Aug. 1, 1961 D. LEWIS 2,994,328

ROD PATENTING

Filed July 20, 1956 4 Sheets-Sheet 1

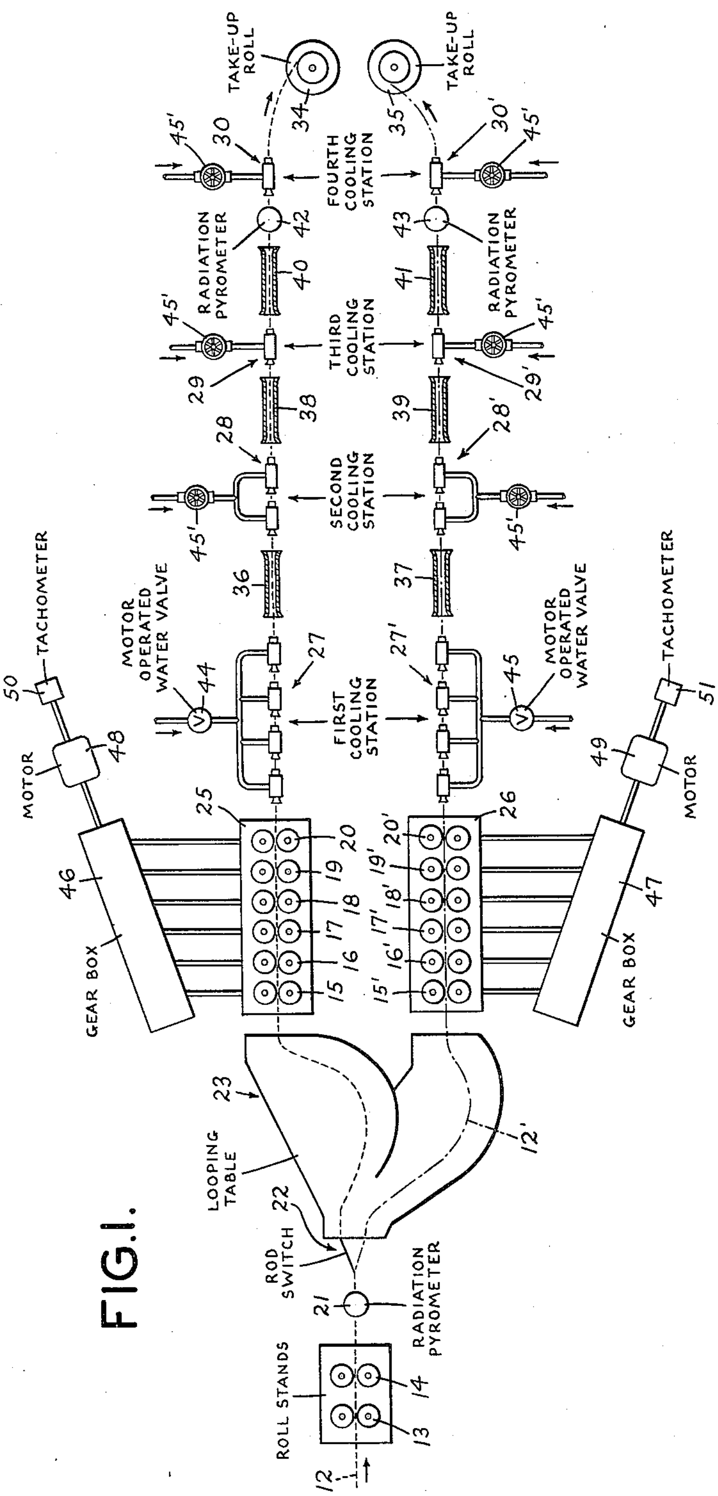

FIG. 1.

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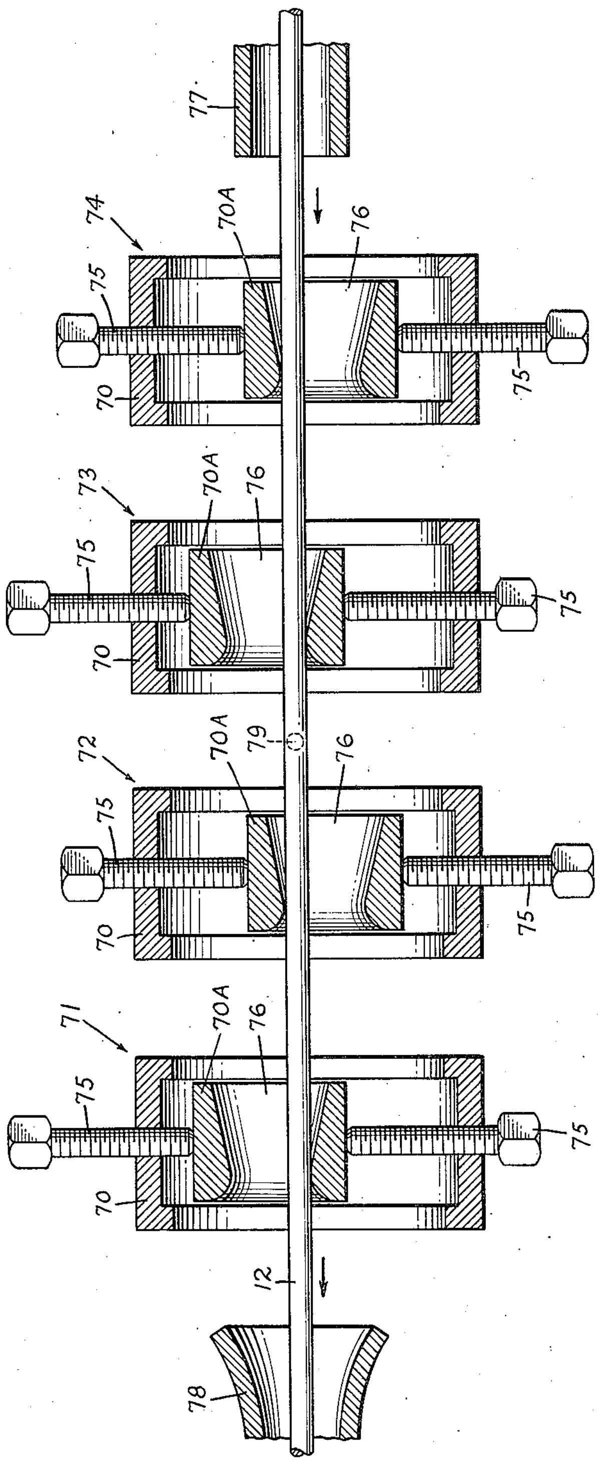

FIG.2.

FIG. 3.

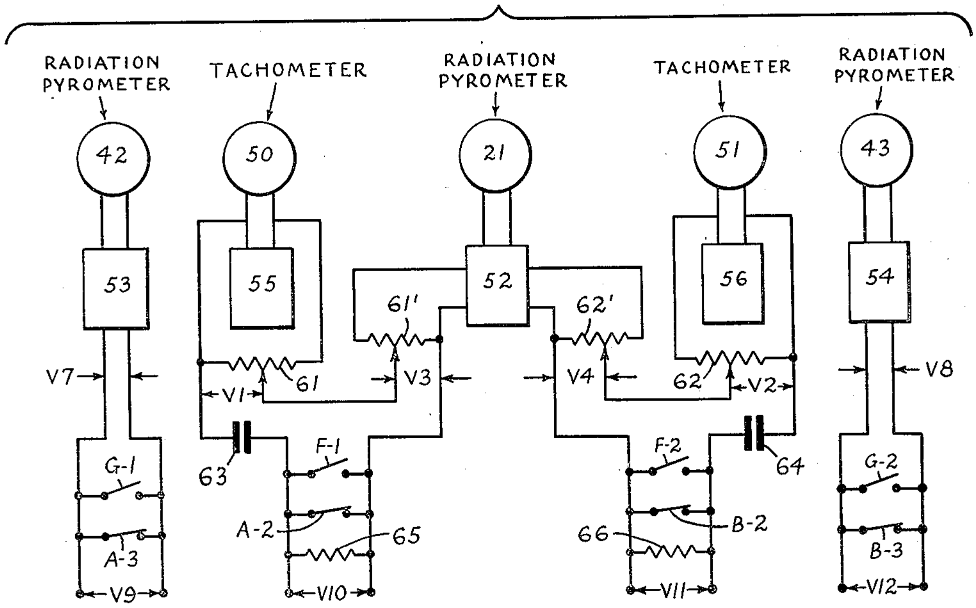
RADIATION PYROMETER
TACHOMETER
RADIATION PYROMETER
TACHOMETER
RADIATION PYROMETER
42
50
21
51
43
53
55
52
56
54
61'
62'
V7
V1
61
V3
V4
62
V2
V8
63
F-1
F-2
64
G-1
A-3
A-2
65
66
B-2
G-2
B-3
V9
V10
V11
V12

FIG. 5.

