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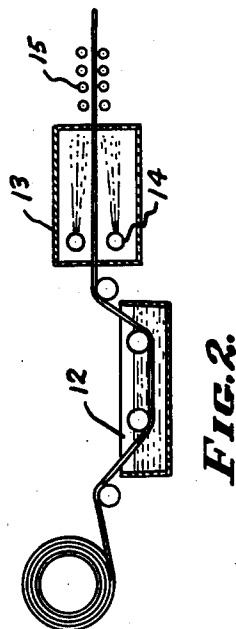
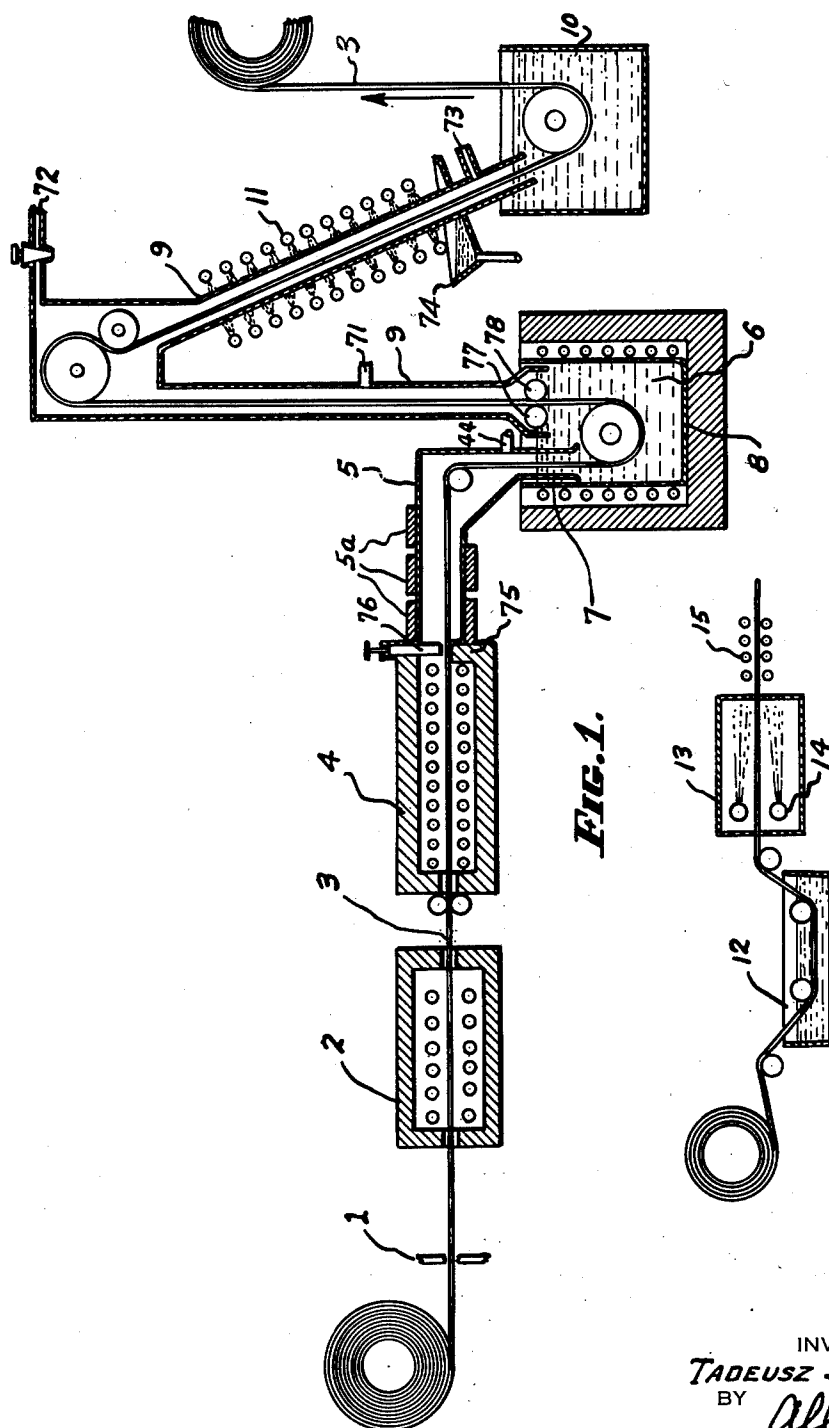
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2,197,622

