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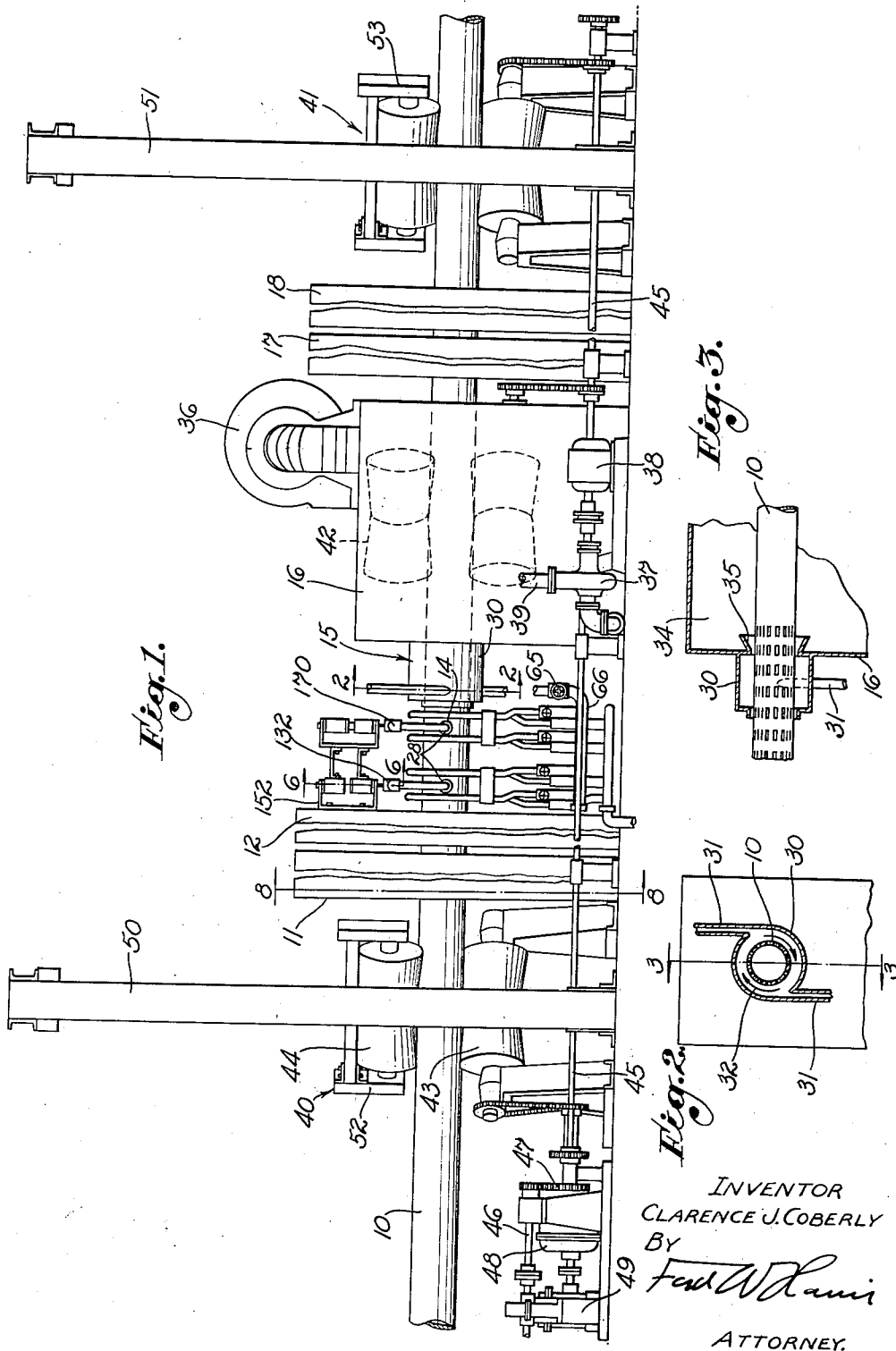
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2,067,436

