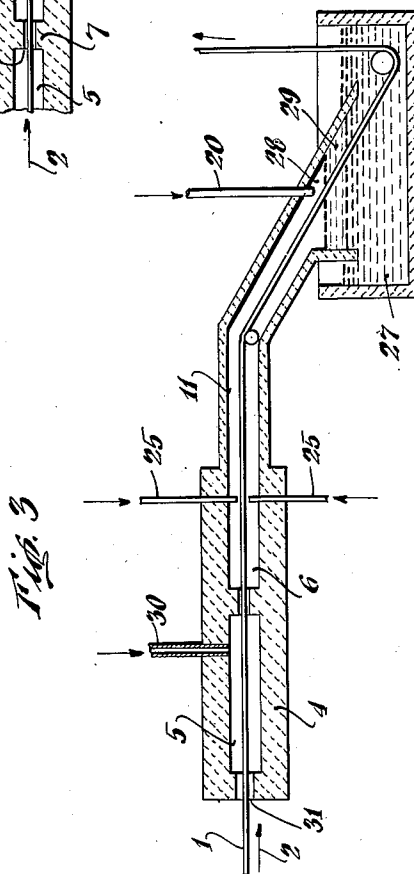
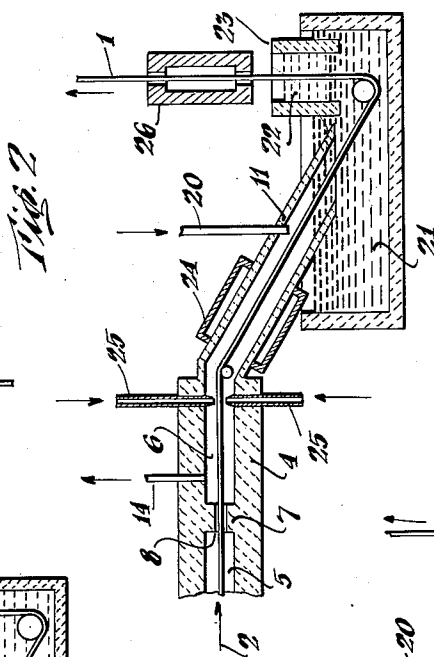
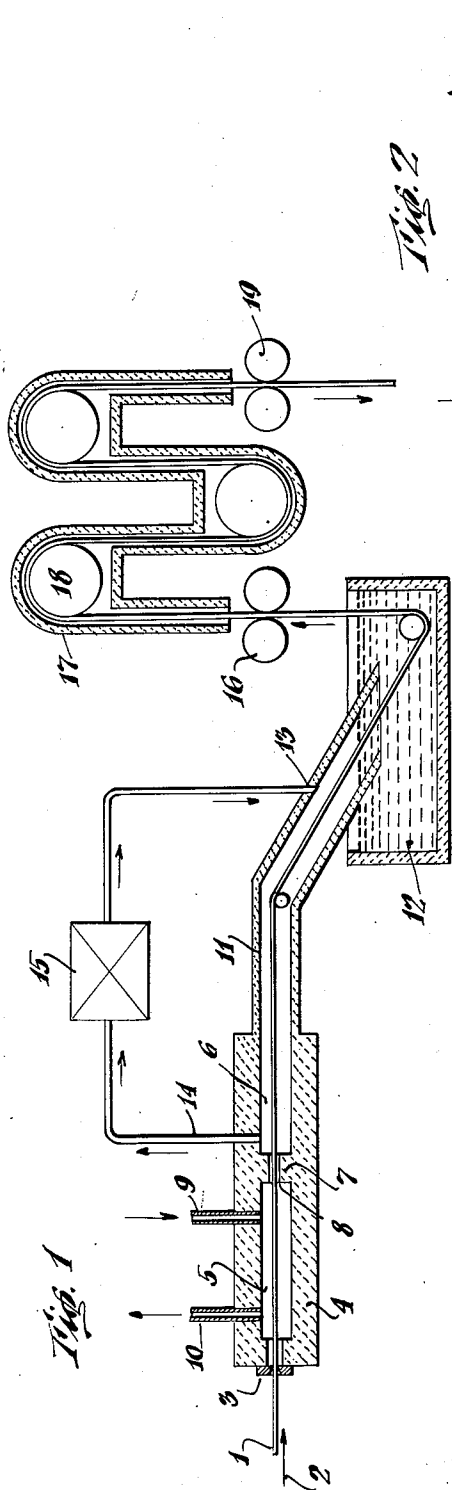