PROCESS FOR GALVANIZING SHEET METAL

Filed April 22, 1937

2 Sheets-Sheet 1



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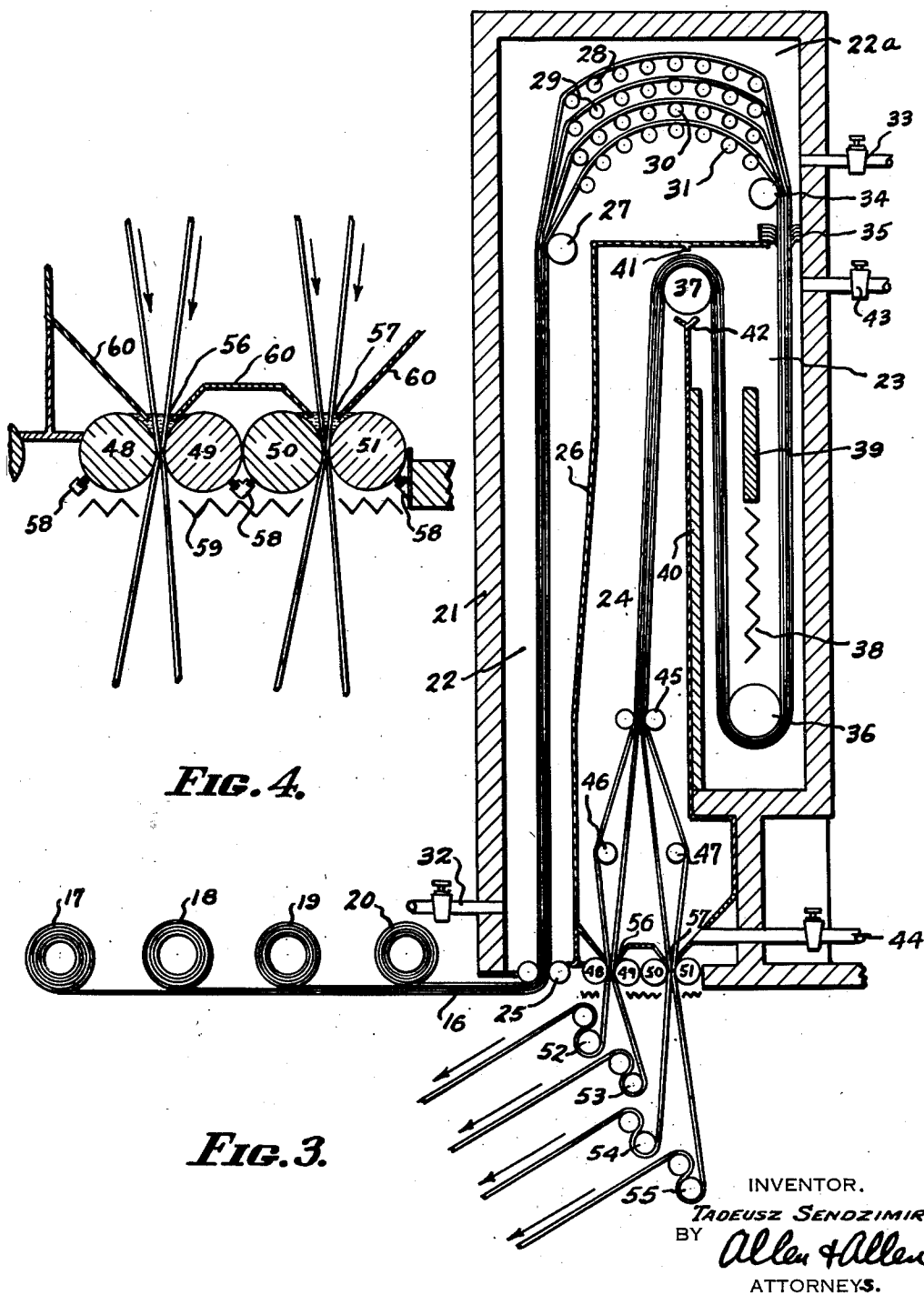
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PROCESS FOR GALVANIZING SHEET METAL

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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,197,622

PROCESS FOR GALVANIZING SHEET METAL

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Application April 22, 1937, Serial No. 138,432

11 Claims. (Cl. 91—70.2)

This case is a continuation in part of my co-
pending application entitled Process for coating
metallic objects with layers of other metals, filed
July 16, 1935, Serial No. 31,699 Pat. No. 2,110,893.

5 The invention relates to the coating of metallic
objects with a layer of another metal or with mul-
tiple layers of different metals by submergence in
a bath of the coating metal or metals; and has
to do specifically with a process for the galvaniz-
10 ing of sheet metal or metallic objects. In the
present disclosure, bath control forms part of the
process claimed.

Hitherto, according to general practice, metal-
lic sheets have been coated by a process which
15 includes pickling the sheets, and then dipping the
clean sheets into a bath of molten coating
metal through a flux. Difficulties have been had
with unsatisfactory and irregular surfaces of the
coating and insufficient adhesion of the coating
20 to the base metal, so that the coating has a tend-
ency to chip off or flake, particularly during bend-
ing or working. This tendency is, of course, en-
hanced by a lack of ductility in the layer of coat-
ing metal. It is a fundamental object of my
25 invention to avoid these difficulties and to provide
a method and apparatus which renders possible
the production of much better products than
those made by the conventional processes.

