June 25, 1957 J. D. KELLER 2,797,177

METHOD OF AND APPARATUS FOR ANNEALING STRIP STEEL

Filed Jan. 14, 1953

3 Sheets-Sheet 1

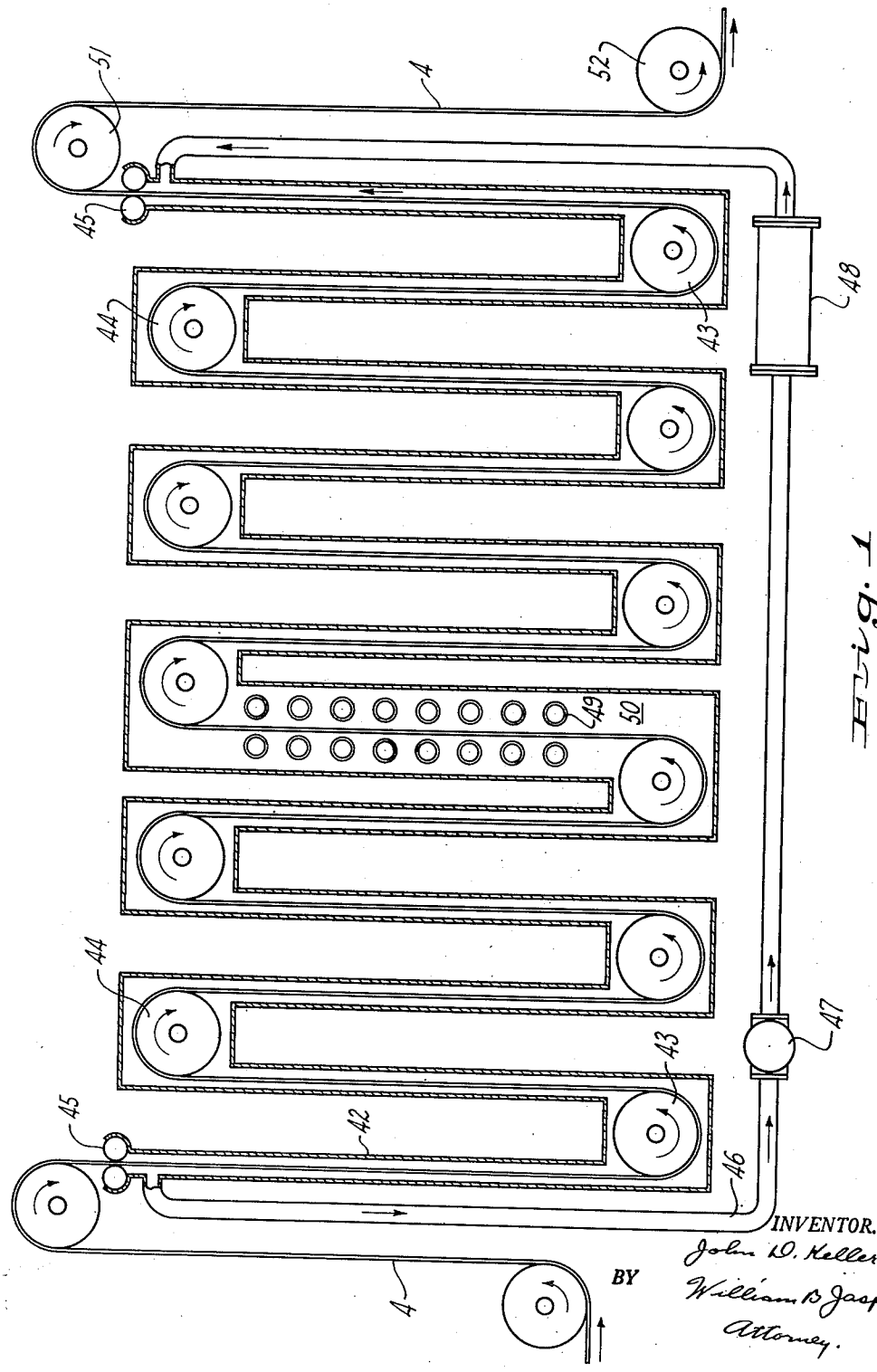


Fig. 1

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3 Sheets-Sheet 2

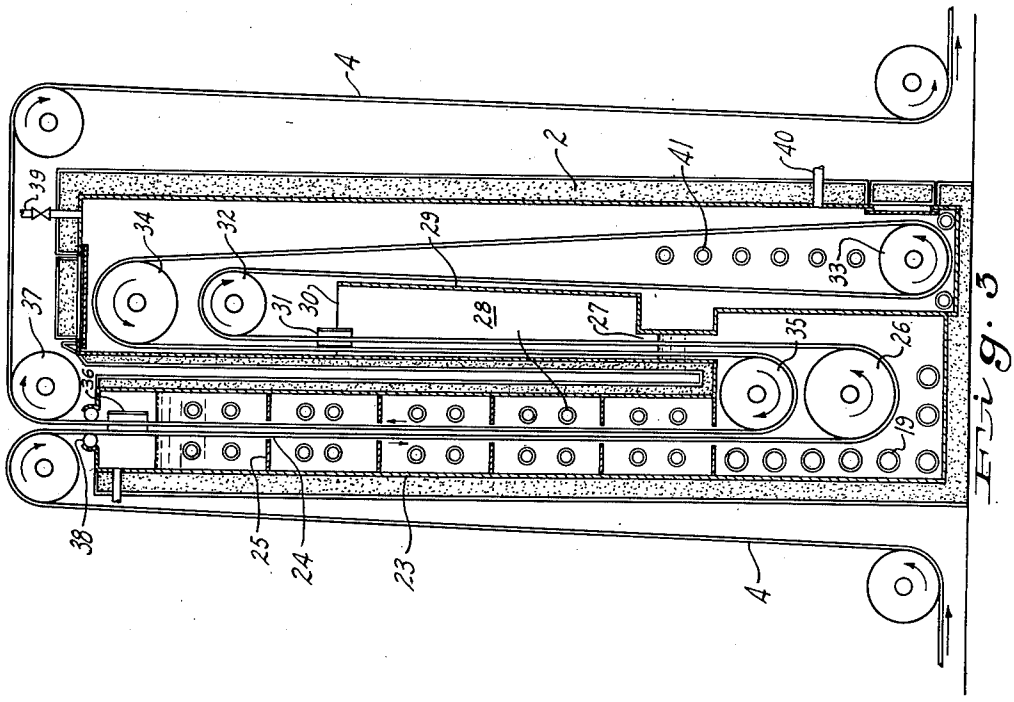


Fig. 3

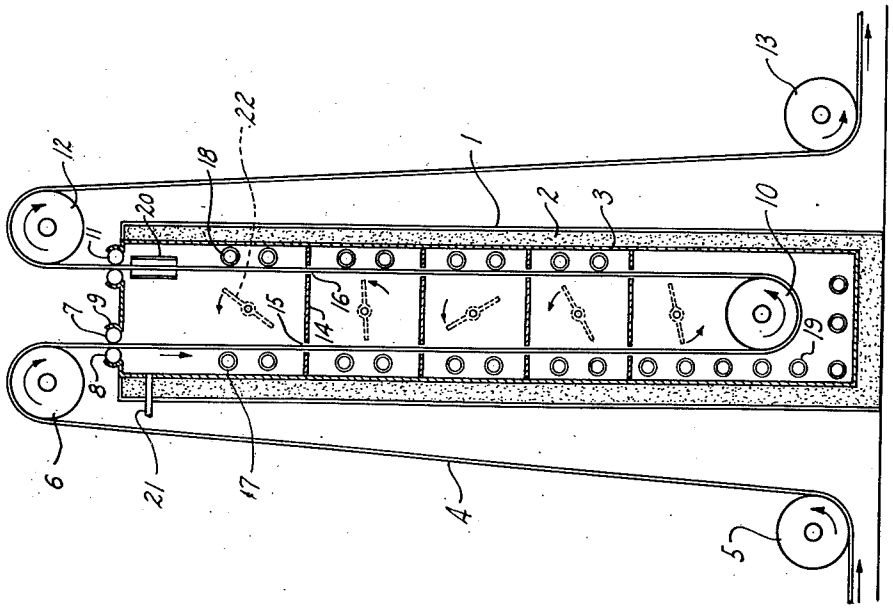


Fig. 2

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3 Sheets-Sheet 3