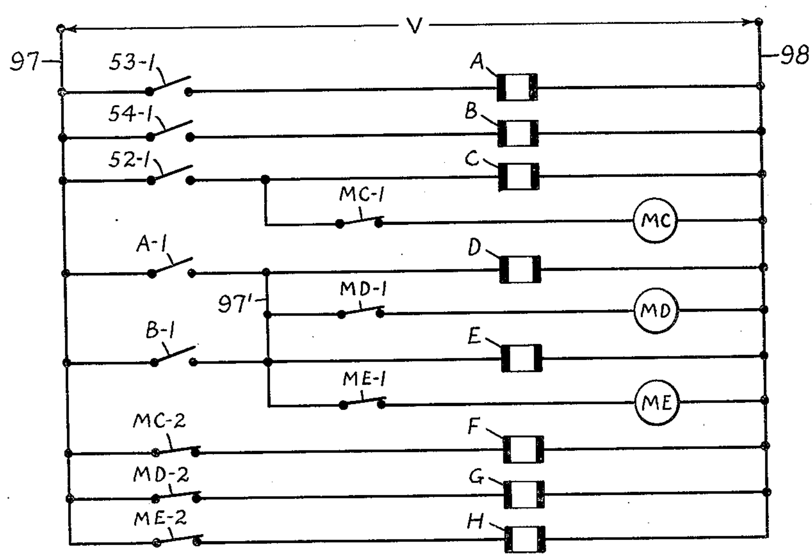
V
97
98
53-1
54-1
52-1
A
B
C
MC-1
MC
A-1
D
97'
MD-1
MD
B-1
E
ME-1
ME
MC-2
MD-2
ME-2
F
G
H

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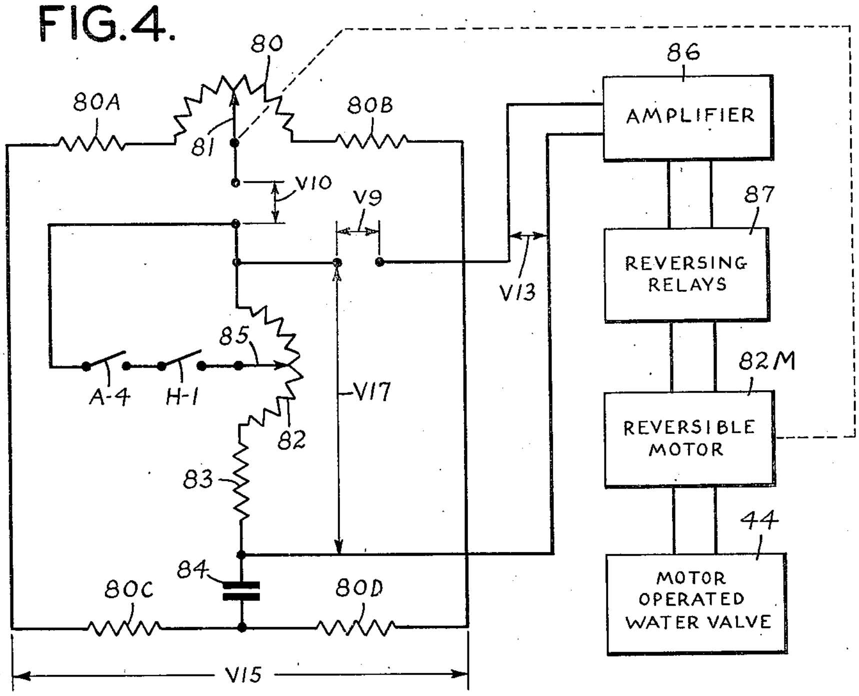
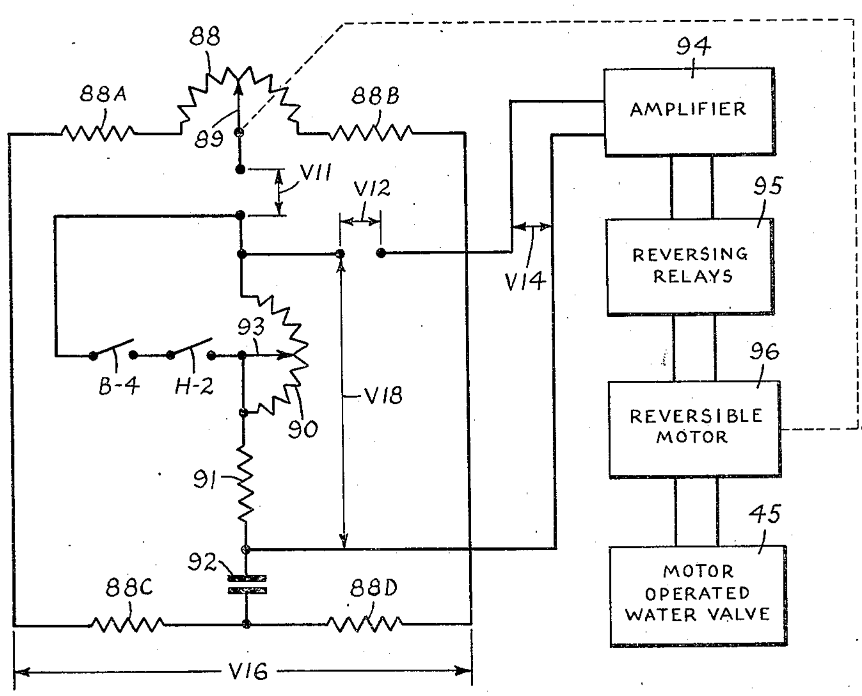
FIG. 4.





United States Patent Office

2,994,328

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2,994,328

ROD PATENTING

Dartrey Lewis, Trenton, N.J., assignor, by mesne assignments, to Morgan Construction Company, Worcester, Mass., a corporation of Massachusetts

Filed July 20, 1956, Ser. No. 599,187

22 Claims. (Cl. 134—57)

The present invention relates to the hot rolling and heat treating of carbon steel rods to facilitate their being drawn into wire.

In the production of steel wire it is customary to reduce the steel ingots by hot rolling first to billets and then to rods of the desired size, such as 5/16" or 3/8" in diameter. The rolled rods are then heat treated as a separate operation generally known as "patenting." This is a heat treatment which produces a metallurgical structure in the rod that makes it especially suitable for wire drawing. Such patenting has frequently involved passing the rod very slowly through a furnace in which it is reheated to a temperature of about 1550 to 1850° F. The rod as it emerges from the furnace is allowed either to cool naturally in the air, which is known as "air patenting," or to be quenched in a bath of molten lead, usually within the temperature range 900 to 1300° F. Most of the steel rods subjected to this treatment are of a plain carbon steel composition in which the carbon content ranges usually from about 0.20 to 0.95%. Rods of such composition as hot rolled contain a very coarse sructure of pearlite, which is of irregular formation and makes the rods unsuitable for cold wire drawing except to a very limited extent. The patenting operation improves this structure by first getting the carbon back into solid solution in the iron and then allowing the carbon to come back out of solution in the form of very fine plates of iron carbide (cementite) closely spaced. In fact, the pearlitic structure thus obtained is frequently so fine that it cannot readily be resolved under the microscope even at 1000 magnifications. Such a structure has much higher strength and is suitable for cold drawing through six or more successive dies until the total reduction of area is 90% or more of the original cross-sectional area.

