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METHOD OF AND APPARATUS FOR ANNEALING AND COATING STEEL SHEETS

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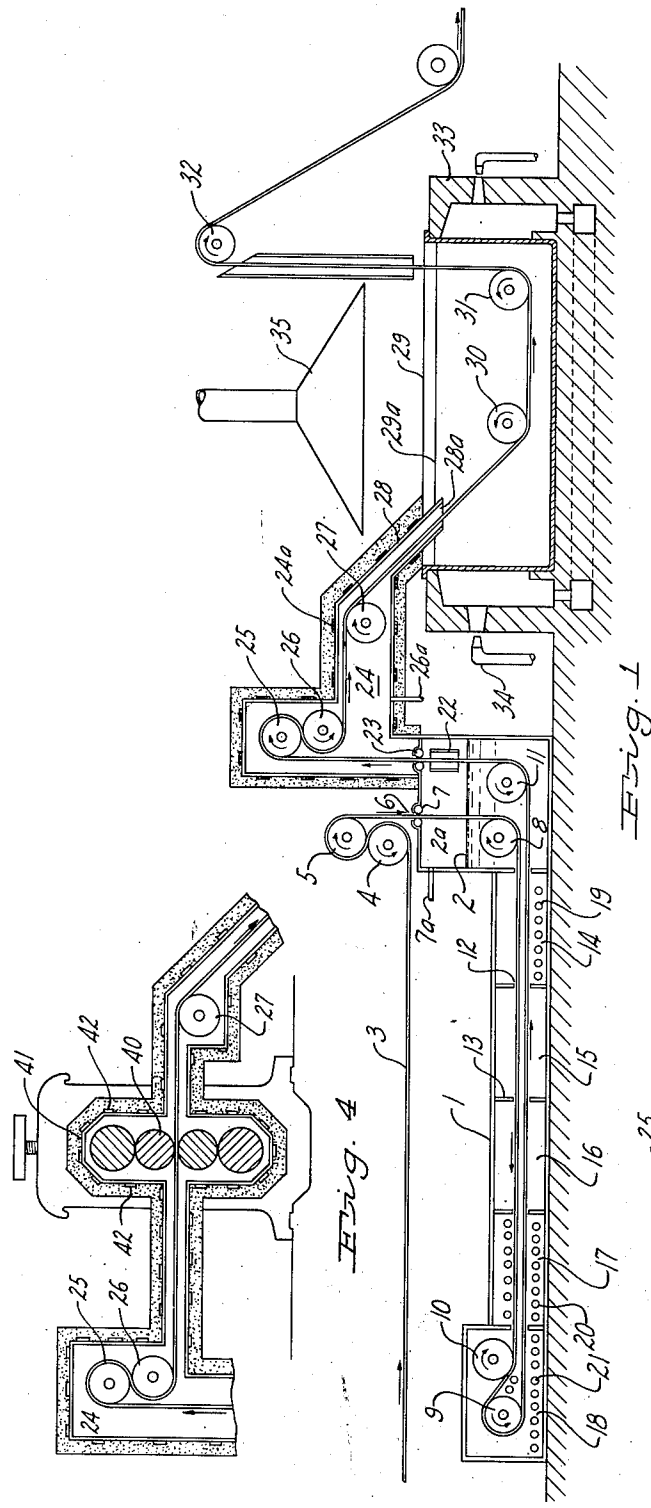


Fig. 1

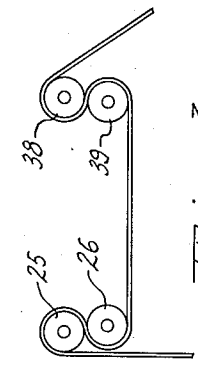


Fig. 3

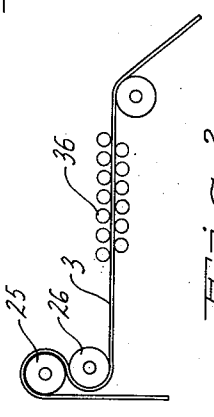


Fig. 2

Fig. 4

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METHOD OF AND APPARATUS FOR ANNEALING AND COATING STEEL SHEETS

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12 Claims. (Cl. 117—51)

This invention relates to new and useful improvements in method of and apparatus for the continuous annealing and galvanizing or coating steel sheets or strip, wire, or tubing, with zinc by the hot dip process, and the present invention is a continuation-in-part of an application Serial No. 331,225, filed January 14, 1953.