Oct. 9, 1951

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PROCESS FOR COATING METALLIC
OBJECTS WITH OTHER METALS
Filed Dec. 21, 1946

2,570,906



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2,570,906

PROCESS FOR COATING METALLIC
OBJECTS WITH OTHER METALS

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Application December 21, 1946, Serial No. 717,773
In Spain July 31, 1946

10 Claims. (Cl. 117—51)

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The present invention relates in general to a method of coating metals with layers of other metals and has as one of its more special objects the obtention of a hot dipped coating of iron or steel with pure aluminium or with corrosion resisting aluminium alloys or with aluminium-iron compounds.

The fundamental object and nature of my invention is the obtention of metal products of various forms, such as sheets, strip and wire, of highly improved mechanical and surface qualities, provided with continuous, uniform, adherent and ductile, corrosion resisting coatings free of traces of foreign substances and built up of pure homogeneous metal or an alloy or definite metal compounds. These results are obtained in a more economical, efficient and simple way than by any of the heretofore known methods.

The most economical and rational method of metal coating, advanced by modern technical practice, consists in combining in one continuous operation conducted in a reducing atmosphere the three principal manufacturing steps of usual hot-dipped metal coating production, which, as it is known, are: the base metal annealing, the deoxidation of the surface to be coated, and the immersion in the molten coating metal bath.

Such a method presents, moreover, the well known economical and technical advantages of continuous production, the possibility of suppressing the conventional pickling in acid which, besides its expensive cost, causes, as it is well known, undesirable phenomena, such as hydrogen absorption by the treated metal and the formation on the surface of the latter of intercrystalline fissures retaining by capillarity salt particles derived from reaction of the acid with the metal treated.

However, heretofore, it has not been possible to obtain by this method an entirely satisfactory product, because of the porosity, poor adherence or brittleness of the coating, which imperfections result in part at least from the insufficiency of the control of the atmosphere maintained in the preparatory heat treatment step and/or from the methods of application of the coating. It also appears that the above and other insufficiencies of the products of the prior coating processes that have omitted the pickling step, such as poor corrosion resistance of the coating, partly result from the presence in the said coating of foreign substance particles and absorbed gases. The low mechanical qualities of the manufactured product appear also in part to result from the presence in the base metal and in the coating of

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gases absorbed during the previous treatments and from the difficulties of obtaining a satisfactory heat treatment when using the different temperature ranges heretofore proposed for the various manufacturing steps. For instance, a large scale application of this method for tinning or for aluminium coating has been prevented hitherto because of an excessive porosity and/or poor adherence, brittleness, roughness and exaggerated thickness of the coatings.

Its application to the easiest case of the metal-coating art, viz., galvanizing, also resulted in the production of lower quality coatings, as compared to those obtained with the conventional methods using the acid pickling step, especially in respect to the poor adherence of the zinc coating. Attempts to overcome this drawback by additions to the coating metal bath of other metals, such as aluminum or "silver metal," have allowed of an increase of the adherence of the zinc coating, but lead, on the contrary, to decrease of the corrosion resistance of the latter as a consequence of the structural heterogeneity of the obtained coating and the resulting formation and action of microscopic electrochemical couples.

My invention obviates all the aforementioned difficulties and procures moreover important advantages, which will be set forth in the following disclosure.