In the co-pending United States patent application of John H. Corson et al., Serial No. 190,954, filed October 19, 1950, now Patent No. 2,756,169, there is set forth a method of heat treating hot rolled steel rods in which the hot rolling and patenting processes are combined to avoid the necessity for reheating the rods and the necessity for all the separate handling operations necessarily involved in the foregoing procedure. The present invention is concerned with a process of the type set forth in said Corson et al. application. Finishing temperatures in a hot rolling mill are frequently of the order of 1800° F., and in order to develop a metallurgical structure in this rod similar to that produced by customary patenting operations it is necessary to cool the rod rapidly and uniformly from the finishing temperature to a temperature within the range of about 900 to 1300° F. and then hold the rod within that range for a period of 10 seconds or more while the carbon comes out of solution. If the rod is not cooled sufficiently, the pearlitic structure will be too coarse, especially in the center of the rod. If the rod is cooled too much, the center of the rod may be of the proper fine pearlitic structure but the surface will be acicular or Bainitic in structure. In fact, if the cooling is too great, definite hardening may be produced with the formation of sorbite, martensite, or similar structures, which greatly impair the ability of the rods to be drawn.

In order to maximize the benefits to be secured from a patenting operation of the type indicated, it is desirable

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that the cooling of the rod be carefully controlled with regard to the temperature of the rod from point to point, and also with regard to differences in temperature between one rod and the next. For example, it frequently occurs that the final portion of a rod has a higher temperature than those portions preceding the final portion. Usually the billets which are to be rolled into rod are heated in a furnace having a sloping hearth down which the rods are pushed in a direction at right angles to their length. The furnace is heated by multiple burners located in the wall of the furnace towards which the billets are moving. The temperature of the billets will vary along their length depending upon burner adjustment. It is common practice to heat the ends of the billets which will be rolled last to a higher temperature as this helps in controlling overfills in the last end of the rod.

It is thus a principal object of the invention to provide, in a patenting operation, means for maintaining substantially constant the rod tempertaure at a particular early point in the patenting operation, despite the variations in temperature from point to point in the rod passing such early point of the patenting operation.

Another object of the invention has been to provide means for controlling the cooling water or other liquid pressure in the cooling system in accordance with variations in temperature from rod to rod and in accordance with variations in temperature along the length of any particlular rod.

Another object of the invention has been to provide means for delaying control action on the water pressure control until the temperature indicating means exposed to a new rod has arrived at an indication corresponding to the temperature of the rod.

Still another object of the invention has been the provision of means for presetting the cooling water pressure prior to passage of a rod through the cooling system.

A further object of the invention has been to provide means for varying the cooling water pressure in a patenting operation in response to changes in rod speed.

A feature of the invention has been the provision of rod guide means arranged to guide the moving rod within the field of vision of an optical pyrometer and adapted to permit fins and other variations in rod diameter to pass without causing the rod to cobble.

Other and further objects, features and advantages of the invention will appear more fully from the following description.

In accordance with the invention, in a patenting operation in which a rod to be cooled is passed through successive spaced liquid cooling stations, a uniform desired temperature is maintained throughout the length of a hot rolled rod by providing means for varying the cooling liquid pressure at a first cooling station in response to fluctuations of temperature along the rod as measured before the rod reaches the first cooling station, and in response to deviations from the desired temperature as measured after the rod passes the first cooling station.

The invention will now be described in greater detail with reference to the appended drawings, in which:

FIG. 1 is a schematic diagram of apparatus in accordance with the invention for heat treating steel rods as they come from a conventional mill for the continuous hot rolling of such rods;

FIG. 2 is a sectional plan view of a rod guide in accordance with the invention;

FIG. 3 is a circuit diagram illustrating a portion of the control circuit in accordance with the invention;

FIG. 4 is a circuit diagram illustrating another portion of the control circuit in accordance with the invention; and

FIG. 5 is a circuit diagram illustrating another portion of the control circuit in accordance with the invention.

Referring now to the drawings, and more particularly to FIG. 1, steel billets may be heated to hot rolling temperature in a furnace (not shown) and rolled through a suitable hot rolling mill, which might be, for example, a conventional tandem-type hot rolling mill consisting of 20 roll stands. Roll stands 13–20 of such a mill are shown diagrammatically in FIG. 1. The rod being rolled is designated by the reference numeral **12**. After passing roll stand **14**, the rod **12** is guided past a radiation pyrometer or other suitable temperature indicating device **21** and through a switch mechanism **22** onto a looping table **23**. From the looping table **23** the rod **12** passes through finishing stand **25**, which consists of roll stands **15–20**. The switch **22** may be moved to direct the rod across a looping table **24** and through another finishing stand **26**. The stand **26** consists of roll stands **15′–20′**. The path of the rod in this case is shown by the dashed line designated **12′**. In general, the finishing stands **25** and **26** will be used alternately for rods being rolled from successive billets.

After leaving the finishing stand **25**, the rod **12** is guided through a first cooling station **27**, then through a second cooling station **28**, then through a third cooling station **29**, and then through a fourth cooling station **30**. When the finishing stand **26** is used instead of the stand **25**, the rod therefrom passes through a first cooling station **27′**, then through a second cooling station **28′**, then through a third cooling station **29′**, and then through a fourth cooling station **30′**. The cooling stations **27** and **27′** may conveniently be provided with four cooling or quenching units each, the stations **28** and **28′** with two each, and the stations **29, 29′, 30** and **30′** with one each. The cooling medium may be water or other suitable quenching liquid. Rod from the fourth cooling station **30** is coiled on a takeup reel **34**, while rod from the fourth cooling station **30′** is coiled on a takeup reel **35**. The cooling stations **27** and **28** are separated by a length of guide pipe **36**, the cooling stations **27′** and **28′** are separated by a length of guide pipe **37**, the cooling stations **28** and **29** are separated by a length of guide pipe **38**, the cooling stations **28′** and **29′** are separated by a length of guide pipe **39**, the cooling stations **29** and **30** are separated by a length of guide pipe **40**, and the cooling stations **29′** and **30′** are separated by a length of guide pipe **41**. The guide pipes **36–41** provide time for the temperature at the center of the rod and at the outside of the rod to equalize after each water cooling. This equalization is necessary because each water cooling stand cools the surface of the rod more than it does the center. Although omitted from the drawings for simplicity, a suitable water separating or draining unit should be provided between each water cooling station and its succeeding guide pipe. The cooling stations and the water separating units may, if desired, be constructed in accordance with the teachings of the aforementioned Corson et al. application. Between the end of the equalizing section or guide pipe **40** and the fourth cooling station **30**, the rod **12** passes a radiation pyrometer or other suitable temperature indicating device **42**. Similarly, between the end of the equalizing section or guide pipe **41** and the cooling station **30′**, the rod **12′** passes a radiation pyrometer or other suitable temperature indicating device **43**. The radiation pyrometers **42** and **43** should be spaced from the preceding respective cooling stations by a distance sufficient to allow the interior and surface of the rod to equalize substantially in temperature, a time of travel preferably not less than 0.3 second.

Water flow to the first cooling station **27** is controlled by a motor operated water valve **44**. Water flow to the first cooling station **27′** is controlled by a motor operated water valve **45**. Water flow to the second, third and fourth cooling stations may be controlled by manually adjustable valves designated **45′**.

The finishing stands **25** and **26** may be driven by gear boxes **46** and **47**, respectively. The gear boxes **46** and **47** are in turn operated by the motors **48** and **49**, respectively. The motor **48** is furnished with an electric tachometer **50**, while the motor **49** is provided with an electric tachometer **51**.

The rod passing radiation pyrometers **21, 42** and **43** should not be permitted to move out of the field of focus of the pyrometer. For example, a pyrometer having a field of focus ⅛″ in diameter may be used with a rod 3⁄16″ in diameter, which will require the rod to be guided within ±1⁄32″. In order to achieve this close tolerance in rod path a guide may advantageously be used. Hot rolled rod may have overfills, fins or other dimensional defects, and the guide must allow such defects to pass through without causing a cobble. In accordance with one aspect of the invention, the rod path past the radiation pyrometers may be controlled within a close tolerance by means of the offset guide arrangement illustrated in FIG. 2. It will be understood that a rod guide of the type illustrated in FIG. 2, while not shown in FIG. 1, may be used for each of the radiation pyrometers **21, 42** and **43**.