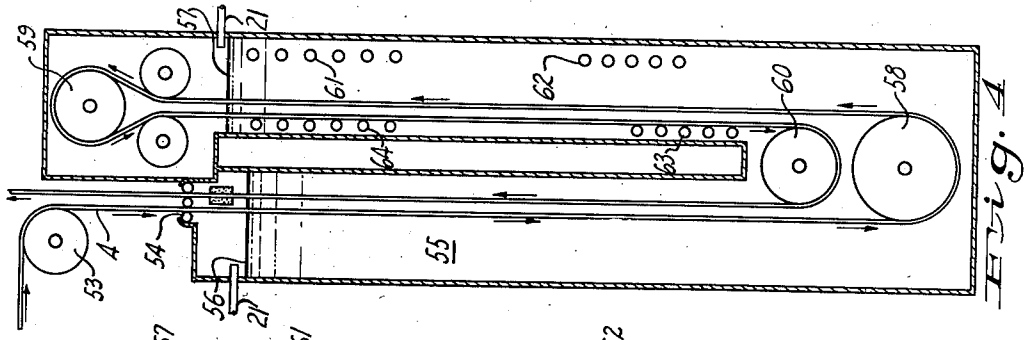


Fig. 4

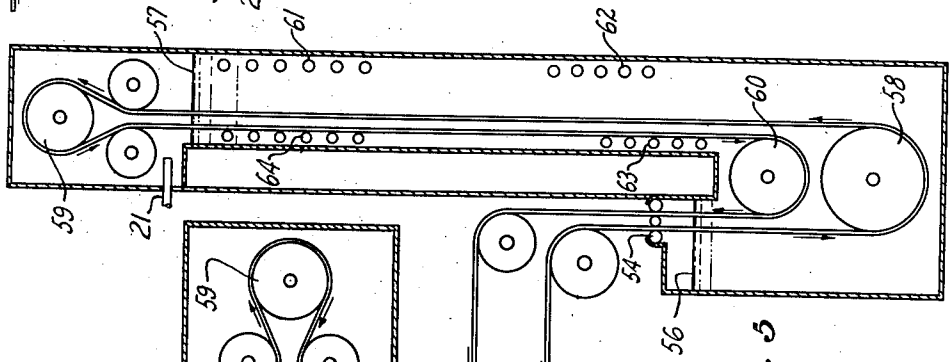


Fig. 5

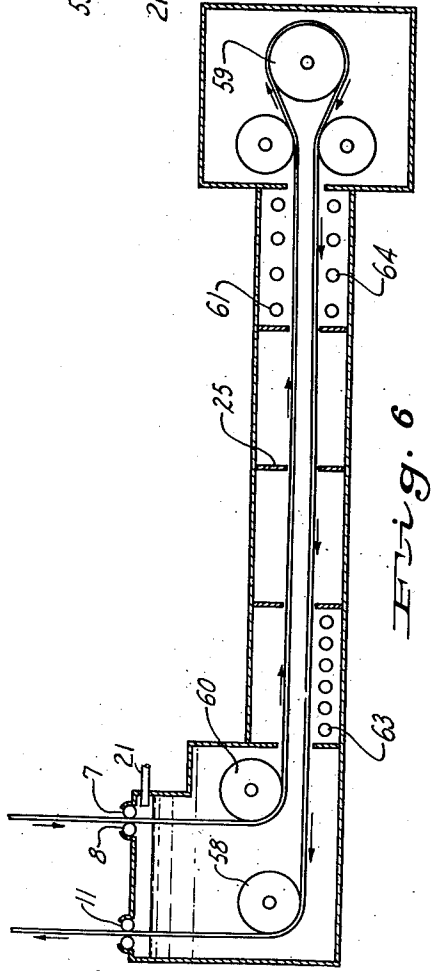


Fig. 6

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METHOD OF AND APPARATUS FOR ANNEALING STRIP STEEL

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14 Claims. (Cl. 148—15)

This invention relates to new and useful improvements in a method of and apparatus for annealing strip steel, and it is among the objects thereof to materially reduce the time required for annealing sheet steel or strip by conventional methods and to reduce the space needed for present type of furnaces.

It is the particular object of the invention to provide a method and apparatus for annealing strip at a rapid rate of from ten to fifteen times as fast as present continuous annealing methods and to obtain uniform physical properties in the strip material treated.