I have discovered that the utilization of a determined heat treatment method in the presence of certain gas mixtures, as well as the application of certain treatments during the coating step, makes it possible to obtain, in any one of the aforementioned cases of metal coating, products of a much higher quality than that obtained by any one of the heretofore known methods. In particular, applying my process to the most difficult case of the metal coating art, the coating of steel with pure aluminium, I am able to obtain a coating without any porosity and one that is exceptionally adherent and uniform. Likewise this invention has been applied, with greatly improved result to copper tinning.

According to my invention, the bodies that are to undergo the coating treatment are heated to or somewhat below the temperature desired in the subsequent occluded gas removing step in the presence of an atmosphere which accomplishes a reducing action. An inert atmosphere is subsequently used, in which the said bodies are consecutively maintained at the desired gas evolving heat treatment temperature, cooled to or below the temperature of the coating bath, and finally

dipped in the latter. The maintenance of the inert atmosphere during the heat treatment allows the evolution of the gases absorbed by the bodies or objects during the previous steps of their treatment and the evacuation of the so evolved gases. Gas absorption by the base metal that is to undergo the coating occurs during heat treatment in all the known reducing atmospheres with a great velocity and in a great quantity, especially when using hydrogen as the reducing atmosphere. It also occurs during the initial metal manufacturing steps, such as melting and refining, as well as during pickling in acid after hot rolling or prior to cold rolling or drawing and similar mechanical transformations of metals into their conventional shapes, such as strips, sheets or wire. Such absorption causes the low mechanical qualities of the article, porosity of the coating and, probably, the poor adherence of the latter.

It has been discovered that the treatment according to this invention makes it possible to accomplish the indispensable perfect deoxidation of the surface of the base metal by the action of a reducing atmosphere while at the same time completely avoiding the pernicious effects of the absorption of this atmosphere by the base metal and by the coating bath. Moreover, in some cases, the quantity of gases already occluded by the base metal before its deoxidation by annealing in a reducing atmosphere may be even considerably lowered.

My invention furthermore makes it possible to carry out the essential preliminary deoxidation of the metal shapes or bodies with considerably increased efficiency by mixing with the reducing atmosphere a strictly controlled quantity of water vapor in order to obtain a gaseous mixture exerting the most effective purifying action while avoiding all presence of such water vapor in the succeeding gas removal step of heating in the inert atmosphere.

The fact that the process according to this invention has been applied with greatly improved results to the aluminizing, tinning and galvanizing of steel and to copper and brass tinning, shows clearly that, contrary to the opinion previously held, the coating formation process is just the same in all the mentioned cases, provided that the base metal can be put in contact with the coating metal in absence of any occluded gas and of any particle of other foreign substance or chemical combination of gases with metals.

Now, this invention permits equally to improve considerably the qualities of the obtained coating by applying determined treatments subsequent to the coating cooling step, and especially in the particular cases of coating steel or iron with aluminium or aluminium alloys. All these particular cases being completely identical as far as the invention is concerned, I shall henceforth, in order to simplify this disclosure, use the word "aluminium" not only to designate pure aluminium but equally aluminium alloys, and the word "steel" to designate either steel or iron.

In fact, it has been discovered, that the ductility and uniformity of the aluminium coating obtained according to this invention may be greatly improved by subjecting the latter, after its solidification and before cooling it to the temperature of 300° F., to a controlled light rolling treatment. The ductility and uniformity of the coating may be further improved by retarding the cooling of the treated bodies in a certain determined way during the solidification of the aluminium coating and the subsequent cooling

of the latter to a temperature ranging between 750 and 400° F.

Preferred exemplary embodiments of the invention applied to the particular case of coating of cold rolled mild steel strip with aluminium will be now described in detail with reference to the accompanying drawings, such disclosed embodiments constituting only representative examples of the numerous cases and ways in which the principle of the invention may be used.

