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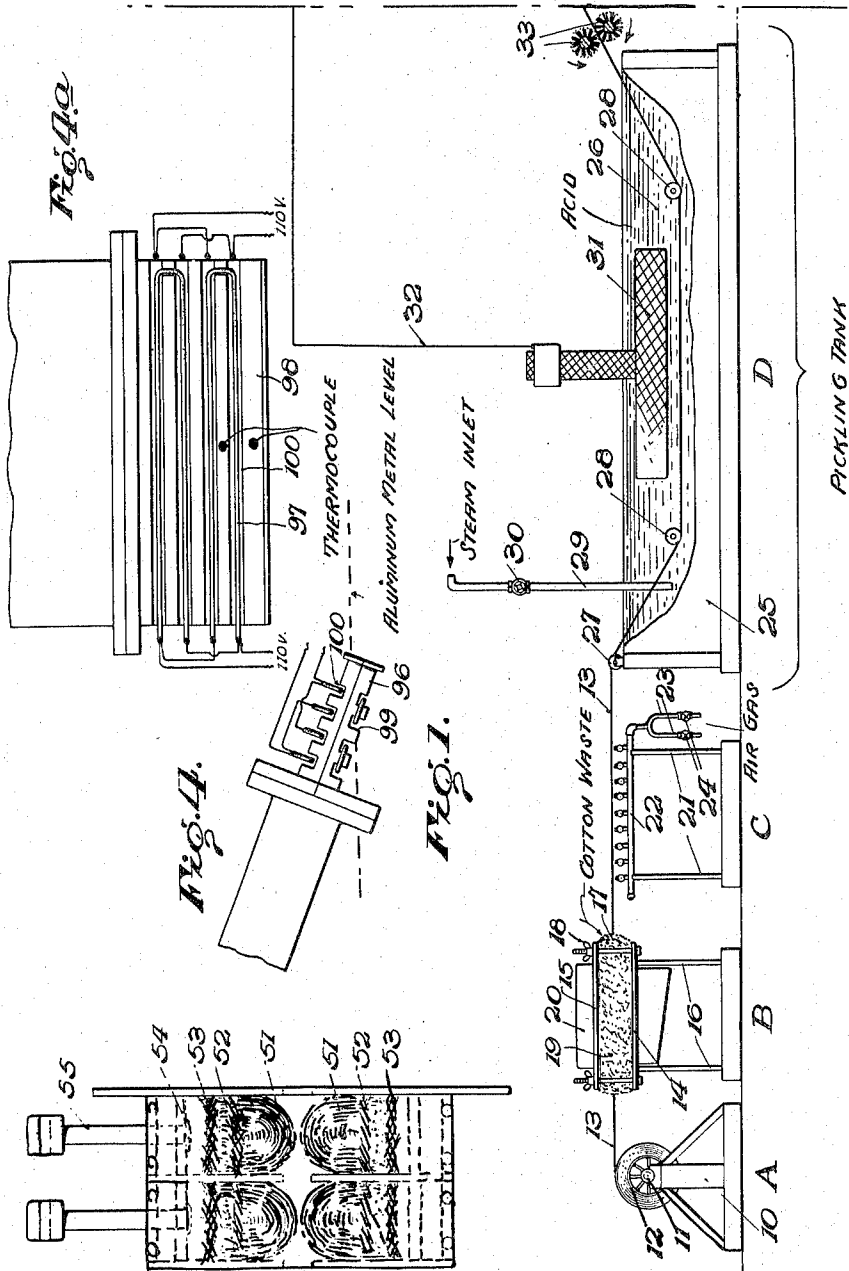
M. G. WHITFIELD ET AL

2,203,606

APPARATUS FOR COATING METAL STRIPS

Filed Sept. 24, 1936

3 Sheets-Sheet 1



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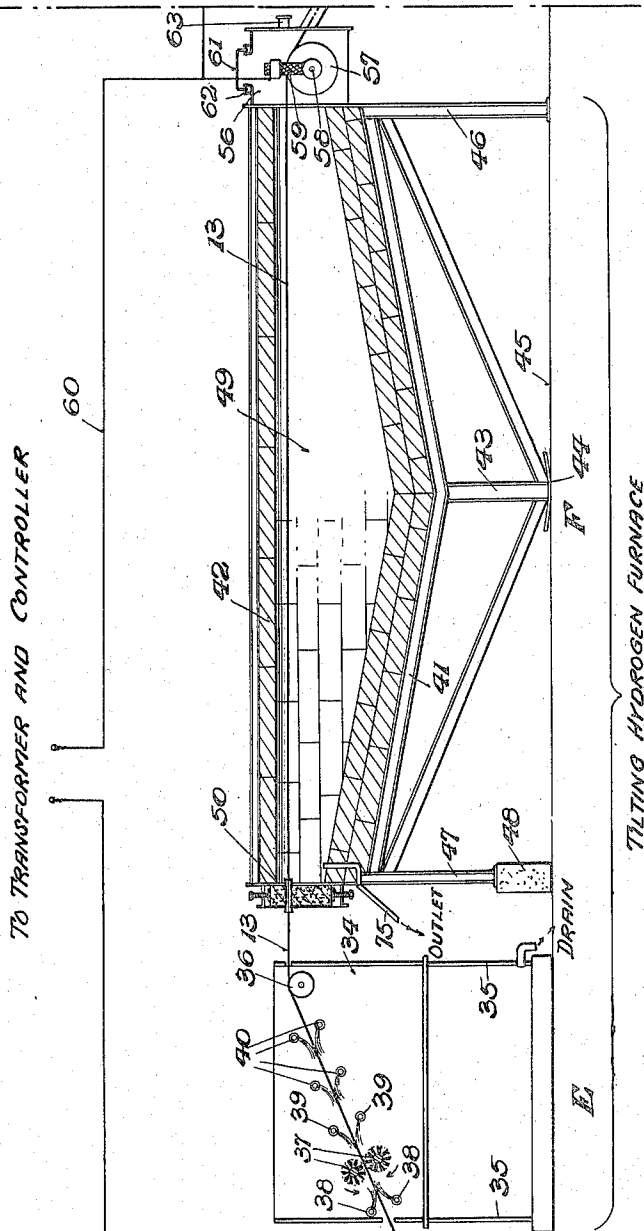
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Fig. 10