It is still a further object of this invention to utilize a molten bath of metal as the heating and cooling medium and to employ such metals in containers designed to occupy a minimum of space in an industrial plant. Present methods of annealing strip consist of heating a coil of the strip under cover to prevent atmospheric oxidation and permitting it to cool slowly. Very long cycles of from 60 to 120 hours are required by this process and the cost of the necessary equipment per ton of daily capacity is quite high. Such methods further result in considerable differences of temperature in different parts of the coils being treated and the resulting product lacks uniformity. It has also been proposed to anneal strip in strand form as distinguished from the coil by unwinding it and passing it through a furnace filled with protective gases wherein the strip is first heated and then cooled while moving through the furnace, after which it is recoiled. Such heating is done by radiant heat with either electric resistors or tubes internally heated by gas flames, and cooling is effected by water-cooled chutes enveloping the strip. In such processes the heating and cooling of the strands is quite slow because of the bright reflecting surfaces of the strip being a poor absorber of radiated heat and because the temperatures at which usually the heating elements can be operated must be limited to a rather low value to obtain reasonable length of life of the elements which are of a nickel-chrome alloy base. The radiation from the bright reflecting surfaces of the strip to the water-cooled chutes is even slower so that the cooling of the strip requires a considerable length of time. Because of the time lag in such annealing operations, there must be many strands of strip in the furnace passing successively over numerous rollers which adds to the possibility of marring the surface of the strip and creates complicated problems in the use of suitable driving mechanism for the rollers, gas seals on the shafts, and tension regulating means for the strip which further creates the possibility of breakage of the strip in the furnace with resultant decrease in furnace capacity caused by rethreading, etc. Such furnace must be very large for a moderate output. For example, to anneal 30 tons an hour of strip 30 inches wide by .01 inch thick, the furnace must have at least 8 strands 30 feet high in the heating and soaking zones, and 12 strands of this height in the cooling zone, a minimum of 20 strands in all. Because of the slow heating process, there is the further disadvantage that the strip is only partially annealed and has, therefore, limited uses.

In accordance with the present invention, the uncoiled strip is heated very rapidly, almost instantaneously, to the annealing temperature to produce what is known metallurgically as "flash-over" resulting in instant transformation of the metal to almost a fully annealed condition. The present invention further contemplates economical use of heat energy which is recovered in part from the annealed strip by virtue of the fact that the strip is annealed in a liquid bath. The liquid bath not only functions as a heat transferring medium, but also as a protective medium in that it does not attack or contaminate the steel or affect its finished surface. The strip is passed through the liquid bath in such manner that the same liquid is both heating and cooling the strip and at the same time recovers the greater part of the heat from the outgoing strand of the annealed strip and transfers it to the incoming cold strand of the strip, with the result that the heat consumption is only about 15% of that used in present continuous annealing processes.

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:

Fig. 1 is a vertical cross sectional view of apparatus for annealing sheet or strip material embodying the principles of this invention,

Fig. 2 a similar view of a modified form of apparatus,

Fig. 3 a similar view of still another modification of the apparatus shown in Fig. 1, and

Figs. 4, 5 and 6 are vertical cross sectional views diagrammatically illustrating other modifications of the apparatus shown in Fig. 1.

The invention will be more clearly apparent from a consideration of the apparatus shown in Fig. 2 of the drawing in which the numeral 1 designates a sheet metal housing for retaining insulating material 2 against a container wall 3 which is preferably of stainless steel. A molten bath of metal is charged in the container 3, the metal being of a low melting point alloy, preferably either liquid sodium or potassium or an alloy of the two. Metals such as lead, bismuth or mercury possess suitable characteristics to carry out the processes as hereinafter described or in a modified form but these metals are undesirable because of their contaminating and poisonous properties. Sodium melts at 208 degrees F., slightly below the boiling point of water and under atmospheric pressure it boils at 1620 degrees F., which is 270 degrees higher than the maximum desired annealing temperatures for low carbon steel strip of 1350 degrees F. The stainless steel container withstands the action of liquid sodium at temperatures up to 1600 degrees F. for long periods without deterioration. Consequently it is desirable to construct all of the parts of the apparatus of stainless steel that are immersed in or contact the liquid sodium.

