

May 19, 1959

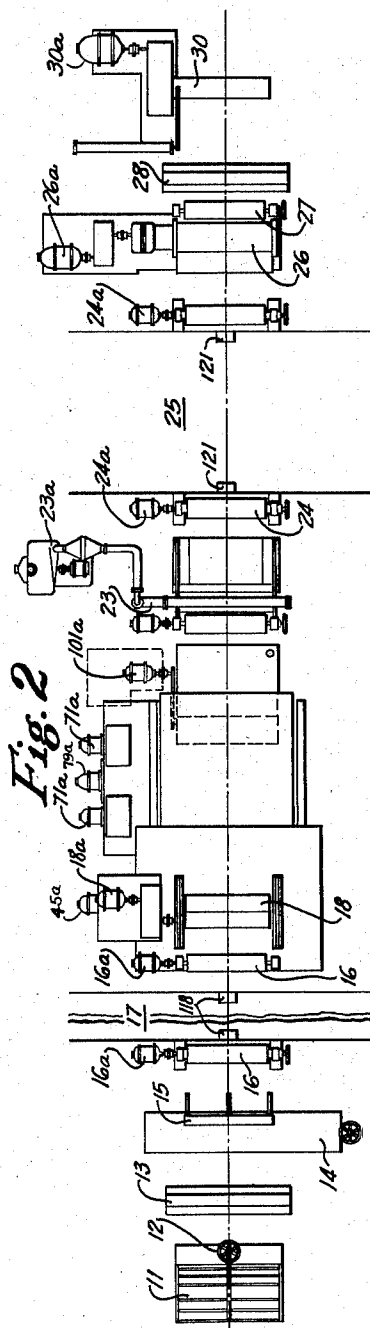
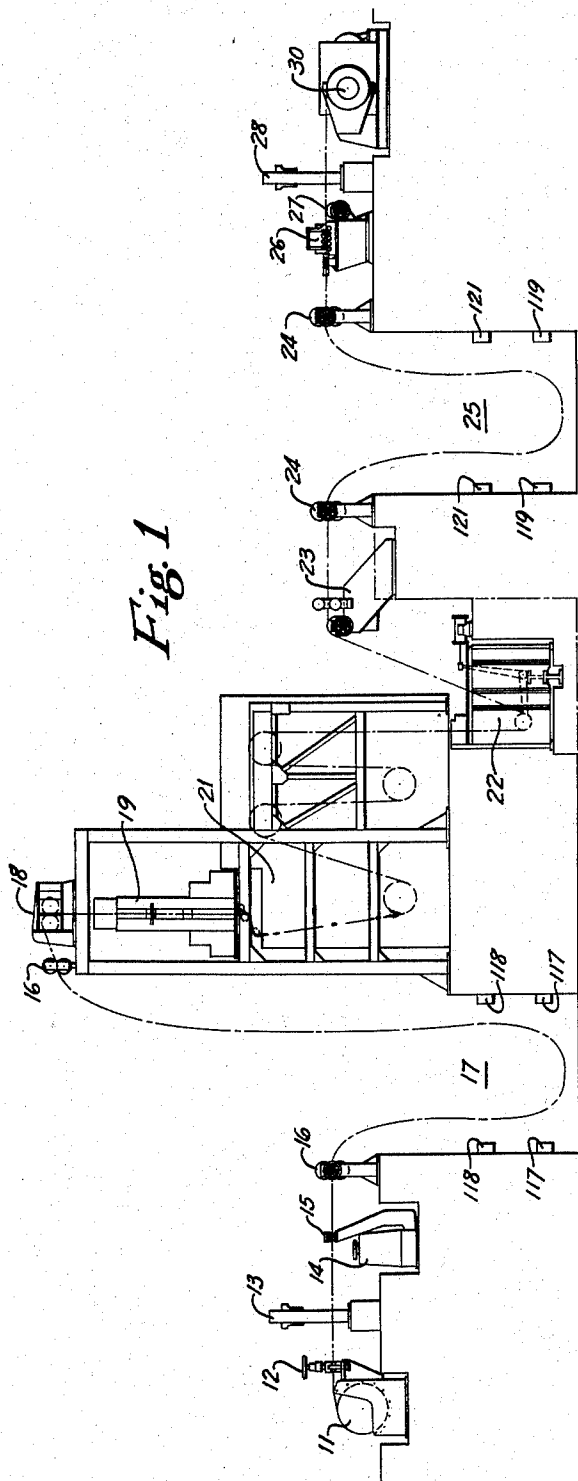
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2,887,422

