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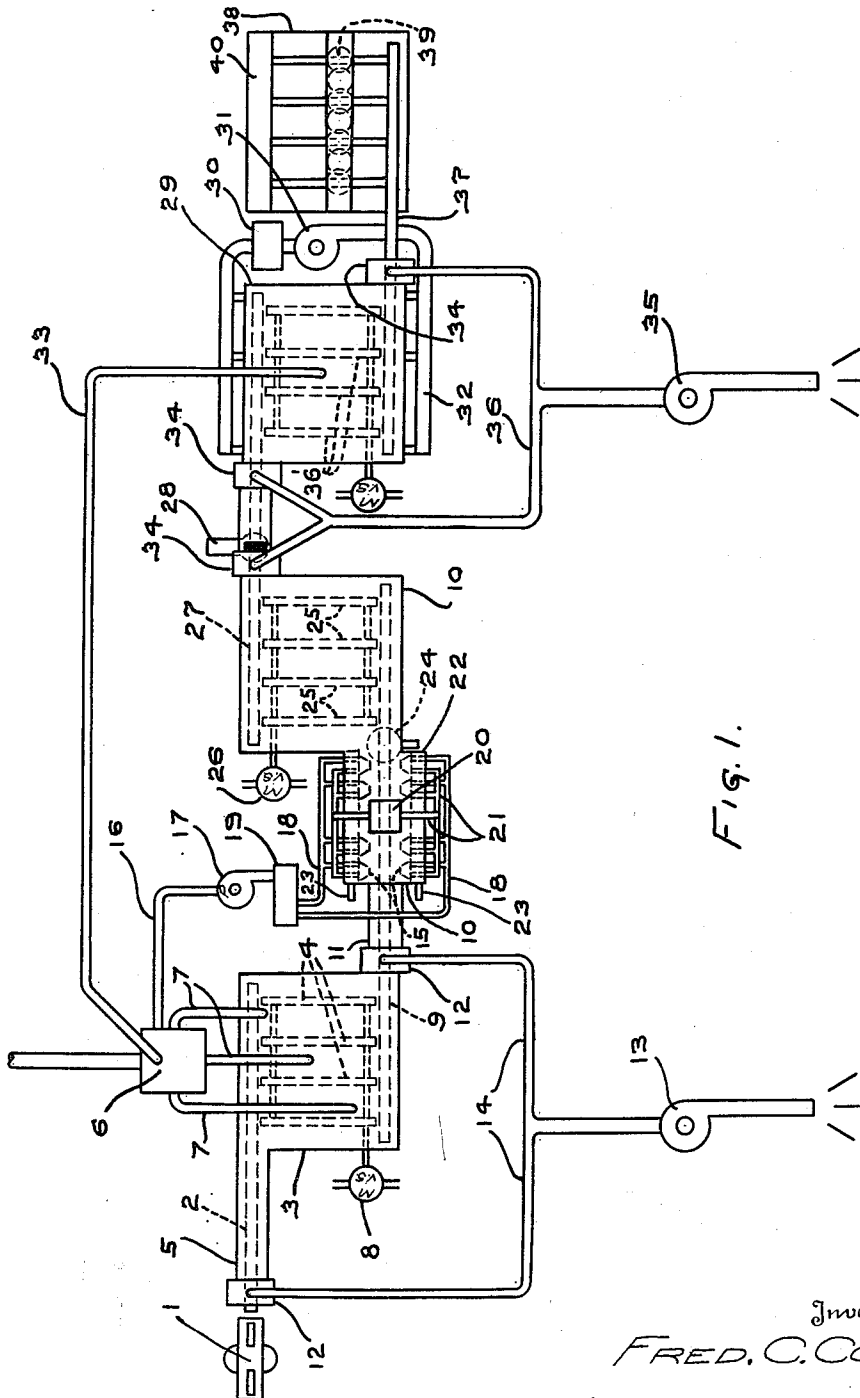
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2,442,485

METHOD OF DESCALING AND COATING HOT-ROLLED FERROUS METAL

Filed June 24, 1944

5 Sheets-Sheet 1



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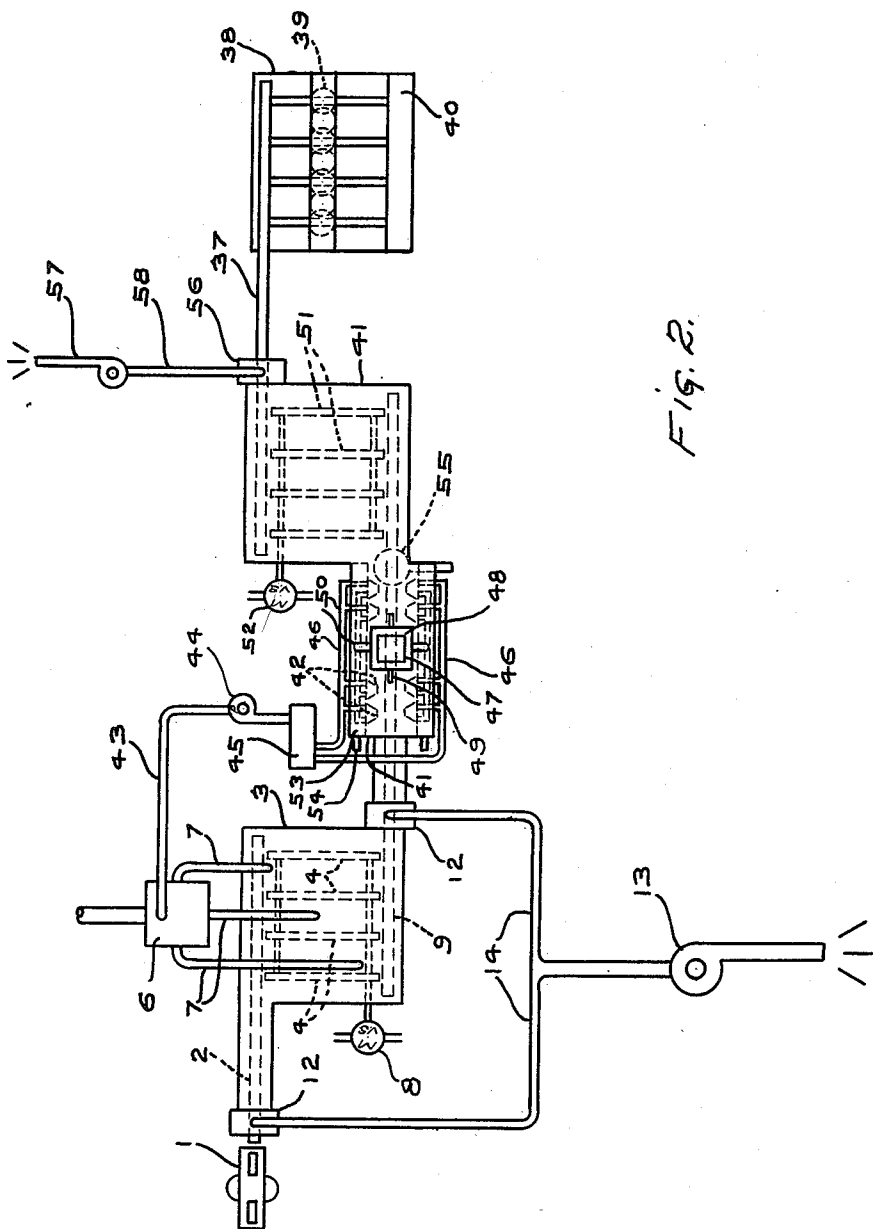


Fig. 2.