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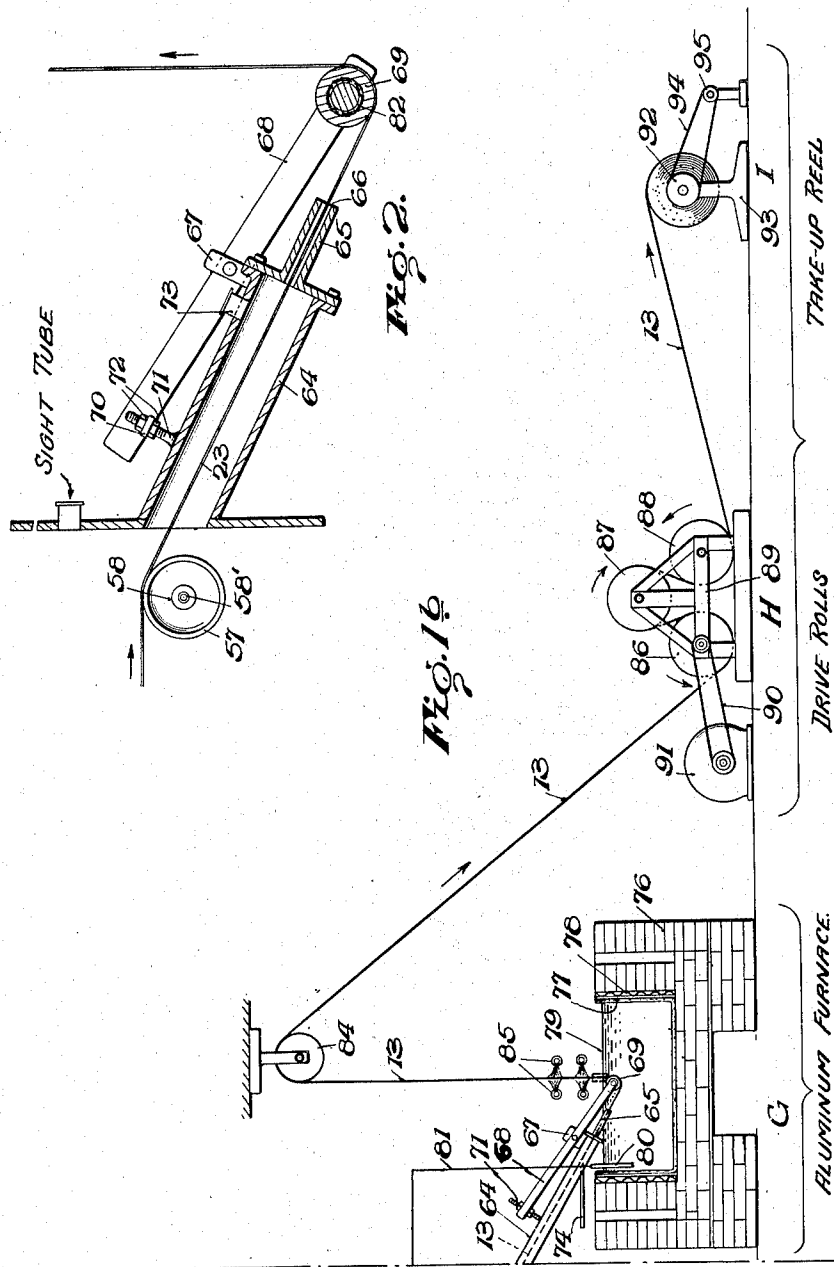
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APPARATUS FOR COATING METAL STRIPS

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,203,606

APPARATUS FOR COATING METAL STRIPS

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18 Claims. (Cl. 91—12.1)

This invention relates to apparatus for the metal coating of elongated strips, such as wires, bands, sheets, etc., which will be referred to hereinafter generically by the single term "strips," but it is to be expressly understood that the term, "strip" is intended to embrace elongated material of any suitable width, any suitable thickness, and any suitable cross section, whether round, rectangular, or otherwise.

While as respects certain features of this invention the apparatus herein disclosed is of utility in coating strips of various metals with a variety of coating metals, the invention has particular utility and will be illustrated by reference to its use in the coating of iron or steel strips with aluminum.

It has heretofore been proposed to form a ductile strip of aluminum coated iron or steel by first prepacking the iron or steel strip with a suitable reducing gas and thereafter introducing the prepacked strip into an aluminum bath below the level of the surface thereof so as to avoid as far as possible the presence of aluminum oxide at the interface between the base metal and the aluminum, but efforts to apply this method in practice have encountered certain practical difficulties which have interfered with the efficient practice of this method. It is an object of this invention to provide apparatus which is simple in character and yet both effective and efficient for the carrying out of the method above identified.

Another object of this invention is to provide an apparatus of the type characterized which will assure that the base metal is thoroughly degreased or cleaned of any oily material at the surface thereof.

Another object of this invention is to provide apparatus of the type characterized which will assure that any scale or oxide on the base metal is loosened and completely removed from the surface thereof.