Referring now to FIG. 2, the rod guide illustrated comprises four offset guide elements **71, 72, 73** and **74**. As few as two guide elements can be used if desired. Each guide element comprises a short, hollow, rectangular block **70** within which is carried a rectangular guide block **70A** having an internal diameter decreasing (wall thickness increasing) toward the left in FIG. 2, which is the direction of travel of the rod through the rod guide. The guide blocks are held in desired offset positions within the blocks **70** by means of screws **75** acting against their peripheral surfaces. The guide blocks are fixed vertically but may be moved horizontally by adjustment of screws **75**. The screws **75** are threaded through suitable holes provided in the walls of the blocks **70**. Preferably, three or four screws **75** will be used for each guide element. The center of each guide block **70A** constitutes a hole **76** through which the rod **12** may pass. The guide blocks are offset from the center line of the guide elements by suitable adjustment of the screws **75**. Thus in FIG. 2 the upper portion of the element **74** is in contact with the rod **12**. For the element **73**, the lower portion of the block **70A** contacts the rod **12**. For the element **72**, the upper portion of the block **70A** contacts the rod **12**. For the element **71**, the lower portion of the block **70A** contacts the rod **12**. The minimum diameter of holes **76** is considerably larger than the rod **12** (preferably at least three times the rod diameter) and is large enough to pass any variations in rod dimensions. The guide elements **71–74** are spaced from each other sufficiently to permit dimensional defects to snake through. This spacing is preferably at least five rod diameters. The rod **12** may enter the rod guide through a pipe **77** and may leave the rod guide through a pipe **78**. The field of view of the optical pyrometer associated with the rod guide is designated **79**. It will be observed that the guide blocks of the various guide elements are offset so as to maintain the rod **12** within the field of focus of the optical pyrometer. Although not shown in FIG. 1, a rod guide of the type shown in FIG. 2 may be provided for each of the radiation pyrometers.

Referring now to FIG. 3, there are shown radiation pyrometers **21, 42** and **43** and tachometers **50** and **51** of FIG. 1. Each radiation pyrometer produces a D.C. voltage which increases with rod temperature. The radiation pyrometers **21, 42** and **43** are connected to recording controllers **52, 53** and **54**, respectively. These recording controllers each produce a D.C. output voltage proportional to the deviation of the indicated temperature from the control temperature. For this purpose each controller is provided with a temperature or speed indicating pointer and with a manually operated control pointer which may be set at the desired control temperature. The magnitude of the controller output voltages is manually adjustable by means of potentiometers 61′ and 62′. These output voltages also change in polarity according to whether the indicated temperature is above or below the control temperature. The recording controllers 52–54 may be electronically operating machines of the type described in Callender et al. Patent 2,175,985, issued October 10, 1939, and in Davis Patent 2,666,170, issued January 12, 1954.

As shown in FIG. 3, tachometer 50 is connected to a recorder 55 and to a potentiometer 61, the output voltage of which is designated V1. Tachometer 51 is similarly connected to a recorder 56 and to a potentiometer 62, whose output voltage is designated V2. Radiation pyrometer 21 is connected to recording controller 52, which produces two output voltages designated V3 and V4. Radiation pyrometer 42 is connected to recording controller 53, which produces an output voltage V7. Radiation pyrometer 43 is connected to recording controller 54, which produces an output voltage V8. The voltage V1, which is a portion of the output voltage of tachometer 50, as determined by the setting of potentiometer 61, is a D.C. voltage which increases with the speed of motor 48. Similarly, the voltage V2 is a portion of the output voltage of tachometer 51, as determined by the setting of potentiometer 62, and increases with the speed of motor 49. The voltages V3 and V4 are D.C. voltages whose magnitude and polarity vary with the deviation in the temperature indicated by radiation pyrometer 21 from a desired control temperature set into recording controller 52. Similarly, the voltages V7 and V8 vary in magnitude and polarity with deviations in the temperature indications of radiation pyrometers 42 and 43, respectively, from the desired control temperatures as set into the recording controllers 53 and 54, respectively.

The voltages V1 and V3 are connected in series with each other and the combined voltage is applied to series connected capacitor 63 and resistor 65. Similarly, voltages V2 and V4 are connected in series with each other and the combined voltage is applied to series connected capacitor 64 and resistor 66. The direction of connection of voltage V1 with voltage V3 and of voltage V2 with voltage V4 is chosen so that increase in rod temperature or increase in rolling speed changes the voltages in the same direction. For example, an increase in rod temperature above the preset control temperature may cause the voltage V3 to increase from zero to some positive value. An increase in rolling speed of the rod will cause the voltage V1 to increase in a positive sense so that increase in speed, increase in temperature, or increase in both speed and temperature, will result in a higher net positive voltage applied to series connected capacitor 63 and resistor 65. Capacitor 63 and resistor 65 preferably have a fairly large time constant, for example, one minute. Capacitor 64 and resistor 66 should have a similar time constant. The time constant of the RC circuits is related to the time required for a billet to be rolled into rod. For example, when the time for rolling one billet is one minute, the time constant should be at least one-half minute, and preferably one minute or more. When a local variation in temperature of rod is sensed by radiation pyrometer 21, the voltage V3 or the voltage V4 will change. Similarly, a change in speed will cause a variation in voltage V1 or V2. Such a change will cause current to flow through resistor 65 or 66, as the case may be, in order to change the charge on capacitor 63 or 64. If the time constant selected is one minute, at the end of this time, assuming the change persists so long, capacitor 63 or capacitor 64, as the case may be, will have received approximately 64% of its new charge. However, once the capacitor is fully charged, no current will flow in resistor 65 or 66, even if the change still persists. Thus, the voltages appearing across resistors 65 and 66, designated V10 and V11, respectively, will not be maintained and will gradually drop off toward zero. Voltages V10 and V11 only reflect changes in temperature or speed, but, because of the presence of capacitors 63 and 64, do not reflect the absolute level of either. Normally open relay contacts F–1 and normally closed relay contacts A–2 are connected in parallel with resistor 65 and are used to switch voltage V10 on and off in a manner to be described hereinafter. Normally open relay contacts F–2 and normally closed relay contacts B–2 are each connected in parallel with resistor 66 for switching voltage V11 on and off. The output voltage of recording controller 53, i.e., voltage V7, may be switched on or off by normally open relay contacts G–1 and normally closed relay contacts A–3. The resulting output voltage is designated V9. Similarly, voltage V8 may be switched on or off by normally open contacts G–2 or normally closed contacts B–3, the resulting output voltage being designated V12.

Output voltages V9 and V10 are used as input voltages in the circuit of FIG. 4 and their end effect in this circuit is to control the movement of water valve 44. Similarly, voltages V11 and V12 are used as input voltages in FIG. 4 and their end result is to control the operation of water valve 45.

In the upper part of FIG. 4 there is shown a bridge network comprising resistors 80A, 80B, 80C and 80D. Resistors 80A and 80B are interconnected through a potentiometer 80, the slider 81 of which constitutes one terminal of the bridge. The opposite terminal of the bridge is formed by the junction of resistors 80C and 80D. The other two terminals of the bridge are formed by the junction of resistors 80A and 80C and by the junction of resistors 80B and 80D, respectively. A source of constant D.C. voltage V15 is connected to these latter two bridge terminals. The slider 81 is arranged to be driven by a reversible D.C. electric motor 82M, which motor also operates water valve 44. One terminal of voltage V10 is connected to the slider 81. The other terminal of voltage V10 and one terminal of voltage V9 are connected to one end of a potentiometer 82 and also to slider 85 of potentiometer 82 through normally open relay contacts A–4 and H–1. Voltages V9 and V10 are connected in additive relationship. The other end of potentiometer 82 is connected to the junction of resistors 80C and 80D through a series connection of a resistor 83 and a capacitor 84. The voltage across series connected potentiometer 82 and resistor 83 is designated V17. The free terminal of voltage V9 is connected to one input terminal of a D.C. amplifier 86. The junction of resistor 83 and capacitor 84 is connected to the other input terminal of amplifier 86. The input voltage to amplifier 86 is designated V13. The output of amplifier 86 is applied to a pair of reversing relays 87 which control reversible electric motor 82M. Thus, an output of amplifier 86 having a positive polarity will cause motor 82M to rotate in one direction, while an output having the opposite polarity will cause motor 82M to rotate in the other direction.

The amplifier input voltage V13 may be considered the bridge network output voltage. The connections are such that presence of a voltage V13 will cause electric motor 82M to rotate slider 81 in a direction or sense to reduce voltage V13 substantially to zero by balancing the bridge. The bridge is thus a self-balancing one. Water valve 44, which controls the water supplied to the first cooling station 27, is also operated by the motor 82M. The water supplied to the first cooling station 27 is thus increased or decreased as the motor 82M is rotated in one direction or the other.