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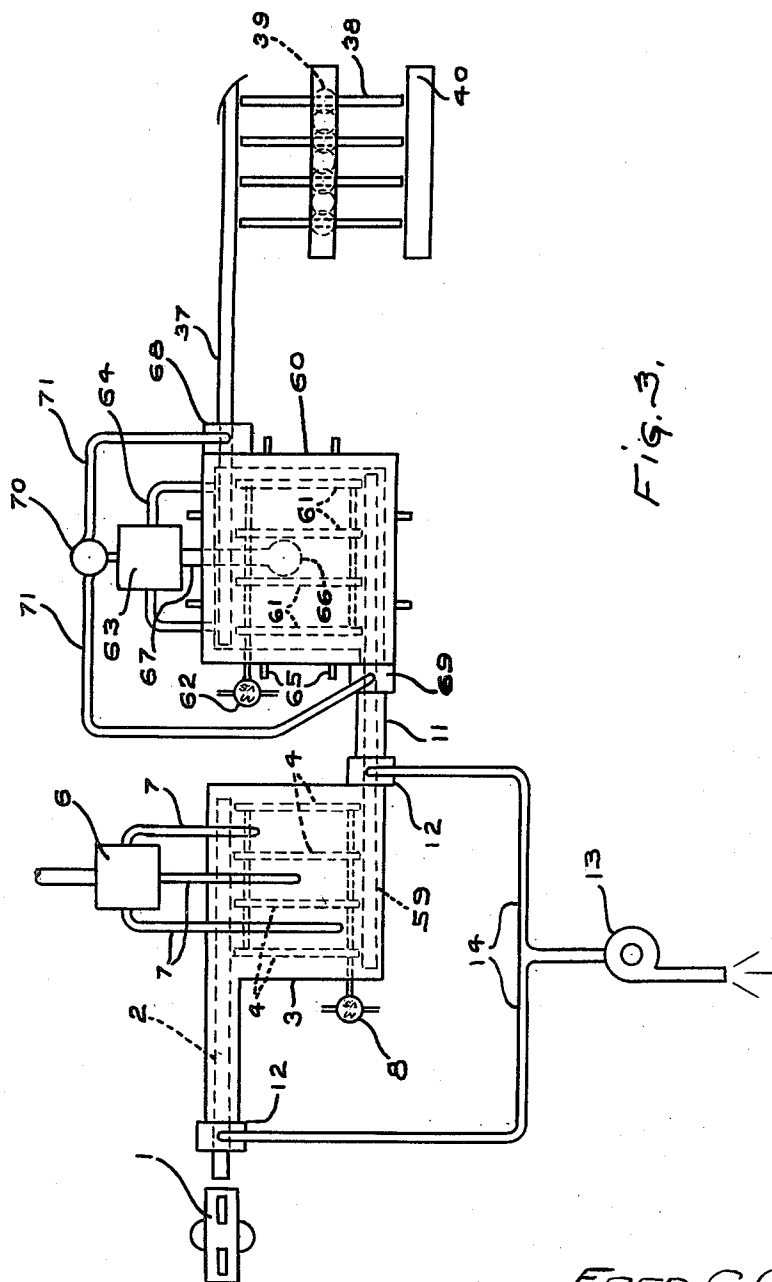


Fig. 3.