As shown in Fig. 2, the strip steel to be annealed passes under guide roller 5 to the top of the container housing 3 where it is directed by a pulley 6 to a pair of sealing rollers 7 and 8, these rollers being mounted in curved bearings 9 to prevent the escape of the sodium and gases at the top of the container. A guide roll 10 is mounted in the bottom of the container 3 for guiding the strip in its downward travel through the molten sodium and upward to the sealing rollers 11 from which it passes over pulley 12 to the outside of the container underneath guide roll 13 from which it is delivered to a coiler. A series of partitions 14 having slots 15 and 16 through which the strand passes are mounted in superposed relations in the container 3 to divide the latter into zones that are individually controlled to maintain desirable heating or cooling temperatures by tubes 17 and 18 and the tubes 19 at the bottom of the container, the tubes, partition and guide rolls, also the sealer rolls being made of stainless steel. Sup-

plied near the top of the container 3 is a wiper 20 for wiping the sodium from the strand as it passes out of the treating chamber. A gas inlet 21 is provided at the top of the container to supply a protective gas such as nitrogen which maintains a slight pressure in the container above the liquid metal surface and prevents the leakage of the sodium out of the container. By varying the gas pressure on the molten bath, the temperature of the bath may be varied as a means for obtaining temperature control of the bath within the desired annealing range.

A series of rotating paddles 22 are mounted between partitions 14 to equalize the temperature laterally within each partitioned zone. The paddles may be employed where the strands of the strip are separated substantially as shown in Fig. 2. Where they are closely spaced as in Fig. 3, the paddles may be dispensed with. The partitions are necessary to prevent inverting of the temperature which normally would be highest at the top of the molten bath due to the lower specific gravity of the hot sodium which would rise to the top.

In the operation of the apparatus shown in Fig. 2 for the annealing of steel strip, the tubes 19 below the bottom partition are heated to the maximum desired annealing temperature to raise the temperature of the sodium to above 1350 degrees F. The tubes 17 on the left hand side of the container 3 are heated at successively lower temperatures, the minimum heat being supplied in the tubes above the upper partition. The tubes 18 on the right hand side of the container 3 are cooling tubes through which a cooling medium such as, for example, air is circulated. By operation of the rotating paddles 22, the temperature in the partition chambers is maintained substantially uniform throughout.

The strand 4 after passing through the sealer rolls 7 and 8 is passed through the slots 15 of the partitions and threaded around the guide roll 10, then passes upward through slot 16 of the partition between the wipers 20 and through the sealing rolls 11, thence over the guide roll 12 to a coiler, and while so passing through the container is gradually brought up to the annealing temperatures as it passes downward as shown by the arrow, reaching a maximum temperature at the bottom of the container. As it passes upward through the slots 16, it is subjected to the reduced temperature of the successively decreasing temperature zones until it reaches a low temperature of several hundred degrees in the upper chamber of the container before passing out of the container. In passing upward through the container the annealed strip gives off its heat to the sodium bath in the successive chambers in which this heat is utilized in maintaining the temperature of the molten sodium in the respective chambers to heat the incoming strip. Because of the extremely high heat transferring capacity of the sodium bath, which by use of the present equipment is a function of the speed of travel of the strand through the molten bath, the time for annealing is reduced to substantially 1/15 of the time consumed in the annealing of strip by conventional methods. This is due to the fact that flash-over of the molecular structure of the strip takes place almost instantly when the strip is thus heated almost instantaneously to the annealing temperature.

Where it may be desired to provide for a soaking and retarded cooling period after the strip has been brought to the annealing temperature, a soaking chamber may be provided as shown in Fig. 3. In Fig. 3 the stainless steel container 23 is substantially like the container 3 of the Fig. 2 and the heating and cooling tubes are employed in the partitioned chambers in the same manner as described in connection with Fig. 2. Both strands of the strip, however, pass through a single slot 24 in the center of the partitions 25 and are in close relationship in their downward and upward travel through the molten bath. In Fig. 3 the strand passing downwardly into the molten bath is guided by pulley 26 to a restricted passage 27 of chamber 28 constituted by the housing 29

and which is open at the top as shown at 30. A wiper 31 is provided to wipe off the strand as it passes upward into the soaking chamber around guide pulley 32, thence downward to guide pulley 33, upward to guide pulley 34, thence downward through the constricted passage 27 into the molten bath again where it is directed by guide pulley 35 upwardly through partition slots 24, where it again passes through the wiper 36 and out around guide pulley 37 to the coiler, the sealing rolls 38 being the same as the rolls 8 and 9 of Fig. 2.

The top of the soaking chamber is provided with an outlet 39 for purging the chamber of undesirable gases, and a gas inlet 40 is provided adjacent the bottom of the soaking chamber for charging nitrogen or other protective gas under pressure into the cooling chamber.