If the temperature of the rod 12 at the position of radiation pyrometer 42 differs from the desired control temperature, a voltage will exist at V9. The magnitude of this voltage will be dependent upon the difference between the rod temperature and the control temperature, and its polarity will depend upon whether the actual temperature is above or below the control temperature. The existence of a voltage V9 will produce a voltage at V13 which will cause the bridge to rebalance by moving slider

81 and causing a change in voltage V17 which will exactly balance V9 and thus reduce voltage V13 to zero. However, voltage V17 will gradually decrease toward zero as capacitor 84 becomes charged. If the rod temperature is still incorrect and voltage V9 persists, the bridge will rebalance again with another movement of slider 81. Movement of slider 81 will continue until a position thereof is found at which the water flow controlled by the valve 44 causes the rod temperature at pyrometer 42 to coincide with the desired control temperature at that point. At this time the voltages V9 and V17 will both approach zero. The rate of response of the reset action which causes the successive changes in the position of slider 81 will depend upon the time constant of the circuit including potentiometer 82, resistor 83 and capacitor 84. This time constant may be changed manually by moving the slider 85 to vary the effective resistance of potentiometer 82.

If the temperature of rod 12 varies at the position of radiation pyrometer 21 or if the rod speed varies as determined by tachometer 50, a voltage will be produced at V10 which will produce a voltage at V13, thereby causing a rebalancing of the bridge by a change in voltage at the slider 81, which will exactly balance V10. In the case of voltage V10, reset action is not involved since voltage V17 will not change except momentarily, and thus no change will occur in the voltage across capacitor 84. The effect of change in position of slider 81 to balance V10 is to increase or decrease the water flow to the first cooling stations 27 and 27′ according to changes in temperature along the length of the rod at pyrometer location 21 and according to changes in speed. The magnitude of the increase or decrease in water flow for any given change in temperature may be altered by manual adjustment of potentiometers 61′ or 62′, and for any given change in speed by potentiometers 61 and 62. In operation these potentiometers are adjusted so that variations in temperature and speed are compensated for by variation in water flow at the first cooling stations 27 and 27′ so that the rod leaving these cooling stations is substantially unchanging in temperature along its length.

The effect of change in position of slider 81 to balance V9 is to increase or decrease water flow in the first cooling stations 27 or 27′ according to the deviation of temperature of the rod at pyrometer location 42 from the control temperature at which the controller has been set. Thus it is the function of controllers 52, 55 and 56 to reduce variations of temperature along the length of the rod and it is the function of controllers 53 and 54 to maintain the rod temperature at the right magnitude.

In the lower part of FIG. 4, there is shown another bridge circuit identical with the one just described. This bridge circuit, which includes a potentiometer 88 and resistors 88A, 88B, 88C and 88D, is intended to control water valve 45 and thus the cooling water supplied to cooling station 27′ which acts on the rod 12′. Potentiometer 88 is provided with a slider 89 corresponding to the slider 81. A potentiometer 90, a resistor 91 and a capacitor 92 correspond to the potentiometer 82, resistor 83 and capacitor 84, respectively. Slider 93 and normally open relay contacts H–2 and B–4 correspond to slider 85, contacts H–1 and contacts A–4, respectively. The voltage V11 and voltage V12 are applied to this circuit and operate in the same way as the voltage V9 and the voltage V10, respectively, applied to the upper bridge circuit. A D.C. amplifier 94, a set of reversing relays 95, and a reversible D.C. electric motor 96 correspond to the elements 86, 87 and 82M, respectively, previously described. The bridge output or amplifier input voltage is designated V14, while the voltage across potentiometer 90 and resistor 91 is designated V18. Variations in temperature or speed of the rod 12′ will cause changes in voltages V11 and V12, which in turn will cause self-balancing of the bridge circuit in the lower half of FIG. 4 with a resulting change in the setting of water valve 45, in a sense to cause the rod temperature to approach the desired control temperature at radiation pyrometer 43.

The control circuit which has been described in connection with FIGS. 3 and 4 would be capable of maintaining a uniform temperature in a continuously running rod. However, the rod in this case is rolled from individual billets so that at the location of radiation pyrometer 21 there will be intervals between successive rods during which the pyrometer will indicate a much lower temperature. The same thing is true at the locations of radiation pyrometers 42 and 43, except that in this case the intervals of low temperature indication will be extended because the rods are switched alternately to the left-hand and right-hand sides of the mill. The control as so far described would act to close the motor operated water valves during the time interval between rods. Consequently, the water pressure would be too low for the starting end of each subsequent rod and therefore each rod would be too hot at the start. In accordance with one aspect of the invention, the proper amount of water pressure at the start of each rod is provided.

Referring now to FIG. 5, there are shown two conductors 97 and 98, to which are applied a suitable supply voltage V. A number of series circuits are connected across conductors 97 and 98. One of these circuits includes the coil of a relay A and normally open contacts 53–1. Normally open contacts 53–1 are located in recording controller 53 and are arranged to be closed at a predetermined temperature below the control temperature set into the controller 53. The temperature at which the contacts 53–1 close is usually set at about 100° F. below the control temperature. Thus, when a rod enters the location of radiation pyrometer 42, contacts 53–1 close when the indicated temperature reaches a temperature of about 100° F. below the control temperature. Closing of contacts 53–1 will result in energization of relay A.

Another circuit comprises the coil of a relay B and normally open contacts 54–1. The contacts 54–1 are located in recording controller 54 and are set to operate in the same way as contacts 53–1 when a rod approaches pyrometer 43.

Another circuit is formed by a timer clutch coil C in series with normally open contacts 52–1. Contacts 52–1 are located in recording controller 52 and are set to operate in the presence of a rod in the same way as contacts 53–1 and 54–1. A series circuit formed by timer motor MC and a normally closed switch MC–1 is connected across the clutch coil C. When contacts 52–1 close, which will occur when a rod reaches the zone of radiation pyrometer 21, so that the temperature indicated by this pyrometer will be about 100° F. below the control temperature, clutch roll C and motor coil MC of the timer will both be energized. At the end of a pre-set time, switch MC–1 will be opened, stopping the motor MC. When contacts 52–1 open after the trailing end of a rod has passed radiation pyrometer 21, clutch coil C will be de-energized and the clutch will be released, thereby resetting the timer for another timing cycle.

Anothr circuit is formed by relay coil D and normally open contacts A–1. Still another circuit is formed by relay coil E and normally open contacts B–1. The junction of contacts A–1 and coil D and the junction of contacts B–1 and coil E are connected by a conductor 97′. A series circuit formed by a timer motor MD and a normally closed switch MD–1 is bridged between conductors 97′ and 98. A similar circuit formed by timer motor ME and a normally closed switch ME–1 is likewise connected between conductor 97′ and conductor 98.

Three other series circuits are connected between conductors 97 and 98. A first of these is formed by a relay coil F and a normally closed switch MC–2. A second is formed by relay coil G and a normally closed switch MD–2. A third is formed by a relay coil H and a normally closed switch ME–2.

When relay A or relay B is energized by the closing of contacts 53–1 or 54–1, contacts A–1 or B–1 will be closed, thereby connecting conductor 97' to conductor 97. This will result in the starting of timer motors MD and ME and the energization of their clutch coils D and E, respectively. At the end of a preset timing interval, switches MD–1 and ME–1 will be opened, stopping timer motors MD and ME. Timer motors MC, MD and ME act to open normally closed switches MC–2, MD–2 and ME–2, respectively, at the same times that switches MC–1, MD–1 and ME–1, respectively, are opened. Relay coils F, G and H are normally energized. When contacts 52–1 close, timer MC will be energized so that at a predetermined time later switch MC–2 will open, de-energizing relay F. Similarly, when contacts 54–1 close, relay B will be energized, closing contacts B–1 and energizing timer motors MD and ME, so that at predetermined times later switches MD–2 and ME–2 will open, de-energizing relays G and H. Relays G and H will be similarly de-energized upon the closing of contacts 53–1. Opening of contacts 52–1 and A–1 or B–1 will result in prompt re-energization of the coils F, G and H.