APPARATUS FOR HEAT TREATING STEEL

Original Filed July 10, 1929

3 Sheets-Sheet 1



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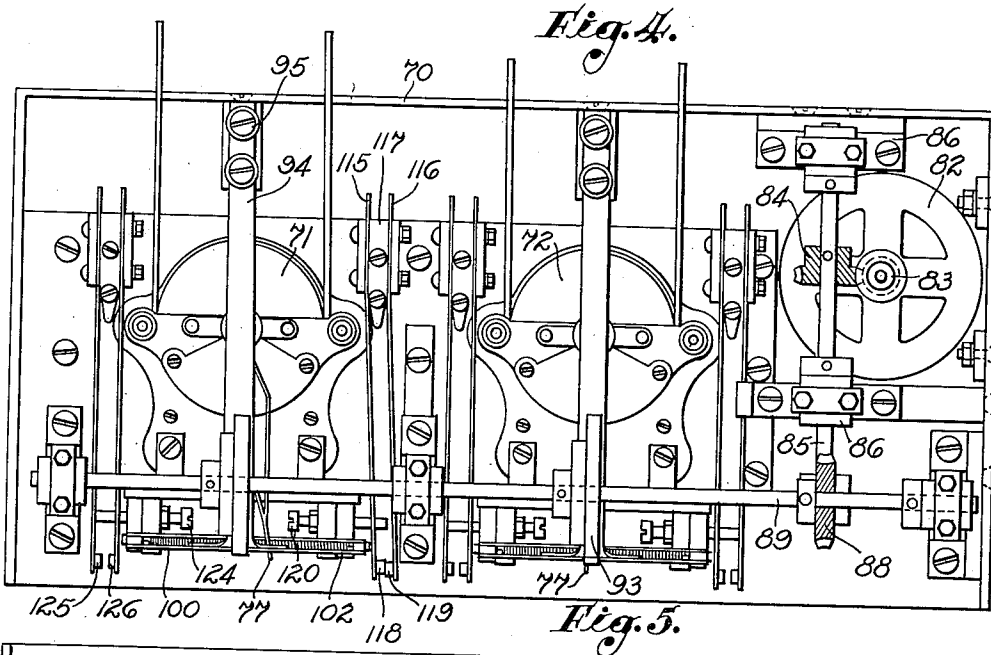
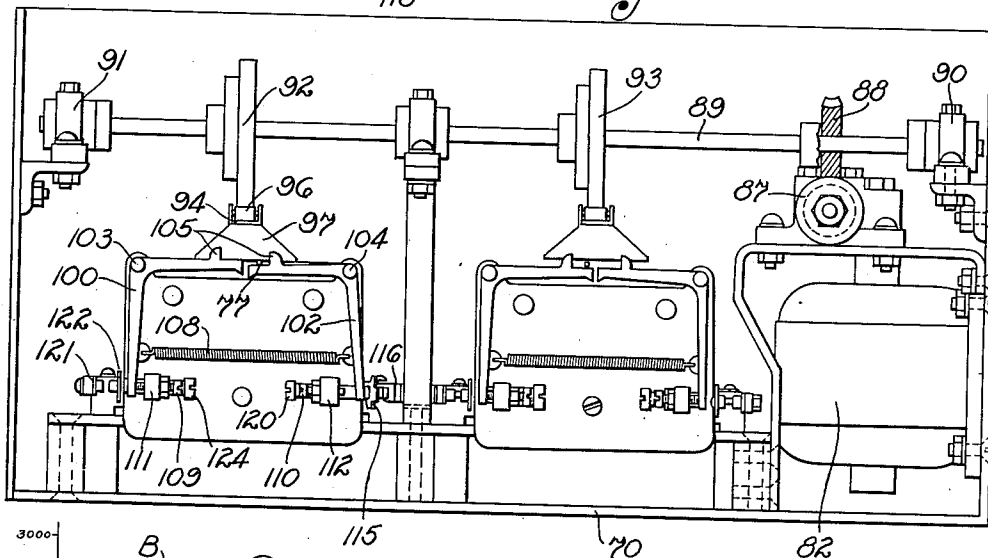
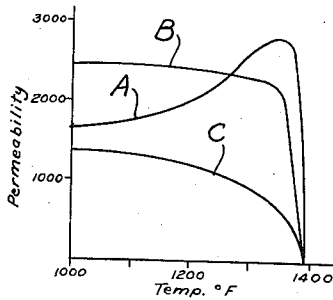
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APPARATUS FOR HEAT TREATING STEEL

Original Filed July 10, 1929 3 Sheets-Sheet 2



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APPARATUS FOR HEAT TREATING STEEL

Original Filed July 10, 1929 3 Sheets-Sheet 3

Fig. 6.

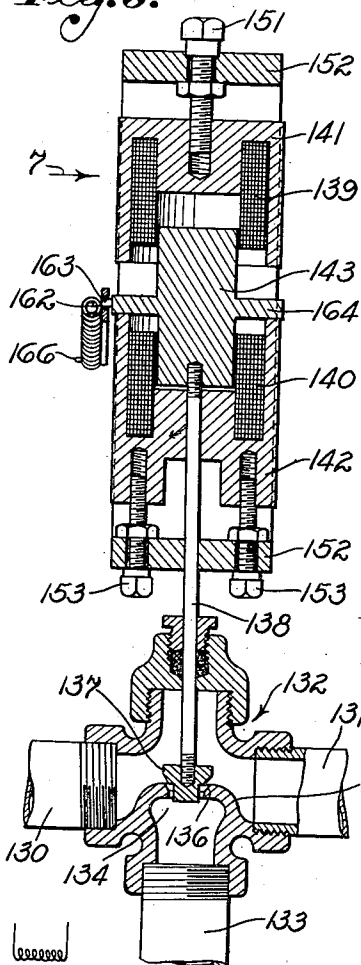


Fig. 7.

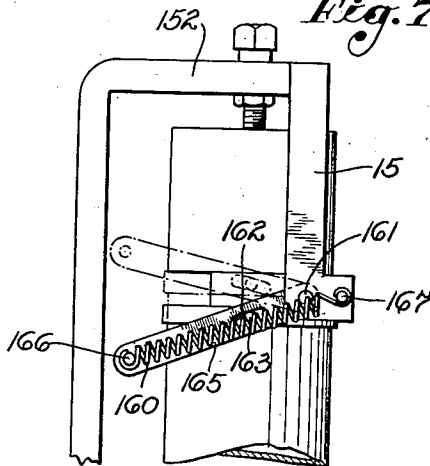


Fig. 8.

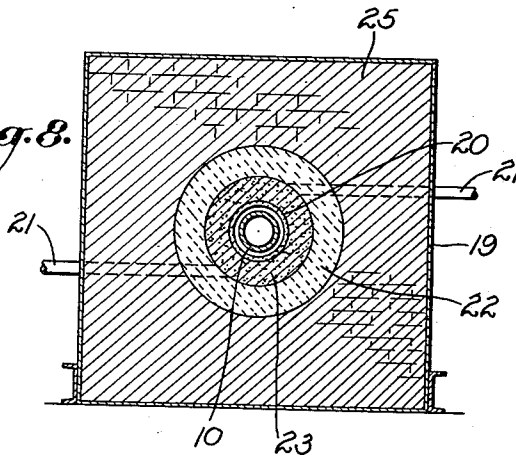
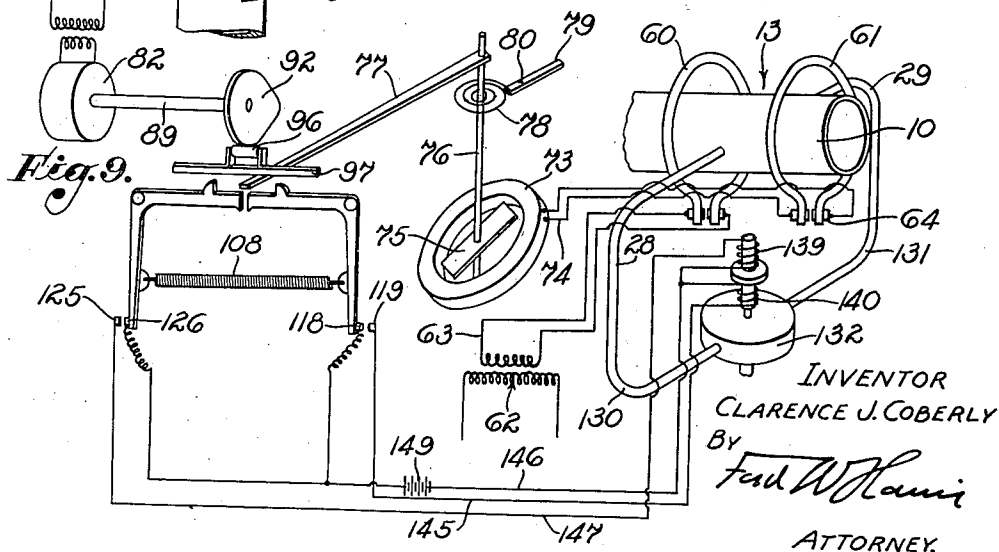