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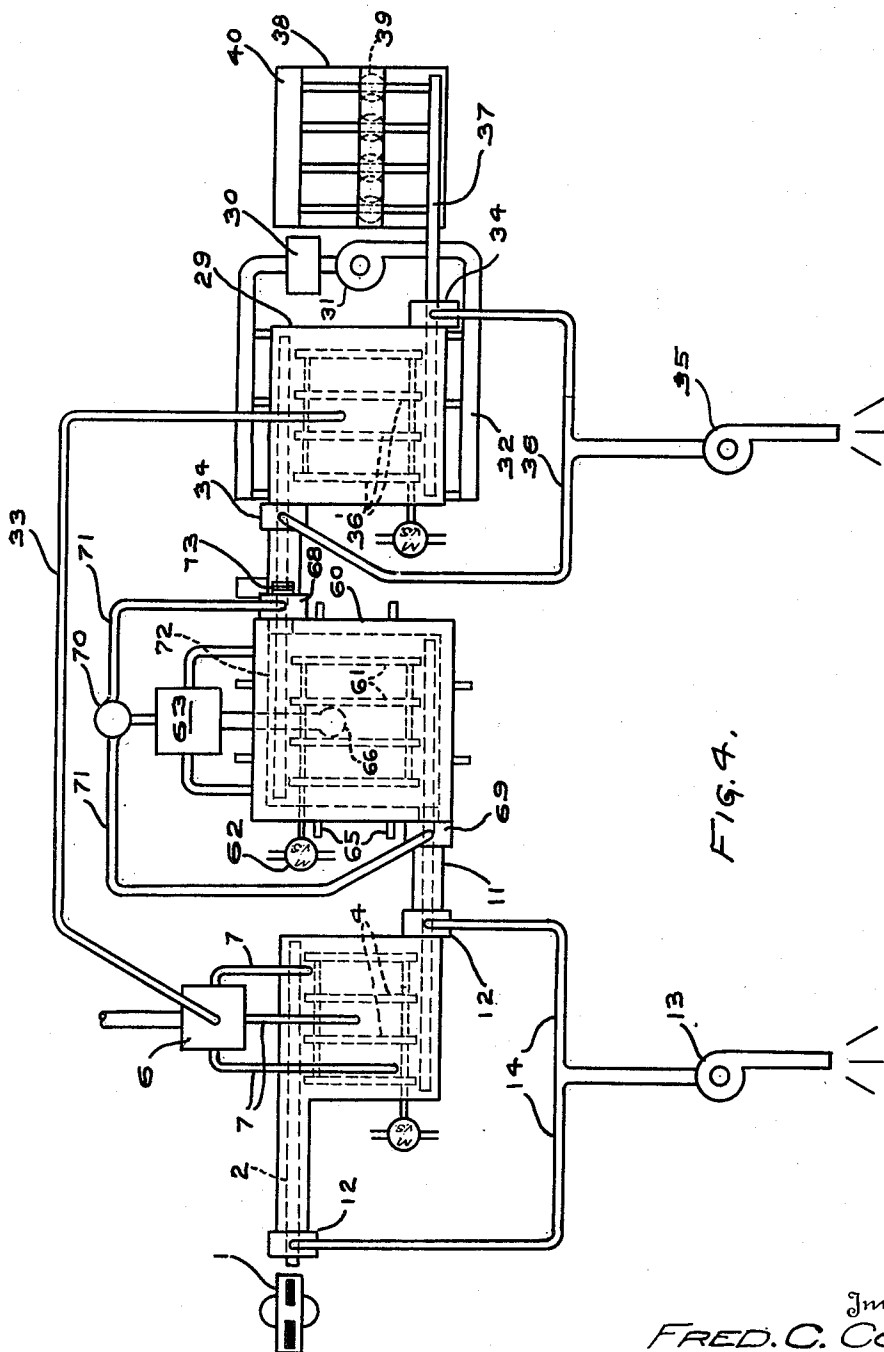
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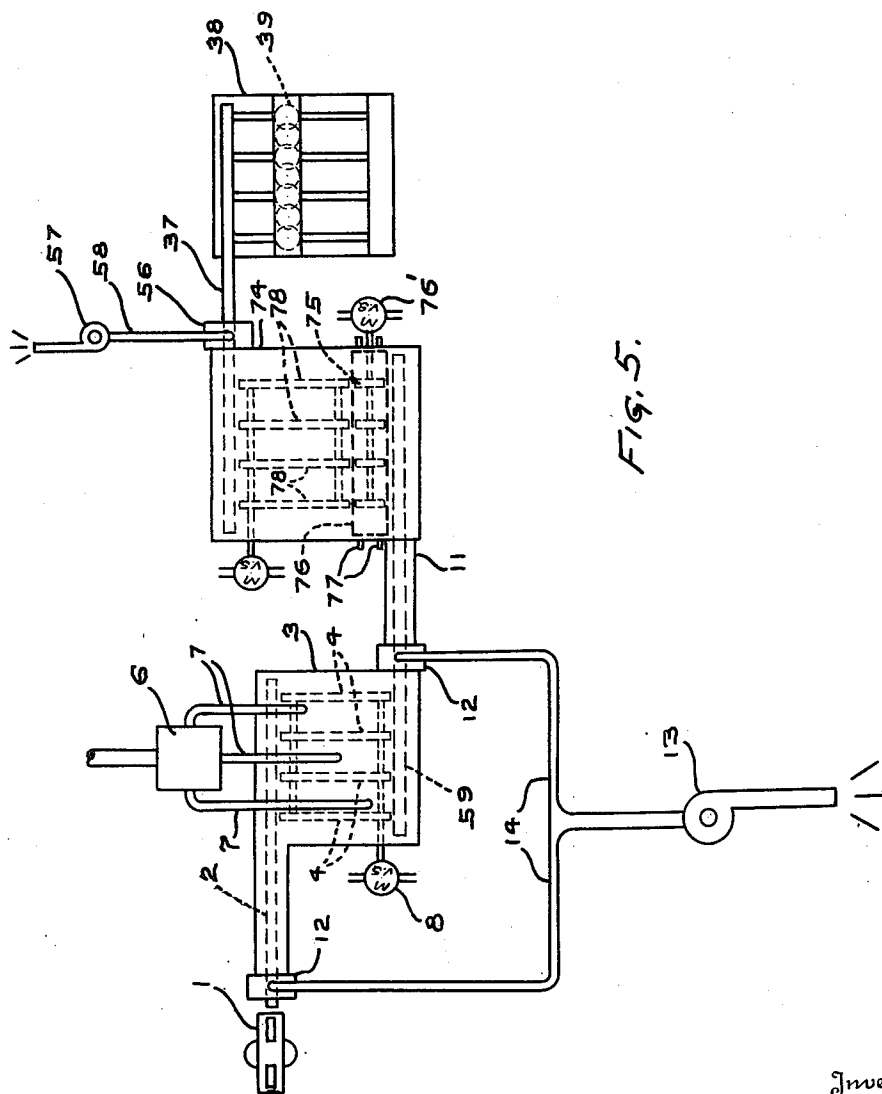
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METHOD OF DESCALING AND COATING HOT-ROLLED FERROUS METAL

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UNITED STATES PATENT OFFICE

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METHOD OF DESCALING AND COATING
HOT-ROLLED FERROUS METAL

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Application June 24, 1944, Serial No. 541,985

4 Claims. (Cl. 117-50)

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This invention relates to the coating of a foundation metal, such as iron or steel, with a coating of either another metal, such as zinc or an enamel, and it aims particularly to coat the foundation metal by using the heat remaining therein after the final passes in the hot rolling of metal bodies such as sheets, rods, bars and pipes, by a process continuous with the rolling.

In the general practice of applying such coats, the foundation metal is rolled to final form and cooled in air, where it oxidizes heavily, then pickled to remove the oxide, and often further pickled to etch the surface, so that the coating material will bend with the foundation metal. It is then reheated or fluxed before galvanizing or applying the coat of other metal. This practice not only uses more heat, but also more metal than is required by this invention.

In the practice of this invention, the metal body comes from the final roll, after rolling hot, at a higher temperature than red heat, and instead of giving the body the final usually light, or smoothing up pass in the rolls, it is given a heavy, or break down pass that actually gives a definite reduction in cross-section and a definite elongation. This break down pass, while the metal is quite plastic, and the scale brittle, breaks off the scale, so that the metal emerges from the rolls practically scale free, and with a residual heat temperature of from 1400° F. to 1800° F. The metal is immediately passed from the rolls to a closed chamber of deoxidizing gas which reduces any oxide or scale remaining on the body, leaving a clean product with a sponge surface.

This clean hot metal is then coated with the desired coating of metal or other material, such as enamel or enamel and ceramic, the residual heat remaining from the rolling mill assuring a strong bond with the foundation metal.

Zinc may be applied to the hot, clean foundation metal by spraying zinc dust thereon, with a spray gun, or molten zinc can be sprayed thereon, or the metal may be passed through a chamber containing zinc vapor, or "blue powder," i. e., zinc particles encased in zinc oxide, or the metal may be immersed in molten zinc, or enamel or a ceramic could be sprayed on instead of zinc. The cooling of the product, both during this coating process and subsequent thereto, is controlled by the speed of conveyors carrying the metal and the use of other cooling means to produce the best results.

By the processes of this invention, the coating metal first contacting the foundation metal forms an alloy of coating and foundation metal and further added coating metal makes a firm coating of the metal used, and after proper cooling, the coat adheres firmly to the foundation metal, which may be bent or otherwise worked to a much

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greater degree than is possible with other methods of coating.

The saving of metal by this process is considerable, especially in the larger plants, one handling ten thousand tons a month might well save one hundred tons a month, which in the old practices is largely lost in pickling operations for cleaning and etching. The saving in heat, there is no need of cooling to pickle and then reheating or fluxing to coat, is also considerable. The improvement of the bond between the foundation metal and coating is also important. Some of the processes likewise lend themselves to the use of zinc dust, scrap zinc, and non-premium zinc products of different forms. The continuity of the process is also most important.