I shall describe my invention in connection
30 with the coating of iron or steel sheets or strips
with a coating metal, the primary component of
which is zinc. Further, I shall describe it in con-
nection with the treatment of continuous bands
of metal of sheet width. It will be understood, of
35 course, that these are not necessary limitations
upon my invention; and in the claims which fol-
low this specification, I have endeavored to ex-
press the fundamental inventive concept in-
volved.

40 In the process to which the present invention is
addressed I am employing a number of steps set
forth in the co-pending application referred to
hereinabove, and am also employing in general
the apparatus set forth in a co-pending case
45 Ser. No. 90,292 filed July 13, 1936 Patent No.
2,136,957 and entitled Apparatus for coating me-
tallic objects with layers of other metals.

The fundamental objects of my invention
which have been set forth, and other ancillary
50 objects which will be pointed out hereinafter or
will be apparent to one skilled in the art upon
reading these specifications, I accomplish by that
certain series of process steps of which I shall
now describe the aforesaid exemplary embodi-
55 ment. The annexed drawings show in a diagram-

matic manner an assembly of apparatus suitable
for the carrying on of the invention.

Briefly, in the practice of my invention, I treat
the metal sheet to be coated in such a way as
to make it particularly receptive to the coating
5 of molten metal; I treat the bath of molten metal
itself to prevent the production of unfavorable
conditions; and throughout the process I control
the environment of the objects to be coated and
the bath, as will hereinafter be more fully de-
scribed. In the specific exemplary embodiment, I
10 take a scale-free metallic object, such for exam-
ple, as a sheet or strip of iron or steel and, by
subjecting it to heat, I burn off any carbonaceous
matters which may be adhering to the surface of
15 the object and produce upon that surface a very
thin, controlled film of oxide of the base metal.
Next I treat the object with heat in a reducing
atmosphere to the extent of reconverting the
oxide film into the base or parent metal in a
20 thin layer tightly adherent to, if not actually in-
tegral with the body of the article, and of pure
characteristics. After properly cooling the arti-
cle as hereinafter set forth, I dip it beneath
25 the surface of a bath of the coating metal while
still protecting it, as well as the entrance of the
bath, with an inert or reducing atmosphere, and
I further treat the bath to control the nature of
its effect upon the metal to be coated. All of
30 these steps will be more fully explained. How-
ever, by the process herein described, I have
succeeded in producing galvanized sheet metal
having a bright appearance, an attractive spangle
and enhanced malleability in the coating, and a
35 coating adherence and workability well beyond
any materials made by other processes which
I have examined.

The kind and character of starting material is
not a limitation upon my invention. My process
40 may be employed in the coating of wire. I may
likewise use iron or steel sheets manufactured
either by hot rolling or cold rolling, or com-
binations of the two processes. I prefer, for
economy's sake to employ material in continu-
ous form, since this facilitates the continuous
45 operation of the process. However, individual
sheets can be stitched or welded or fastened to-
gether just as strips can be, so as to provide a
continuous supply of the metal to be coated. If
50 desired suitable conveyor, roller or walking beam
mechanism may be used to transport the sheets
or ready formed articles through the furnaces
and chambers, while a similar machinery can
also transport them through the coating bath, or, 55

especially in the case of sheets, a roll arrangement similar to the standard sheet galvanizing machines may be employed. The starting material should be as clean as is practicable, though it need not necessarily be grease-free and the like. It should be scale-free, for reasons hereinafter set forth. The surface finish of the sheets or strips is not likewise a limitation upon my process; and I may employ materials having the well-known, smooth, cold rolled finish or materials having a hot rolled finish, or material having roughened or smooth surfaces formed in other ways. For convenience and economy I prefer to employ the cold rolled strip sheet material which is the product of the modern continuous mills. In my process a smooth, cold rolled surface does not present any problems or difficulties.

In the drawings Figure 1 is a semi-diagrammatic sectional view of one form of apparatus which may be employed in carrying out my invention.

Figure 2 is a diagrammatic sectional view of another apparatus for forming a reducible coating upon material being treated.

Figure 3 is a diagrammatic sectional view of a modified form of apparatus, and in particular an apparatus designed for the simultaneous treatment of a plurality of metal strips.

Figure 4 is an enlarged or detailed sectional view of the exit structure of this apparatus.

I have indicated at 1 in Figure 1 a station at which pieces of sheet material may be fastened together to provide a continuous supply. This may be a station at which the lapped ends of sheet or strip materials are stitched together or spot welded together; or it may be a station at which butt welds are formed between the ends of sheets or strips with or without the cutting away of any flash formed during the welding operation.