In said accompanying drawings:

Figure 1 is a diagrammatic sectional view of one form of apparatus adapted to the aluminium coating of steel strip which may be used to perform the process embodying my invention;

Figure 2 is a diagrammatic sectional view of a modified form of one part of the apparatus of Figure 1;

Figure 3 is a diagrammatic sectional view of another apparatus for coating a steel strip with an aluminium-iron combination layer.

As it may be seen by reference to Figure 1, the treated strip 1, is moved in the direction of the arrow 2 and enters through a conventional gas-tight entrance device 3 into a conventional gas-tight furnace 4 which contains two heating chambers 5 and 6 separated by a gas-tight inner wall 7 provided with the orifice 8 which permits the passage of the strip 1 from chamber 5 to chamber 6.

It is to be understood that the strip introduced into the furnace 4 has been brought to a dustless and perfectly degreased state by one of the known present day processes such as the electrolytic degreasing process. Degreasing by an imperfect process, such for example as the out of date method of decomposition by pyro-rogenation which consists in burning the oil when heating the steel in an oxidizing atmosphere to the temperature of the temper colours appearance, must be excluded, due to the presence after such a treatment of particles of carbon incrustated in the steel surface, which prevents the formation of a continuous coating.

In the chamber 5 filled with an atmosphere effecting a reducing action, the strip is heated, according to the mechanical qualities desired for the finished product, either to the conventional annealing temperature or to the normalizing temperature, viz., from 1470 to 1710° F., or when necessary, to a temperature from 35 to 180° F. lower than the above mentioned, increasing in this way, as it has been found, the efficiency of the next succeeding treatment designed to bring about evacuation of the absorbed gases. The said reducing atmosphere is continuously supplied to the chamber 5 through the inlet 9 and may be eventually withdrawn and recovered by the outlet 10. This atmosphere may have the usual composition of one of the conventional atmospheres called "reducing," which are used in practice to reduce the superficial oxide layer of metals during their heat treatment. Preferably, however, strictly determined quantity of water vapour is simultaneously and continuously supplied to the inlet 9 in order to increase the purifying action of the said reducing atmosphere, as explained above.

Contrary to the practice of the known metal coating processes involving the de-oxidation of the base metal by a heat treatment in a reducing atmosphere, in which the presence of water vapour in the said atmosphere is rigorously avoided, it has been found that the voluntary addition of water vapour to the latter, according

to this invention, produces the following desirable results: acceleration of the deoxidizing action of the reducing atmosphere, increase of the efficiency of said action and, in certain cases, a superficial decarburization of the base metal that facilitates the formation of an uninterrupted, uniform and homogeneous coatings. The negative effects of the presence of the water vapour in the reducing atmosphere, in the case of metal coating practice, are the following: (1) absorption by the hot base metal and by the molten coating metal bath of the hydrogen liberated by the water vapour in contact with these metals; (2) reoxidation of the base metal during the cooling step prior to its immersion in the coating bath, which is explained by the fact that the same atmosphere, called "reducing," which contains a determined amount of water vapour and which produces a reducing action at a determined temperature, has an oxidizing action at a lower temperature range. These negative effects are completely suppressed by this invention, firstly, due to the fact that all presence of water vapour is strictly avoided during the steps of the base metal cooling and the immersion in the bath, and, secondly, due to the subsequent treatment which permits the evolution and the evacuation of the gases absorbed by the base metal.

To perform this last treatment the strip 1 passes through the heating chamber 6, being maintained during this passage at the normal annealing or normalizing temperature in the presence of an energetically renewed inert atmosphere, then the said strip consecutively passes, always under the said inert atmosphere protection, through the chamber 11 where it is cooled to, or slightly below, the temperature of the molten aluminium coating bath 12; said cooling chamber 11 being sealed at its exit end by said bath 12 and forming with the chamber 6 a gas-tight hole.

The said inert atmosphere must not possess the property of being absorbed by hot steel or by molten aluminium, or at least it should not be absorbed with the same intensity and with the same pernicious effects as all the known reducing atmospheres. On the other hand, it must permit by its nature and by the methods of its application the most complete disengagement of the active components of the reducing atmosphere absorbed by the strip, such as hydrogen. Moreover, the said inert atmosphere must not exercise an oxidizing action on the surface of the treated objects during the cooling step prior to the immersion in the coating bath and it must be, therefore, as free of oxygen and water vapour as possible.