The detailed processes will now be described in connection with the accompanying diagrammatic drawings forming a part hereof, and in which:

Figure 1 is a plan view of the apparatus required using zinc dust.

Figure 2 is a similar view of apparatus required utilizing sprayed molten zinc.

Figure 3 is a similar view showing the apparatus required for zinc vapor.

Figure 4 is a similar view of the apparatus required in the "blue powder" vapor method.

Figure 5 is a similar view of the apparatus required for the immersion process.

In the drawings similar numerals refer to similar parts throughout the several views.

The initial treatment of the iron or steel for receiving the coating is identical in each of the processes, and the apparatus required for that initial treatment is likewise identical.

The process of coating using zinc dust will first be described. Zinc dust is cheaper than many other forms of zinc.

The first step in preparation for coating is made on the set of rolls 1 of the rolling or forming or shaping mill when the body of iron or steel has been rolled hot. In this last set of rolls a definite reduction in cross-section together with an accompanying elongation of the metal body is made instead of the usual light pass given the body to smooth it up as in ordinary practice. The temperature of the body is the normal finishing rolling temperature of between 1400° F. and 1800° F.

This is above the red heat of the body. In the instant processes an effort is made to "roll cold" for each size, as the colder is the finishing temperature, the more scale will be mechanically cracked off. Even at temperatures that are used when rolling hot the scale is brittle while the iron or steel is quite plastic with the result that as the body emerges from the rolls after this final "break down" pass, it is substantially scale free, this is particularly true if there is appreciable elongation.

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From the rolls the body goes out on the run out table 2, which is a travelling chain conveyor driven from a motor driven sprocket. This run out table takes the body into the deoxidizing chamber 3, in which at the end of the travelling chain conveyor 2, it is kicked off by electro-magnetic relays to the travelling rack 4. This chamber is extended over the run out table as shown at 5 so that as soon as possible after the last hot rolling the body is enveloped with deoxidizing gas to prevent any further oxidation or scaling of the iron or steel surface.

The deoxidizing chamber is supplied with gas by a deoxidizing gas producer 6 which is fed by mill gas which is usually a combination of blast furnace and coke oven gas of 500 B. t. u. per cu. ft. of heat content. The producer has towers which remove the sulphur and water vapor since both of these constituents would stain the surface of the iron or steel and interfere with creating a good bond by the coating. In the producer the mill gas is burned in a closed chamber with the flame smothered by controlling the amount of air or oxygen admitted to the chamber. Enough oxygen is withheld from the chamber so that the products of combustion are from two to three times as rich in carbon monoxide, CO, as they are in carbon dioxide, CO₂.

This gas rich in carbon monoxide is referred to as deoxidizing gas, and it then flows from the producer 6 through pipes 7 which insure an even distribution of the gas to the deoxidizing chamber 3. Other deoxidizing or reducing gases could be used.

Inside the chamber 3 the gas comes into contact with the surface of the hot iron or steel as it is carried through the chamber on the travelling rack or conveyor 4. The temperature of the steel, 1400° F. to 1800° F., is high enough so that the carbon monoxide burns to carbon dioxide at the expense of the oxides or scale, FeO, Fe₂O₃, Fe₃O₄, which may have remained on the iron or steel or formed since the cracking off of the scale in the last hot roll or pass. Thus while the product is still on the conveyor 4, the action of the gas leaves a clean surface of sponge iron, Fe.

The conveyor 4 is driven by a motor 8 controlled in its speed by a rheostat. The longer the iron or steel body remains on the conveyor 4, the greater will be the drop in temperature due to radiation losses. By slowing down or speeding up the motor 8 the temperature of the body on exit from the chamber can be accurately controlled within limits. This control of temperature is important since the success of the coating chamber is dependent upon the temperature of the foundation metal. For coating normal low carbon steels with zinc dust it is preferred that the temperature of the body range from 1400° F. to 1600° F.

At the end of conveyor 4 the body drops off onto a series of magnetic rolls 9 which take it out of the deoxidizing gas chamber and into the coating chamber 10. This transfer is made through an enclosed tunnel 11 so that the body is not permitted to come into contact with the atmosphere which would oxidize its surface.

At both the entrance and exit ends of the deoxidizing gas chamber 3 are hoods 12 through which exhaust deoxidizing gas is drawn by fan 13 connected to the hoods by pipes 14. This prevents escaping gas from fouling the shop atmosphere.

As the body enters the coating chamber on magnetic rolls at a temperature of from 1400° F.

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to 1600° F., it passes a series of spray guns or nozzles 15 which coat the body with zinc dust. These spray guns are activated by deoxidizing gas taken from the producer 6 through pipe 16 and pressure is given to the gas by blower 17 from which the gas flows through pipes 18 to the respective nozzles. A pressure equalizing tank 19 is interposed between the blower 17 and pipes 18 to equalize the pressure of deoxidizing gas to the spray guns. Zinc dust is stored in bin 20 which is replenished periodically. Pipes 21 carry the dust from the bin to the individual nozzles of the guns. The chamber 10 is jacketed as shown at 22, and the jackets are heated by gas burners 23. This jacketing is used to keep the zinc dust from accumulating on the inner wall of the coating chamber 10. Zinc dust that flows down the heated chamber walls is collected in the pit 24 from which it is periodically tapped for reclamation. When the dust strikes the hot iron or steel the dust becomes plastic due to the high temperature of the iron or steel and adheres to its surface. As more dust is sprayed on the undercoat becomes flowing and alloying between the zinc and iron or steel takes place. The thickness of the coating is determined by the amount of zinc dust sprayed on the iron or steel. This can be controlled either by changing the density of the sprays or varying the speed of the rolls so that either more or less time is spent under the sprays.

After coating, the body is kicked from the magnetic rolls by electro-magnetic relays similar to those used in the deoxidizing gas chamber onto a travelling conveyor 25 driven by a motor 26 controlled by a rheostat so that the temperature at exit, from the coating chamber, or the wiping temperature of the body can be controlled between the range of 1100° F. to 1300° F. The walls of the coating chamber 10 are insulated on the outside to prevent escape of heat.

The burners 23 are turned on only before the equipment is put into operation, to give a preliminary heat to the walls and prevent the zinc dust from accumulating on them. As the unit goes into operation, these burners are cut down until the radiant heat from the heated body maintains the temperature of the walls above the melting point of the zinc, and the zinc which then comes into contact with the walls melts and flows down to the collection pit. At the exit of the coating chamber is placed a wiper 28. It may be either a mechanical wiper using steel or asbestos or more conveniently, it is a blast of deoxidizing gas under pressure. The magnetic conveyor rolls 27 drive the body through the wiper.