In the former application I have disclosed a method of continuously annealing strip by passing the same through a molten metal bath, such as sodium or potassium, having a low and high temperature range controlled in zones to subject the strip to a suitable annealing temperature while passing through the molten bath and returning the annealed strip through a cooler zone in the bath before it is exposed to the atmosphere.

In accordance with the present invention the ferrous strip, which alone is herein shown for demonstrating the invention, after it leaves the molten metal bath and before exposing it to any external atmospheric conditions, is passed into a sheet galvanizing tank, the annealing and galvanizing constituting a continuous method. Also the present invention contemplates work hardening of the annealed strip, wire or other materials, in a controlled atmosphere and as a step in the continuous process of annealing and galvanizing, the work hardening of the strip taking place prior to the dipping of the strip in the hot zinc solution.

It is an object of this invention to accomplish the annealing, the temper-passing or work-hardening when this is necessary, and the coating with zinc or galvanizing, in sequence in one continuous process.

It is another object of this invention to recover a large part of the heat which is ordinarily wasted in annealing and at the same time to supply the annealed strip or wire to the galvanizing bath at approximately the galvanizing temperature, so that little or no heat need be supplied to the strip by conduction through the walls of the galvanizing pot.

It is still another object of the invention to utilize for annealing a liquid metal of the alkali group such as sodium, potassium, lithium or a mixture of these metals or any other liquid metal which will not only transfer heat so rapidly as to effect practically instantaneous annealing as explained in the copending application Serial No. 331,225, but will also remove all impurities from the strip surfaces and render them chemically clean; and to protect said clean surfaces from re-oxidation or other contamination until the strip enters the zinc bath, thereby in most cases eliminating the necessity for using a flux to effect the coating with zinc.

The invention will become more apparent from a consideration of the accompanying drawings, constituting a part hereof, in which like reference characters designate like parts, and in which—

Figure 1 is a vertical cross-sectional view taken longitudinally of an annealing and galvanizing apparatus;

Figure 2 is a diagrammatic illustration of a plurality of straightening rolls employed in work hardening the strip as it passes from the annealing tank to the galvanizing tank through a chamber interposed between said tanks;

Figure 3 is a similar view of producing work hardening by means of a plurality of pinch rolls; and

Figure 4 is a vertical cross-sectional view of a temper mill which may be employed in the continuous process.

With reference to the drawings, the numeral **1** designates an annealing chamber containing molten metal designated by the numeral **2**, preferably of the alkali or alkali-earth group of metals, such as sodium, potassium, lithium or their alloys, through which is passed the sheet or strip to be annealed, designated by the numeral **3**, over guide pulleys or drums **4** and **5** to an opening **6** as indicated by the arrows. A pair of sealing rolls **7**, between which the strip **3** passes, seals the chamber above the level of the molten metal bath, and a sealing gas, such as nitrogen, is introduced as by inlet pipe **7a** above the molten metal to maintain a neutral atmosphere. The sheet or strip **3** is guided through the molten metal by drums **8**, **9** and **10** and by a drum **11** to maintain the strip **3** in closely spaced relation in the forward moving and return strands thereof and to guide the strands through openings **12** between the partitions **13**.