METHOD OF CONTINUOUSLY HEAT TREATING ALUMINUM STRIP

Filed Feb. 25, 1950

5 Sheets-Sheet 1



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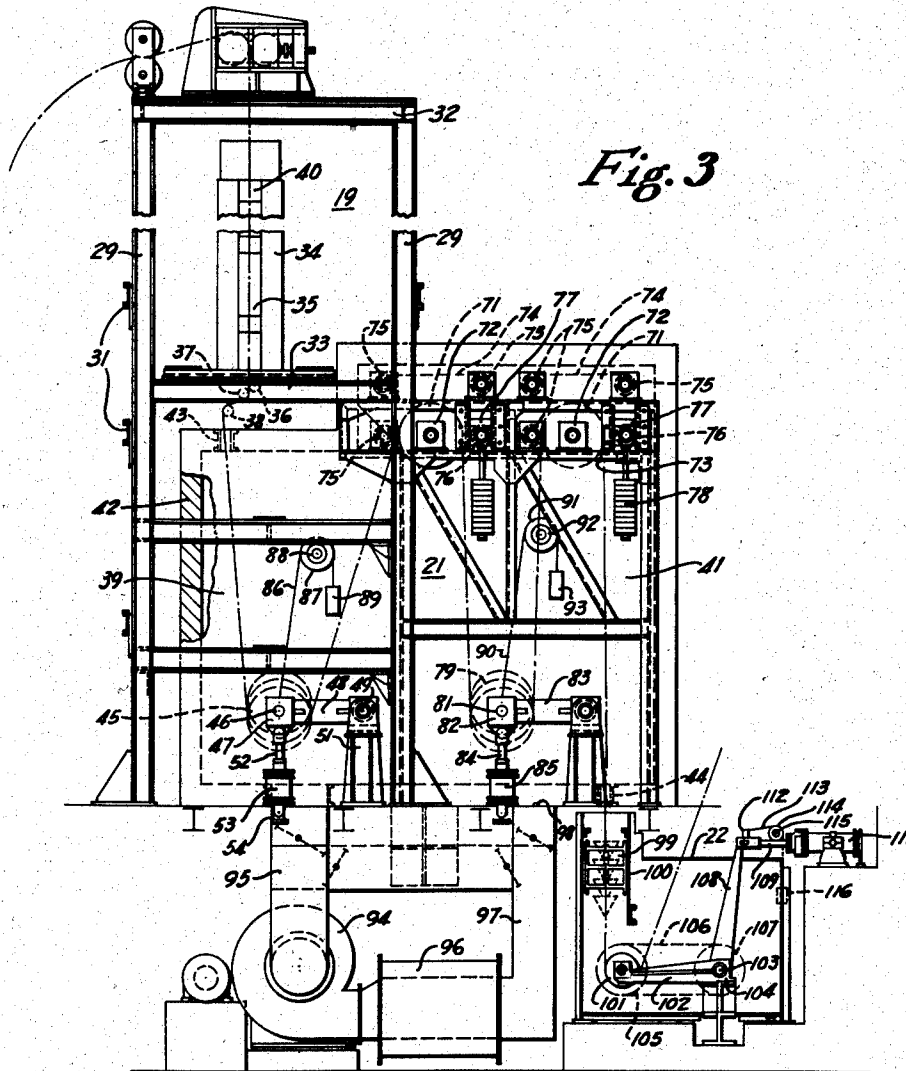
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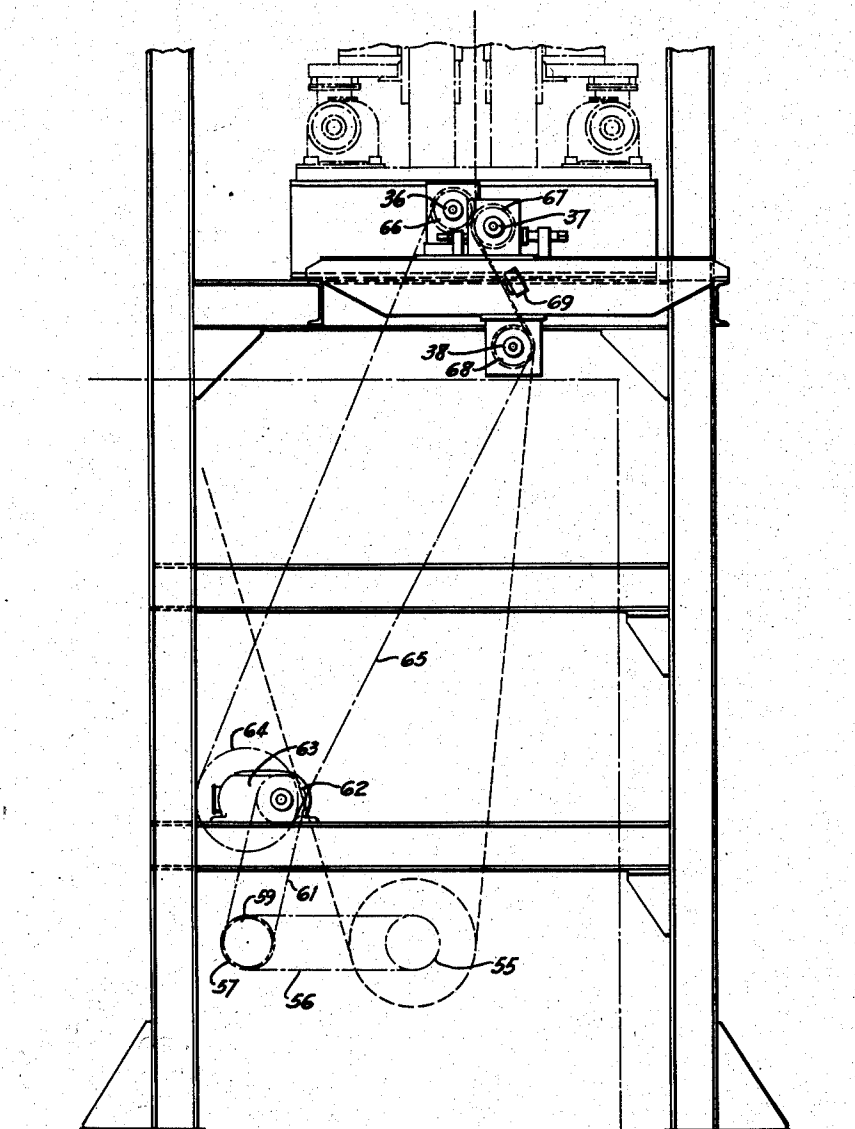