The use of this wiper is optional. If the product is to be used under very corrosive conditions where appearance is not a controlling factor, the wiper is not used. This method of coating gives a thick, dull gray coating that is very serviceable since the outside coating of oxide is also corrosive resistant. However, for normal commercial work which is subject to bending and where a bright surface is desired the wiper is employed. The resultant coat, using the wiper which strips off the outer surface of oxide, is a tight, thin, very adherent coating of silvery appearance. The coating chamber 10 is in the two sections, one containing the spray guns through which the products pass on the magnetic conveyor 9 and from which they are kicked off and to the conveyors 25 and from conveyors 25 which are operated by motor 26 controlled by a rheostat to vary the speed of the motor, the products pass

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to further magnetic roll conveyor 27 from which they are carried through the wiper 28 out of the coating chamber 10.

The magnetic roll conveyor 27 carries the product into the cooling chamber 29. Since the temperature of the product is then in the range of 1100° F. to 1300° F. it must be cooled to substantially 900° F., in a reducing atmosphere, otherwise the coating would oxidize to total powder. This cooling is accomplished in the cooling chamber 29.

The cooling chamber is constructed of thin black steel in order to radiate as much heat as possible. In high tonnage installations it may be necessary to run water through jacketing in the walls of the chamber in order to dissipate heat rapidly enough to bring the temperature below 900° F. upon exit from the cooling chamber. Normally, however, cooling will be rapid enough by recirculating the deoxidizing gas in the chamber through the cooler 30 by means of fan 31. The fan forces the gas into the chamber 29 through pipes 32. Enough fresh deoxidizing gas is admitted to the chamber through pipe 33 from the deoxidizing gas producer 6 to maintain an atmosphere in the cooling chamber rich in carbon monoxide, or in other words to keep a reducing atmosphere in the cooling chamber at all times. Over the exit of the cooling chamber and of the coating chamber and the entrance to the cooling chamber are placed hoods 34 connected to a blower 35 by piping 36 to exhaust the fumes from the deoxidizing chamber. The cooling chamber has therein conveyors 36' onto which the product is kicked by an electro-magnetic relay from the magnetic rolls 27 and the product falls from the conveyors 36 to the traveling chain conveyor 37 which carries it out of the cooling chamber to the cooling rack 38. While on the cooling rack the product passes under water sprays 39 to aid in rapid cooling. From the cooling table on which the product is carried by conveyors the product is dropped into a bin 40 from which it can be removed by a crane.

Molten zinc may likewise be sprayed onto the product in a rather similar manner, see Figure 2. The product up to the time of its entrance into the coating chamber goes through identical treatment to that above described except that as the product is removed from the deoxidizing chamber 3 and for coatings of zinc on low carbon steels the temperature will range from 900° F. to 1400° F. This difference in temperature from the preceding method is obtained by carrying the product through the chamber 3 at a slower rate of speed. As the product enters the coating chamber 41 it passes by a series of spray guns 42 which coat the product with molten zinc. These spray guns are activated by reducing gas from the deoxidizing gas producer 6 passing through pipe 43, booster blower 44, equalizing pressure tank 45 and pipes 46. Molten zinc is fed into the moving stream of gas from a heated pot 47 having a heating chamber 48 therearound heated by gas burners 49. Pipes 50 lead the molten zinc from the pot to the spray guns 42. The zinc in the pot is maintained at approximately 850° F. by the gas burner which is so arranged that its products of combustion also heat the lines to the spray guns so as to keep the zinc flowing at all points. The molten zinc as soon as it strikes the heated steel adheres to it and immediately begins to alloy, since both the steel and the zinc are above alloying temperature. The thickness of the coating is determined by

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the amount of zinc sprayed on the steel. This can be controlled, as in the previous process, by either changing the density of the sprays or varying the speed of the rolls so that the time spent under the sprays is varied.

Using a spray of molten zinc gives a smooth coat and as a result it is not necessary to wipe it. The effect of the alloying due to the high temperature of the foundation iron or steel is to give a uniform coat free from any plane of weakness and one with a soft white finish.

After coating and while still in the coating chamber 41, the product is kicked off the magnetic roll conveyor by electromagnetic relays onto conveyor 51, which is driven by a motor 52 controlled by a rheostat to vary the speed of the conveyor 51 so that the product on exit from the chamber has a temperature of between 850° F. and 950° F. The walls of the coating chamber are jacketed at 53 only where the spraying takes place and gas is admitted to the burners 54 to maintain the temperature of the inner wall slightly above the melting temperature of the zinc. Any zinc spray which strikes the walls is maintained in the molten state and flows down to the collecting pit 55. From this pit zinc is periodically tapped and placed again into the heating pot. The coating chamber has a hood 56 through which exhausted gas fumes are taken by blower 57 through pipe 58. From the traveling rack conveyor 51 in the coating chamber 41 the product is dropped onto a traveling chain and cooling table identical to that above described. No wiper is required as the exit temperature of the product is approximately 900° F. which is so low that rapid oxidation does not take place.

Another method of coating the iron or steel in which the product emerges from the deoxidizing chamber 3 at the temperature mentioned above for coating with molten zinc, 900° F. to 1400° F., is to pass the product into a coating chamber containing zinc vapor. See Figure 3. At the end of conveyors 4 in the deoxidizing chamber 3 the product drops to traveling chain conveyor 59 which carries the product into the coating chamber 60. The product passes through an enclosed tunnel 11 with hoods at the entrance and exit of the deoxidizing chamber identical to those above described.

Inside the coating chamber 60 the product is kicked off the traveling chain 59 by electro-magnetic relays onto traveling rack conveyor 61 driven by motor 62 operated through a rheostat to vary the speed of the conveyor 61.

The coating chamber is supplied by a zinc vaporizing furnace 63. This is a small furnace built of refractory brick and fired by gas. Zinc is fed to the inner crucible where the temperature is brought up to a range of 2200° F. to 2500° F., well above 1660° F., the vaporizing temperature of zinc. The gas is burned in the firing chamber which surrounds the inner crucible so that the products of combustion go out the stack and do not come in contact with the zinc. Heat is supplied to the zinc by conduction through the carbide refractory walls similar to the method used in smelting zinc from ore.

From the inner chamber the zinc vapor flows through pipes 64 to the coating chamber 60. These pipes are arranged so that the hot products of combustion from the firing chamber flow around them, thus maintaining the temperature of the vapor until it enters the coating chamber. The outer walls of the coating chamber are insulated to prevent the escape of heat. The inner

walls are jacketed so that heat from gas burners 55 passes through them. These burners are turned on only before the equipment is placed into operation to give a preliminary heat to the walls in order to prevent the zinc from condensing and accumulating on them. As the unit goes into operation these burners are cut down until the radiant heat from the hot iron or steel products maintains the temperature of the chamber 60 and its walls above the melting point of zinc, 790° F. The zinc condensing on the walls is then in a molten state and flows down to collection pit 66 where it is periodically tapped off and permitted to flow back through way 67 to the vaporizing chamber 63, where it is re-vaporized.