In the operation of the apparatus in Fig. 3, additional heating tubes 41 are supplied in the soaking chamber to supply the heat lost through the housing wall and insulation materials, and the liquid of the molten bath is maintained as shown in Fig. 3 to be confined within the narrow passage 24 leading to the expansion chamber 28 by means of the pressure of the protective gas supplied through the inlet 40. Should this pressure fail, the expansion chamber 28 will receive the molten bath which would drop by gravity from the vertical column or chamber on the left hand side of the expansion chamber. In treating the strip passing though the annealing apparatus of Fig. 3, it is gradually heated by passing successively downward through the partitioned chambers from the top to the bottom of the container housing the molten bath and when it reaches its maximum temperature at the bottom of the container, it passes upward through the restricted passage 27 and around guide pulley 32 into the soaking chamber wherein it is maintained at the desired temperature for a sufficient time to permit the strip to become uniformly heated throughout before it again passes downward through the restricted passage 27 into the molten bath and vertically upward and out at the top of the treating chamber.

Because of the flash-over heating of the steel strip, it is not deemed necessary to provide either a soaking chamber or a soaking period but the structure of Fig. 3 will accomplish this end where it may be desired.

In the apparatus shown in Fig. 1 of the drawing, the containers for the molten sodium are constructed to provide a single passage for the strand 4. The strand is guided through the passage by guide rolls 43 and 44 and the end passages 42 are provided with the sealing rollers 45 as for the purpose described in connection with Fig. 2 of the drawing. The molten sodium is circulated through the passage 42 by means of an outside conduit 46 having a pump 47 and a cooler 48, the pump circulating the molten bath in the direction shown by the arrows and delivering it to the top of the outlet passage on the right hand side of the figure, the direction of flow being counter to the direction of travel of the strand 4 through the passages 42.

The heating of the molten bath is provided by a plurality of tubes 49 in the enlarged compartment or chamber shown in the center of Fig. 1 and the annealing process consists of feeding the strand between the sealer rollers 45 into passage 42 at the left hand side of Fig. 1 and causing it to pass through successive passages into the heating zone which may be generally designated by the numeral 50 which is the zone of maximum temperatures. The strand then passes through the successive passages to the guide rolls 51 and 52 on the right hand side of the apparatus as viewed in Fig. 1 of the drawing. By means of the apparatus shown in Fig. 1, the cooling of the annealed strip may be controlled by regulating the cooler 48 so that the liquid sodium passing into the vertical housing on the right hand end of Fig. 1 will cool the annealed strand that is passing upward as shown by the arrow and out of the treating equipment. The sodium as it is forced through successive passages towards

the center of the treating apparatus will increase in temperature by absorbing heat from the hot strip and will acquire its maximum or annealing temperature in the heating zone **50**. It then gradually cools as it passes toward the left to the outlet or circulating conduit **46** by virtue of contacting the cold metal strand entering the treating apparatus.

The apparatus shown in Fig. 4 of the drawing differs from that disclosed in Figs. 2 and 3 in that the maximum temperature is provided in the upper part of the treating equipment and partition members that would prevent normal inversion of the temperature are not required. The strand to be annealed, designated by the numeral **4**, passes over guide roll **53** which directs it to the roller seals **54** through which it enters the treating container **55** having the liquid level designated by the line **56** adjacent to the top thereof. A column of liquid sodium in the right hand side of the apparatus may be at a different level as shown by the line **57** which is maintained by pressure of the nitrogen gas that is introduced at the top of the container. After passing around the bottom guide roll **58**, the strand passes upward through the sodium bath around guide roll **59** and again passes downward around guide roll **60** and vertically upward to adjacent the place of entry from which it is directed to a coiler not shown.

In the apparatus of Fig. 4 the heating tubes **61** are provided at the top of the container in the right hand side as shown and also at a mid portion of the right hand side of the container as shown by the numeral **62**. Cooling tubes **63** and **64** may be provided on the side where the strand passes downward after it has passed through the maximum temperature zone so that after passing around the guide roll **60** it will lose its heat which is transferred through the sodium bath to the incoming strand.