Fig. 9.



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UNITED STATES PATENT OFFICE

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APPARATUS FOR HEAT-TREATING STEEL

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Original application July 10, 1929, Serial No.
377,182. Divided and this application April 11,
1934, Serial No. 720,058

13 Claims. (Cl. 266—4)

My invention relates to the heat-treating of metals to improve their properties, and more particularly to a novel apparatus for heat-treating relatively long bodies of metal such as metal bars, rails, pipes, etc.

The present application is a division of my application entitled Process of heat-treating steel, filed July 10, 1929, Serial No. 377,182.

The physical properties of all steels are improved by proper heat-treatment, but great difficulty has been heretofore encountered in heating, quenching, and tempering relatively long and narrow bodies such as long lengths of shafting, pipe, etc. Some success has been achieved by performing these operations with the longitudinal axis of the pipe or shafting in a vertical position, and lowering this pipe or shafting into a deep quenching bath in the usual manner. It is also true that more or less successful attempts have been made to slide the pipe or shafting into the quenching medium at an angle of about 45° from the horizontal. However, in either event the equipment necessary is both bulky and expensive, inasmuch as the lengths of pipe and shafting are frequently very long, often exceeding forty feet in length.

Such long lengths of pipe find a particular utility in the oil-well drilling and pumping industries, where seamless tubing is being more and more widely used. Seamless tubing is used not only in the capacity of well casing, but is also used in drilling operations, and I have found that the yield point and ultimate strength of such seamless tubing may be increased respectively from sixty thousand pounds per square inch and ninety thousand pounds per square inch, to one hundred and twenty thousand pounds per square inch and one hundred and sixty thousand pounds per square inch by proper heat-treatment. Furthermore, by proper heat-treatment the treated steel will have a ductility equal to that of the untreated steel. Even greater increases in strength and even greater maximum yield point and ultimate strength may be obtained by properly heat-treating alloy steels. The adoption of such alloy steels in the oil-well drilling and pumping industry has been retarded by the high cost thereof.

It is primarily an object of this invention to provide an improved apparatus for heat-treating bodies of metal.

A further object of this invention is to provide an apparatus for successfully heating and quenching relatively long bodies when these bodies are in a horizontal position.

My apparatus is furthermore not limited to any

length of pipe or other body to be heat-treated, but will successfully heat-treat bodies of any desired length.

Still a further object of this invention is to provide an apparatus capable of heat-treating and tempering a relatively long body in a continuous operation.

Still another object of this invention is to provide a novel apparatus for moving a long body horizontally through a heat-treating apparatus, and to turn this body to insure a uniform heating thereof.

In the oil-well pumping industry perforated pipe finds numerous utilities, and it is desirable that this pipe be heat-treated.

Another object of this invention lies in the provision of a novel apparatus for quenching such a perforated pipe while in a horizontal position without danger of the quenching medium backing up into the furnace in a manner to prematurely quench the pipe being heated therein.

It is known that steel experiences a change in magnetic properties when passing through the critical temperature. In other words, iron in the alpha allotropic form is highly magnetic below the A₁ transformation point, and at least partially changes into the very feebly magnetic beta allotropic form when heated between the A₂ and A₃ transformation points. At this last transformation point the gamma allotropic form of iron suddenly appears which is substantially non-magnetic. Temperatures corresponding to the A₂ and A₃ transformation points form a basis for determining the correct temperature for quenching a given steel.

Thus, when raising the temperature of a piece of steel, the magnetic properties thereof suddenly change as the steel passes through the critical temperature or critical range. Becoming suddenly non-magnetic, the permeability of this steel correspondingly increases at a very fast rate, and it is this change in permeability which I utilize for controlling the quenching temperature of the steel. Inasmuch as the critical temperature or range is dependent upon the analysis of the steel, and inasmuch as the magnetic properties of the steel vary correspondingly, it follows that my process compensates for any irregularities in composition of the steel body, and insures that all portions of the body will be raised to the critical temperature or range corresponding to the analysis of the body at any particular section.

It is an object of this invention to provide an apparatus for heat-treating a body which includes mechanism for controlling the quenching

temperature as a function of the magnetic properties of this body.

A further object of this invention is to provide heating apparatus comprising a first and a second heating element, the first heating element being adapted to heat a body to a temperature slightly below the critical temperature or range, and the second heating element being adapted to heat the body further to a temperature at or slightly above the critical temperature, the second heating element operating as a function of the magnetic properties of the heated body.

A further object of this invention is to provide an apparatus for heat-treating a body wherein the body is utilized as the core of a transformer in a manner to magnetically connect a primary and secondary winding, the primary winding being utilized for setting up a magneto-motive force which passes a magnetic flux through the body, this flux linking the secondary winding in a manner to generate an electromotive force in the secondary winding, this induced electromotive force in the secondary winding being utilized for controlling the amount of heat transmitted to the body.