Partitions **13** are preferably, though not necessarily, provided to reduce the longitudinal transfer of liquid due to the viscous drag produced by the motion of the strip therethrough, and also to reduce the conduction of heat horizontally from one portion of the bath to another. The areas between the partitions may be considered different temperature zones **14**, **15**, **16**, **17** and **18** in which the heat or cooling medium is supplied by conduits **19**, **20** and **21**. Since the partitioned portion **14** is nearest the inlet side of the strip to be annealed, it may be provided with either a low temperature heating medium or a cooling medium supplied by the conduits **19** disposed therein, as may be required to control the outgoing strand to the desired temperature. As the strip advances toward the hot end of the annealing vat or chamber, the zone **17** may be heated to a much higher temperature and the zone **18** to the final annealing temperature so that the strip **3** will gradually pass from a cool zone to the highest temperature zone **18** and then return through gradually diminishing temperature zones into the sealed chamber.

Emerging from the sodium bath **2**, the strip passes between wipers **22** and a pair of sealing rolls **23** into a chamber generally designated by the numeral **24**, through which it is guided by drums **25**, **26** and **27** to a passage **28** leading to the galvanizing tank, designated by the numeral **29**.

Rolls **25** and **26** act as pinch rolls to produce the tension necessary to draw the strip through the annealer, while pinch rolls **4** and **5** draw the strip to the inlet of the annealer. Rolls **25** and **26** may be either driven through a slip clutch from the same motor or other power source as rolls **4** and **5** to compensate for the thermal expansion of the strip as it passes through the sodium bath; or preferably the rotational motion of rolls **25** and **26** may be so controlled as to maintain a constant tension in the strip leaving the annealer, by the use of any of the usual tension-controlling devices which are well known and do not themselves form part of this invention.

Chamber **24** provides a protective atmosphere of either inert or reducing gas, introduced through inlet pipe **26a**, for the strip passing from the molten metal solution to the galvanizing tank so that the chemically clean surface of the strip produced by the action of the sodium bath is maintained until the strip enters the zinc bath of the tank **29**. The walls of chamber **24** and passage **28** are preferably insulated and provided with heating means either inside the chamber, or outside it but between the chamber wall and the insulation, to prevent any appreci-

able drop of temperature of the strip between its exit from the annealer and its entrance into the galvanizing bath. In the illustrations the heating means have been indicated as electric strip heaters **24***a*.

The end **28***a* of passage **28** is desirably made of material which is resistant to attack by molten zinc, and it preferably dips into the zinc bath **29***a* to a depth sufficient to form a liquid seal against escape of gas, but alternatively it may end just above the level of the zinc without dipping into the same.

The arrangement of the annealing chamber containing the liquid sodium is not limited to the horizontal type which is shown by way of example in Figure 1, but may be vertical or inclined. Several vertical arrangements are shown in my copending application Serial No. 331,225.

Since it is sometimes desired to provide in chamber **24** an atmosphere consisting of a mildly reducing gas such as the so-called "de-ox" gas which contains about ten percent of hydrogen, or even a gas mixture containing hydrochloric acid, and since in those cases where a flux is used on top of the zinc bath at the place where the strip enters it there may be hydrochloric acid given off and entering passage **28**, and furthermore since these gases must not be allowed to enter the chamber **2***a* containing the sodium because of their violent reaction with the latter, the inflow of inert gas through inlet **7***a* into chamber **2***a* is controlled by a sensitive pressure regulator of any standard type, in such manner that the gas pressure above the seal rolls **23** is always very slightly lower than the gas pressure below these rolls, thus preventing any backward flow of gas which might otherwise occur by leakage past seal rolls **23**.

The strip is guided through the galvanizing bath in container **29** by drums **30** and **31** and then is guided out of the bath by drum **32** from which it is taken to a coiler or other processing device. The galvanizing tank is provided with suitable insulating walls **33** and burners **34**, as is conventional practice, and constitutes no part of the present invention. A hood **35** is provided above the tank for removing the fumes.