Referring again to FIGS. 3 and 4, as well as to FIG. 5, when relay coil A is energized, normally closed contacts A–2 and A–3 will be opened and normally open contacts A–4 will be closed. When relay B is energized, normally closed contacts B–2 and B–3 will be opened and normally open contacts B–4 will be closed. When relay F is energized, normally open contacts F–1 and F–2 will be closed. When relay G is energized, normally open contacts G–1 and G–2 will be closed. When relay H is energized, normally open contacts H–1 and H–2 will be closed. When the starting end of a rod enters the locations of optical pyrometers 21, 42 or 43, control action by the recording controllers is delayed by appropriate setting of the timers until a steady temperature indication has been reached. For example, when the starting end of a rod approaches radiation pyrometer 21, so that the temperature thereof reaches about 100° F. below the control temperature, contacts 52–1 will be closed, energizing clutch coil C and timer motor MC. Until the time interval at which contacts MC–2 are to be opened has passed, relay F will remain energized, so that contacts F–1 will be closed, effectively shorting control voltage V10. Since contacts F–2 are likewise closed, control voltage V11 will also be shorted out. When the time interval for the timer MC has expired, contacts MC–2 will open, de-energizing relay F and opening contacts F–1 and F–2. However, control action is still prevented since voltages V10 and V11 will still be shorted out by normally closed contacts A–2 and B–2. Contacts A–2 cannot open until relay A is energized by closing of contacts 53–1, which will occur when the starting end of a rod causes the indication produced by radiation pyrometer 42 to reach about 100° F. below the established control temperature for the recording controller 54. Voltage V9 is similarly shorted out by normally closed contacts A–3, which will not be opened until relay A is energized. Voltage V12 likewise is shorted out by normally closed contacts B–3, which will not be opened until relay B is energized. In other words, control action on motor operated water valve 44 can only take place a selected time interval after a rod has arrived at the location of radiation pyrometer 42. Similarly, control action on motor operated water valve 45 can only take place a selected time interval after a rod has arrived at the location of radiation pyrometer 43. This selected time interval is determined by the response time of the recording controllers. The control action which then occurs is such as to maintain the rod temperatures at the location of radiation pyrometer 42 or 43 equal to the desired control temperatures at these points and to adjust the water flow to the incoming rod temperature level.

When the trailing end of a rod leaves the location of radiation pyrometer 42, motor operated water valve 44 should be moved to the proper opening to cool the starting end of the next rod to the control temperature. Similarly, when the trailing end of a rod leaves the location of radiation pyrometer 43, motor operated water valve 45 should be moved to the proper opening to cool the starting end of the next rod to the control temperature. These desired results are also achieved by the control circuit of the invention. When the starting end of a rod enters the location of optical pyrometer 21, recording controller 52 shows the temperature increase, and when the temperature corresponding to the setting of contacts 52–1 is reached, contacts 52–1 are closed. Closing of contacts 52–1 energizes clutch coil C and timer motor MC. The timer MC is adjusted so that before it times out the recording controller reaches the temperature indication corresponding to the temperature of the rod. When the timer MC times out, switch MC–2 opens and de-energizes relay coil F. This in turn opens switch F–1, which has been short circuiting output voltage V10 from recording controller 52. Assuming that the rod switch 22 is set for the rod to go down the side containing radiation pyrometer 42 and motor operated water valve 44, when the rod reaches pyrometer 42 the temperature indication of recording controller 53 will rise until, at the temperature setting for contacts 53–1, these contacts will close, thereby energizing relay coil A. Energization of relay A will open contacts A–2, which were also shorting the output voltage V10 from recording controller 52. In this way, voltage V10 is applied to the upper bridge circuit in FIG. 4 and starts controlling water valve 44. Had the switch 22 put the rod on the other side, where radiation pyrometer 43 is located, by a similar action contacts F–2 and B–2 would be opened and output voltage V11 would start controlling water valve 45. The shorting of resistors 65 and 66, which will occur from the shorting of voltages V10 and V11, respectively, will maintain full charge on capacitors 63 and 64. Thus, control action from tachometers 50 and 51 and radiation pyrometer 21 will only be due to changes occurring after the control becomes effective, and are not affected by the initial level of speed or temperature.

When the starting end of the rod enters the location of pyrometer 42, the associated recording controller 53 shows an increase in temperature which, when it arrives at a predetermined level, e.g., about 100° F. below the control temperature, closes contacts 53–1, thereby energizing relay A. This in turn closes contacts A–1 and operates clutch D and timer motor MD. The timer MD is adjusted to allow time for the recording controller 53 to reach a reading corresponding to the rod temperature before the timer times out. When the timer MD times out, switch MD–2 opens, de-energizing relay G, which in turn opens contacts G–1, which had been short circuiting output voltage V9. Contacts A–3, which had also been short circuiting voltage V9, have already been opened by the prior energization of relay coil A. Thus, output voltage V9 joins voltage V10 in controlling motor operated water valve 44. Had the rod been switched to the other side containing radiation pyrometer 43, contacts A–3 would not have opened, but, by a similar sequence, contacts G–2 and B–3 would have opened, enabling output voltage V12 to join voltage V11 in controlling motor valve 45.

As previously explained, reset action is involved in the valve control effected by voltages V9 and V12. The amount of reset action depends upon the value of resistance of potentiometers 82 or 90. Reset is rapid when these resistances are low, giving a low time constant, and slow when they are high, giving a large time constant. Contacts A–4, H–1, B–4 and H–2 operate to change the reset action. Assuming that the rod is to go down the side containing radiation pyrometer 42, when contacts 53–1 are closed in recording controller 53 and relay coil A is energized, contacts A–4 will be closed. Normally open contacts H–1 will also be closed at this time, because normally closed switch ME–2 is closed, so that relay coil H will be energized. Thus, at the start of the rod slider 85 short circuits a part of potentiometer 82. By adjusting the position of slider 85, the increased speed of the reset action may be made as great as desired. Faster reset action will be maintained until relay H drops out, at which time contacts H–1 open. Relay H will drop out when switch ME–2 opens upon the timing out of timer ME. The time interval provided by timer ME was initiated by the energization of relay A and the closing of contacts A–1. The resulting increased resistance of potentiometer **82** will act to slow the reset action. By adjusting the timer ME, a higher reset rate may be obtained for the starting end of the rod and a slow reset rate for the balance of the rod. This arrangement will result in the proper pressure of cooling water for the start of each rod providing the rod temperatures do not change substantially between successive rods, which is generally true.

The setting of the motor operated water valve **44** at the start of the rod is determined by the voltage across capacitors **84**, because before the start of the rod voltages **V9**, **V10** and **V17** are zero. Consequently, the voltage across capacitor **84** equals the voltage difference between the junction of resistors **80–C** and **80–D** and slider **81**. The position of the slider **81** is determined by the position of motor operated water valve **44**. Thus, when the rod runs out and voltages **V9** and **V10** are shorted out, the water valve **44** will return to a position determined by the charge of capacitor **84**. This charge will determine the water pressure for the starting end of the next rod. When the next rod enters, if the temperature is incorrect, contacts A–4 and H–1, being closed, will cause reset action to bring the charge on capacitor **84** to a value determined by the average temperature of the rod during the period the timer ME leaves contacts H–1 closed. After contacts H–1 open, the larger value of the entire potentiometer **82** prevents a significant change in the charge on capacitor **84** for the balance of the rod. Consequently, the water pressure at the start of each rod is determined by the water pressure required to hold previous rods at the control temperature for a period at the starting end determined by the setting of the timer ME. In this way, any tendency for the trailing end of a rod to have a higher temperature than the starting end of the rod will not cause increased water pressure for the starting end of the next rod. However, action of voltage **V10** will cause the trailing end of a rod to receive more cooling water than the starting end, if this is necessary. If conditions are such that the rod temperature is substantially uniform from end to end, it may be satisfactory to have reset action taking place over the full length of the rod. In this case contacts A–4, H–1, B–4 and H–2 and timer ME would not be required. Sliders **85** and **93** would be connected directly to **V10** and **V11**, respectively, in order to provide adjustable reset action which would be constant over the full length of the rod.

While the invention has been described in connection with a specific embodiment thereof and in a specific use, various modifications thereof will occur to those skilled in the art without departing from the spirit and scope of the invention, as set forth in the appended claims.