The continuous supply of sheet material is preferably carried through an oxidizing furnace indicated at 2, which may be a furnace fired with fuel or heated by suitable electrical resistance elements. It is a furnace of the continuous type and having within it an oxidizing atmosphere which may be produced either by the entrance of the outside air or steam, etc., or, in a fuel fired furnace, by a suitable control of the character of the flame. The object of the step carried on in the furnace is to produce upon the surfaces of the strip material being operated upon, a thin, even, uniform, and tightly adherent coating of oxide of the base metal. The oxide film is exceedingly thin and may well be described as microscopic or submicroscopic in thickness. The conditions in this furnace are not such as to produce a definite scale. In the commercial operation of my process upon iron or steel, the material as it leaves the furnace 2 will usually have the characteristic straw to blue, up to the very light gray appearance of a slightly oxidized iron or steel sheet. The light gray oxide is about the thickest oxide coating which responds well to the subsequent treatment.

The degree to which the metal is heated is not critical. The temperature should be high enough to burn from the surface of the metal any carbonaceous material which may be there. I prefer to operate at a temperature of about 700-900° F. Not only are the surfaces of the sheet material freed in this furnace from any combustible materials, but the surfaces are also oxidized in a controlled manner as above described.

I am not, however, limited to the formation of an oxide film by heat. With grease-free iron and steel materials which are also scale-free, I may form upon the surfaces controlled films of hydroxides and kindred combinations with iron, which films are likewise reducible by procedures hereinafter set forth. In forming such films it is my practice to treat the surfaces of the materials with water and/or maintain the materials in an atmosphere charged with water vapor for an appropriate length of time, afterward drying the materials under heat, as set forth in my co-pending application referred to above.

Referring to Figure 2 I have indicated a modified apparatus for the formation of a reducible coating. Here the material may first be led through a water bath 12 and then through a space 13 where it is subjected to an atmosphere charged with water vapor or steam, as by spray means 14. With a suitable length of the space 13, the bath 12 may be entirely omitted. Emerging from this space the material may be rapidly dried as by heater means 15. In this way by proper apportionment of the times a coating of hydroxide or kindred substances of reducible character may be built up upon the surfaces of the strip.

Referring again to Figure 1 the material 3 may be conducted through the air from the furnace 2 to a reducing furnace 4. During the passage of the metal through the air oxidation continues; but it immediately stops and changes into reduction upon the entry of the metal into the reducing furnace where its temperature is further increased. This reducing furnace is one heated in any suitable way desired, but has a reducing atmosphere. It may be a fuel fired furnace, and a reducing atmosphere may be otherwise supplied, or may be furnished in whole or in part by control of the combustion characteristics in the furnace. However, I prefer to provide artificially a reducing atmosphere in the furnace, and I prefer also to employ an electrically heated furnace.

The object of the treatment in this furnace is to reduce or destroy the very thin and controlled film of oxide formed in the furnace 2. Under suitable reducing conditions the thin film of oxide will be converted into a film of the base metal of the sheets or strips, which is pure in the sense of being freed of carbon, oxides, various other elements and inclusions. The reduced film will be found to be tightly adhering to the base metal.

The oxidizing furnace and the reducing furnace may of course, be combined into a single structure if desired by converting into an oxidizing furnace the entering end of the reducing furnace. This may be accomplished by admitting to the furnace a suitable proportion of oxidizing components such as air, water vapor, or the like to form an oxidizing atmosphere at or near the entrance end, preferably separating this atmosphere from the atmosphere of the reducing portion of the furnace by baffle plates or the like so as to minimize gas diffusion.

It is impracticable to attempt to treat in this way metallic articles, sheets, or strips, which carry on their surfaces scale or thick coatings of oxide whether even or uneven. If a piece of metal bearing on its surface an oxide scale is passed through the reducing furnace an apparent reduction of the oxide may take place and the sheet may appear bright. However, in some instances the reduction does not take place

entirely throughout the body of the scale. In other instances the reduction takes place non-uniformly though apparently completely, so that one has imposed upon the body metal a layer of weak or spongy reduced metal. In neither event, however, does the reduced metal itself come into intimate and adhering contact with the base metal. A coating of molten metal imposed on a surface produced this way will be peculiarly subject to flaking and scaling, and if the flakes or scales are examined, it will be found that the separation has occurred in a layer of oxide or in a layer of loosely knit, rather spongy, wholly or partially reduced metal. This is the reason why it is essential to form on the surfaces of scale-free pieces of iron or steel a controlled reducible film, thin enough for complete reduction in such a way that the reduced film of metal comes back to the crystalline constitution of the base metal.