The preferred apparatus for heating the body utilizes one or more gas burners, or other burners which will produce a heating flame which is directed externally against the body, the supply of combustible gas, or the supply of certain of the ingredients thereof, being controlled by the voltage induced in the secondary winding previously mentioned. By using a contacting voltmeter for measuring the voltage induced in the secondary, this arrangement can be used to operate a circuit controlling the amount of heat reaching the body from the heating flame so as to maintain a temperature corresponding to a certain state of magnetization, or having a definite relation to this temperature. The time lag of such a system can be made relatively low.

It is an object of this invention to provide an apparatus for heat-treating a body by directing a heating flame against or adjacent the body, the amount of heat transmitted to this body from the flame being a function of the magnetic properties of the heated body.

A further object of this invention is to provide a novel electrically operated regulating mechanism for controlling the heating of such a body.

Still a further object of this invention is to provide a novel water-cooled winding which surrounds, or is adjacent to, the body in such a manner that the winding is influenced by the flux passing through the body, or so that the body is in the magnetic path of the flux generated by the winding.

Further objects of this invention lie in the particular apparatus utilized, and especially in the novel magnetically operated control valve, and the motor-operated timing switch for regulating the control valve.

Referring particularly to the drawings, in which I have illustrated one form of my invention:

Fig. 1 is a diagrammatic utility view illustrating the respective positions of the pieces of apparatus utilized in my process.

Fig. 2 is a cross-sectional view of the quenching device of my invention taken on the line 2—2 of Fig. 1.

Fig. 3 is another sectional view of the quenching device taken along the line 3—3 of Fig. 2.

Fig. 4 is a top view of the novel motor-operated control switch of my invention.

Fig. 5 is a front view of the switch shown in Fig. 4.

Fig. 6 is a sectional view of the control valve of my invention taken along the line 6—6 of Fig. 1.

Fig. 7 is a detailed view of the toggle mechanism of the control valve, and is taken in the direction of the arrow 7 of Fig. 6.

Fig. 8 is a diagrammatic sectional view of one of the furnaces utilized in my invention, this view being taken along the line 8—8 of Fig. 1.

Fig. 9 is a partial wiring diagram of the apparatus of my invention.

Fig. 10 is a graphical representation of the relationship between permeability and temperature.

The successive steps of my process may be best understood by reference to Fig. 1 wherein I have diagrammatically shown a combination of elements for performing my process. It should be understood that this combination of elements is not the only one by which the novel steps of my process may be performed, but is herein shown and described only for the purpose of illustration and definiteness.

The apparatus shown in Fig. 1 is adapted to heat-treat a relatively long and narrow body such as a pipe 10. For the purpose of illustration we will assume that the pipe 10 is perforated inasmuch as such a pipe presents the most difficult problems in the heat-treating thereof by a continuous process.

A given section of the pipe 10 is successively passed through a surface combustion furnace 11, a furnace 12, primary and secondary sets of gas burners 13 and 14, a quenching device 15, a vacuum hood 16, and a pair of standard annealing furnaces 17 and 18, the horizontal axes of all of these pieces of apparatus being in alignment so that the pipe 10 may pass successively and continuously therethrough. The surface combustion furnace 11 is of novel construction, and the details thereof are best shown in Fig. 8. This furnace has a shell 19 through which a tube of refractory material 20 extends, this tube surrounding the pipe 10 and being preferably formed of coarse-grained carborundum, or other material which will stand very high temperatures.

The space around the tube 20 is suitably heated by any means such as gas jets 21 which extend through an outer porous tube 22 concentric with the tube 20, the gas discharging into an annular space 23 therebetween. The space 23 is preferably filled with loose carborundum particles. Combustion takes place near and in the tube of refractory material 20. A suitable brickwork 25 supports the porous tube 22 inside the shell 19. The heat is transmitted to the pipe 10 mostly by radiation from the heated tube 20. This furnace operates at a temperature of 3000° F., and is utilized for preliminarily heating the pipe to a point somewhat below the critical temperature or range thereof. The temperature of the pipe will depend, of course, upon numerous factors including the initial temperature thereof, the speed at which it passes through the furnace, the size of the pipe, etc. The furnace 11 may be provided with a temperature-regulating pyrometer, but I have found it preferable to operate this furnace at a temperature close to the maximum obtainable therein, this temperature being manually controlled. A pyrometer is preferably utilized for measuring the furnace temperature, and an optical pyrometer for measuring the temperature of the pipe as it passes from this furnace.

The pipe then moves to the furnace 12 which is automatically controlled by a pyrometer, not shown, the temperature thereof being only slightly less than the critical temperature or range of the steel in the pipe 10. This temperature is ordinarily around 1450° F., but will, of course, vary with different steels.

Hence the pipe passes successively into the path of the sets of gas burners 13 and 14, each of which is composed of two burners spaced 180° apart and directed against the external surface of the pipe, the burners of set 13 being designated by numerals 28 and 29. The heat transmitted to the pipe by each of these gas burners is regulated as a function of the magnetic properties of the heated pipe in a manner to be described, so that the temperature of the pipe after it leaves the vicinity of the set of gas burners 14 is at, or slightly above, the critical temperature or range of the steel.

The temperature of the pipe drops only a few degrees before the pipe enters the quenching device 15. Here the pipe is suddenly cooled by means of a cooling medium tangentially supplied to the interior of a circular shell 30, this medium being supplied through tangential nozzles 31. The nozzles 31 are designed to convert substantially all of the potential energy of the quenching medium, supplied thereto under pressure from a suitable source, into kinetic energy so that this cooling medium is circulated in the housing at a high velocity in a direction indicated by arrows 32 of Fig. 2, this medium forming a cylinder of rotating quenching medium which contacts the periphery of the pipe. The centrifugal force on this medium continuously throws it outward and does not exert an undue radial pressure on the walls of the pipe.