As the clean, heated iron or steel comes into contact with the zinc vapor in the coating chamber, two separate actions take place. There is condensation on the steel since the steel temperature is below the vaporizing temperature of the zinc, 1660° F., the second action is that of alloying of the zinc with the steel since the temperature of the steel is above the melting point of zinc, 790° F. The higher the temperature of the foundation metal, the more rapid will be the alloying action and correspondingly the slower the condensing action will be. By controlling the speed of the conveyor in the deoxidizing gas chamber so that the steel is between 1200° F. and 1400° F. upon entering the coating chamber and then controlling the speed of the conveyor in the coating chamber so that the exit temperature will be between 900° F. and 1000° F., a very tight ductile coating results.

The action upon entering the coating chamber is heavily alloying and as the steel proceeds through the chamber and the temperature drops, due to radiation and convection losses, the action becomes increasingly condensing. As a result the alloy layer, which in normal galvanized coatings is concentrated as a plane of weakness next to the foundation metal, is dispersed with an even gradient from a high alloy content next to the steel to the outside of the coating which is practically pure zinc.

From the rack conveyor 61 the product is dropped upon a traveling chain conveyor 37, as described in the previous processes. Hoods 68 and 69 are at the exit and entrance of the coating chamber to catch any escaping zinc vapor which is drawn out by the fan operated collector 70 through pipes 71, and since the pipes are unheated the vapor solidifies and as a powder is drawn to the collector 70 from which it passes to vaporizing furnace 63.

One of the economies of this process is that inferior grades of zinc, zinc dross, scrap zinc and the like can be used as only pure zinc will be vaporized off. It is possible that under certain conditions zinc vapor might be obtained from smelting ore.

While the above vapor method works satisfactorily where large quantities of iron or steel are handled, two difficulties occur as the size of the equipment is increased. First, the greater the volume of zinc vapor that is handled, the greater is the tendency of the zinc to oxidize itself as a powder. Second, the loss from condensation of the zinc on the chamber walls increases as the size of the equipment increases. On large installations which handle small tonnage an appreciable amount of zinc vapor condenses on the walls of the coating chamber and the coat on the product becomes a dull, fairly rough, powdery gray. These difficulties are overcome by using the

method now to be described and which may be called the "blue powder" method. The blue powder is finely divided globules of pure zinc individually coated with zinc oxide. In the vapor method, previously described, since some blue powder will be formed, in the "blue powder" method enough deoxidizing gas is permitted to enter the coating chamber to insure that all the zinc vapor form as blue powder. Zinc has a high affinity for oxygen at elevated temperatures and large quantities of zinc vapor having any contact with furnace gases cause the formation of the blue powder. In the "blue powder" method the temperature of the foundation metal is much higher than in the vapor method. As a consequence, in the cooling stage, the temperature must be dropped appreciably in a cooling chamber before the product is permitted to come into contact with the air, otherwise oxidation of the surface will occur which will harmfully affect the appearance of the coating.

The equipment, see Figure 4, for the "blue powder" method is identical to that heretofore described up to the point of exit from the coating chamber, except that instead of dropping the products from the conveyors 61 onto a chain run out conveyor, they are dropped onto magnetic rolls 72 as the run out conveyor.

In the "blue powder" method, gas from the furnace 6 is permitted to flow through the enclosed tunnel 11 by reducing the opening for hood 12 and preventing all of the gas from being drawn off by the hood. This helps maintain a clean surface on the iron or steel right up to the moment that coating begins. In this method the conveyor 4 is speeded up so that the temperature of the iron or steel delivered to the coating chamber is between 1400° F. and 1600° F. This temperature is several hundred degrees hotter than when using the vapor method above described. As a result the temperature of the chamber walls 60 is materially increased from transfer of heat by convection and radiation and the amount of zinc condensing on the walls is greatly reduced.

The effect of admitting deoxidizing gas to the coating chamber through the tunnel 11 is to give a more fluid coat since of course the gas retains a richness of carbon monoxide. At certain temperatures carbon monoxide disassociates according to the reversible reaction $2\text{CO} \rightleftharpoons \text{C} + \text{CO}_2$. Above 1800° F. the rate of this reaction is rapid while below 1500° F. it is very slow, thereby requiring a long period of time for attainment of equilibrium. However, the presence of carbon dioxide does create this formation of a certain amount of blue powder by reason of the reaction $\text{CO}_2 + \text{Zn} = \text{ZnO} + \text{CO}$. Thus the resulting coat is a combination of particles of zinc oxide embedded in a matrix of pure zinc. As the steel progresses across the rack conveyor 61 and more zinc is deposited, the undercoat becomes flowing zinc which is rapidly alloying with the steel while the surface becomes heavier in oxide. At the end of the conveyor 61 the product drops onto the run out conveyor 72, which is a series of magnetized rolls set in line that take the product out of the chamber 60 through the wiper 73, which may be either of a mechanical nature using steel or asbestos, but it is more conveniently a blast of deoxidizing gas under pressure. The magnetic rolls of course drive the product through the wiper. The use of the wiper is optional. If the product is to be used under very corrosive conditions where appearance is not a controlling factor the wiper is not used. This method gives a thick, dull gray

to further magnetic roll conveyor 27 from which they are carried through the wiper 28 out of the coating chamber 10.

The magnetic roll conveyor 27 carries the product into the cooling chamber 29. Since the temperature of the product is then in the range of 1100° F. to 1300° F. it must be cooled to substantially 900° F., in a reducing atmosphere, otherwise the coating would oxidize to total powder. This cooling is accomplished in the cooling chamber 29.

The cooling chamber is constructed of thin black steel in order to radiate as much heat as possible. In high tonnage installations it may be necessary to run water through jacketing in the walls of the chamber in order to dissipate heat rapidly enough to bring the temperature below 900° F. upon exit from the cooling chamber. Normally, however, cooling will be rapid enough by recirculating the deoxidizing gas in the chamber through the cooler 30 by means of fan 31. The fan forces the gas into the chamber 29 through pipes 32. Enough fresh deoxidizing gas is admitted to the chamber through pipe 33 from the deoxidizing gas producer 6 to maintain an atmosphere in the cooling chamber rich in carbon monoxide, or in other words to keep a reducing atmosphere in the cooling chamber at all times. Over the exit of the cooling chamber and of the coating chamber and the entrance to the cooling chamber are placed hoods 34 connected to a blower 35 by piping 36 to exhaust the fumes from the deoxidizing chamber. The cooling chamber has therein conveyors 36' onto which the product is kicked by an electro-magnetic relay from the magnetic rolls 27 and the product falls from the conveyors 36 to the traveling chain conveyor 37 which carries it out of the cooling chamber to the cooling rack 38. While on the cooling rack the product passes under water sprays 39 to aid in rapid cooling. From the cooling table on which the product is carried by conveyors the product is dropped into a bin 40 from which it can be removed by a crane.