It will be appreciated that such a cycle of operations comprising an oxidation or hydroxidation or the like of a very thin surface layer of the base metal and an immediate destruction of that combination, as by reduction, to form a layer of the base metal tightly adhering to such base metal, has the apparent associated effect of a purification of such surface layer, as only the base metal is reduced to a metallic condition while such ingredients as sulphur, phosphorus, carbon and some dissolved gases will be gone. This fact may perhaps, in part, explain the effect of this process on the ductility and adherence of the coating. I avoid introducing into the reducing furnace, any material with organic matters such as oil, etc. or remnant carbon not completely removed from its surface, as their removal while in the reducing chamber, as by gradual dissolution in hydrogen, is usually too slow, and they would prevent the promotion of a proper metallic coating if introduced into the coating bath. In cases, however, where it is essential not to decarburize the metal while it passes through the reducing furnace I may purposely leave a certain small amount of them on the surface of the metal objects to be coated, or I may add carbonaceous gases to the reducing atmosphere of such character and in such proportions as to render such decarburization impossible.

I prefer to operate the reducing furnace 4 at a temperature of approximately 1500-1800° F. for galvanizing mild steel, for example.

It will be observed that there is between the reducing furnace 4 and the pot 6 which contains the molten coating metal a hood 5. The purpose of this hood is to provide a controlled atmosphere by which the metal sheets or objects may be protected after reduction and until they are carried beneath the molten bath of metal. I prefer to introduce the reducing gases into the cooling chamber as by a pipe 44, so that the gases move within said chamber in counterflow with the object to be coated, then pass through a sill 75 and an adjustable baffle plate 76 into the reducing furnace 4, the latter means restricting the free passage and consequently the diffusion into the cooling chamber of the reducing furnace atmosphere, which is slightly contaminated as it contains the gaseous products of reduction of the oxide film, as hereinabove described. The hood 5 will normally produce some cooling of the metal being operated upon and the temperature may be controlled by adjustable insulative means 5a, or the hood may be artificially cooled if desired,

as by means of water-jackets. I prefer to cool the strip or object to a temperature slightly but only slightly, in excess of the temperature of the molten metal with which it is to be coated. By this I obtain a further advantage in that I derive the major portion of the heat necessary to keep the coating metal pot at a uniform temperature, from the metallic object itself, so that the walls of the pot need not always be heated and, in case of galvanizing, the formation of dross is greatly reduced.

A reducing atmosphere is preferably artificially supplied to the hood as well as to the furnace. While theoretically it is practicable to have the atmosphere in the hood of neutral character rather than strongly reducing, yet it will be observed that the hood is in direct connection to the furnace and may therefore partake of the character of the atmosphere in the furnace, although I prefer to restrict such passage by baffle plates and other means disposed in the furnace and in the cooling chamber. Thus it will be most convenient to supply to the hood a reducing atmosphere under slight pressure, so that the hood and furnace are maintained at a pressure somewhat in excess of atmospheric pressure. The hood will be sealed off at one end by the bath of molten metal (for which a bell shaped part 7 dipping into the bath may be employed.) A slight excess pressure in the hood and furnace will cause some of the reducing gases to blow out the entrance end of the furnace and thus prevent contamination of the atmosphere in the furnace.

I prefer to ignite such reducing gases as they blow out of the furnace since the flame retards the diffusion of air into the furnace and also gives the operator a proof that the furnace is filled with a reducing gas.

The reducing atmosphere may be generated or supplied in any suitable way and may be widely varying in characteristics. I have successfully employed hydrogen, either pure or diluted. Cracked gases, such as cracked butane may be employed. The choice will also depend upon economic considerations. It has been found that cracked or dissociated ammonia is a convenient and adequate source of reducing atmosphere. The nitrogen present in dissociated ammonia appears to act simply as a diluent. Its proportion may be increased as by burning the gas with some air and condensing and removing the resultant water vapor. I have been unable to detect in my process any difference in results between the use, for example, of pure hydrogen and the use of hydrogen diluted with nitrogen, as in dissociated ammonia. The problem, however, is not alone the provision of a reducing or non-oxidizing atmosphere in the hood, but the maintenance of that atmosphere. It will be clear that by the reduction of an oxide or hydroxide coating, as well as by the interaction of the atmosphere with oxides and the like in metal, quantities of more or less oxidizing materials including water vapor and dissociated products thereof, may be formed in the reducing atmosphere. Atmosphere, for example, charged with a certain percentage of water vapor may have a reducing effect under certain conditions of temperature and an oxidizing effect under other conditions of temperature in the presence of steel at atmosphere pressure in both cases. The equilibrium conditions are shifted over towards oxidation, of course, as the temperature is lowered. Consequently it becomes necessary, in addition to providing for

the actual reduction of the oxide or hydroxide film, to provide also for the maintenance of the atmosphere in the hood in a non-oxidizing condition. This may be done in any of several ways, as by continuous treatment of the gas in the hood by such means as are set forth in my co-pending application, hereinabove referred to, by continuously sweeping the atmosphere out of the hood and displacing it with fresh gases free of oxidizing substances, or by recirculating the gases in the hood and treating them elsewhere than in the hood to free them from materials which would have an oxidizing tendency.