Eventually, however, the medium flows through the perforations of the pipe, in the event that the pipe 10 is perforated, and into the vacuum hood 16. This vacuum hood provides a vacuum chamber 34 which communicates with the interior of the circular shell 30 through the opening of an apron 35, best shown in Fig. 3. This opening is only slightly larger than the periphery of the pipe. The intake of a blower 36 communicates with the chamber 34 and decreases the pressure therein so that any of the quenching medium passing through the perforations of the pipe will be drawn to the right and into the vacuum hood 16 rather than flowing leftward along the pipe, thus prematurely quenching this pipe.

The quenching medium drawn into the vacuum hood by the blower 36 drops to the lower end thereof and is withdrawn therefrom by a circulating pump 37 driven by a motor 38, this pump forcing the quenching medium through a pipe 39 to a cooling tower, not shown, where the quenching medium is cooled and again supplied to the nozzles 31 under pressure.

After leaving the vacuum hood 16, the pipe passes through the standard annealing furnace 17 where it is brought up to a tempering temperature. Subsequently, the pipe passes through the furnace 18 which holds the pipe at the correct tempering temperature for such a length of time that a correct amount of tempering takes place. The pipe is then cooled in the air after leaving the furnace 18.

The pipe 10 is continuously fed through the furnaces 11, 12, 17, and 18 and the remainder of the apparatus, by three driving devices, one being situated before the furnace 11 and indicated by the numeral 40, another being situated after

the furnace 18 and indicated by the numeral 41, and the third being in the vacuum hood 16 and indicated by dotted lines 42. Each of these driving devices comprises a pair of skewed rolls, individually designated as a drive roller 43 and an idler roller 44. The drive roller 43 of each of the driving devices 40, 41, and 42 may be simultaneously driven by a shaft 45 geared to a shaft 46 by gears 47. The shaft 46 is in turn driven by a motor 48 through a suitable gear reduction box 49. The pipe 10 rests on the drive roller 43, and the idler roller 44 rests on top of the pipe 10 and due to its weight holds the pipe firmly against the drive rollers.

The driving devices 40 and 41 have frames 50 and 51 in which journalling structures 52 and 53 may vertically slide, these structures journalling the idler rollers 44. Due to the fact that the rollers 43 and 44 of each driving device are skewed, a rotation of the drive rollers will cause the pipe 10 to be turned about its longitudinal axis, and also pushed forward through the furnaces and quenching device. The center of each of the rollers 43 and 44 is of smaller diameter than the ends, as clearly shown in Fig. 1, to increase this turning and driving action. It is entirely possible to drive the rollers 44 as well as the rollers 43, but I have found that such a procedure is unnecessary.

In certain instances it is desirable to drive the rollers 43 of the three driving devices 40, 41, and 42 separately. By thus doing, it is entirely possible by having these rollers run at slightly different speeds to place a tension on that portion of the pipe passing through the furnaces 11 and 12 or the furnaces 17 and 18. Similarly, it becomes possible to place compressive stresses on the pipe when passing through these furnaces. I am thus not limited to a unitary drive for all of the rollers 43.

An important part of this invention lies in the provision of the regulating means for regulating the amount of heat transmitted to the pipe 10 by the sets of gas burners 13 and 14 as a function of the magnetic properties of the pipe being treated.

There are numerous methods whereby the magnetic properties of the pipe may be utilized for controlling the quenching temperature of the pipe 10, but the preferred method comprehends impressing on the heated pipe a magnetomotive force which tends to pass magnetic flux through the heated pipe, the amount of this flux being suitably measured. If the magnetomotive force is substantially constant the flux passing through the pipe will vary inversely as the permeability thereof. If a curve of permeability be plotted against temperature, it is possible to obtain several curves of different shapes depending upon the flux density in the pipe.

In Fig. 10 I have illustrated three typical curves, curve A being for low flux density, curve B for medium flux density, and curve C for high flux density. From these curves it will be apparent that as the material in the pipe approaches and passes through the critical temperature or range, the permeability thereof drops very rapidly. I utilize this sudden change in permeability for regulating the amount of heat transmitted to the pipe 10 by the sets of burners 13 and 14. The means for accomplishing this end is best illustrated in Figs. 1 and 9, and inasmuch as the sets of gas burners 13 and 14 are identical, only one set is shown in Fig. 9 and will be particularly described.

Referring particularly to Figs. 1 and 9, I have

illustrated primary and secondary windings 60 and 61 surrounding the pipe 10 and being spaced a small distance therefrom. Each of these windings comprises a single turn of copper tubing bent around the pipe, as shown in Fig. 9, and spaced from each other a distance of one inch or more. I prefer to direct the heating flame issuing from the burners 28 and 29 between the primary and secondary windings 60 and 61, although this arrangement is not essential to the operativeness of the device. The primary winding 60 is connected to the secondary of a step-down transformer 62 which delivers a low voltage and high amperage to the primary 60 through a circuit 63, the wires of this circuit being connected to the winding 60 by clamp members 64 which clamp around the tube forming the primary winding 60 leaving the ends of the pipe free so that a cooling medium in the form of water or other fluid may be passed therethrough, as indicated by the arrows of Fig. 9.

This cooling medium is supplied thereto through a pipe 65 and a manifold 66, this manifold also supplying cooling medium to the secondary winding in a similar manner, the flow of cooling medium being suitably controlled by valves positioned both in the pipe 65 and in the individual pipes communicating with the tubing forming the primary and secondary windings 60 and 61. The transformer 62 supplies a low voltage current of several hundred amperes through the primary winding 60, this current setting up a magnetomotive force which acts upon the pipe 10 to force magnetic flux therethrough. The secondary winding 61 is linked with the primary winding 60 by means of the flux passing through the pipe 10, and the amount of voltage generated in the secondary winding 61 will be, of course, a function of the amount of flux passing through the pipe 10. If, now, the permeability of the pipe 10 suddenly decreases, the voltage generated in the secondary winding 61 will correspondingly decrease. Thus, by connecting a contact voltmeter or other voltage-responsive means to the secondary winding 61, it becomes possible to utilize this voltmeter for controlling the amount of heat reaching the pipe 10 from any suitable electrically controlled heating means.