For those grades of strip in which greater hardness and stiffness are desired than can be obtained without work-hardening, means may be provided for work-hardening the material or strip, as by means of the roller leveler shown in Figure 2, in which the rolls **36** between which the strip passes produce successive reverse bending of the strip, such roller leveler being disposed in the chamber **24** between the annealing and galvanizing chambers; or instead of the roller levelers, pairs of pinch rollers **25—26** and **38—39** may be employed, the latter being driven at a slightly higher speed than the pinch rolls **26—27** to produce tensile stretching of the strip to the extent of a few percent of its length. Such a work-hardening device is also disposed in the protective atmosphere of the chamber **24**.

Where still greater work-hardening is desired, the strip on its way to the galvanizing bath may be made to pass from chamber **24** through the rolls **40** of a temper mill of the conventional type, as shown in Figure 4. The rolls of the temper mill are located within a gas-tight insulated enclosure **41**, and heating means **42** are preferably provided to maintain the enclosure and the rolls within it at a temperature sufficiently high to prevent appreciable cooling of the strip. Either a non-oxidizing atmosphere, such as nitrogen, or a mildly reducing atmosphere, is maintained in the enclosure and passages. By thus work-hardening the strip in a protective atmosphere after it is annealed instead of after the strip has been galvanized, there is less danger of causing cracks in the zinc coating. However, when the amount of work-hardening is not greater than can be attained without cracking the zinc after the coating has been applied, it may be preferred to do the temper rolling subsequently to the galvanizing.

In the operation of the above described apparatus the

acid dip ordinarily employed preceding the galvanizing, and the necessity for cooling the strip to 200° F. or below following the annealing, are eliminated. Also by making use of the simple and compact container for the liquid metal bath of sodium, potassium, lithium or a mixture of these metals, the bulky, costly furnace requiring inflammable protective gas atmospheres, as presently employed, may be dispensed with.

Because of the extremely high heat transfer ability of the liquid metal bath of sodium or the like, but a short distance of travel of the strip through the bath is required while permitting the heating up of the strip to annealing temperature and its subsequent cooling to about 800° F. If, for example, with reference to Figure 1, the molten metal bath in the zone **14** is maintained at 800° F. the strip will pass into the annealing apparatus through a low temperature to a high or annealing temperature zone **18** where the temperature of the molten liquid bath may be 1350°, or more.

As the strip passes from the zone **14** at approximately 800° F. to the high temperature zone **18**, it will pass in close proximity to the return strand leaving the high temperature chambers **17** and **18** and because of the very high heat-transmitting characteristics of the sodium it will rapidly absorb the heat from the annealed strip which passes to the cooler zone **14** and thence into the neutral chamber **24** at a temperature of around 800° F. to 900° F. which is approximately the same as the temperature of the molten zinc bath into which it passes. During this travel from the annealing compartment to the galvanizing compartment, the strip is protected from oxidation and retains its chemically clean surface resulting from its contact with the molten sodium annealing bath which removes the grease, the carbon smut, the iron oxide surface film which always exists on the surface of the incoming strip even though very thin and actually invisible, or other foreign substances, in toto. The actual metallic steel surface thus exposed alloys instantly with the zinc as the strip enters the galvanizing bath and eliminates the need for a flux to effect alloying.

Furthermore, it is not necessary that the wiping pads **22** and sealing rollers **23**, which may be designed to effect a squeegee action on the surface of the strip as well as to seal the protective atmosphere within the chamber, wipe every trace of sodium from the strip before it enters the zinc bath, because the sodium at the temperature attained during the annealing process wets the steel surface, and this has an advantage in reference to aiding the subsequent zinc coating, because if a slight film of sodium or other of the metals mentioned remains on the strip as it enters the zinc bath, the wetted surface acts to assist the initial alloying or bonding of the zinc with the steel. Since only a very thin layer of zinc-iron alloy is desired to bond the zinc to the steel, a small percentage of aluminum may be employed in the zinc bath in accordance with well known practice in continuous galvanizing operations to inhibit the growth of the alloy layer.