What is claimed is:

1. In apparatus for heat treating rapidly moving hot rolled rod including a plurality of liquid quenching means for cooling said rod, said liquid quenching means being arranged at spaced intervals along the path of travel of said rod and each developing a sufficiently high rate of heat abstraction from said rod that a substantial temperature difference exists at the exit from each quenching means between the center and outside of said rod, the combination comprising means for determining the temperature of said rod at a selected point in said path located at a substantial distance from the preceding quenching means sufficient for the interior and surface of the rod substantially to equalize in temperature, and means responsive to the difference between said determined temperature and a predetermined control temperature for increasing or decreasing the supply of said quenching liquid to at least one of said quenching means depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature.

2. In apparatus for heat treating rapidly moving hot rolled rod including a plurality of liquid cooling stations arranged at spaced intervals along the path of travel of said rod and each developing a sufficiently high rate of heat abstraction from said rod that a substantial temperature difference exists at the exit from each cooling station between the center and outside of said rod, the combination comprising a radiation pyrometer for determining the temperature of said rod at a selected point in said path located at a substantial distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, and means responsive to the difference between said determined temperature and a predetermined control temperature for increasing or decreasing the supply of said cooling liquid to one of said cooling stations preceding said selected point depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature.

3. In apparatus for heat treating rapidly moving hot rolled rod including a plurality of liquid cooling stations arranged at spaced intervals along the path of travel of said rod and each developing a sufficiently high rate of heat abstraction from said rod that a substantial temperature difference exists at the exit from each cooling station between the center and outside of said rod, the combination comprising a radiation pyrometer for determining the temperature of said rod at a selected point in said path located at a substantial distance from the preceding cooling station corresponding to the rod travel time of not less than about 0.3 second, and means responsive to the difference between said determined temperature and a predetermined control temperature for increasing or decreasing the supply of said cooling liquid to the first one of said cooling stations depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature.

4. In apparatus for heat treating rapidly moving hot rolled steel rod including a plurality of liquid cooling stations arranged at spaced intervals along the path of travel of said rod and each developing a sufficiently high rate of heat abstraction from said rod that a substantial temperature difference exists at the exit from each cooling station between the center and outside of said rod, the combination comprising means for determining the temperature of said rod at a selected point in said path located at a substantial distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, means to produce a voltage whose magnitude is proportional to the difference between said determined temperature and a predetermined control temperature and whose polarity is dependent on whether said determined temperature is higher or lower than said predetermined control temperature, and means responsive to the magnitude and polarity of said voltage to increase or decrease the supply of cooling liquid to a selected cooling station preceding said selected point depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature.

5. In apparatus for heat treating rapidly moving hot rolled steel rod including a plurality of liquid cooling stations arranged at spaced intervals along the path of travel of said rod, the combination comprising means for

determining the temperature of said rod at a selected point in said path located at a distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, means to produce a voltage whose magnitude is proportional to the difference between said determined temperature and a predetermined control temperature and whose polarity is dependent on whether said determined temperature is higher or lower than said predetermined control temperature, means responsive to the magnitude and polarity of said voltage to increase or decrease the supply of cooling liquid to a selected cooling station preceding said selected point depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature, and means responsive to the magnitude and polarity of said voltage for adjusting the supply of cooling liquid to said selected cooling station after a particular rod has been treated and prior to arrival of the succeeding rod to be treated.

6. In apparatus for heat treating rapidly moving hot rolled steel rod including a plurality of liquid cooling stations arranged at spaced intervals along the path of travel of said rod, the combination comprising means for determining the temperature of said rod at a selected point in said path located at a distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, means to produce a voltage whose magnitude is proportional to the difference between said determined temperature and a predetermined control temperature and whose polarity is dependent on whether said determined temperature is higher or lower than said predetermined control temperature, means responsive to the magnitude and polarity of said voltage to increase or decrease the supply of cooling liquid to a selected cooling station preceding said selected point depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature, and means responsive to the magnitude and polarity of said voltage during a predetermined interval corresponding to travel of a first portion of a rod past said selected point for adjusting the supply of cooling liquid to said selected cooling station after a particular rod has been treated and prior to arrival of the succeeding rod to be treated.

7. In apparatus for heat treating rapidly moving hot rolled steel rod including a plurality of liquid cooling stations arranged at spaced intervals along the path of travel of said rod, the combination comprising means for determining the temperature of said rod at a selected point in said path located at a distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, means to produce a voltage whose magnitude is proportional to the difference between said determined temperature and a predetermined control temperature and whose polarity is dependent on whether said determined temperature is higher or lower than said predetermined control temperature, means responsive to the magnitude and polarity of said voltage to increase or decrease the supply of cooling liquid to a selected cooling station preceding said selected point depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature, and means responsive to the magnitude and polarity of said voltage during a predetermined interval for adjusting the supply of cooling liquid to said selected cooling station after a particular rod has been treated and prior to arrival of the succeeding rod to be treated, said last mentioned means including a resistor and a capacitor forming a series circuit, said circuit being arranged so that said capacitor is charged by said voltage.

8. In apparatus for heat treating rapidly moving hot rolled steel rod including a plurality of liquid cooling stations arranged at spaced intervals along the path of travel of said rod, the combination comprising means for determining the temperature of said rod at a selected point in said path located at a distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, means to produce a voltage whose magnitude is proportional to the difference between said determined temperature and a predetermined control temperature and whose polarity is dependent on whether said determined temperature is higher or lower than said predetermined control temperature, means responsive to the magnitude and polarity of said voltage to increase or decrease the supply of cooling liquid to a selected cooling station preceding said selected point depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature, means responsive to the magnitude and polarity of said voltage during a predetermined interval for adjusting the supply of cooling liquid to said selected cooling station after a particular rod has been treated and prior to arrival of the succeeding rod to be treated, said last mentioned means including a resistor and a capacitor forming a series circuit arranged so that said capacitor is charged by said voltage, and switching means for suppressing said voltage when a rod is not passing said selected point.

9. Apparatus as set forth in claim 8 in which said predetermined interval corresponds to passage of a first portion of said rod past said selected point and in which additional switching means is provided to reduce the resistance value of said series circuit during passage of said first portion of said rod past said selected point, said additional switching means being operatively connected to said resistor.

10. Apparatus as set forth in claim 9 in which said additional switching means includes a timer arranged to time said predetermined interval starting in response to approach of a rod to said selected point, said timer causing said additional switching means to increase the resistance value of said series circuit at the end of said predetermined interval.

11. Apparatus as set forth in claim 10 in which the time constant of said series circuit during said predetermined interval is sufficiently small to cause the charge across said capacitor to stabilize at a value determined by said voltage and in which the time constant of said series circuit except during said predetermined interval is sufficiently large so that changes in said voltage will not materially affect the charge on said capacitor.

12. In apparatus for heat treating rapidly moving hot rolled rod including a plurality of liquid quenching means arranged at spaced intervals along the path of travel of said rod, the combination comprising means for determining the temperature of said rod at a selected point in said path, controller means for producing a voltage having a magnitude proportional to the difference between said determined temperature and a predetermined control temperature and whose polarity is dependent on whether said determined temperature is higher or lower than said predetermined control temperature, valve means for increasing or decreasing the supply of said quenching liquid to at least one of said quenching means, means responsive to the magnitude and polarity of said voltage for changing the setting of said valve means to increase or decrease the supply of said quenching liquid dependent on whether said determined temperature is greater or less than said predetermined control temperature, and switching means operatively connected to said controller means to suppress said voltage when said determined temperature is a predetermined value lower than said control temperature.

13. In apparatus for heat treating rapidly moving hot rolled rod including a plurality of liquid quenching means

arranged at spaced intervals along the path of travel of said rod, the combination comprising means for determining the temperature of said rod at a selected point in said path, controller means for producing a voltage having a magnitude proportional to the difference between said determined temperature and a predetermined control temperature and whose polarity is dependent on whether said determined temperature is higher or lower than said predetermined control temperature, valve means for increasing or decreasing the supply of said quenching liquid to at least one of said quenching means, means responsive to the magnitude and polarity of said voltage for changing the setting of said valve means to increase or decrease the supply of said quenching liquid dependent on whether said determined temperature is greater or less than said predetermined control temperature, and switching means operatively connected to said controller means to suppress said voltage when said determined temperature is a predetermined value lower than said control temperature, suppression of said voltage being maintained for a predetermined time interval after said determined temperature exceeds said predetermined value.