I have developed a particular type of contacting voltmeter which finds a particular utility in conjunction with the present apparatus, although its use is not confined thereto. The details of this voltmeter are best illustrated in Figs. 4, 5, and 9.

Referring to these figures, I provide a box structure 70 in which is mounted a pair of voltmeters 71 and 72. These meters are preferably of the iron vane type due to the inherent sturdiness of such a meter. However, other types of meters might be utilized without departing from the spirit of this invention. In Fig. 9, I have diagrammatically illustrated such a meter as having a coil 73 connected to the secondary 61 by conductors forming a circuit 74. The vane of the voltmeter is shown at 75, this vane being mounted on a shaft 76 to which a pointer or hand 77 is secured.

The coil 73 exerts a torque on the vane 75, thus tending to turn the shaft 76 against the action of a spiral spring 78 connected thereto, the free end of this spring being connected to a zero-adjustment means in the form of a lever 79 pivoted at 80 so that a movement of this lever about the pivot 80 changes the zero reading of the hand 77, and consequently changes by a pro-

portionate amount the readings throughout the scale over which this hand normally moves.

Mounted in one end of the box structure 70 is a motor 82 driving a worm 83 meshed with a pinion 84 secured to a countershaft 85, this countershaft journalling in bearings 86. Also secured to the countershaft 85 is a worm 87 which is meshed with a pinion 88 secured to a countershaft 89 journalled in pillow blocks 90 and 91.

Also mounted on the countershaft 89 are cams 92 and 93. A spring arm 94 extends under each cam and is mounted on the rear of the box structure 70 by screws 95. The forward end of each spring arm carries a roller 96 which bears against the cam immediately thereabove, and is held in contact with this cam by the arm 94. The extreme forward end of the spring arm is bent downward to form a blade 97 which is moved downward at fixed time intervals due to the action of the cam 92 on the roller 96. The motor 82 is so geared to the countershaft 89 that the cams 92 and 93 make one complete revolution approximately every ten seconds so that the blade 97 is lowered at intervals of approximately ten seconds.

Mounted on the box structure 70 are primary and secondary switch arms 100 and 102, shaped as best shown in Fig. 4, and pivoting on pivot pins 103 and 104. These switch arms are in the form of bell cranks, and the upper arm of each extends toward each other and is bifurcated, as best illustrated in Fig. 4. The blade 97 is disposed directly above the space between the bifurcations of these upper arms, so that were it not for the hand 77 of the voltmeter, the blade 97 would move downward between the bifurcations of the primary and secondary switch arms at fixed intervals of time. However, the voltmeter is so mounted that the plane of movement of the hand 77 is between the lower edge of the blade 97 and the upper edges of the primary and secondary switch arms 100 and 102. In other words, when the blade is in its uppermost position the hand 77 is between the lower edge of the blade 97 and the upper edge of the primary and secondary switch arms 100 and 102.

The amount of movement of the hand 77 is, however, mechanically limited by stops 105 formed on each of the primary and secondary switch arms 100 and 102. These switch arms are always held in such a position that the upper edges thereof lie just below the hand 77, this being made possible by a spring 108 connecting the two switch arms and holding the lower ends of these arms respectively in engagement with arm-adjusting screws 109 and 110 which are threaded through bosses 111 and 112 and engage the lower end of their respective switch arms, as best shown in Fig. 5.

The current through the primary winding 60 is so regulated, and the position of the zero-adjustment lever 79 is so regulated, that the hand 77 is positioned above or adjacent the ends of both switch arms 100 and 102 when the pipe 10 is at a correct quenching temperature. In this capacity it should be clear that the position of the hand 77 is determined by the permeability of the pipe 10 which is in turn controlled by the temperature of this pipe. Thus, if the temperature of the pipe 10 is too high, the hand 77 will move to the right, as viewed in Fig. 5, and when the blade 97 momentarily moves downward this blade will come into contact with the hand 77 and will force the hand downward into contact

with the secondary switch arm 102, thus momentarily moving this arm into a position shown in the left half of Fig. 5. If, on the other hand, the temperature of the pipe 10 is not high enough, the permeability thereof will be high and the voltage induced in the secondary winding 61 will be high, thus causing the hand 77 to move leftward as viewed in Fig. 5 above the primary switch arm 100 during the time that the blade 97 is raised. When this blade is again momentarily lowered, the hand will be forced into contact with the primary switch arm 100 and will momentarily depress this arm.

The switch arms 100 and 102 thus become a very convenient means for operating electric circuits which control the amount of heat transmitted to the pipe by the sets of gas burners 13 and 14.

In accomplishing this end, I provide contact springs 115 and 116 mounted in a block 117 and extending leftward beyond the secondary switch arm 102. These contact springs have contacts 118 and 119 thereon which are normally separated, but which are closed whenever the upper arm of the secondary switch arm 102 is depressed. Both these contact springs 115 and 116 normally tend to move leftward, the spring 115 remaining in contact with the lower end of the arm 102, and the spring 116 moving leftward until it engages a contact-adjusting screw 120, after which the contacts 118 and 119 separate until the secondary switch arm is again momentarily depressed. A similar set of spring contacts 121 and 122 are similarly mounted and extend forward beyond the primary switch arm 100, these contact springs having a normal rightward tension which keeps the spring contact 122 in engagement with the lower end of the primary switch arm 100 and maintains the spring contact 121 in engagement with a contact-adjusting screw 124.

I utilize the apparatus illustrated in Figs. 4 and 5 for controlling the amount of heat supplied to the pipe by the sets of gas burners 13 and 14. In this capacity, the windings of the voltmeter 71 are connected to the secondary winding 61 associated with the set of gas burners 13, while the winding of the voltmeter 72 is connected to the secondary winding associated with the set of gas burners 14.