With the two strands of strip, one being heated and the other being cooled, moving in opposite directions, approximately parallel to each other and preferably in close proximity, because of the extremely high heat-transferring ability of the sodium that part of the heat which is required to raise the strip from 800° F. to the annealing temperature which is usually between 1050° F. and 1350° F., is recovered, and only the heat required to raise the strip from room temperature to about 800° F. need be imparted in the annealer; whereby a very considerable economy of fuel or electric energy is effected. Furthermore, because of the very much smaller size of the sodium annealer as well as the considerably lower average internal temperature, the loss of heat from the walls of the annealer is reduced to a small fraction of the loss which occurs from the extremely bulky gas-filled continuous annealers hitherto used.

Although one embodiment of the invention has been herein illustrated and described, it will be evident to those skilled in the art that various modifications may be made in the details of construction without departing from the principles herein set forth; for example the method of annealing, work hardening and coating may be carried out without reversing the strip in the annealing step and by cooling instead of heating the strip in the connecting chamber to prepare the same for the zinc coating.

I claim:

1. The method of heat treating and galvanizing ferrous metal sheet or strip which comprises the steps of passing the strip continuously through a liquid bath of alkali metals of increasing temperature range having the properties of removing iron oxide and impurities from the surface of the strip, returning the strip from the high to the initial low temperature zone of the bath to cool said strip to a temperature approximating the galvanizing temperature of molten zinc and passing the strip continuously through a non-oxidizing substance into and through a bath of molten zinc.

2. The method of heat-treating and galvanizing ferrous metal sheet or strip which comprises the steps of passing the strip continuously through a liquid bath of alkali metals of homogeneous consistency and of increasing temperature range, returning the strip from the high to the low temperature zone of the bath to cool said strip to a temperature approximating the galvanizing temperature of molten zinc, withdrawing the annealed strip from the annealing bath between wipers into a non-oxidizing atmosphere maintained at a temperature suitable for galvanizing the strip, and passing the strip from said non-oxidizing atmosphere by submerging it into a molten bath of zinc to coat the strip before it is exposed to the outer atmosphere.

3. The method of heat-treating and galvanizing ferrous metal sheet or strip which comprises the steps of passing the strip continuously through a liquid bath of alkali metals of homogeneous consistency and of increasing temperature range, returning the strip from the high to the low temperature zone of the bath, withdrawing the annealed strip from the annealing bath into a non-oxidizing atmosphere maintained at a temperature suitable for galvanizing the strip, work hardening the strip while passing through said atmosphere, and submerging the same into a molten bath of zinc to coat the strip before exposing it to the outer atmosphere.

4. The method of heat-treating and galvanizing ferrous metal sheet or strip which comprises the steps of passing the strip continuously while under tension through a liquid bath of alkali metals of homogeneous consistency and of increasing temperature range, returning the strip from the high to the low temperature zone of the bath to cool said strip to a temperature approximating the galvanizing temperature of molten zinc, passing the strip continuously through a non-oxidizing atmosphere into and through a bath of molten zinc, and work hardening the strip while passing through said atmosphere.

5. Apparatus for heat treating and galvanizing steel strip by continuous process comprising a closed tank containing a liquid bath of alkali metals of constant composition and varying temperature zones from one end to the other through which the strip is passed to anneal the same, a second tank containing molten zinc, a connecting chamber between said tanks through which the metal passes in a reducing atmosphere, and means for continuously conveying the strip through the annealing bath from a low temperature zone to a high temperature zone and thence returning on itself to the low temperature zone, thence through the connecting chamber, and through the zinc bath.

6. Apparatus for heat treating and galvanizing steel strip by continuous process comprising a closed tank containing a liquid bath of alkali metals of constant composition and varying temperature zones from one end to the other through which the strip is passed to anneal the same, a second tank containing molten zinc, a connecting chamber between said tanks through which the metal passes in a reducing atmosphere, heating means in said connecting chamber for maintaining a desired temperature of said strip approximating the temperature of the zinc bath, and means for continuously conveying the strip through the annealing bath from a low temperature zone to a high temperature zone and thence returning on itself to the low temperature zone, thence through the connecting chamber and through the zinc bath.