To obtain the aforementioned results, I prefer to use the inert atmosphere anhydrous nitrogen, adding to the latter a little quantity of anhydrous hydrogen, just in the proportion required to counterbalance any penetrations of atmospheric air into the cooling chamber 11, which are practically impossible to avoid completely, and which would promote without this hydrogen addition a reoxidation of the objects cooled in this chamber 11. The said inert atmosphere is constantly supplied by the inlet 13 into the cooling chamber 11 and passing through it, as well as through the heating chamber 6, is aspirated through the outlet 14 out of the furnace 4 by a pump not represented in the drawing, carrying away with it the reducing gases released by the treated strip. Once out of the furnace the said atmosphere is separated from the foreign sub-

stances, which had contaminated it, by a conventional regenerating apparatus 15 and, possessing its initial analysis, is finally sent again through the inlet 13 into the chamber 11. Thus the necessary intense circulation of this inert atmosphere is realized at low cost. It can be noted, as an example, that I obtain a perfect result in treating cold rolled mild steel strip, using as the said inert atmosphere a mixture, practically free of water vapour, composed of 90 to 98% of nitrogen and of 2 to 10% of hydrogen and, as the said reducing atmosphere, a mixture of 75 to 98% of hydrogen and from 2 to 25% of water vapour; the said strip being heated in the chamber 5 to a temperature ranging from 1470 to 1670° F., then maintained in the chamber 6 during a period from 1/3 to 2 minutes at a temperature ranging from 1510 to 1710° F., and being finally cooled in the chamber 11 to a temperature ranging from 1110 to 1260° F. The temperature of the pure aluminium bath 12 is maintained at a temperature only slightly above its melting point and not exceeding 1290° F.

The strip treated in this way and immersed in the coating bath 12 is instantly covered by a continuous and regular layer of chemical compounds of the two metals, aluminum and iron. As is known, the presence of such a layer is indispensable for obtaining adherent coating. But, as this combination is usually very brittle, its layer has to be as thin and regular as possible, in order to be able to overcome without breaking or flaking the mechanical transformations of a finished product. It is well known that the thickness of this compound layer decreases when the time of immersion of the base metal in the coating bath and the temperature at which occurs the formation of these compounds are decreased. The great speed of formation of the compound layer and the fact that the treated bodies are dipped at a moment when they are cooled to or slightly below the temperature of the said bath, according to the invention, allows a reduction of the time of immersion in the bath only to a few seconds, and even to a fraction of a second, and make it possible to obtain the formation of compound layers at practically the lowest possible temperature. The chemical compound layer thus obtained is uninterrupted and much thinner and regular, and therefore more ductile, than any one produced by the known methods. The said treated strip is withdrawn from the bath 12 upwardly with or without the use of the conventional wiping and/or oxidation preventing exit devices, such as exit rolls, flux exit box or a protective gas flow.

After the solidification of the coating and before it is cooled to the temperature of 300° F. the said coating may be subjected to a light rolling treatment, not affecting the steel base of the product, by passing between the rolls 16; said treatment being particularly efficient when applied immediately after the moment of coating solidification. To this end the rolls 16 may be placed above the bath 12 at a convenient height corresponding to the place where the said solidification occurs. It was equally found that the efficiency of the said rolling treatment may be further improved when it is performed not by a conventional rolling mill, but when adopting for the rolls 16 as small a diameter as possible, viz., for example, from 2" to 8". The highly positive results of this treatment are probably explained on the ground that the coating, which must be very ductile at such a temperature range,

is in this way subjected to a certain stress of compression without affecting the much harder steel base, thus enabling the internal intercrystalline strains to disappear, which otherwise would be present in such a coating due to the shrinkage of aluminium during its solidification and during the cooling of the product, the expansion coefficient of aluminium being higher than that of the steel base.