The burners 28 and 29 of the set of gas burners 13 are supplied with a combustible mixture through pipes 130 and 131 respectively, these pipes also connecting to a suitable magnetically operated globe valve 132, best illustrated in Fig. 6.

Referring to Fig. 6, the valve 132 has an inlet pipe 133 communicating with an inlet passage 134, this passage being separated from the pipes 130 and 131 by a wall 135 having a valve seat 136 therein. Adapted to engage this seat is a valve member 137 mounted on a stem 138. The vertical position of the stem 138, of course, determines the amount of gas supplied to the pipes 130 and 131. The position of this stem is controlled by a pair of windings 139 and 140 which are mounted respectively in a head member 141 and a base member 142 and act upon an armature 143. The winding 140 is connected to the contact springs 115 and 116 by conductors 145 and 146, while the winding 139 is connected to the contact springs 121 and 122 through the conductor 146 and a conductor 147. A source of potential 149 is inserted in the conductor 146. Thus, when the contacts 125 and 126 momentarily come into engagement a circuit is completed through the winding 139, thus tending to attract the arma-

ture 143 and move this armature upward in a manner to allow a greater quantity of gas to reach the burners 28 and 29. The uppermost position of this armature is determined by contact with the head member 141, and I prefer to make this head member adjustable by means of a bolt 151 passing through a supporting frame 152 and threaded into the head member 141.

Similarly, the lowermost position of the armature 143 is determined by contact between the base member 142 and this armature, and I provide a pair of adjusting bolts 153 for controlling the position of the base member 142 in a manner to control the lowermost position of the valve member 137. The bolts 153 are threaded into the base member 142 and pass through openings in the supporting frame 152.

I prefer to provide a toggle mechanism for holding the armature either in its extreme upper position or in its extreme lower position. This toggle mechanism may be of any desired type, the one illustrated in Fig. 7 comprising an arm 160 pivoted to the supporting frame 152 by a pin 161. A slot 162 formed in the arm 160 is adapted to receive a pin 163 which is mounted in a ledge 164 of the armature 143. A toggle spring 165 connects a pin 166 on the free end of the arm 160 and a pin 167 fastened in the supporting frame 152. These pins are so arranged that when the armature is in its lower position, the axis of the spring 165 lies below the axis of the pin 161 and when the armature is moved into its upper position, the axis of the spring moves to the upper side of the axis of the pin 161, thus insuring that the armature will remain in either extreme upper or extreme lower positions until moved therefrom by the energization of the correct winding. Thus, when the armature is moved into its lower position due to the momentary energization of the winding 140, the globe valve 132 will be opened to admit a minimum amount of combustible mixture to the gas burners 28 and 29.

Any successive energizations of the winding 140 due to a successive closing of the contacts 118 and 119 will not move the armature 143. The amount of heat transmitted to the pipe will decrease, due to the limited amount of combustible mixture passing through the valve 132 and when the temperature has been sufficiently lowered the permeability will rise and increase the voltage generated in the secondary winding 61 which will in turn move the hand 77 above the primary switch arm 100.

Upon the next movement of the blade 97 by the cam 92, the contacts 125 and 126 will be momentarily closed, thus completing a circuit through the upper winding 139 which moves the armature 143 into an upper position wherein a maximum amount of gas is allowed to pass through the valve 132. The amount of gas passing through the valve when the armature is in an upper position and in a lower position may be readily determined by adjusting the bolts 151 and 153. By making the difference in flow when the valve is in these two positions relatively small, a very uniform temperature may be maintained due to the action of the gas burners 28 and 29. This arrangement is very sensitive, especially if the flux density in the pipe is adjusted to such a value that the change in permeability near the critical temperature is rapid.

It should be understood that Fig. 9 shows the control for only the set of gas burners 13, and that a similar control is utilized for a valve 170

which controls the amount of heat transmitted to the pipe from the set of gas burners 14, this valve being magnetically controlled in a manner similar to the valve shown in Fig. 6, and being controlled by the voltmeter 72 in the same manner that the voltmeter 71 controls the valve 132. The setting of the voltmeters 71 and 72 is slightly different due to the fact that the set of burners 13 raise the temperature somewhat above the temperature developed in the furnace 12, and the set of burners 14 raise this pipe to the proper quenching temperature or slightly above to compensate for the slight cooling which takes place before quenching. In certain installations it is possible to dispense with one of the sets of burners 13 and 14 and to utilize a single burner for raising the temperature of the pipe from that of the furnace 12 to the proper quenching temperature.

It should be understood that it is not necessary to control the flow of combustible gas to the gas burners, this particular combination being shown only for illustration. It is entirely possible to control the flow of one or more of the ingredients of any combustible mixture supplied to the burners, whether this be a liquid or a gas. Furthermore, the contacting voltmeters illustrated in Figs. 4 and 5 may be utilized for controlling the movement of the burners 28 and 29 toward and away from the pipe so as to vary the amount of heat transmitted to this pipe. Such systems fall within the scope of the appended claims.

Furthermore, it should be understood that I am not limited to any particular type of voltmeter 71 and 72, the one illustrated in Fig. 9 being of the iron vane type only for the purpose of illustration. Furthermore, the relative position of the vane 75 and the hand 77, as shown in Fig. 9, has been shown only for the purpose of clearness. It is ordinarily desirable that the hand 77 be in the upper portion of its path of travel over the ordinary meter scale at the time that it lies between the stops 105 on the primary and secondary switch arms 100 and 102. This is due to the relationship which ordinarily exists on an alternating current meter, whereby the hand 77 is much more sensitive to small changes in voltage over this portion of the scale than over the lower portion of the scale.