Another object of this invention is to provide apparatus of the type characterized which assures that all foreign material is removed from the surface of the metal to be coated.

Another object of this invention is to provide apparatus of the type characterized with a furnace for treating the base metal with reducing gas in advance of coating the same that may be readily manipulated to facilitate threading of the strip therethrough and the proper positioning of the exit therefrom with respect to the coating bath.

Another object of this invention is to provide apparatus of the type characterized with a fur-

nace for treating the base metal with reducing gas in advance of coating the same that has improved means for preventing escape of the gas where the strip is admitted thereto and which at the same time will not unduly interfere with the movement of the strip into the furnace.

Another object of this invention is to provide apparatus of the type characterized wherein the means for delivering the strip to the bath may be readily moved with respect to the bath so that its exit end may be immersed in the bath or withdrawn therefrom.

Another object of this invention is to provide apparatus of the type characterized with means whereby the temperature of the strip may be nicely controlled and predetermined at various positions in its traverse through the apparatus.

Another object of this invention is to provide apparatus of the type characterized wherein the means for delivering the strip beneath the surface of the bath is of improved construction and preferably readily accessible so that it may be readily opened.

Another object of the present invention is to provide apparatus of the type characterized with means immersed within the coating bath for guiding the direction of the strip and which is not readily attacked or interfered with by the metal of the bath.

Another object of this invention is to provide apparatus of the type characterized with means to prevent the oxide skin on the surface of the metal bath from being drawn onto the moving strip.

Another object of this invention is to provide apparatus of the type characterized with means for quenching the coated strip as it leaves the bath so as to predetermine the depth of interaction between the base and coating metals.

Another object of this invention is to provide apparatus of the type characterized with improved means for moving the strip through the apparatus.

Another object of the present invention is to provide apparatus of the type characterized which is effective and efficient in enabling the rapid coating of continuous strips with a substantially uniform layer of coating metal united to the base strip by a substantially uniform and continuous alloy bond of predetermined thickness.

Another object of the present invention is to provide apparatus of the type characterized which is inexpensive to assemble and install,

which may be readily manipulated by unskilled labor, and which is strong and durable.

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

- 5 The invention is capable of receiving a variety of mechanical expressions, one of which is shown on the accompanying drawings, but it is to be expressly understood that the drawings are for purposes of illustration only, and are not to be
10 construed as a definition of the limits of the invention, reference being had to the appended claims for that purpose.

Referring in detail to the drawings, wherein the same reference characters are employed to
15 designate corresponding parts in the several figures—

- Figs. 1, 1a and 1b are complementary views, somewhat diagrammatic in character, illustrating apparatus embodying the present invention, Fig.
20 1 illustrating one end of the apparatus, Fig. 1a illustrating the intermediate portion of the apparatus, and Fig. 1b illustrating the opposite end of the apparatus;

Fig. 2 is a fragmentary view on an enlarged
25 scale illustrating the mechanism for delivering the gas treated strip from the furnace to the coating bath;

Fig. 3 is a fragmentary view on an enlarged
30 scale illustrating the means for effecting a seal at the entrance to the furnace; and

Figs. 4 and 4a show a nozzle with provision for heating the same.

- In the embodiment illustrated the apparatus, which is composed of a plurality of devices
35 that may be separately mounted or, if preferred, provided with a common bed plate or support, includes supply means for the base strip, generally designated A, degreasing apparatus, generally designated B, bluing apparatus, generally
40 designated C, pickling apparatus, generally designated D, washing apparatus, generally designated E, apparatus for treating the strip with gas, generally designated F, coating apparatus, generally designated G, drive mechanism, generally
45 designated H, and take-up means, generally designated I. Referring to these several pieces of apparatus in the order just referred to, because that is the order in which a strip to be coated preferably passes through said several pieces of
50 apparatus:

The supply means A may be of any suitable character for the length and form of the strip to be coated. As shown, a standard 10 carries a
55 suitable axle 11 by which a reel 12 may be mounted on said standard to rotate thereon. In order to impose suitable tension on the strip 13 to be coated, suitable braking means, as a friction drum, is preferably associated with said reel, so
60 that the reel may not rotate so rapidly as to enable the strip to become slack as it is drawn off.

- From the supply means A the strip passes to degreasing apparatus B to remove all oil or greasy material from the surface of the strip. Said degreasing apparatus may be of any suitable
65 character, being shown as composed of a pair of plates 14 and 15, mounted upon a suitable standard 16 and adjustably spaced by bolts 17 carrying wing nuts 18. Retained between said plates 14 and 15, in the form shown, is cotton
70 waste 19, which may be compressed by adjustment of the wing nuts so as to engage the strip 13 with the proper pressure. Carried by the plate 15 is a suitable receptacle 20 as a tank provided with a perforated bottom, to maintain the cotton
75 waste suitably soaked or saturated with a solvent

material, such as carbon tetrachloride, that will act upon the grease and oil and effect the removal thereof. It is to be expressly understood, however, that any other suitable degreasing apparatus may be employed within the broader aspects
5 of the present invention.

From the degreasing apparatus B the strip 13 passes to the bluing apparatus C. Experience has demonstrated that merely applying a solvent to the surface of the base metal is not sufficient to
10 thoroughly degrease the iron or steel so as to enable its proper prepacking with reducing gas and the proper adherence of the coating metal uniformly throughout the surface of the base metal. To avoid regions where proper adherence
15 between the base and coating metals is lacking—where, as preferred, the ultimate product is to be not only ductile but capable of being bent, drawn, rolled or otherwise worked without danger of the aluminum coating peeling, stripping or
20 otherwise separating from the base metal—extreme care must be exercised in thoroughly cleaning the surface of the base metal. We have discovered that if the base metal is heated so as to form a deep blue oxide on the surface thereof,
25 following the application of a solvent for the oil or grease and before passing the strip into a pickling bath, the surface of the iron or steel is so conditioned that the coating metal may adhere thereto uniformly throughout its entire sur-
30 face.