Fig. 4

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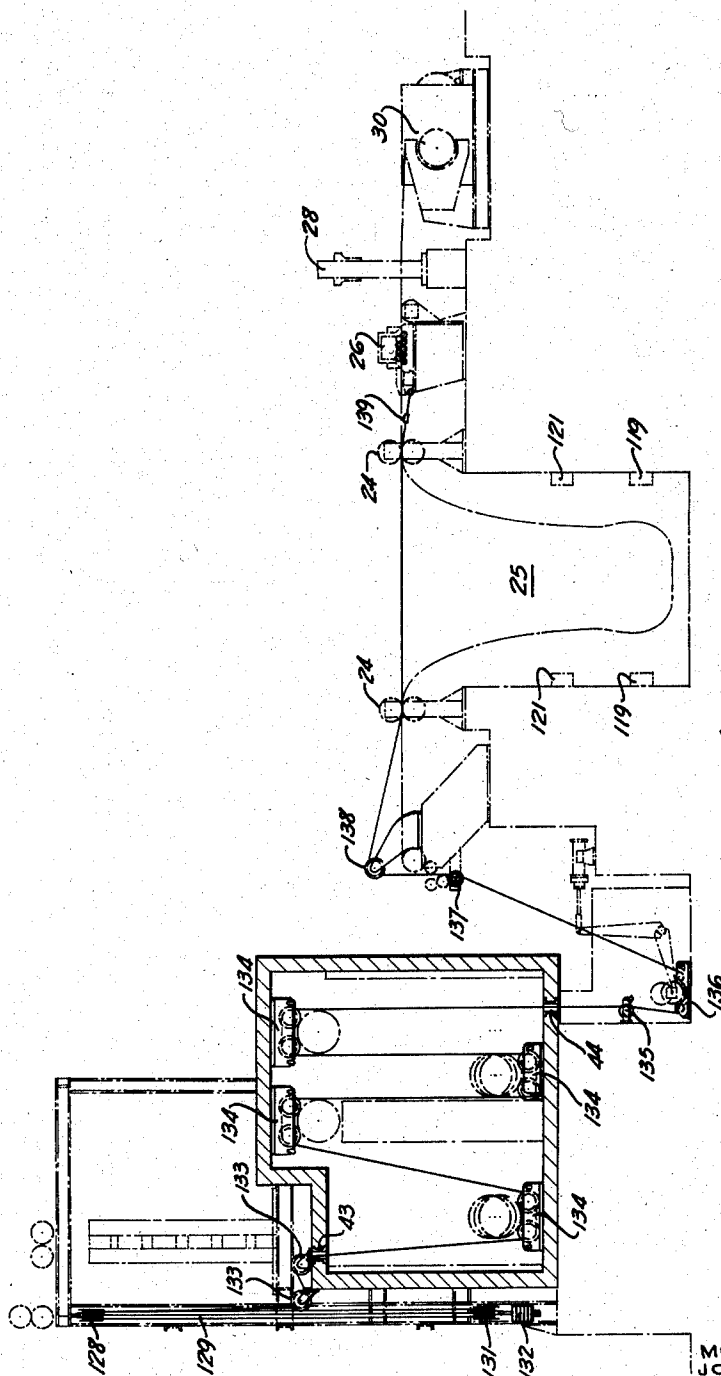
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5 Sheets-Sheet 4