In the particular exemplary embodiment of my invention, the bath 6 is a bath comprising primarily molten zinc. The galvanizing pot 8 may be heated in any way desired to maintain the bath molten. Preferably the bath is essentially heated by the incoming strip, the difference if any being supplied from an external heat source. Not only is my process and apparatus, as hereinabove set forth, especially suitable for control of the conditions of the bath; but by control of the bath conditions in my process, I am capable of securing results very much superior to those results which are obtained by mere control of the bath without the other features of my process. Ordinarily in the practice of my process, I employ a bath of zinc containing aluminum in a range of .001% to say .35% as a means of bath control. More than .35% aluminum may be used, of course, when a distinct zinc-aluminum alloy coating is desired.

I do not desire to be bound by theoretical consideration as to the effect of aluminum. The addition of aluminum to ordinary galvanizing baths within these ranges has heretofore been proposed and has been said to have a deoxidizing function. It seems clear that the actual inclusion of oxides in the galvanizing coating will contribute to the brittleness and weakness of the coating. I am inclined to believe that the function of aluminum in controlling the bath, while it has, of course, an incidental deoxidizing function, is much more particularly concerned with a control or retardation of the development of the several alloy coatings. It is known that coating iron or steel with molten zinc results in the formation of an iron-zinc alloy next the iron, one or more intermediate alloy layers, with a layer of substantially pure zinc on the top. These alloy coatings have differing characteristics. The matter of workability and tenacity of the coating is a matter to be distinguished perhaps from bare adherence and yet the nature of the alloy coatings appears to have a controlling effect upon both characteristics of the coating. The addition of aluminum appears to cut down the formation of the primary iron-zinc alloy and to control the formation of the other alloy or alloys. The action is apparently one of retardation; since with different times of immersion, different relationships of alloy coatings may be formed in spite of the presence of aluminum. It will be seen, however, that where time is an element the other features of my process are of importance in connection with the use of aluminum, the most important one being the shortening of the time of immersion to a small fraction of the time usually employed, with ordinary galvanizing methods. The use of aluminum as a means for retarding the formation of certain zinc-iron alloys within the coating produced does not, generally speaking, interfere with the use of other alloying elements such as the practice has shown are bene-

ficial either by influencing the character of the spangle or by rendering the coating more resistant to corrosion, or other. Neither does it necessitate having the spelter used more free from incidental contaminations and especially metallic inclusions, although I prefer to have the iron content low.

Again, the other aspects of my process bear a distinct relationship to the use of a bath control medium which is of strongly oxidizable character. By treating the metal to be coated in the manner in which I have described and by leading it into a bath of zinc and aluminum under a non-oxidizing atmosphere, I have completely eliminated those troubles which have heretofore been found at the entrance end of the galvanizing bath, and have eliminated entirely any necessity for the use of flux.

Again it has been pointed out in the literature that pure zinc appears to have a property of dissolving oxides in the surface layer of iron or steel to be coated, thereby forming a better bond with the underlying surface, whereas a zinc bath containing aluminum does not appear to have this property. This may explain why the results obtained hitherto in the use of aluminum in open galvanizing baths have not been as favorable as the results which I secure. It will be clear that by the pretreatment of the metal sheets or articles to be coated which I have set forth hereinabove, I have obviated any oxides in or on the surfaces of the metal and therefore, any necessity for any property in the zinc bath of dissolving or removing these oxides.

The use of aluminum also appears to have an effect upon the viscosity of the bath, tending to decrease it.

Finally since I am treating completely oxide-free surfaces of the metal to be coated and am protecting at least the entrance end of the bath from oxidation, I do not have the difficulties with the formation of aluminum oxides that are encountered in attempts to use bath control elements in ordinary galvanizing operations. Aluminum oxides tend to make a zinc bath more viscous. They float upon the top of the zinc bath and are a source of great inconvenience and trouble, as well as a frequent source of inclusions in zinc coatings. In my process the formation of oxides of aluminum is greatly reduced and may be substantially eliminated, as by the use of a neutral or reducing atmosphere to protect the rest of the surface of the spelter bath. Such protection also eliminates the difficulties usually associated with the use of exit rolls due to the formation of zinc and aluminum oxides on their surfaces.