During the solidification of the coating and the subsequent cooling of the treated strip, or after the passage of the latter through the rolls 16, the said strip may pass through the heat-insulated muffles 17, which must possess a sufficient heat insulation and a sufficient length in order to hinder gradually and during at least from 2 to 5 minutes the cooling of the strip to the temperature comprised between 700 and 400° F.; the effect of the said gradual cooling being the improved ductility of the coating, which results probably from the uniform distribution of the forementioned intercrystalline strains in the coating obtained according to this invention. I prefer to perform the said gradual cooling step while advancing the strip in vertical planes passing it upwardly and downwardly around the pulleys 18. The strip coming out from the muffles 17 may be subjected to a second light rolling treatment performed by another pair of rolls 19 before the strip is cooled to the temperature of 300° F.

In cases where it is not possible to avoid atmospheric air infiltrations into the cooling chamber 11, the proportion of hydrogen in the atmosphere of the last chamber may be increased correspondingly, for example, up to 20% in order to prevent the risk of re-oxidation of the strip in the said chamber; this, by adopting the methods represented in the Figure 2. According to the modifications of this latter embodiment of my invention, an atmosphere composed, for example, of 80% nitrogen and 20% hydrogen, is introduced at a low rate into the cooling chamber 11 through the inlet 20. In order to avoid the contact of this last atmosphere relatively rich in hydrogen with molten aluminium and thus to avoid hydrogen absorption by the latter, the end of the chamber 11 is sealed by the molten lead bath 21, in which the treated strip is immersed and from which it is withdrawn passing through a layer of molten aluminium 22 floating above the said lead bath in a container 23. It has been found that aluminium being much lighter than lead, these two metals do not mix and do not react together. Likewise, the steel strip is not affected in any way by this passage through the lead bath. In order to diminish the danger of reoxidation of the strip, the time necessary for the cooling of the strip in the chamber 11 may be reduced and the latter may be provided at this end with water jacketing 24. In this case the inert atmosphere formed by pure nitrogen is introduced directly at a high rate into the heating chamber 6 by multiple pipes 25, which distribute the flow of this last gas upon the whole surface of the treated strip in order that the hydrogen partial pressure may be constantly maintained very low on the surface of the strip, all hydrogen released by the latter, as well as the hydrogen diffusing from the chamber 11, being immediately evacuated by this flow of nitrogen.

In case when the speed of advancement of the strip has to be slow, the bath represented in the Figure 2 may be used in order to decrease the time of contact of the strip with the molten aluminium; the layer 22 of this latter metal be-

ing in this case as thin as desired. In view of special applications of the product, the corrosion resistance at high temperatures and the surface electronic emission power of the aluminium coating may be greatly improved by an additional treatment, which is represented in the embodiment of invention shown by this Figure 2. Here the strip, after its aluminium coating solidification and before being cooled to the temperature of 930° F. is subjected to an additional treatment, passing through a furnace 26 where the strip surface is heated to a temperature from 1290 to 1830° F. during a few seconds until a blackish lustreless coating is obtained.

Referring to Figure 3 I have indicated a modified apparatus for coating steel strip with an aluminium-iron chemical compound layer. Here the coating bath is formed by the molten lead 27, wherein is submerged the bell 28, formed by the exit end of the cooling chamber 11, containing a molten aluminium layer 29 floating on the said lead. Both aluminium and lead are maintained at a temperature slightly higher than that of the aluminium melting point. The treated strip is passed through the molten aluminium layer 29, where it is coated by a layer of iron and aluminium compounds, into the lead bath 27, from which it is withdrawn coated with a layer of the said compounds free of lead or of free aluminium. The formation of a pure aluminium layer is prevented by this method, which makes it possible apart from the economy of aluminium thus obtained, to produce a coating formed exclusively by iron-aluminium compounds possessing a high melting point and thus furnishing an efficient protection against corrosion at temperatures which may reach 1920° F. Such a coating has a surface showing a very uniform structure of simple crystals presenting an agreeable pattern. The micrographic and X-ray study of this compound layer shows that it is formed by: (1) a solid solution of aluminium in iron; (2) an overstructure of Fe_3Al and of FeAl ; (3) a non-identified phase, probably Al_2Fe ; (4) and finally by the phase Al_3Fe ; the total thickness of such a coating being of about 1-5 microns.