The bluing apparatus C may be of any suitable character for producing the deep blue oxide on the opposed faces of the strip. As shown, said apparatus includes a suitable standard 21 which carries
35 a bank of burners 22 supplied with gas and air through pipes 23, which may be provided with suitable valves 24 for adjusting the flow and the proportioning of the air and gas. Said burners 22 are positioned closely adjacent the path of
40 movement of the strip 13, and a cover (not shown) is preferably supplied, so that the strip 13 as it passes through the bluing apparatus may be properly raised to a temperature at which the deep blue oxide forms with relative uniformity
45 over both surfaces of the strip. The valves 24 enable the flames of the burners to be adjusted so as to effect the desired heating of the strip to attain this end. The oxide so formed may be easily removed, and with its removal the oil or
50 grease is entirely removed from the surfaces of the strip. In place of a gas heated bluing apparatus, however, any other suitable furnace may be used, as one heated by electricity.

From the bluing apparatus C the strip 13 passes
55 into and through a pickling apparatus D. Said apparatus may be of any suitable size and construction, and as shown takes the form of a container 25 holding a pickling liquid 26 of any suitable character, an 8% hydrochloric acid solution
60 having been found suitable. The end of the container 25 adjacent the bluing apparatus carries a suitable guide roller 27 over which the strip passes into the tank, and interiorly the tank has
65 one or more guide rollers 28 over which the strip passes in its traverse of the tank. The pickling tank is preferably placed closely adjacent the bluing apparatus so that the strip, when it enters the tank, is still at a relatively high temperature,
70 as it has been discovered that the scale is removed more easily if the strip enters the pickling liquid while hot. The pickling solution is preferably maintained somewhat below the boiling point to avoid undue evaporation, as around 170° F., and to this end a steam pipe or coil 29 leads into
75

the liquid, and is provided with a suitable control valve 30, so that the temperature of the bath may be maintained at the desired degree of heat. If preferred, the flow of steam may be controlled by a thermostat subjected to the temperature of the bath so that the bath temperature will be maintained uniform. The pickling bath is also preferably used to afford one terminal for the electric heating of the strip, so that the temperature of the strip will be progressively increased as it leaves the pickling tank until it has passed through the gas treating apparatus hereinafter described. As shown, a carbon electrode 31 is disposed within the tank and is connected through wire 32 with any suitable source of electricity. Said electrode is preferably out of contact with the strip, so that surface contact between the strip and electrode will not impose an undue drag upon the movement of the strip, the pickling liquid acting as a conductor between the strip and the electrode.

From the pickling apparatus D the strip 13 passes directly to a washing apparatus E of any suitable character. The strip preferably runs directly from the pickling tank to the washing apparatus so as to minimize drag on the strip, and the application of streams of hot and cold water and steam to the strip before the strip has had an opportunity to dry also facilitates removal of any dirt that the strip may have picked up from the surface of the liquid in the pickling apparatus. As shown, a pair of rotary brushes 33 engage the strip as it leaves the pickling tank to effect a preliminary removal of the scale and oxide that has been loosened in the pickling bath, and thence the strip enters a housing 34 mounted on any suitable standard 35 and in which is disposed a suitable roller 36 so that the strip passes in a straight line from the outlet of the pickling tank to and through the washing apparatus. Also mounted in the washing apparatus 34 is a second pair of rotary scrubbing brushes 37. These rotary brushes, 33 and 37, preferably rotate in a direction so that the friction exerted thereby on the strip 13 tends to feed the strip in its direction of normal traverse, thereby maintaining the strip under proper tension and facilitating its forward movement, but said brushes preferably rotate at a peripheral speed which is materially greater than the linear speed of the strip 13 so that there is a substantial relative movement between the brushes and strip to effect the desired scrubbing action thereon. Said brushes 37 are preceded and succeeded by a suitable number of jets of water, 38 and 39, which may be either cold water or hot water or both, said jets being disposed so as to spray the water directly upon the two faces of the strip both in advance of the action of scrubbing brushes 37 and after the strip has passed through said brushes so that the action of said jets, when taken in conjunction with the action of said brushes, is to loosen and remove any foreign material such as scale, oxide, dirt, etc. that is still adhering to the strip, to the end that a perfectly clean strip of iron or steel is obtained. The washing apparatus is also preferably provided with steam jets 40 coacting with both faces of the strip for directing high pressure steam directly against the faces of said strip to assist in heating and drying it before it reaches the furnace F.

From the washing apparatus the strip 13 passes directly into the furnace for treating the strip with a suitable reducing gas. As here shown, the furnace F consists of a suitable casing 41 of

any suitable size, construction and material and lined with a suitable refractory 42 so as to render it gas-tight. The furnace is shown as mounted approximately midway of its length on a supporting member 43 having attached thereto a curved or other suitable rocking surfaced element 44 in engagement with the support 45. Said furnace adjacent its outlet end is provided with legs or other suitable supports 46, preferably of such length that they will engage the support 45 when the furnace is in its normal position as illustrated on the drawings, while the entrance end of said furnace is provided with legs or other suitable supports 47 which are materially shorter than said legs 46 and which are designed to be engaged with blocks 48 or other suitable elements when the furnace is in its normal position. When blocks 48 are removed the furnace may be rocked as a whole on its rocking element 44 so as to tilt the outlet end of the furnace with respect to the metal coating bath, for a purpose that will appear hereinafter.