The material may be withdrawn from the galvanizing bath and will be found to be in finished condition. If it is merely withdrawn upwardly from the bath without the use of exit rolls or the like, the rate of production must necessarily be somewhat retarded, as will be clear. For a higher rate of production, I prefer to employ exit rolls 77 and 78 or other wiping devices for rapidly controlling the thickness of the metal coating. The use of aluminum in the bath, of course, complicates the problems attendant upon the use of exit rolls; but these problems can be overcome in various ways as by the continuous cleaning and treating of the exit rolls, the use of floating abrasive materials against the rolls, the use of fluxes or cleaning compounds, and the like. Instead, or in addition, I may provide a neutral or reducing atmosphere at the exit end of the gal-

vanizing pot. I have indicated at 9 a hood extending from the exit end of the galvanizing pot to a water seal or other mechanism 10. This hood may be kept filled with a neutral or reducing atmosphere by means and of a character hereinabove discussed. Although, with the employ of a liquid seal at each end, and with the role of the atmosphere being reduced to protection against oxydation, that is with no chemical reactions affecting the purity of the gases within the hood 9. I prefer to provide in and outlets 73 and 71 for admission and 72 for an occasional scavenging of this hood. I prefer to employ accurate means of supply and evacuation of such gases, as this gives me the additional possibility of slightly varying the pressure, within said hood 9 and thereby influencing the level of the molten metal bath, at the bite of the exit rolls 77 and 78 which has an important effect upon the weight and characteristics of the coating. Thereby I make it independent of the level of metal in the bath 6 as periodically altered by adding new metal and I greatly facilitate the control of the bath in view of the diminished accessibility of it, by the introduction of hood 9, necessary for other reasons. A portion of the hood 9 may be cooled if desired by means of water sprays 11 and a trough 14. Any moisture present within the hood 9 will be condensed and returned to the water seal 10.

In Figures 3 and 4 I have shown a modified form of apparatus and indicated it as being used for the simultaneous treatment of a plurality of strips, although its use is, of course, not so limited. As shown I have a series of four strips 16 derived respectively from coils 17, 18, 19 and 20 and fed together into a mechanism which combines a pre-heating and oxidizing furnace and an annealing and reducing furnace. This apparatus is indicated broadly at 21. An oxidizing compartment is indicated at 22, a reducing compartment at 23, and a cooling compartment at 24. The general construction of the apparatus will be clear from the drawing and heat may be applied to the various parts by any means desired. The strips are fed together into the oxidizing compartment 22 through a pair of entrance rolls 25. There will be an exchange of heat between the incoming untreated strips and the outgoing strips through the wall 26 which separates the cooling compartment 24 from the compartment marked 22. The strips may be deflected by a roll 27 and separated over a series of rolls indicated at 28, 29, 30 and 31 so that in the upper portion of the oxidizing space, indicated at 22a the oxidizing atmosphere will have access to all sides of the strips individually. Heating elements (not shown) may be disposed in the upper part of the oxidizing furnace portion to supply heat to the upper strips if the ordinary heat exchange and convection is not enough. In some instances the strips will be heated sufficiently for oxidizing purposes by the heat exchange hereinabove referred to. The atmosphere in the oxidizing portion of the furnace will be controlled as desired and I have indicated entrance and exit means 32 and 33 for air, water vapor, steam and the like.

The strips, bearing a thin film of oxide on their surfaces, are preferably again brought together over a pulley 34 and passed together through a sealing means 35 into the reducing furnace portion 23. This sealing device may comprise a number of heat resisting flexible strips of metal which bear against the surface of the juxtaposed strip material and effectively

prevent interchange of atmosphere by the two furnace portions.

In the reducing furnace portion 23 the strip may pass downwardly under a pulley 36 and then upwardly over a pulley 37. Suitable heating elements such as electrical heating means 38 are disposed primarily in the lower part of the reducing furnace portion and an insulating plate or wall 39 may be disposed above the heating elements. Likewise the partition means 40 between the reducing furnace portion and the cooling portion of the apparatus is insulating but this insulation may be thinner so as to permit a certain passage of heat from the reducing portion to the cooling portion. The strips are soaked at a predetermined heat between the wall portions 39 and 40. It will be understood that while the strips travel together yet their surfaces do not conform so closely as to prevent reduction of the film on the interior surfaces. However, it is within the scope of my invention to separate the strips in the reducing furnace by means similar to those which have already been described.

The juncture between the reducing furnace portion and the cooling portion is interrupted as well as may be by baffle means 41 and 42 so as to decrease the free passage area for gases between the furnace 23 and the cooling chamber 24. The reducing gases may be admitted first to the cooling chamber 24 by means indicated at 44, since in this part of the apparatus a strongly reducing atmosphere is most necessary. From there they gradually pass into the reducing furnace 23, through the baffle plates 41 and 42 which somewhat reduce the free diffusion of gases and prevent the products of reduced oxides from the object to be coated from entering the cooling chamber 24. Such of the reducing gases as may pass through the sealing means 35 merely burn in the oxidizing furnace portion 22a. In order to prevent a diffusion of oxidizing atmosphere into the reducing furnace 23, the atmosphere in this furnace may be maintained at a somewhat higher pressure than the atmosphere in the oxidizing furnace, thus causing the gases to flow with a certain velocity through the sealing means 35. It must be borne in mind that such dry sealing means intended to operate under such temperature and other conditions as here encountered, and designed to let through freely welds and junctures of the strips, and designed not to scratch or mar the surface of the strip, cannot be made to be entirely leakproof but will, in the best case, only effectively reduce the area of free passage of the gases from the chamber into the furnace or vice versa.

