at least approximately 1300° F., reducing the metal to a point between substantially 400° F. and 900° F. in a non-oxidizing atmosphere and introducing the metal without exposure to oxidizing influences into a bath of aluminum, removing the aluminum coated steel from said bath and cooling the same by playing a blast of air upon the sheet.

4. In the art of manufacturing aluminum coated sheet steel the method which comprises continuously traveling and heating sheet steel in a reducing atmosphere for a sufficient length of time to raise the temperature of the metal to at least approximately 1300° F., reducing the metal to a point between substantially 400° F. and 900° F. in a non-oxidizing atmosphere and introducing the metal without exposure to oxidizing influences into a bath of aluminum, re-

moving the aluminum coated steel from said bath, and heating the same in a non-oxidizing atmosphere to maintain the coating molten, and then giving the coating a quick cooling in a non-oxidizing atmosphere.

5 5. In the art of manufacturing aluminum coated sheet steel the method which comprises continuously traveling and heating sheet steel in a reducing atmosphere for a sufficient length
10 of time to raise the temperature of the metal to at least approximately 1300° F., reducing the metal to a point between substantially 400° F. and 900° F. in a non-oxidizing atmosphere and
15 introducing the metal without exposure to oxidizing influences into a bath of aluminum, removing the aluminum coating steel from said bath and cold-rolling the same.

6. In the art of manufacturing aluminum coated sheet steel the method which comprises
20 continuously traveling and heating sheet steel in a reducing atmosphere for a sufficient length of time to raise the temperature of the metal to at least approximately 1300° F., reducing the metal to a point between substantially 400° F.
25 and 900° F. in a non-oxidizing atmosphere and

introducing the metal without exposure to oxidizing influences into a bath of aluminum, the temperature of the steel introduced in the bath and the period of immersion in the bath being
5 such as to retard formation of FeAl₃ whereby the aluminum coated steel may be cold-rolled and removing the aluminum coated steel from the bath and cold-rolling the same.

7. In the art of manufacturing aluminum coated sheet steel, the steps of continuously pass-
10 ing a strip of steel through a heating means and heating the strip therein to a temperature of at least approximately 1300° F. in a non-oxidizing atmosphere, then while maintaining the sheet
15 in a non-oxidizing atmosphere, cooling the same while traveling to an aluminum bath to a temperature of between substantially 400° F. and
20 900° F., continuously introducing the strip from the cooling means to the aluminum bath while maintaining the strip and the bath in a non-oxidizing atmosphere, continuously passing the
strip through the bath, and after the strip emerges, hardening the coating and cold-rolling the aluminum coated sheet.

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