Referring again to Figure 3 the inert atmosphere is constantly introduced firstly through the inlet 29 of the chamber 11, in a small quantity which is just sufficient to prevent the re-oxidation of the treated strip in this chamber 11, and secondly, in a great quantity, by multiple pipes 25 in the heating chamber 6, exactly in the same way as it was described with reference to Figure 2. The whole of the inert atmosphere flows continuously into the heating chamber 5, where a reducing gas, such as hydrogen, optionally mixed with water vapour in the required proportion and continuously introduced through the inlet 30, transforms this inert atmosphere in one exerting a reducing action previously described. The whole of the used gases may escape to the atmosphere by the entrance orifice 31 of the furnace 4.

The treated strip may be advanced during all the previously described treatments by uncoiling it at the entrance of the furnace 4 and coiling it at the end of the treatments, avoiding in this way the use of expensive conveyors. It is clear that wire may be treated exactly in the same way. Discontinuous objects, such as sheets and tubes, for example, may be advanced during the aforementioned treatments by suitable conveying means.

It is evident that the said coating of iron and

aluminium chemical compounds, which constitutes a particularly efficient protection against the corrosion at high temperature, may be obtained in the same way on ferrous objects such as strip, wire, sheets or any other objects, which may be used, for example, for manufacturing heating apparatus, pipes and containers for hot gases or liquids.

The coating of the said chemical compounds, with or without a final aluminium layer, manufactured according to the invention, has the properties of being particularly adherent and ductile, and may endure the mechanical deformations to which the coated objects may be submitted, such as deep drawing, folding and bending, without scaling nor flaking. Moreover it has a valuable quality of presenting an exceptionally efficient underlayer for subsequent application of adherent layers of paints, varnishes, enamels, lacs and glasses for example, steel sheets thus coated may be used for the manufacture of automobile bodies, being painted or varnished after forming and drawing steps, or for the production of elements for refrigerators and stoves enamelled after their forming. The steel wire thus coated may be used, for example, as a stainless and undetachable core in the manufacturing of reinforced glass.

The aluminium coated steel strip or sheet manufactured according to the invention, may be advantageously used, for the aforementioned reasons and in view of the physical and chemical properties of the aluminium, in manufacturing of canning boxes, receptacles for products to be preserved dry, boxes for paints, varnishes, lacs, waxes, boot polish, cans for gasoline, alcohol and oil, kitchen implements, roofing, protectors for electric wires and cables, light reflectors and infra-red ray reflectors.

Modifications may be made in my invention, without departing from the spirit of it.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A process of coating metallic bodies with a metal selected from the group consisting of aluminum, zinc, lead, cadmium and tin which comprises heating the said bodies to a temperature within the range 1470°-1670° F. in the presence of a reducing atmosphere consisting predominantly of hydrogen and containing from 2 to 30% water vapor, then expelling occluded gases from said bodies by heating them to at least the temperature attained in said first heating step while in direct contact with an inert atmosphere consisting predominantly of nitrogen, and while maintaining said bodies wholly protected by an inert atmosphere consisting predominantly of nitrogen and substantially free from water vapor, cooling them to a temperature not exceeding the temperature of the molten bath of the coating metal, and then passing them into said coating metal bath.

2. A process as set forth in claim 1 wherein the metallic bodies in the gas expelling heating step are heated to a substantially higher temperature, within the range 1510°-1700° F., than was attained during the initial heating step to thereby enhance the gas expulsion action.