The strips passing through the cooling chamber, may be separated by roll means 45, 46 and 47 before they are brought into contact with the molten coating metal. In the particular embodiment shown the strips are passed downwardly through pools of coating metal held in the bite of exit roll means 48, 49, 50 and 51. Finally the strips are carried off separately for solidification of the coating, cooling and use over pairs of rolls indicated at 52, 53, 54 and 55.

The nature of the particular coating means here shown will be appreciated more clearly from Figure 4 where like parts are given the same index numerals. Here the pools of molten coating metal are indicated at 56 and 57. The metal will be supplied to the bite of the rolls by any suitable means (not shown) from any suitable source of molten coating metal. The rolls 48 to 51, inclusive, not only serve to maintain reser-

voirs of the molten metal but also serve as exit rolls, to which end they may be provided with wipers 58. Heat may be applied to the rolls to maintain the metal molten as by means of electrical heating elements 59 or the rolls may be internally heated. The bottom portion of the cooling chamber 24 is provided with means 60 which dip into the molten metals so as to form a gas seal for the chamber.

- 10 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:

- 15 1. A process of coating ferrous bodies with molten zinc and aluminum without the use of flux, which comprises producing upon the surfaces of the ferrous bodies a thin and uniform reducible film by treating said bodies with an oxidizing medium under conditions to produce
- 20 said reducible film having a thickness characterized by a color ranging from light yellow to purple and as far as gray, then under conditions of heat and a reducing atmosphere completely
- 25 reducing the said film so as to form a reduced metal layer in intimate contact with the body metal, and while the ferrous bodies are continuously protected by a non-oxidizing atmosphere, leading them in a flux-free condition be-
- 30 neath the flux-free surface of a bath of zinc to which aluminum has been added.
2. A process as set forth in claim 1 in which the quantity of aluminum in the bath ranges in amount from .001% to .35%.
- 35 3. A process as set forth in claim 1 in which the treatment of the ferrous bodies with an oxidizing medium is carried on in the presence of water or water vapor, and the said reducible film comprises in part at least a hydroxide of the body metal.
- 40 4. A process as set forth in claim 1 wherein the ferrous bodies, after the reducing treatment, are cooled to a temperature only slightly above the temperature of the said bath of zinc before being led beneath the surface thereof.
- 45 5. A process as set forth in claim 1 involving carrying the metal bodies out of the bath while

protecting them by a non-oxidizing atmosphere.

6. A process of coating iron or steel strip with molten zinc and aluminum without the use of flux, which comprises passing said strip material continuously through a heated zone con-
- 5 taining an oxidizing atmosphere so as to form upon the surfaces thereof a uniform coating of oxide appearing as a light yellow to purple and ranging as far as gray, thereupon passing said strip through a heated zone having a reducing
- 10 atmosphere in which zone said film of oxide is reduced to form a purified and strongly adhering film of the body metal, then cooling said strip to a temperature above but not greatly above the temperature of a coating bath into which said
- 15 strip is to be conducted, while maintaining said strip in a reducing atmosphere, and finally passing said strip in a flux-free condition while still protected by said atmosphere beneath the flux-free surface of a bath of coating metal the pri-
- 20 mary component of which is zinc, which bath also contains a minor quantity of aluminum, while protecting at least the entrance portion of said bath by said reducing atmosphere.

7. A process as set forth in claim 6 including
- 25 the step of carrying said strip out of said bath of coating metal while protecting it and said bath by a non-oxidizing atmosphere.

8. A process as set forth in claim 6 including
- 30 the step of carrying said strip out of said bath of coating metal through exit rolls, which exit rolls contact a flux-free surface of said bath.

9. A process as set forth in claim 6 including
- 35 the step of carrying said strip out of said bath of coating metal through exit rolls, which exit rolls contact a flux-free surface of said bath, while protecting said metal strip, said rolls and said bath by a non-oxidizing atmosphere.

10. A process as set forth in claim 6 in which
- 40 said strip in said reducing zone is heated to a temperature of between 1500° F. and 1800° F.

11. A process as set forth in claim 6 in which
- 45 said strip in said reducing zone is heated at an annealing heat for a sufficient length of time to effect a softening of said strip.

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