The strip 13 enters the gas-containing chamber 49 through a slot or aperture 50. In order that leakage of gas shall be minimized and at the same time in order that there shall be a minimum opposition to movement of the strip due to the presence of the sealing means, said entrance is preferably provided with a sealing means such as is more particularly illustrated in Fig. 3. As here shown, the strip is made to pass between surfaces of metal foil pressed into yielding contact with the moving strip, said metal foil being preferably pressed into contact with opposed faces of the strip at more than one point in the length of its traverse through the sealing means. As shown, two opposed sets of sealing surfaces are provided, each sealing surface being formed of a plurality of sheets of metal foil 51, preferably copper foil, backed up by crumpled metal foil 52, preferably aluminum foil, the latter foil in turn being backed by asbestos 53, which may be provided in a loose mass or in the form of sheets or blocks. In engagement with the asbestos is a plate or block 54 of any suitable material that is acted on by a thumb screw 55 having its threads engaged in a nut suitably provided in the cover of the sealing unit and projecting to the exterior of the unit where said thumb screw may be rotated to impose the desired degree of pressure on the opposed sets of foil surfaces 51 in contact with the moving strip 13. Experience has demonstrated that a seal formed by metal surfaces as described keeps the strip clean, does not scratch the surface of the strip, and effectively cuts down the leakage of gas to a minimum, while the frictional opposition to movement of the strip imposed thereby is kept within reasonable limits. The metallic parts of the seal are suitably insulated so as to prevent short circuiting of the strip which is being heated by current flowing therethrough as hereinafter explained.

At its outlet end the furnace F carries an extension 56 in which is mounted a roller 57 on a shaft 58. The preferred details of construction at the outlet end of the furnace are illustrated in the enlarged view of Fig. 2. As here shown, the roller 57 conveniently takes the form of a piece of tubing provided with ends suitably apertured for mounting on the shaft 58, so that the roller is hollow in order that cooling water may be passed through the same, the cooling water being admitted and discharged through suitable openings 58' in the shaft 58 and pipes leading to and from the same. Roller 57 or shaft 58 also serves as

the contact for a brush or electrode 59 connected by main 60 with a source of electric current as hereinbefore referred to, so that electricity may flow to and through the strip 13, to the outlet electrode 31 heretofore described in the pickling apparatus, and thereby said strip, owing to its inherent resistance, is suitably heated throughout its traverse through the furnace F to facilitate the elimination of any oxygen adhering to the strip and also to facilitate the pretreatment of the strip with the reducing gas which constitutes the atmosphere in said furnace. It will be understood that the support for the shaft 58 is suitably insulated so as to prevent short circuiting of the current designed to flow through the strip 13, as are also the roller 36 and other metallic elements contacting the strip between the electrodes 31 and 59. Extension 56 is preferably provided with a safety cover 61 which makes a sealed contact with said extension 56, as by a seal employing a low fusing metal as indicated at 62, so that in the event of an explosion in the hydrogen or other gas in the furnace F said cover may be blown off without damage to the furnace. Extension 56 is also shown as provided with a sight tube 63 closed by a suitable transparent window so that the condition of the strip in the furnace may be observed.

Projecting from the extension 56 (see particularly Fig. 2) is a tube 64 which provides a tubular extension of the furnace chamber and through which the strip 13 is designed to pass after it leaves the roller 57. Attached to the end of the tube 64 is a nozzle 65 which provides a restricted outlet 66 that is little larger than the cross section of the strip being acted upon. Projecting laterally from the tube 64 is a lug 67 on which is pivotally mounted a lever 68 carrying at its end a roller 69 which is designed to be immersed in the molten metal of the coating bath and over which the strip 13 is made to pass as it traverses said bath. Lever 68 is preferably made adjustable so that the roller 69 may be suitably located with respect to the outlet orifice 66, and to this end lever 68 has a laterally extending apertured lug 70 which cooperates with a threaded stem 71 carrying lock nuts 72 and suitably mounted on the wall of the tube 64. Lock nuts 72 enable the lever to be locked in its adjusted position. A sight tube 73 closed by a transparent window of any suitable character is also preferably positioned in the wall of the tube 64 adjacent the nozzle 65 so that the condition of the strip passing through the tube 64 can be observed. Tube 64 may also be provided with the inlet pipe 74 for the gas of the furnace F, and an outlet pipe for said gas may be provided at 75 as shown in Fig. 1a.

Thus it will be seen that the strip 13 may be passed through the furnace F and simultaneously heated by a current of electricity traversing said strip from the electrode 59 to the electrode 31—although if preferred the strip may be suitably heated in any other way. Thereby, by suitably controlling the current flow, the strip 13 may be raised to that temperature which is best suitable for the pretreatment of the particular metal being coated in advance of its passage through the coating bath. The water cooled roller 57 enables a relatively high temperature to be reached and maintained at this point without danger of injury thereto. From the roller 57 the temperature of the strip is graduated downward to the temperature produced at the washing apparatus and in the pickling tank. Any suitable

means may be employed for controlling the current inlet through the electrode 59 so as to maintain the desired temperature, and this means may be automatically controlled so that a substantially uniform temperature of the strip is maintained.