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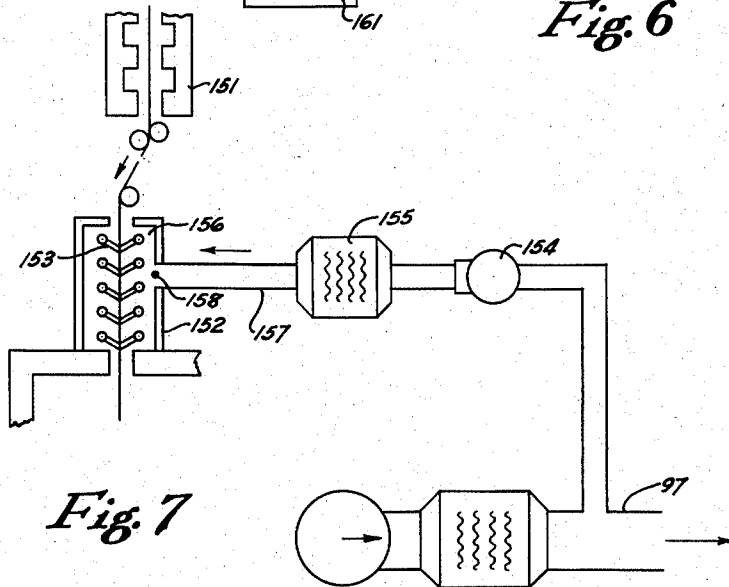
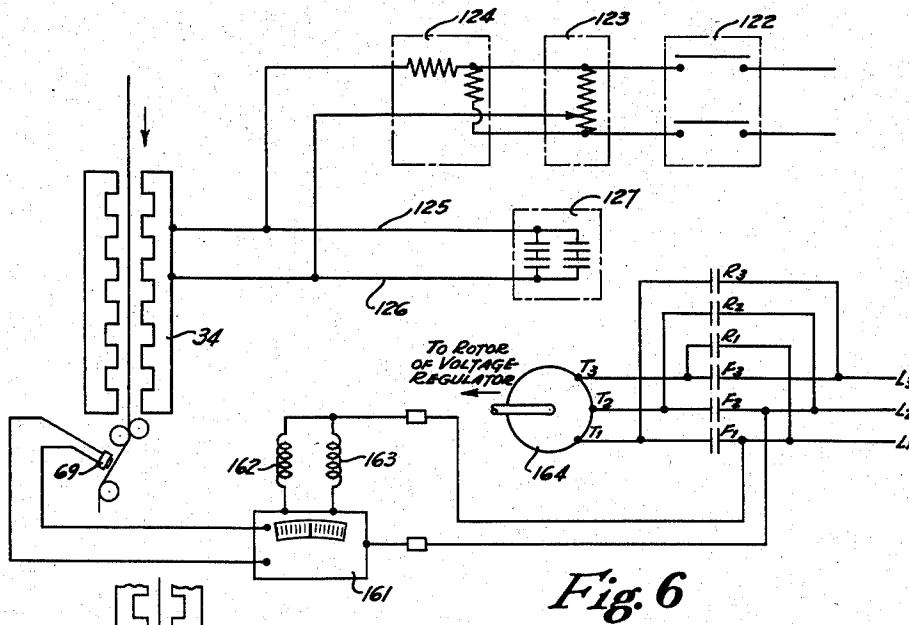
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1

2,887,422

METHOD OF CONTINUOUSLY HEAT TREATING ALUMINUM STRIP

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Application February 25, 1950, Serial No. 146,376

6 Claims. (Cl. 148—21.91)

This invention relates to a method of heat treating metallic strip and, in particular, for the heat treatment within the solution heat treating temperature range of aluminum alloy, as well as the various other continuous strip alloy materials having similar metallurgical characteristics, which is followed by rapid quenching to a temperature sufficiently below the heat treating range to initially retain the high temperature metallurgical structure and, as required for the particular alloy involved, aging at either normal or elevated temperatures. The solution heat treating temperature range of a particular alloy is the range within which complete solid solution of the alloy constituents occurs within the parent metal. For example, in the case of the duralumin alloy, known commercially as 24S, one of the principal alloying elements copper may be present in percentages varying from 3.8% to about 4.9%, and when the alloy is heated to a temperature within the solution heat treating range, all of the copper is thrown into solid solution in the aluminum.

For a particular aluminum alloy, the temperatures comprising the solution heat treating zone or range are readily obtainable from standard handbooks and published articles dealing with the physical and chemical properties of metals and their alloys. The solution heat treating zone of the above referred to commercially designated 24S aluminum alloy, as is well known in the metallurgical art, is approximately 920° F. plus or minus 10° F.

The present day practice for the solution heat treatment of light gauge aluminum alloys involves suspending groups of sheets of the material within a furnace or heated salt bath at a temperature within the solution heat treating range for from twenty to thirty minutes and then removing the heated sheets therefrom, quenching rapidly in a cold water bath, drying, straightening by roller leveling and then, if necessary, stretcher leveling and skin passing for temper as may be required. Such processing of individual sheet material, however, is quite expensive inasmuch as considerable manual labor is required, the operation is time-consuming, and the scrap loss is excessive.

By experiment, it has been determined that once aluminum alloy strip material attains the required solution heat treating temperature, it is merely necessary to retain that temperature for from a minimum time of about one half minute to a maximum of about three minutes and then to quench rapidly in order to obtain acceptable physical properties. Where the strip may be held at the solution heat treating temperature, for example, up to twenty minutes, the additional gain in ultimate strength thereof is negligible in view of the aforementioned disadvantages encountered in processing sheets individually. Inasmuch as it has been the practice of retaining the alloy for a long period of time at the solution heat treating temperature before quenching, as opposed to the short time cycle herein disclosed, previous attempts of continuous solution heat treating alloy materials were discouraged.