It is evident that partitions may be used in the apparatus of Fig. 4 where the strip is passed through the apparatus at a high rate of speed to prevent drag of the metal by the friction of the strip which would disturb the desired temperature distribution. The structure of Fig. 4 may be modified in the manner shown in Fig. 5 by increasing the pressure of the nitrogen gas in the upper chamber in the left hand column of the apparatus so as to maintain the desired liquid level in the right hand column of the container. This is useful only in minimizing the amount of molten sodium used in the annealing process.

With reference to Fig. 6 of the drawing, the arrangement of the sealing and guiding apparatus as well as the heating and cooling coils and partitions is similar as shown in Figs. 2 and 3 and differs from that shown in Fig. 5, for example, in that it is disposed horizontally, the annealing process being otherwise the same. In Fig. 6 the coils **61** and **64** are the heating coils and **63** the cooling coils.

By means of the protective gas such as nitrogen, shown by way of example, the sodium is protected from exposure to the air or to water vapor which would cause it to ignite and burn and especially at the high temperatures in which it is used in the annealing apparatus. Sodium does not so react with nitrogen, argon, or helium.

Lithium when added in small proportion of approximately 5% to the molten sodium bath will reduce the drag out of the liquid metal with the treated strip to avoid loss of the treating metal. It also reduces adherence of the liquid metal to the surface of the metal being treated.

Furthermore, lithium has a very high boiling point, about 2500 deg. F., hence either lithium alone or lithium alloyed with other low-melting point metals such as sodium or potassium or NaK, is suitable for use in the present invention where temperatures higher than those customary for ordinary annealing are required, such as 1800 deg. F. for normalizing, or 2000 to 2200 deg. F. for heat-treating the highest grades of silicon steel strip.

It is evident from the foregoing description of this invention that annealing may be effected by means of the apparatus described and employment of the liquid metal of extremely high heat transferring capacity such as sodium. The annealing process may be made continuous by uncoiling the strand from a coil, passing it through the annealing apparatus and recoiling it after treatment. It is also apparent that because of the low melting point of sodium or sodium and potassium alloys, most of the heat put into the strip to bring it to the annealing temperature can be recovered in the sodium bath before the strip leaves the apparatus, and therefore a minimum of heat energy is required to maintain a proper treating temperature and only such heat input is necessary as would be required to maintain the annealing temperature of 1350 degrees. By means of the use of the molten bath as the medium of heat transfer, the annealing apparatus may be of a minimum size and take up very little space in an industrial plant. Such apparatus may be interposed to anneal the strand in a continuous mill between successive rolling operations where this is desired because of the great speed at which the strip may be passed through the annealing bath, which as heretofore mentioned, effects a flash-over of the molecular structure of the metal instantaneously.

Although several modifications of the invention have 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.

I claim:

1. The method of heat-treating relatively thin ferrous metal bodies which comprises feeding the same into a liquid bath of sodium of constant composition throughout having a relatively low melting point and a high boiling point, said bath having gradually increasing temperature zones to heat the metal uniformly to a suitable annealing temperature and withdrawing the ferrous metal through said bath to a point of exit at least part way from the place of highest temperature toward the point of entry to cool the same.

2. The method of heat-treating relatively thin ferrous metal bodies which comprises feeding the same into a liquid bath of potassium of constant composition throughout having a relatively low melting point and a high boiling point, said bath having gradually increasing temperature zones to heat the metal uniformly to a suitable annealing temperature and withdrawing the ferrous metal through said bath to a point of exit at least part way from the place of highest temperature toward the point of entry to cool the same.

3. The method of annealing relatively thin metal sheets or strip which comprises feeding the strip into a liquid bath divided into separately controllable temperature zones of constant composition throughout having a relatively low melting point and a high boiling point, said bath having gradually increasing temperatures from the top of the bath to the bottom thereof, while maintaining an inert atmosphere to the top of the bath, and withdrawing the strip from said bath from the bottom zone of maximum temperature through gradually diminishing temperature zones as it travels to the top of the bath and through the inert atmosphere to the outside of the bath.

4. The method of annealing relatively thin metal sheet or strip material which comprises feeding the strip into a liquid bath of constant composition throughout having a relatively low melting point and a high boiling point, said bath having gradually increasing temperature zones to heat the strip uniformly to a suitable annealing temperature, passing the strip out of said bath into an inert atmosphere to soak and cooling the strip by returning the same into the molten bath and passing it from the high to the low temperature zone to remove it from said bath.