Molten zinc may likewise be sprayed onto the product in a rather similar manner, see Figure 2. The product up to the time of its entrance into the coating chamber goes through identical treatment to that above described except that as the product is removed from the deoxidizing chamber 3 and for coatings of zinc on low carbon steels the temperature will range from 900° F. to 1400° F. This difference in temperature from the preceding method is obtained by carrying the product through the chamber 3 at a slower rate of speed. As the product enters the coating chamber 41 it passes by a series of spray guns 42 which coat the product with molten zinc. These spray guns are activated by reducing gas from the deoxidizing gas producer 6 passing through pipe 43, booster blower 44, equalizing pressure tank 45 and pipes 46. Molten zinc is fed into the moving stream of gas from a heated pot 47 having a heating chamber 48 therearound heated by gas burners 49. Pipes 50 lead the molten zinc from the pot to the spray guns 42. The zinc in the pot is maintained at approximately 850° F. by the gas burner which is so arranged that its products of combustion also heat the lines to the spray guns so as to keep the zinc flowing at all points. The molten zinc as soon as it strikes the heated steel adheres to it and immediately begins to alloy, since both the steel and the zinc are above alloying temperature. The thickness of the coating is determined by

the amount of zinc sprayed on the steel. This can be controlled, as in the previous process, by either changing the density of the sprays or varying the speed of the rolls so that the time spent under the sprays is varied.

Using a spray of molten zinc gives a smooth coat and as a result it is not necessary to wipe it. The effect of the alloying due to the high temperature of the foundation iron or steel is to give a uniform coat free from any plane of weakness and one with a soft white finish.

After coating and while still in the coating chamber 41, the product is kicked off the magnetic roll conveyor by electromagnetic relays onto conveyor 51, which is driven by a motor 52 controlled by a rheostat to vary the speed of the conveyor 51 so that the product on exit from the chamber has a temperature of between 850° F. and 950° F. The walls of the coating chamber are jacketed at 53 only where the spraying takes place and gas is admitted to the burners 54 to maintain the temperature of the inner wall slightly above the melting temperature of the zinc. Any zinc spray which strikes the walls is maintained in the molten state and flows down to the collecting pit 55. From this pit zinc is periodically tapped and placed again into the heating pot. The coating chamber has a hood 56 through which exhausted gas fumes are taken by blower 57 through pipe 58. From the traveling rack conveyor 51 in the coating chamber 41 the product is dropped onto a traveling chain and cooling table identical to that above described. No wiper is required as the exit temperature of the product is approximately 900° F. which is so low that rapid oxidation does not take place.

Another method of coating the iron or steel in which the product emerges from the deoxidizing chamber 3 at the temperature mentioned above for coating with molten zinc, 900° F. to 1400° F., is to pass the product into a coating chamber containing zinc vapor. See Figure 3. At the end of conveyors 4 in the deoxidizing chamber 3 the product drops to traveling chain conveyor 59 which carries the product into the coating chamber 60. The product passes through an enclosed tunnel 11 with hoods at the entrance and exit of the deoxidizing chamber identical to those above described.

Inside the coating chamber 60 the product is kicked off the traveling chain 59 by electro-magnetic relays onto traveling rack conveyor 61 driven by motor 62 operated through a rheostat to vary the speed of the conveyor 61.

The coating chamber is supplied by a zinc vaporizing furnace 63. This is a small furnace built of refractory brick and fired by gas. Zinc is fed to the inner crucible where the temperature is brought up to a range of 2200° F. to 2500° F., well above 1660° F., the vaporizing temperature of zinc. The gas is burned in the firing chamber which surrounds the inner crucible so that the products of combustion go out the stack and do not come in contact with the zinc. Heat is supplied to the zinc by conduction through the carbide refractory walls similar to the method used in smelting zinc from ore.

From the inner chamber the zinc vapor flows through pipes 64 to the coating chamber 60. These pipes are arranged so that the hot products of combustion from the firing chamber flow around them, thus maintaining the temperature of the vapor until it enters the coating chamber. The outer walls of the coating chamber are insulated to prevent the escape of heat. The inner

walls are jacketed so that heat from gas burners 65 passes through them. These burners are turned on only before the equipment is placed into operation to give a preliminary heat to the walls in order to prevent the zinc from condensing and accumulating on them. As the unit goes into operation these burners are cut down until the radiant heat from the hot iron or steel products maintains the temperature of the chamber 60 and its walls above the melting point of zinc, 790° F. The zinc condensing on the walls is then in a molten state and flows down to collection pit 66 where it is periodically tapped off and permitted to flow back through way 67 to the vaporizing chamber 63, where it is re-vaporized.

As the clean, heated iron or steel comes into contact with the zinc vapor in the coating chamber, two separate actions take place. There is condensation on the steel since the steel temperature is below the vaporizing temperature of the zinc, 1660° F., the second action is that of alloying of the zinc with the steel since the temperature of the steel is above the melting point of zinc, 790° F. The higher the temperature of the foundation metal, the more rapid will be the alloying action and correspondingly the slower the condensing action will be. By controlling the speed of the conveyor in the deoxidizing gas chamber so that the steel is between 1200° F. and 1400° F. upon entering the coating chamber and then controlling the speed of the conveyor in the coating chamber so that the exit temperature will be between 900° F. and 1000° F., a very tight ductile coating results.

The action upon entering the coating chamber is heavily alloying and as the steel proceeds through the chamber and the temperature drops, due to radiation and convection losses, the action becomes increasingly condensing. As a result the alloy layer, which in normal galvanized coatings is concentrated as a plane of weakness next to the foundation metal, is dispersed with an even gradient from a high alloy content next to the steel to the outside of the coating which is practically pure zinc.

From the rack conveyor 61 the product is dropped upon a traveling chain conveyor 37, as described in the previous processes. Hoods 68 and 69 are at the exit and entrance of the coating chamber to catch any escaping zinc vapor which is drawn out by the fan operated collector 70 through pipes 71, and since the pipes are unheated the vapor solidifies and as a powder is drawn to the collector 70 from which it passes to vaporizing furnace 63.

One of the economies of this process is that inferior grades of zinc, zinc dross, scrap zinc and the like can be used as only pure zinc will be vaporized off. It is possible that under certain conditions zinc vapor might be obtained from smelting ore.

While the above vapor method works satisfactorily where large quantities of iron or steel are handled, two difficulties occur as the size of the equipment is increased. First, the greater the volume of zinc vapor that is handled, the greater is the tendency of the zinc to oxidize itself as a powder. Second, the loss from condensation of the zinc on the chamber walls increases as the size of the equipment increases. On large installations which handle small tonnage an appreciable amount of zinc vapor condenses on the walls of the coating chamber and the coat on the product becomes a dull, fairly rough, powdery gray. These difficulties are overcome by using the

method now to be described and which may be called the "blue powder" method. The blue powder is finely divided globules of pure zinc individually coated with zinc oxide. In the vapor method, previously described, since some blue powder will be formed, in the "blue powder" method enough deoxidizing gas is permitted to enter the coating chamber to insure that all the zinc vapor form as blue powder. Zinc has a high affinity for oxygen at elevated temperatures and large quantities of zinc vapor having any contact with furnace gases cause the formation of the blue powder. In the "blue powder" method the temperature of the foundation metal is much higher than in the vapor method. As a consequence, in the cooling stage, the temperature must be dropped appreciably in a cooling chamber before the product is permitted to come into contact with the air, otherwise oxidation of the surface will occur which will harmfully affect the appearance of the coating.