The apparatus herein disclosed is adapted to handle

2

aluminum alloys in strip form supplied continuously from coils introduced into the entry end of the line. An induction heating unit, through which the strip passes for initial heating, is adapted to raise rapidly the temperature of the particular alloy to the necessary solution heat treating temperature or to a temperature closely adjacent thereto at which point additional heat may be applied from a separate source in order to bring the temperature into the solution heat treating zone. Within the chambers of a temperature holding furnace, through which the strip next passes, the initial strip temperature is maintained by means of heated air supplied from a closed auxiliary air reheating, recirculating system. Sufficient looping of the strip is permitted in order that the strip will be held within the solution heat treating temperature zone for a relatively short period of time extending from a minimum of one half minute to three minutes at rated line speeds. At the delivery end of the holding furnace there is provided a quenching bath within which the strip is rapidly quenched to achieve the desired metallurgical and physical properties, especially that of resistance to corrosion.

With the foregoing in mind, it is one of the objects of this invention to provide an efficient, economical method for the solution heat treating of continuous metal strip.

Another object of this invention is to provide a method adapted to be practiced for the rapid heating of continuous strip metal to a temperature within the solution heat treating range and for maintaining the temperature within the range for a sufficient period of time prior to quenching which will result in a heat treated product having satisfactory metallurgical properties.

Still another object of this invention is to provide a heat treating method adapted to be practiced for solution heat treating metal in continuous strip form by passing the strip through a critical heat treating zone under controlled conditions of temperature, speed and tension.

A further object of this invention is to provide a method of heat treating metal in continuous strip form by which the metal is rapidly heated to the temperature desired, maintained at that temperature for a desired period of time, and then quickly quenched and recoiled.

These objects, as well as the various other novel features and advantages of this invention, will become apparent from the following description and accompanying drawings, of which,

Figure 1 is a side elevation view of a continuous metal strip heat treating line embodying the features of this invention;

Figure 2 is a plan view of the apparatus illustrated in Figure 1;

Figure 3 is a side elevation view of the holding furnace;

Figure 4 is a side elevation view taken from the drive side of the holding furnace;

Figure 5 is a side elevation view showing the heat treating line threading device;

Figure 6 is a diagram showing the circuit and the controls for the induction heating unit, and

Figure 7 is an elevation view of a modified form of the invention herein disclosed.

With reference to the drawings, particularly Figures 1 and 2, the continuous heat treating line comprises a coil box 11, a friction drag 12, a snip shear 13, a stitcher or welder 14 and a clamp 15 associated therewith, a pair of pinch rolls 16 on either side of a looping pit 17, a horizontally disposed pinch roll unit 18, induction heating unit 19, a strip temperature retaining or holding furnace 21, a quenching tank 22, a hot air drier 23, a pair of vertical pinch roll units 24 on either side of a looping pit 25, a strip leveler 26, a deflector roll 27, a snip shear 28 and a strip recoiling reel 30. The pinch roll units 16 are driven by motors 16a, the pinch roll unit 18 by a motor 18a, the pinch roll units 24 by mo-

3

tors 24a, the hot air drier 23 provided with an air heater and blower 23a, the leveler 26 driven by a motor and gear reduction unit 26a and the reel 30 operated by a motor 30a. As the controls for the various motors include separate speed adjustment means such as rheostats or the like, which are well known in the art, by which the speed of each motor can be initially adjusted to provide for a uniform feeding of the strip through the line, it is deemed to be unnecessary to set forth and illustrate specifically the details thereof.

The induction heating unit 19 as shown more specifically in Figure 3, within which the continuous strip material is elevated to the desired temperature, includes a frame made up of vertical spaced channels 29 to the sides of which are welded spaced cross channels 31 and to the top thereof channels 32. Supported by cross members 33 welded to the channels 29 at the entry end of the furnace is an induction heating unit coil assembly 34, between the poles of which a suitable channel 35 is provided through which the strip is passed for continuous heating to the temperatures desired. On either side of the magnets of the induction heating unit there are elongated edge shields 40 having slots therein through which the edges of the strip pass. Although a cooling system is provided, consisting of both a blower and a hydraulic system for forcing air and a cooling fluid through various parts of the coils, the sides and the framework thereof are open to the air to permit additional cooling of the coils by direct contact with the atmosphere.

Between the bottom of the induction heating unit 19 and the top of the strip heat retaining or holding furnace 21, there are three strip straightening rolls 36, 37 and 38, shown in Figure 4, supported in suitable bearings at the ends of the shafts thereof, adapted to have the strip pass therebetween for removing the kinks from the material and to provide a flat surface therefor as it is discharged from the induction unit and prior to the entry thereof into the holding furnace 21.

The holding furnace 21, as best shown in Figure 3, comprises two chambers or sections 39 and 41 which are in direct communication with one another and which are, on the outer surface thereof, totally enclosed by means of metal sheets and a suitable heat resistant lagging material 42. At the entry side of the holding furnace there is a narrow opening 43 through which the strip is adapted to pass without permitting an undue amount of heat to escape therefrom. A similar opening 44 is also provided at the discharge side of the furnace.

Within the furnace section 39 and near the bottom thereof, there is a looping roll 45 which is supported on a shaft 46. The ends of the shaft pass through suitable openings in the sides of the furnace and are mounted in floating bearings 47 attached to one end of a lever 48 pivotally mounted on a shaft 49 supported by pedestal bearings 51. To each of the floating bearings 47 there is secured at its outer end a piston rod 52 adapted to be extended and withdrawn by a cylinder 53 pivotally mounted on a bracket 54. On one end of the shaft 49, Figure 4, there is keyed a sprocket 55 over which passes a chain 56 driven by a sprocket 57 mounted on the shaft of a motor 45a. Also on the motor shaft is a second sprocket 59 which is engaged by a chain 61 which passes over a sprocket 62 of a PIV unit 63 whereby a sprocket 64 on the output side of the unit is rotated. The sprocket 64 is engaged by a continuous chain 65 which also engages and drives sprockets 66, 67 and 68 mounted on the shafts of rolls 36, 37 and 38 respectively.