If the furnace F be heated by gas rather than by using the strip itself as an electrical resistance element, the roller 57 need not ordinarily be water cooled, but water cooling may be employed if desired; the water cooled roller being of particular utility in controlling the temperature of the strip to facilitate the cooling thereof to a temperature approximating or somewhat below that of the coating bath where such is found to be desirable as in the case of coating iron or steel strips with aluminum. To assure the desired cooling of the strip before it enters the coating bath, the tube 64 may also be suitably water cooled in whole or in part so as to secure a predetermined temperature of the strip when it reaches the outlet 66 of the nozzle 65.

Disposed adjacent the outlet end of the furnace F, and in a position so that the outlet 66 of the nozzle 65 may be immersed in the molten metal, is the coating apparatus G. As here shown, a furnace 76 of any suitable size, construction and character has mounted therein a melting pot 77 which may be heated in any suitable way, as by an electric resistor element 78. The surface of the bath is indicated at 79, and the temperature of the bath may be controlled by use of any suitable thermostatic or thermoelectric mechanism subjected to the temperature of the bath and connected to suitable control switches in circuit with the resistor 78. As shown, a contact electrode 80 is immersed in the bath and connected to the main through wire 81. The bath itself constitutes a conductor path to complete the heating circuit, and wire 81 may be connected with any suitable rheostat for varying the temperature of the strip, either automatically or manually. As shown in Fig. 1b, the outlet of the nozzle 65 is normally disposed below the surface of the bath so that the strip 13 may pass directly from the reducing atmosphere in the furnace and its extension into contact with the molten metal of the bath without preliminary contact with the air and without having to traverse more of the surface of the molten metal in the bath than is defined by the cross section of the passage in the furnace extension or nozzle which, as before pointed out, approximates the cross section of the strip. Hence in order to preliminarily thread the strip through the apparatus it is necessary to remove the nozzle from the bath. While within the broader aspects of this invention this can be done by lowering the bath with respect to the nozzle or swiveling the nozzle with respect to the furnace or its tubular support 64, a rocking furnace as herein disclosed provides a particularly simple and easily manipulated construction for withdrawing the nozzle from the bath at will, whether to thread the strip through the apparatus or to clean out the nozzle if it becomes caked with coating metal, etc. To further facilitate threading, cleaning of the nozzle, etc., nozzle 65 is preferably made in two parts separable on a plane extending lengthwise of the passage there-through and secured together in any suitable way so that the upper part of the nozzle may be removed with respect to the lower part to completely expose the passage therethrough.

The roller 69 immersed in the molten metal of the bath must be of special construction so as to

enable it to function satisfactorily in the presence of molten metal. In conformity with the present invention a single roller is preferably employed in the molten bath, and as heated aluminum is much more active than other coating metals ordinarily used, said roller to prevent its sticking to its shaft or other mounting means is provided with graphite bearings. Preferably, as shown in Fig. 2, said roller is mounted on two graphite sleeves 82 so as to give a graphite-to-graphite contact and a double possibility of relative movement. The surface of the roller 69 is preferably crowned to facilitate its holding of the strip in its central guided position.

From the coating bath G the strip 23 is passed over a roller 84 preferably suspended from the ceiling or other elevated support, so that the reach of the strip 13 as it leaves the coating bath is vertical or steeply inclined. Immediately after the strip leaves the surface 79 of the coating bath it is preferably subjected to the action of a suitable quenching means, here shown as a plurality of quenching sprays 85 which operate on both sides of the strip 13 and which may use compressed air, water, water atomized by compressed air, or any other suitable cooling medium to promptly chill the strip and thereby limit the extent of interaction between the coating metal and the strip. For particular types of coating it is also desirable to provide means where the strip 13 leaves the metal bath to prevent the oxide film on the surface of the molten metal being drawn up onto the surface of the moving strip. When such is desirable, a pair of metal strips or plates may be partly immersed in the molten metal and provide an exit slot therebetween, said exit slot exceeding the thickness of the strip by a substantial amount so as not to wipe any of the coating metal from the strip while acting at the same time to dam back the surface of the molten metal and prevent its unrestricted flow to and into contact with the moving strip. Experience has demonstrated that the use of an exit orifice of this character also tends to increase the thickness of the coating obtained.

From the roller 84 the strip 13 moves to driving mechanism H of any suitable character. As here shown, said driving mechanism consists of a plurality of rollers, three being shown and designated 86, 87 and 88, which have interconnected driving mechanism (not shown), and which are mounted upon a suitable standard 89. One of said rollers, as 86, is shown as having a direct drive through a belt 90 from an electric motor 91, although any other source of power for driving said rollers 86, 87, 88 may be employed. By preference variable speed drive mechanism is associated with said motor 91 so that the speed of the drive rolls may be adjusted to maintain the proper value. The strip 13 passes under the roller 86, over the roller 87 and under the roller 88, these rollers being spaced by an ample clearance, say from 2 to 3 inches, so that the strip is not compressed between the same and the drive of the strip is effected only by the action of friction on one side of the strip. Driving mechanism of this character can handle all types of coatings and a wide variety of coating thicknesses. At the same time if in starting the apparatus any lumps of metal adhere to the strip as a result of its passing through an incompletely molten bath, no undue strain is imposed on strip 13 as would be the case if its feed were effected by pinching rolls. In the structure illustrated, the drive is effected by friction and only a pre-

determined small tension is maintained on the strip 13 to hold it firmly in contact with the arcuate surfaces of the three rollers around which it passes.

From the drive mechanism H the strip 13 passes to the take-up mechanism I, which may be of any suitable construction. As shown, a reel 92 is suitably mounted on a standard 93 and has a suitable friction drive, as by belt 94, from any suitable source of power, as an electric motor driven shaft 95. Said take-up mechanism is preferably adjustable so that the friction therein assures an even and predetermined tension on the strip 13 to the end that said strip is properly maintained in driving engagement with the rolls 86, 87 and 88 as herein referred to.