5. The method of annealing relatively thin metal sheet or strip which comprises feeding the strip into and through

a liquid bath of constant composition throughout having a relatively low melting point and a high boiling point, said bath having gradually increasing temperature to heat the strip uniformly to a suitable annealing temperature and then continue to feed the strip through said bath at a gradually reducing temperature to cool the same while maintaining circulation of the bath counterflow to the movement of the strip in said bath.

6. The method of heat treating relatively thin ferrous metal bodies which comprises feeding the same into a liquid bath of constant composition throughout having a melting point below 450° F. and a boiling point above 1350° F., said bath having gradually increasing temperature zones to heat the strip uniformly to a suitable annealing temperature, and cooling the metal by returning the same from the high to the low temperature zones of said bath to the atmosphere outside of the bath.

7. The method of heat treating relatively thin ferrous metal bodies which comprises feeding the same into a liquid bath of constant composition throughout having a melting point below 450° F. and a boiling point above 1800° F., said bath having gradually increasing temperature zones to heat the strip uniformly to a suitable annealing temperature, and cooling the metal by returning the same from the high to the low temperature zones of said bath to the atmosphere outside of the bath.

8. The method of annealing steel strip comprising passing the strip continuously through a liquid metal bath of homogeneous consistency and of increasing temperature range, and returning the strip from the high to the low temperature zone of the bath in a path parallel and proximate to the forward travel of the strip to effect heat exchange between the hot and cold strip body.

9. The method of heat-treating relatively thin ferrous metal bodies which consists of bringing said ferrous metal and a homogeneous liquid having high heat-transferring ability into contact, causing relative motion between the ferrous metal and said liquid, producing progressively increasing temperatures of the liquid along at least a portion of the path of relative motion to a maximum not less than the desired heat-treatment temperature of the ferrous metal succeeded by temperatures progressively decreasing over at least a portion of the remainder of said path of relative motion.

10. The method of heat-treating relatively thin ferrous metal bodies which consists of bringing said ferrous metal and a homogeneous liquid having high heat-transferring ability into contact, causing relative motion between the ferrous metal and said liquid, producing progressively increasing temperatures of the liquid along at least a portion of the path of relative motion to a maximum not less than the desired heat-treatment temperature of the ferrous metal succeeded by temperatures progressively decreasing over at least a portion of the remainder of said path of relative motion, and effecting the entrance of the ferrous metal into contact and its exit from contact with said liquid through a non-oxidizing substance.

11. The method of heat-treating relatively thin ferrous metal bodies which comprises feeding the same into a liquid bath of constant composition throughout, consisting of a sodium-potassium alloy having a melting point below 100 deg. F., said bath having gradually increasing temperature zones to heat the ferrous metal to a suitable heat-treating temperature, and cooling the ferrous metal by returning the same from the high to the low temperature zones of said bath to the atmosphere outside of the bath.

12. The method of annealing relatively thin metal sheet or strip material which comprises feeding the strip into a liquid bath of constant composition throughout having a relatively low melting point and a high boiling point, said bath having gradually increasing temperature zones to heat the strip uniformly to a suitable annealing temperature, passing the strip out of said bath into an inert atmosphere and allowing the strip to cool slowly through the highest part of the temperature range, then cooling the strip rapidly through the lower part of the temperature range by returning the same into the molten bath and passing it through zones of progressively decreasing temperature to remove it from said bath.

13. Apparatus for heat-treating relatively thin ferrous metal bodies comprising a substantially U-shaped treating tank for receiving a liquid bath of constant composition throughout, means for heating and cooling said bath to maintain gradually increasing and diminishing temperature zones through which the metal passes, one leg of said U-shaped tank being under pressure in excess of that required to maintain the liquid bath as a column in the other leg of the tank, and means for heating the gaseous or other atmosphere to allow the temperature to equalize throughout the metal before passing it through the diminishing temperature zones of the liquid bath.

14. Apparatus for annealing relatively thin metal sheets or strip comprising a tank of substantially U-shape for receiving a liquid treating medium of constant composition throughout forming a double column through which the strip is fed, one of said columns having an inert atmosphere at the top of the treating medium at a pressure to maintain the other column at a desired level and means for heating the liquid bath in the other of said columns and for cooling portions thereof to subject the strip to annealing and cooling temperatures in its passage through said columns, said U-shaped tank being provided with guide rolls for directing the strip from the top of one end of the U-shaped column through the double column of the bath and return the same for removal from the bath at the point of entry of the strip.

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