Mounted within the top enclosed portion and between the two rolls 37 and 38 closely adjacent to the path of the strip is a strip temperature measuring device 69 adapted to respond to the temperature of the strip as it issues from the induction unit and to influence the voltage regulator whereby the voltage will be modified to the extent necessary to effect the desired amount of

4

heat to be imposed upon the strip by the induction heating unit. This is not disclosed in complete detail as the construction thereof may take various forms and suitably constructed units for this purpose are available on the market. Preferably, such a unit should be one in which no contact is made with the strip.

Within and at the top of the holding furnace chamber 41 there are two wrapper rolls 71, the shaft ends of which are extended through the walls of the furnace and supported in suitable bearings 72 secured to cross members 73 extending across the furnace wall. Each of the wrapper rolls 71 is driven by an electric motor 71a directly connected thereto. Encompassing each of the wrapper rolls 71 for a considerable portion of the circumference thereof there is a continuous belt 74 formed of a suitable heat resistant material. The belt 74 is supported by three idler rolls 75, having shaft ends supported in suitable bearings outside the walls of the furnace, and by an additional idler roll 76 supported in floating bearings 77 received in guides on the outside of the furnace wall. To the floating bearings weights 78 are suspended for urging the bearings downward in order to maintain the continuous belts in positive contact with the wrapper rolls 71.

At the bottom of the chamber 41 there is a looping roll 79 supported by a shaft 81. This roll is mounted in a similar fashion to the roll 45, which is provided with bearings 82 secured to levers 83 and to the ends of piston rods 84 extending upward from a pair of cylinders 85. Inasmuch as the tension of the strip material passing around the rolls 45 and 79 is to be quite limited, both of the rolls 45 and 79 can be urged upward by a sufficient force either to permit only a portion of the weight of the rolls and the levers to act upon the strip or to an extent sufficient to remove all tension from the strip with the exception of that induced by the weight of the strip itself.

To the bearings 47 of the roll 45 on the side of the furnace opposite the drive side there is attached one end of a chain 86 which passes over a sprocket 87 secured to the shaft of a rheostat 88 attached to the furnace wall. To the opposite end of the chain 86 is secured a weight 89. The rheostat 88 is connected into the electrical circuit of the first wrapper roll motor 71a and motor 45a and as the looper roll 45 rises or falls, the speed of the looper roll 45 and the following wrapper roll 71 will decrease or increase, by reason of the variation of the resistance within the circuit, in order to control strip length conditions within the first part of the furnace. Similarly, a chain 90 is attached to the bearing of the looper roll 79 and passed over a sprocket 91 secured to the shaft of a rheostat 92 attached to the wall of the furnace. A weight 93 is suspended from the opposite end of the chain. The rheostat 92 is connected into the electrical circuit of the second motor 71a and motor 79a so that as the roll 79 rises or falls, the speed of the looper roll 79 and the second wrapper roll 71 will decrease or increase, by reason of the variation of the resistance within the circuit, to provide the desired strip length control within the latter part of the furnace.

A hot air blowing system is provided for re-circulating and re-heating the atmosphere of the holding furnace and includes a motor driven blower 94 which draws the atmosphere from the furnace chamber 39 through a duct 95 and forces it through an electric resistance heating unit 96 and duct 97 into the furnace chamber 41. A thermostat 98 is positioned at the discharge end of the duct 97 and is connected into the circuit of the resistance heating unit 96 so that the current passing through the unit 96 can be accurately controlled for effecting the desired air temperature.

Below and at the discharge end of the furnace there is a quenching tank 22. This tank includes a cold water spray 99, enclosed within a chamber 100, through which the strip first passes on issuing from the furnace. A de-

5

flexing roller 101 around the lower portion of which the strip passes, is rotatably mounted between the two lower arms of a forked bell crank 102 which is pivotally mounted on a shaft 103 supported in bearings 104 at the bottom of the tank. The roller 101 is provided with a sprocket 105 over which passes in driving relationship a chain 106 from a sprocket 107 attached to the shaft of a driving motor 101a. Upwardly extending from the shaft 103 is an arm 108 pivotally secured at its upper end to a piston rod 109 extending from and actuated by a hydraulic cylinder 111 for counterbalancing the weight of the roller 101 and its assembly so that a controlled strip tension is maintained.

To a pin 112 extending out from the arm 108 is attached one end of a chain 113 which passes over a sprocket 114 secured to the shaft of a rheostat 115. A weight 116 is suspended from the opposite end of the chain. The rheostat 115 is connected into the electrical circuit of the pinch roll unit driving motor 24a at the entry side of the looping pit 25 and that of the driving motor of roller 101, so that as the arm is moved toward or away from the furnace due to a change in length of the strip, the speed of the motors 101a and 24a are caused to increase or decrease, changing the speeds of the roller 101 and the pinch rolls 24 respectively, thereby maintaining the desired condition of balance. This insures that the strip will pass below the level of the water in the tank, for additional cooling, without imposing unnecessary tensioning forces on the strip at the discharge side of the furnace.