The operation of the apparatus will now be apparent from the foregoing detailed description of the component parts thereof. In general, the strip 13 is drawn off of the reel 12, passed frictionally in contact with the waste 19 that is soaked with a suitable solvent for the oil and grease, subjected to the heat of the furnace at C so as to produce a generally uniform deep blue oxide over both faces thereof, and then passed through the pickling tank and the scrubbing and washing apparatus, whereby all scale, dirt, grease, oil, oxide, etc., are thoroughly loosened and removed, leaving the strip completely cleaned at both surfaces thereof.

While in the pickling tank the strip is subjected to the electrode 31 and its temperature progressively increased by contact of high pressure steam therewith as it passes through the washing apparatus so that the strip is also thoroughly dry before entering the reducing atmosphere of the furnace F. Strip 13 passes between the rubbing metal surfaces of the sealing apparatus at the inlet of said furnace F and traverses the reducing atmosphere of said furnace to the roller 57, during which time the temperature of the strip is progressively increased to that temperature desirable for the pretreatment of the strip with the reducing gas. From the roller 57 the strip, still in the reducing atmosphere, passes through the tube 64 and nozzle 65 to a point within the bath of molten metal which is below the surface thereof, so that the strip has contact neither with the air nor with any substantial amount of oxide film on the surface of the molten material, but while in a suitably pretreated condition due to its passage through the reducing atmosphere and its heating to a relatively high temperature, which is preferably on the order of 1350° F. or higher for iron or steel pretreated with hydrogen and to be coated with aluminum, it is passed directly into contact with the molten coating metal under conditions which will minimize oxide formation between the base strip and the coating metal. During this passage from the furnace to the molten metal the base metal is preferably reduced in temperature to a temperature approximating or somewhat lower than the temperature of the molten aluminum, say on the order of 940° F. to 1,000° F. This cooling may be controlled by the water cooling of the roller 57, the tube 64, or in any other suitable way, so as to assure that the strip 13 has the desired temperature when it reaches the outlet 66 of the nozzle 65. From the coating bath the metal passes immediately to the quenching apparatus to limit interaction of the base and coating metals, and thence is drawn through the drive mechanism to the take-up reel.

While the nozzle through which the strip to

be coated enters the aluminum bath may be of the type hereinbefore described, it is sometimes desirable to heat the nozzle other than from the heat of the bath, because, particularly when coating relatively large strips or where the volume of metal passing through the bath is relatively large, sufficient heat is not supplied from the bath to keep the nozzle properly heated and also provide the requisite amount of heat for absorption by the metal to be coated. This may result in the bath freezing up or the nozzle becoming clogged with resultant sticking of the strip therein. By heating the nozzle from an extraneous source of heat it may be maintained at the appropriate temperature and assist in bringing the strip to the proper temperature, abstracting little or no heat from the bath and thereby avoiding interference with the proper operation thereof. Moreover, the use of heating means associated with the nozzle permits the use of a lower average bath temperature and closer control thereof, which in turn enables a more ductile coating to be formed. Therefore, the provision for heating the nozzle may be used to facilitate the securing of a ductile coating even when such heating means is not required by reason of the mass of metal being passed through the bath.

The nozzle may be heated in any suitable way. As shown in Figs. 4 and 4a, the nozzle 96 has associated therewith suitable electric heating elements, here shown as resistance elements 97 suitably embedded in insulating cement 98 and disposed in the channels or grooves 99 formed in the wall of the nozzle. The electric resistance elements are connected in circuit in any suitable way with an appropriate source of current and any suitable thermostatic means as a thermocouple diagrammatically illustrated at 100 may be associated with the heated nozzle and the source of current so as to regulate the current supplied to the end that the desired temperature may be maintained with substantial uniformity.

Experience has demonstrated that apparatus as hereinbefore described may be satisfactorily and efficiently used in the coating of iron and steel strips, wire, etc., with aluminum so as to produce a uniformly adherent coating of aluminum on the iron or steel, said coating being of substantially uniform and predetermined thickness, and the resultant product being ductile and capable of being bent, drawn, rolled, and subjected to other cold working operations without danger of the aluminum coating being stripped, peeled or otherwise detached from the base strip. Depending upon the size of the strip and the thickness of the aluminum coating desired, speeds from ten to twenty-five feet per minute have been satisfactorily used, it being understood that the speed of traverse as well as the temperatures employed will vary with the form, size and material of the base metal, the character of the coating metal, the thickness of coating metal desired, the thickness of alloy bond therebetween to be obtained, etc. The present apparatus provides for ready adjustment of the various temperatures employed, and therefore the apparatus of the present invention is particularly flexible in permitting the coating of strips, wires, etc. of various sizes, cross sections and materials with various coating metals, obtaining varying thicknesses of coating and bond, by suitably controlling the speeds, temperatures, and other factors hereinbefore re-

ferred to. It is to be expressly understood that in the case of temperatures the control may be automatic, as by suitable thermostatic or thermoelectric mechanism, or dependence may be placed upon manual adjustment to obtain the desired degree of heating and uniformity of temperature. Automatic means for controlling speed may also be used if desired.

While the embodiment of the invention illustrated on the drawings has been described with considerable particularity, it is to be expressly understood that the invention is not to be restricted thereto, as the same is capable of receiving a variety of mechanical expressions, some of which will now readily suggest themselves to those skilled in the art, while changes may be made in the details of construction, arrangement, proportion, material, etc., and certain features used without other features, without departing from the spirit of this invention. Various forms of drive mechanism, take-up mechanism, furnaces, baths, pickling apparatus, cleaning apparatus, heating apparatus, drying apparatus, cooling apparatus, etc., may be used without departing from the present invention provided they are suitable for carrying into effect the operations and obtaining the results herein set forth. Reference is therefore to be had to the appended claims for a definition of the invention.