14. In apparatus for heat treating rapidly moving hot rolled rod including a plurality of liquid quenching means arranged at spaced intervals along the path of travel of said rod, the combination comprising means for detecting changes in temperature of said rod at a first selected point in said path prior to the first of said quenching means, means for increasing or decreasing the supply of said quenching liquid depending upon whether the temperature at said first point is increasing or decreasing, means for determining the temperature of said rod at a second selected point in said path located at a distance from the preceding quenching means sufficient for the interior and surface of the rod substantially to equalize in temperature, and means for increasing or decreasing the supply of said quenching liquid depending upon whether said determined temperature is higher or lower than a predetermined control temperature to cause the determined temperature of said second point to coincide with said predetermined control temperature.

15. Apparatus as set forth in claim 14 comprising first and second controller means producing first and second voltages, said first voltage being independent in magnitude and polarity upon changes in temperature at said first selected point and said second voltage being dependent in magnitude and polarity upon the differences and direction of differences between said determined temperature and said control temperature, said first and second voltages being used for producing said increases or decreases in the supply of quenching liquid.

16. Apparatus as set forth in claim 15 comprising a valve mechanism for actually effecting the increases or decreases in supply of quenching liquid, motor means for operating said valve mechanism, a normally balanced bridge circuit having a variable element, said motor means being electrically coupled to said bridge circuit for operation in response to unbalance of said bridge and being mechanically coupled to said variable element whereby operation of said motor means restores said bridge circuit to a balanced condition, and means to apply said first and second voltages to said bridge circuit to unbalance said bridge circuit, resulting operation of said motor means tending to restore the balanced condition of said bridge and to reduce said second voltage toward zero.

17. Apparatus as set forth in claim 16 in which a capacitor is connected to said bridge circuit and is arranged to be charged by said second voltage.

18. Apparatus as set forth in claim 17 in which means is provided to suppress said first and second voltages in the absence of a rod at said first and second selected points, respectively, and in which the charge on said capacitor determines the setting of said valve mechanism while said second voltage is suppressed.

19. In apparatus for heat treating rapidly moving hot rolled steel rod including a first plurality of liquid cooling stations arranged at spaced intervals along a first possible path of travel of said rod and a second plurality of liquid cooling stations arranged at spaced intervals along a second possible path of travel of said rod, the combination comprising a first radiation pyrometer located at a common point of said paths ahead of said cooling stations, second and third radiation pyrometers each located in a respective one of said paths at first and second selected points, respectively, said selected points each being located at a distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, first, second and third controller means each associated with a respective one of said pyrometers for producing first, second and third voltages, respectively, said first, second and third voltages being proportional in magnitude to the differences between the temperatures determined by said respective first, second and third pyrometers and respective first, second and third predetermined control temperatures, the polarity of each of said voltages being dependent on whether the corresponding determined temperature is higher or lower than the corresponding predetermined control temperature, means for converting said first voltage into a fourth voltage proportional to changes in said first voltage, first and second normally balanced bridge circuits each having a variable element, means to apply said fourth and second voltages and said fourth and third voltages to said first and second bridge circuits, respectively, to creat unbalance of said bridge circuits, first and second motor means operative in response to unbalance of said first and second bridge circuits, respectively, and first and second valve means for adjusting the flow of cooling liquid to at least one cooling station in each of said paths, respectively, said first motor means being mechanically coupled to the variable element of said first bridge circuit and to the first valve means, said second motor means being mechanically coupled to the variable element of said second bridge circuit and to said second valve means, said motor means each being arranged to operate in a direction to restore the corresponding bridge circuit to a balanced condition and, by varying the cooling liquid supply, to reduce the corresponding one of the second and third voltages to zero.

20. In apparatus for heat treating rapidly moving hot rolled steel rod including a first plurality of liquid cooling stations arranged at spaced intervals along a first possible path of travel of said rod and a second plurality of liquid cooling stations arranged at spaced intervals along a second possible path of travel of said rod, the combination comprising a first radiation pyrometer located at a common point of said paths ahead of said cooling stations, second and third radiation pyrometers each located in a respective one of said paths at first and second selected points, respectively, said selected points each being located at a distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, first, second and third controller means each associated with a respective one of said pyrometers for producing first, second and third voltages, respectively, said first, second and third voltages being proportional in magnitude to the differences between the temperatures determined by said respective first, second and third pyrometers and respective first, second and third predetermined control temperatures, the polarity of each of said voltages being dependent on whether the corresponding determined temperature is higher or lower than the corresponding predetermined control temperature, means for converting said first voltage into a fourth voltage proportional to changes in said first voltage, first and second normally balanced bridge circuits each having a variable element, means to apply said fourth and second voltages and said fourth and third voltages to said first and second bridge circuits, respec-

tively, to creat unbalance of said bridge circuits, first and second motor means operative in response to unbalance of said first and second bridge circuits, respectively, first and second valve means for adjusting the flow of cooling liquid to at least one cooling station in each of said paths, respectively, said first motor means being mechanically coupled to the variable element of said first bridge circuit and to the first valve means, said second motor means being mechanically coupled to the variable element of said second bridge circuit and to said second valve means, said motor means each being arranged to operate in a direction to restore the corresponding bridge circuit to a balanced condition and to reduce the corresponding one of the second and third voltages to zero, first, second and third circuit means for suppressing said second, third and fourth voltages, respectively, while the temperatures determined by the corresponding pyrometers are below predetermined values, and means operatively connected with each of said bridge circuits for causing said motor means to set said valve means to a liquid flow setting corresponding to the setting provided for the starting end of the preceding rod passed along the corresponding path, said last mentioned means being operative to effect said setting in the absence of the corresponding one of said second and third voltages.

21. In apparatus for heat treating rapidly moving hot rolled steel rod including a plurality of liquid cooling stations arranged at spaced intervals along the path of travel of said rod, the combination comprising means for determining the temperature of said rod at a selected point in said path located at a distance from the preceding cooling station sufficient for the interior and surface of the rod substantially to equalize in temperature, means to determine the speed of said rod, means to produce a first voltage whose magnitude is proportional to the difference between said determined temperature and a predetermined control temperature and whose polarity is dependent on whether said determined temperature is higher or lower than said predetermined control temperature, means to produce a second voltage whose magnitude is proportional to the speed of said rod, control means responsive to the magnitude and polarity of said first voltage and to the magnitude of said second voltage to increase or decrease the supply of cooling liquid to a selected cooling station preceding said selected point depending upon whether said determined temperature is higher or lower than said predetermined control temperature to cause said determined temperature to coincide with said predetermined control temperature and, means responsive to the magnitude and polarity of said first voltage during a predetermined interval for adjusting the supply of cooling liquid to said selected cooling station after a particular rod has been treated and prior to arrival of the succeeding rod to be treated.

22. Apparatus as set forth in claim 21, comprising second means for determining the temperature of said rod at a point in said path located in advance of said cooling stations, means to produce a third voltage whose magnitude is proportional to the difference between said last mentioned determined temperature and a second predetermined control temperature and whose polarity is dependent on whether said last mentioned determined temperature is higher or lower than said second predetermined control temperature, and means to combine said third voltage with said second voltage to produce a fourth voltage which, with said first voltage, operates said control means to control said increases or decreases in supply of cooling liquid.

References Cited in the file of this patent

UNITED STATES PATENTS

1,350,618	Napier	Aug. 24, 1920
2,111,919	Urschel	Mar. 22, 1938
2,163,699	Paul	June 27, 1939
2,205,182	Whitten	June 18, 1940
2,309,745	Bergin	Feb. 2, 1943
2,436,894	Magee	Mar. 2, 1948
2,470,540	Young	May 17, 1949
2,492,434	Mueller	Dec. 27, 1949
2,661,009	Dunnegan et al.	Dec. 1, 1953
2,668,701	Dietrich	Feb. 9, 1954
2,681,793	Miller	June 22, 1954
2,681,874	Linney	June 22, 1954
2,725,265	Daniels et al.	Nov. 29, 1955
2,747,587	Strachan	May 29, 1956

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,994,328 August 1, 1961

Dartrey Lewis

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 53, for "roll" read -- coil --; column 11, line 33, for "larger" read -- large --; column 15, line 44, for "independent" read -- dependent --; column 18, line 24, for "or" read -- and --.

Signed and sealed this 12th day of December 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patent

USCOMM-