At the bottom of each looping pit there are two sets of photocell controls. In the first pit 17, a lower set 117 is connected into the circuit of the pinch roll motor 16a at the entry side of the pit so that when the strip droops so low as to interrupt the beam of light, the first pinch roll motor 16a is slowed down slightly in order to permit the loop to rise. The second set of photocell controls 118 is above the first set and connected into the same electrical circuit as the first. Should the loop in the pit rise so high as to permit the beam of light to pass uninterruptedly to the top photocell, then the motor at the pit entry end is speeded up to cause the loop again to grow in the pit. The photocell controls 119 and 121 in the second pit 25, function in a similar fashion and are connected in the circuit of the pinch roll motor 24a, at the discharge end of the pit 25, for controlling the speed thereof.

With reference to Figure 6, the control system for providing the necessary electrical current for the induction heating unit includes a circuit breaker 122, connected to the power line, as shown, and to an auto transformer 123 which, in turn, is connected to an induction voltage regulator 124 connected through two busses 125 and 126 to the coils of the induction heater coil assembly 34 and to a bank of capacitors 127. The strip temperature measuring device 69, located beneath the induction coil assembly 34, is connected to a temperature indicating unit 161 having leads extending therefrom through which current can be passed for energizing either a forward relay coil 162 or a reverse relay coil 163 depending upon whether the temperature of the strip is above or below a predetermined amount. When, for example, the temperature of the strip tends to become too low, the forward relay coil 162 is energized closing a series of contacts F₁, F₂ and F₃ so that a motor 164 will rotate in the forward direction, which slowly rotates the rotor of the voltage regulator whereby the energy supplied to the induction heating unit is increased. When the strip temperature is above a predetermined amount, the reverse relay coil is energized to close the contacts R₁, R₂ and R₃ causing the motor 164 and the voltage regulator rotor to rotate in the opposite direction to decrease the energy supplied to the induction heating unit. By proper adjustment of the capacitor controls, it is possible at all times to maintain substantially a power factor of unity in the electrical system.

6

For threading the leading end of the strip material through the most inaccessible portions of the line there is shown in Figure 5 a unit having two cables which are adapted to engage the strip end at the entry end of the holding furnace and to carry the strip through the furnace and the remainder of the line to the recoiling reel. Secured to the top of the furnace frame at opposite sides thereof are two tackle blocks 128 around the sheaves of which pass separate cables 129 which in turn are passed over the sheaves of vertically movable tackle blocks 131 having weights 132 secured thereto. The free end of each cable is passed over two sheaves 133 supported by brackets secured to the outside of the furnace, through the opening 43, around several pairs of sheaves 134 within the temperature holding furnace, through the opening 44 at the discharge end of the furnace, and over single sheaves 135, a pair of sheaves 136, and over additional single sheaves 137 and 138 and through the two pinch roll units 24, and finally to the reel 30 where the ends thereof are attached for winding a portion of the cables thereon. The position of the tackle blocks shown in Figure 5 is that of maximum cable storage and is that from which threading of the line takes place. A suitable strip gripper bar 139 is adapted to be secured to the leading end of the strip, at the exit end of the induction heating unit and to the threading cables 129 so that the reel can be rotated for slowly winding the cables thereon to cause the strip to be drawn through the holding furnace to the strip leveling unit 26. As soon as the threading has been completed, the rolls of the pinch roll unit 24 on the exit side of the looper pit 25 are closed, the gripper bar is detached from the strip and the cables, and the strip fed through the leveler and shear and up to the reel 30. The cables are unwound from the reel 30 and by virtue of the weights 132, the tackle blocks 131 move downward so that the excess cable will be gathered for storage between the stationary and the movable blocks. The two cable ends are then detached from the reel and secured preferably to the frame of the roller leveler where they will be easily accessible for future threading operations.

In the operation of the heat treating line, a coil of strip material to be processed is placed in the coil box 11 from which a portion of metal is unwrapped and passed by hand through the wiper 12, the shear 13 where the leading end thereof is cropped, through the stitcher or welder 14 and clamp 15, through pinch rolls 16 and looping pit 17, and through the horizontal pinch rolls 18, the induction heating unit 19 and between the three straightening rolls 36, 37 and 38. At this point, the gripper bar 39 is secured to the leading end of the strip and the ends of the bar attached to the two cables 129. Since in the threading operation the ends of the cables are attached to the reel 30, by rotating the reel, the cables are wrapped thereon and the strip threaded through the holding furnace 21, the quench tank 22, the drier 23, and the two pinch roll units 24 at which point rotation of the reel is interrupted. The gripper bar 39 is thereupon detached from the cables and the strip fed through the leveler and shear and up to the reel. The excess cable is unwound from the reel and gathered between the tackle blocks 128. The ends of the cables are released from the reel and secured preferably to the frame of the leveler 26.