The equipment, see Figure 4, for the "blue powder" method is identical to that heretofore described up to the point of exit from the coating chamber, except that instead of dropping the products from the conveyors 61 onto a chain run out conveyor, they are dropped onto magnetic rolls 72 as the run out conveyor.

In the "blue powder" method, gas from the furnace 6 is permitted to flow through the enclosed tunnel 11 by reducing the opening for hood 12 and preventing all of the gas from being drawn off by the hood. This helps maintain a clean surface on the iron or steel right up to the moment that coating begins. In this method the conveyor 4 is speeded up so that the temperature of the iron or steel delivered to the coating chamber is between 1400° F. and 1600° F. This temperature is several hundred degrees hotter than when using the vapor method above described. As a result the temperature of the chamber walls 60 is materially increased from transfer of heat by convection and radiation and the amount of zinc condensing on the walls is greatly reduced.

The effect of admitting deoxidizing gas to the coating chamber through the tunnel 11 is to give a more fluid coat since of course the gas retains a richness of carbon monoxide. At certain temperatures carbon monoxide disassociates according to the reversible reaction $2CO \rightleftharpoons C + CO_2$. Above 1800° F. the rate of this reaction is rapid while below 1500° F. it is very slow, thereby requiring a long period of time for attainment of equilibrium. However, the presence of carbon dioxide does create this formation of a certain amount of blue powder by reason of the reaction $CO_2 + Zn = ZnO + CO$. Thus the resulting coat is a combination of particles of zinc oxide embedded in a matrix of pure zinc. As the steel progresses across the rack conveyor 61 and more zinc is deposited, the undercoat becomes flowing zinc which is rapidly alloying with the steel while the surface becomes heavier in oxide. At the end of the conveyor 61 the product drops onto the run out conveyor 72, which is a series of magnetized rolls set in line that take the product out of the chamber 60 through the wiper 73, which may be either of a mechanical nature using steel or asbestos, but it is more conveniently a blast of deoxidizing gas under pressure. The magnetic rolls of course drive the product through the wiper. The use of the wiper is optional. If the product is to be used under very corrosive conditions where appearance is not a controlling factor the wiper is not used. This method gives a thick, dull gray

coating that is very serviceable since the outside coating of oxide is also corrosive resistant. However, for normal commercial work which is subject to bending and where a bright surface is desired the wiper is employed. The resultant coating using the wiper which strips off the outer surface of oxide is a tight, thin, very adherent coating of a silvery appearance.

The magnetic rolls 73 carry the product to a cooling chamber 29 from which it passes to cooling rack 38 identical to that described in the first process above. The speed of the conveyor in the coating chamber is so controlled that the exit temperature of the product is in the range of 1100° F. to 1300° F. when the product passes through the wiper. Since this temperature is so high, the coating would oxidize to total powder were the temperature not reduced to around 900° F. in the cooling chamber.

The method of this invention may likewise be worked by immersing the product into a bath of molten zinc. See Figure 5. The cost is a fraction of the normal galvanizing costs since pickling and fluxing are entirely eliminated and since the heat is derived from the residual heat of the rolling mill. The apparatus used is identical to that used in the preceding method up to the time of the entrance of the product into the coating chamber 74. For normal low carbon steels the temperature of the product will be from 900° F. to 1400° F. as it leaves the deoxidizing chamber 3. Inside the coating chamber the product is kicked off the traveling chain conveyor, 59 by electromagnetic relays to traveling conveyor 75 which takes the product down through a bath 76 of molten zinc and out of the bath on the other side. This conveyor is driven by a motor 76' having thereon a rheostat and by controlling the speed of the motor, the thickness of the coating is controlled. The bath of zinc is heated by gas burners 77, but once the process is started, these are cut down since the heat of the iron or steel entering the bath is sufficient to keep it molten. A flow of reducing gas is maintained in the coating chamber so that it is unnecessary to use a flux on the bath of molten zinc. This reducing gas also helps maintain a lustrous surface on the product after it has been coated. This flow of gas may be maintained by having it go through the tunnel 11 as in the immediately preceding process.

The conveyor 75 drops the product onto a second conveyor 78 which carries it across the chamber 74, and which permits the molten zinc to complete its alloying action and approach solidification temperature before it is dropped onto the traveling chain conveyor 37 which takes the product to the cooling rack constructed as above described. A very adherent coating is obtained in this manner due to the uniform gradient of the alloy layer throughout the coat. It is also most efficient since the heat is supplied from the residual heat of the rolling and the use of reducing gas eliminates not only pickling but fluxing and the loss of material caused by those operations.

The surface of the hot steel after cleaning in the deoxidizing chamber could be coated with either liquid or powdered enamel or ceramic coatings similar to the processes first and second above described. The heat of the foundation metal would fuse the enamel or ceramic coating into a solid enamel or vitreous finish. Controlled cooling could be utilized for either type of coating.

Although the methods above described are described as being coatings for iron and steel, it will be apparent that other alloys or metals may similarly be coated. Also although zinc has been described primarily as the coating it will be apparent that other metals may be used as the coating in a similar manner. Other temperatures may likewise be used to produce a satisfactory coating. It will be apparent that many modifications may be made in the processes described without departing from the invention.

What is claimed as new and is desired to be secured by Letters Patent is:

1. The process of continuously placing a permanent tightly adhering metal coating the primary component of which is zinc on a hot rolled ferrous metal body which has been heated red hot and nearly reduced to shape by hot rolling, the body during rolling being plastic and covered with brittle scale, comprising substantially descaling the hot ferrous metal body by a final heavy pass through the rolls, said pass substantially elongating the ferrous metal body and breaking the brittle scale therefrom, passing the body immediately into a chamber containing hot deoxidizing gas, the residual heat in the body and the gas serving to completely remove all scale from the body so that the body presents a sponge surface, enveloping the body with a coating metal comprising zinc, the residual heat causing the coating metal to alloy with and firmly adhere to the sponge surface of the ferrous metal body, and gradually cooling the body to maintain the coating metal thereon.

2. The process set forth in claim 1 in which the coating metal is applied by passing the hot body from the deoxidizing gas chamber into a coating chamber and therein exposing the still hot body to a vapor of the coating metal and controlling the temperature of the body in the coating chamber to condense the coating metal on the sponge surface of the body, causing it at first to alloy therewith and then to form a metal coating thereon.

3. The process set forth in claim 1 in which the coating metal is applied by passing the hot body from the deoxidizing gas chamber into a coating chamber and therein spraying the body with the coating metal and controlling the temperature of the body to cause the coating metal first to form an alloy with the sponge surface of the body and then to form a metal coating thereon.

4. The process set forth in claim 1 in which the coating metal is applied by passing the body from the deoxidizing gas chamber, while the body is still protected from the atmosphere, into a bath of the melted coating metal, the residual heat from the hot rolling causing the coating metal to first alloy with the sponge surface of the body and then form a metal coating thereon.

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