What is claimed is:

1. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, means for thoroughly cleaning said strip in advance of treatment of said strip by a reducing gas including degreasing means and heating means adapted to form a blue oxide layer on said strip after it has passed through said degreasing means, and a furnace in which the cleaned strip is thereafter pretreated with a reducing gas prior to entering into said bath.

2. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, means for thoroughly cleaning said strip in advance of treatment of said strip with reducing gas including means for heating said strip to form a blue oxide layer thereon, means for thereafter removing said oxide from said strip, and a furnace in which the cleaned strip is pretreated with a reducing gas before entering into said bath.

3. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, means for thoroughly cleaning said strip in advance of treatment of said strip with reducing gas including means for heating said strip to form a blue oxide layer thereon, a pickling bath through which said strip is thereafter passed while said strip is still hot, and a furnace in which said cleaned strip is pretreated with a reducing gas before entering into said bath.

4. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, means for thoroughly cleaning said strip in advance of treatment of said strip with reducing gas including means for heating said strip to form a blue oxide layer thereon, a pickling bath into which said strip is passed while it

is still hot, means for scrubbing and washing said strip as it leaves said pickling bath, and a furnace in which the cleaned strip is thereafter pretreated with a reducing gas before entering into said bath.

5 5. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, means for thoroughly cleaning said strip of grease, oxide and scale, means for thereafter pretreating said strip with a reducing gas including an elongated furnace through which said strip is passed on its way to said bath, and means for mounting said furnace whereby it may be tilted about an axis transverse to its length to move the exit of said furnace with respect to said bath.

20 6. In an apparatus for coating a strip of metal with a coating metal of the type embodying a furnace wherein the strip is pretreated with a reducing gas prior to its passage through a coating bath, means for sealing the entrance into said furnace through which said strip passes including packs of metal foil pressed into scaling contact with opposed faces of said strip.

30 7. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace containing a reducing gas through which said strip is passed on its way to said bath, said furnace including an outlet adapted to be immersed in the metal of said bath, and means mounting said furnace whereby it may be tilted about a transverse axis to raise and lower said outlet with respect to said bath.

35 8. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace containing a reducing gas through which said strip is passed on its way to said bath, said furnace including an outlet adapted to be immersed in the metal of said bath, and means mounting said furnace whereby it may be tilted about a transverse axis to raise and lower said outlet with respect to said bath, said means including a rocking support for said furnace intermediate the length thereof.

50 9. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace containing a reducing gas through which said strip is passed on its way to said bath, said furnace including an outlet adapted to be immersed in the metal of said bath, and means mounting said furnace whereby it may be tilted about a transverse axis to raise and lower said outlet with respect to said bath, said means including a rocking support for said furnace intermediate the length thereof, and supports of unequal length at the opposite ends of said furnace whereby the shorter of said last named supports may be blocked to retain said furnace in normal position or unblocked to permit tilting of the furnace about said transverse axis.

70 10. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace containing a reducing gas through which said strip is passed on its way to

said bath, means in said furnace for progressively heating said strip as it passes through said furnace, an extension on said furnace through which said strip passes into said bath at a point below the level of the surface thereof, and means associated with said extension for cooling said strip therein.

11. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace containing a reducing gas through which said strip is passed on its way to said bath and means for retaining said strip in contact with said reducing gas until it enters said bath, said means including a tubular extension through which said strip passes, said extension dipping into the molten metal of said bath, and means carried by said tubular extension and disposed in said bath for guiding the movement of said strip.

12. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace containing a reducing gas through which said strip is passed on its way to said bath and means for retaining said strip in contact with said reducing gas until it enters said bath, said means including a tubular extension through which said strip passes, said extension dipping into the molten metal of said bath, and means carried by said tubular extension and disposed in said bath for guiding the movement of said strip, said means including a roller and a bearing therefor including cooperating graphite sleeves whereby said roller may rotate freely within said molten metal.

13. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace in which said strip is pretreated with a reducing gas on its way to said bath, means for retaining said strip in contact with said reducing gas until it enters said bath, and means disposed above and closely adjacent the surface of said bath for quenching said strip immediately after it leaves said bath.

14. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace in which said strip is pretreated with a reducing gas on its way to said bath, means for heating said strip as it passes through said furnace, means for retaining said strip in contact with said reducing gas until it enters said bath, and means disposed above and closely adjacent the surface of said bath for quenching said strip immediately after it leaves said bath.

15. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace in which said strip is heated on its way to said bath, means for cooling said strip between said furnace and said bath but without contact with the air, and means for quickly quenching said strip as it leaves said bath.

16. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath

through which said strip is passed by said drive mechanism, a furnace through which said strip passes on its way to said bath, means for heating said strip as it passes through said furnace, and means for cooling said strip between said furnace and said bath but without contact with the air.

17. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace having a nozzle projecting into the metal of said bath and through which said strip is introduced into the metal of the bath, and a heating element associated with said nozzle for predeterminately heating the strip passing therethrough.

18. In an apparatus for coating a strip of metal with a coating metal, in combination with drive mechanism for the strip and a coating bath through which said strip is passed by said drive mechanism, a furnace having a nozzle projecting into the metal of said bath and through which said strip is introduced into the metal of the bath, a heating element associated with said nozzle for predeterminately heating the strip passing therethrough, and thermostatic means subjected to the temperature at said nozzle for regulating said heating element.

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