The leading end of the strip is then detached from the gripper bar 39 and passed through the leveler and shear and attached to the reel 30. With the furnace at the required heat, the various motors are energized and the speed thereof adjusted to provide the necessary solution heat treating conditions. On completion of the uncoiling of the first strip, the trailing end thereof is sheared and movement thereof interrupted in the stitcher or welder 14 for attachment to the squared leading end of a new coil inserted in the coil box 11. The looping pit at the entry end of the line provides for a continuous supply of strip during the strip joining operations and

the pit 25 permits the strip, as it issues from the furnace, to be stored therein during the interval that the stitched ends are cut out of the strip at the shear 28 and the coil removed from the reel.

In accordance with Figure 7, illustrating a modification of the invention herein disclosed, an auxiliary heating means is provided for applying additional heat to the strip and raising the temperature thereof to the required holding temperature. If continuous strip metal having cracks at the edges thereof is heated by induction means, a higher temperature will be induced in the zones of the cracked edges due to the concentration of current caused by the crowded divergent path it is required to take. Should the main body of strip having only slightly cracked edges be heated initially to the required temperature, then due to overheating an undesirable considerably higher temperature will occur at the edges. In order to avoid subjecting the strip edges to overheating, the modified apparatus includes an induction heating unit 151, wherein duralumin strip, for example, is heated to a temperature of approximately 880° to 900° Fahrenheit which is slightly below the solution heat treating temperature, and an auxiliary heating unit 152 provided with nozzles 153 which are directed downward at an angle with respect to the strip and through which heated air is passed at a high velocity for uniformly bringing the strip temperature into the solution heat treating zone. Inasmuch as the auxiliary unit 152 is adapted to be inserted into the line shown in Figure 3, heated air can be tapped from the duct 97 and passed through a blower 154, a high temperature electrical resistance heater 155 and into the nozzle manifold 156 through a duct 157. A thermostat 158 is located at the discharge end of the duct 157 and is connected into the circuit of the heater 155 whereby the amount of current supplied thereto is automatically controlled. Thus, the temperature of the strip can be evenly raised to the required temperature without danger of overheating the edges thereof.

In accordance with the provisions of the patent statutes, we have explained the principle and operation of our invention and have illustrated and described what we consider to represent the best embodiment thereof. However, we desire to have it understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

We claim:

1. In the method of continuously heat treating aluminum alloy of the precipitation hardenable class and in the form of endless strip the steps comprising rapidly heating said strip in a first heating zone to a temperature within the solution heat treating range, maintaining the temperature of said strip within said range in a second heating zone for a limited period of time greater than that required for initially heating the strip and of the order of one-half to three minutes and quenching said strip from a temperature within to a temperature substantially below said solution heat treating range.

2. In the method of continuously heat treating aluminum alloy of the precipitation hardenable class and in the form of endless strip the steps comprising rapidly heating said strip in a first heating zone to a temperature slightly below the solution heat treating range, applying additional heat to said strip in a second heating zone to raise the temperature thereof to one within the solution heat treating range, maintaining the temperature of said strip within said range in a third heating zone for a limited period of time greater than that required for heating the strip in said first two heating zones and of the order of one-half to three minutes and quenching said strip from a temperature within to a temperature substantially below said solution heat treating range.

3. In the method of continuously processing aluminum alloy of the precipitation hardenable class and in the form

of endless strip the steps comprising rapidly heating said strip in a first heating zone to a temperature within the solution heat treating range, maintaining the temperature of said strip within said range in a second heating zone for a limited period of time greater than that required for initially heating the strip and of the order of one-half to three minutes, quenching said strip from a temperature within to a temperature substantially below said solution heat treating range and straightening said strip subsequent to the quenching thereof.

4. In the method of continuously heat treating aluminum alloy of the precipitation hardenable class and in the form of endless strip the steps comprising rapidly heating the strip in a matter of seconds to a temperature within the solution heat treating range, thereafter maintaining the strip without interruption of the movement thereof for a period of time not less than one-half minute at a temperature within the solution heat treating range and thereafter immediately and rapidly quenching the strip.

5. In the method of continuously heat treating aluminum alloy of the precipitation hardenable class and in the form of endless strip the steps comprising rapidly and in a matter of seconds heating the strip in a first zone to a temperature slightly below the solution heat treating range, applying sufficient additional heat to said strip without interruption of the movement thereof in a second heating zone to raise the temperature of said strip to one within the solution heat treating range, thereafter in a third heating zone maintaining the temperature of the strip within the solution heat treating range for a period of time of not less than one-half minute and upon leaving said last-mentioned zone immediately and rapidly quenching the strip.

6. The method of heat treating aluminum alloy strip or the like of the precipitation hardenable class in a heat treating line in which there is provided in sequence a first strip heating means, strip flattening means, a second strip heating means, and a quenching means and means for controlling the tension in the strip during its passage through said line which consists in rapidly heating the strip in a matter of seconds in said first heating means to a temperature approximately at but slightly less than one within the solution heat treating range, continuously flattening the strip in said flattening means, additionally heating said strip in said second heating means sufficiently to establish and maintain the temperature of the strip while passing therethrough at one within the solution heat treating range for a period of time of not less than one-half minute and thereafter immediately and rapidly quenching the strip.

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