3. A process as set forth in claim 1 wherein the reducing atmosphere maintained during the first heating step consists essentially of 75-98% of hydrogen and 2-25% of water vapor.

4. A process as set forth in claim 1 wherein the inert atmosphere maintained during the gas

expulsion heating stage consists essentially of 90-98% nitrogen and 2-10% hydrogen and is substantially free from water vapor.

5. A continuous process of coating mild steel strip with a metal selected from the group consisting of aluminum, zinc, lead, cadmium and tin, which includes the steps of heating the said strip to a temperature ranging from 1470° to 1670° F. in contact with an atmosphere consisting predominantly of hydrogen and containing water vapor in an amount not exceeding 30%, then expelling occluded hydrogen from the said strip by heating it during at least 1/3 of a minute at a higher temperature than maintained in the first heating step within the range from 1510° to 1700° F. while subjecting the whole surface of said strip to a continuous flow of an inert atmosphere containing at least 90% of nitrogen to carry away occluded gases given off by said strip to said atmosphere, and while the said strip is wholly protected by an inert atmosphere consisting predominantly of nitrogen, cooling it to a temperature not exceeding the temperature of the molten bath of the coating metal and then passing it into said bath.

6. A process of coating ferrous bodies with aluminum which consists in heating the said bodies to a temperature within the range 1470°-1670° F. in the presence of a reducing atmosphere consisting predominantly of hydrogen and containing 2-30% of water vapor, then expelling occluded active gases from said bodies by heating them to at least the temperature attained in said first heating step while in direct contact with an inert atmosphere consisting predominantly of nitrogen, and while maintaining said bodies wholly protected by an inert atmosphere consisting predominantly of nitrogen and substantially free from water vapor, cooling them to a temperature not exceeding the temperature of the molten aluminum coating bath and then passing them into said bath.

7. A process according to claim 6 in which said bodies, after they have been passed into the molten aluminum bath, are withdrawn therefrom and cooled gradually for at least 2 to 5 minutes to a temperature within the range 400°-700° F., and thereafter cooled to room temperature.

8. A process according to claim 6 in which said bodies, upon cooling to a temperature not exceeding the temperature of the aluminum coating bath and while protected by the inert atmosphere provided during said cooling step, are passed beneath the surface of a molten aluminum coating bath which floats upon the surface and at the entrance side of a molten lead bath, are then passed through said aluminum coating bath into said molten lead bath, and finally are withdrawn from said lead bath at a point thereof which is free of aluminum.

9. A continuous process of coating ferrous metals in strip form with aluminum which comprises passing a ferrous metal strip into and through a first heating zone wherein it is maintained in direct contact with an atmosphere consisting predominantly of hydrogen and containing from 2 to 30% water vapor, and during the travel of said strip through said first heating zone, heating it to a temperature within the range 1470°-1670° F., then leading said strip to and through a second heating zone wherein the strip is maintained at a temperature at least as high as that attained by it in the first heating zone, and during the course of its travel through

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said second heating zone subjecting said strip to direct contact with an inert atmosphere consisting predominantly of nitrogen, causing said inert atmosphere to flow over the surfaces of said strip and carry away occluded gases given off from said strip in its passage through said second heating zone, and while said strip remains wholly protected by an inert atmosphere consisting predominantly of nitrogen and substantially free from water vapor, passing it through a cooling zone to a molten metal bath comprising a body of molten aluminum, and so regulating the temperature and the time of travel of said strip through said cooling zone as to reduce the temperature of said strip to a value not exceeding the temperature of the molten aluminum at the point where it enters the body of molten aluminum.

10. The process as set forth in claim 9 wherein the strip, after it is passed into the molten aluminum coating bath is withdrawn there-

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from and cooled, and while it is cooling within the temperature range between the solidification temperature of aluminum and 300° F., is subjected to a light pass between rolls sufficient to moderately densify the aluminum coating but insufficient to effect any reduction of the thickness of the ferrous base strip.

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