7. Apparatus for heat treating and galvanizing steel strip by continuous process comprising a closed tank containing a liquid bath of alkali metals of constant composition and varying temperature zones from one end to the other through which the strip is passed to anneal the same, a second tank containing molten zinc, a connecting chamber between said tanks through which the metal passes in a reducing atmosphere, work rolls in said connecting chamber for work hardening the strip, and means for continuously conveying the strip through the annealing bath from a low temperature zone to a high temperature zone and thence returning on itself to the low temperature zone, thence through the connecting chamber and through the zinc bath.

8. Apparatus for heat treating and galvanizing steel strip by continuous process comprising a closed tank containing a liquid bath of alkali metals of constant composition and varying temperature zones from one end to the other through which the strip is passed to anneal the same, a second tank containing molten zinc, a connecting chamber between said tanks through which the metal passes in a reducing atmosphere, heating means in said connecting chamber for maintaining a desired temperature of said strip approximating the temperature of the zinc bath, said chamber having a closed passage leading therefrom with its open end submerged in the zinc bath, and means for continuously conveying the strip through the annealing bath from a low temperature zone to a high temperature zone and thence returning on itself to the low temperature zone, thence through the connecting chamber and through the zinc bath.

9. Apparatus for heat treating and galvanizing steel strip by continuous process comprising a closed tank containing a liquid bath of alkali metals of constant composition and varying temperature zones from one end to the other through which the strip is passed to anneal the same, said tank having pairs of sealing rolls at the entrance and exit openings of the tank, guide rolls for directing the movement of the strip from the entrance opening to the high temperature zone and back to the exit opening and for maintaining close parallel spacing of the oppositely moving strip strands in heat exchange relation, pinch rolls for feeding the strip to and from the tank, a second tank containing molten zinc, a connecting chamber between said tanks through which the metal passes in a reducing atmosphere, and means for continuously conveying the strip through the annealing bath, thence through the connecting chamber and through the zinc bath.

10. Apparatus for heat treating and galvanizing steel strip by continuous process comprising a closed tank containing a liquid bath of alkali metals of constant composition and varying temperature zones from one end to the other through which the strip is passed to anneal the same, said tank having pairs of sealing rolls at the entrance and exit openings of the tank, guide rolls for directing the movement of the strip from the entrance opening to the high temperature zone and back to the exit opening and for maintaining close parallel spacing of the oppositely moving strip strands in heat exchange relation, pinch rolls for feeding the strip to and from the tank, then to a second tank containing molten zinc, a connecting chamber between said tanks through which the metal

passes in a reducing atmosphere, and means for drawing the strip from said connecting chamber into the molten zinc and then out of the zinc tank vertically into the atmosphere.

11. The method of heat treating and galvanizing ferrous metal strip which comprises the steps of passing the strip continuously through a liquid bath consisting of an alkali metal, maintaining a range of progressively increasing metal temperature in the bath along the path of the strip, returning the strip from the high to a lower temperature zone of the bath to cool said strip to a temperature approximating the galvanizing temperature of molten zinc, allowing a thin film of alkali metal to remain on the strip and applying molten zinc continuously in contact with the moving strip to coat the same.

12. The method of heat treating and galvanizing ferrous metal strip which comprises the steps of passing the strip continuously through a liquid bath consisting of an alkali metal, maintaining a range of progressively increasing metal temperature in the bath along the path of the strip, returning the strip from the high to a lower temperature zone of the bath to cool said strip to a temperature approximating the galvanizing temperature of molten zinc, wiping off a part of the film of alkali metal adhering to the strip to reduce said film to a controlled thickness, and applying molten zinc continuously in contact with the moving strip to coat the same.

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