The temperature to which the pipe is raised by the burners may, of course, be regulated in numerous ways. With the apparatus illustrated, this regulation may be effected (1) by changing the current through the primary winding, (2) by changing the distance between the primary and secondary winding, (3) by changing the position of the voltmeter relative to the box structure 70, or (4) by changing the position of the lever 79 which controls the zero reading of the hand 77. Any of these or still other means may be utilized without departing from the spirit of my invention.

I claim as my invention:

1. In a device for heat-treating a perforated pipe, the combination with a heating means adapted to raise the temperature of said pipe to a quenching temperature, of quenching means adapted to pass a quenching medium peripherally around said pipe and in contact with the periphery thereof; means for removing from the interior of said pipe any portion of said quenching medium that may enter through said perforations; and means for moving said pipe from said heating means to said quenching means.

2. In a device for heat-treating a body, the

combination of: a first heating element comprised of primary and secondary windings inductively coupled through a portion of said body and having heating mechanism adapted to heat said portion of said body and connected with said secondary winding, the amount of heat transmitted to said body by said heating mechanism being determined by the electromotive force generated in said secondary winding, said first heating element being adapted to heat said portion of said body to a temperature slightly below the quenching temperature of said body; a second heating element similar to said first heating element, said second element being adapted to heat said portion of said body to a temperature slightly in excess of the quenching temperature of said body; and means for moving said body from a position in which said portion is adjacent to said first heating element to a position in which said portion is adjacent to said second heating element.

3. In a device for heat-treating a body, the combination of: a first heating element adapted to heat said body, said first heating element being adapted to heat said body to a temperature slightly below the quenching temperature of said body; a first means for passing a magnetic flux through said body; a first means controlled by said magnetic flux adapted to regulate the amount of heat applied to said body by said first heating element; a second heating element, said second element being adapted to heat said body to a temperature slightly in excess of the quenching temperature of said body; a second means for passing a second magnetic flux through said body as said body is heated by said second heating element; a second means controlled by said second magnetic flux adapted to regulate the amount of heat applied to said body by said second heating element; and means for moving said body from a position in which it is adjacent said first heating element to a position in which it is adjacent said second heating element.

4. In a device for heat-treating a relatively long and narrow body, the combination of: a first heating element adapted to heat a short section of said body, said first heating element being adapted to heat said section to a temperature slightly below the quenching temperature of said short section; a first means for passing a magnetic flux through said short section; a first means controlled by said magnetic flux adapted to regulate the amount of heat applied to said short section by said first heating element; a second heating element, said second element being adapted to heat said short section to a temperature slightly in excess of the quenching temperature of said short section; a second means for passing a second magnetic flux through said short section as said short section is heated by said second heating element; a second means controlled by said second magnetic flux adapted to regulate the amount of heat applied to said short section by said second heating element; and means for moving said body from a position in which said short section is adjacent said first heating element to a position in which said short section is adjacent said second heating element.

5. In combination in a device for heat-treating a relatively long and narrow body by heating, preparatory to quenching, each individual section in degree varying with its metallurgical structure: heating means adjacent which said body advances and heating only a short section of said body opposite said heating means; flux-

producing means passing magnetic flux through said short section opposite said heating means; means for varying the amount of heat applied to said short section by said heating means; and means operatively connected to said last-named means and responsive to the amount of flux moving through said short section at any instant of time to vary the pre-quenching temperature in said short section in response to the characteristics of the short section adjacent said heating means at any instant of time.

6. In combination in a device for heat-treating a relatively long and narrow body by heating, preparatory to quenching, each individual section in degree varying with its metallurgical structure: heating means adjacent which said body advances and heating only a short section of said body opposite said heating means; a first winding on one side of said heating means and sending magnetic flux longitudinally along said body through said short section which is under the influence of said heating means at any particular instant of time; a second winding on the other side of said heating means and inductively coupled to said first winding by said flux flowing along said body and through said short section; and means responsive to the potential generated in said second winding for controlling the amount of heat received by said short section at any instant of time, whereby the pre-quenching temperature of each short section is controlled in response to its own characteristics.

7. In combination in a device for heat-treating a relatively long and narrow body by heating, preparatory to quenching, each individual section in degree varying with its metallurgical structure: a direct-flame heating means producing a flame impinging against a relatively short section of said body; flux-producing means passing magnetic flux through said short section opposite said heating means; means for varying the amount of heat applied to said short section by said heating means; and means operatively connected to said last-named means and responsive to the amount of flux moving through said short section at any instant of time to vary the pre-quenching temperature in said short section in response to the characteristics of the short section adjacent said heating means at any instant of time.

8. In combination in a device for heat-treating a relatively long and narrow body by heating, preparatory to quenching, each individual section in degree varying with its metallurgical structure: a direct-flame heating means producing a flame impinging against a relatively short section of said body; a first winding on one side of said heating means and sending magnetic flux longitudinally along said body through said short section which is under the influence of said heating means at any particular instant of time; a second winding on the other side of said heating means and inductively coupled to said first winding by said flux flowing along said body and through said short section; and means responsive to the potential generated in said second winding for controlling the amount of heat received by said short section at any instant of time, whereby the pre-quenching temperature of each short section is controlled in response to its own characteristics.

9. In combination in a device for heat-treating a relatively long and narrow body by heating, preparatory to quenching, each individual section

in degree varying with its metallurgical structure: means for advancing said body; preliminary heating means for raising the temperature of that portion of said body leaving same to a degree slightly below the quenching temperature; a second heating means adjacent which said body moves and heating only a short section of the advancing body to the quenching temperature; and means controlling said second heating means to supply an increment of heat necessary to raise the short section thereadjacent at any instant of time to the quenching temperature suited to the metallurgical structure of this particular short section, said means including means for passing magnetic flux through the particular short section undergoing heating and including means responsive to the quantity of flux flowing through said short section for controlling the heat applied to said short section by said second heating means.

10. In a device for heat-treating a relatively long and narrow body providing a cylindrical exterior surface, the combination with a heating means for raising to a quenching temperature that section of said body leaving said heating means, of: a cylindrical shell adjacent said heating means and through which each section of said heated body moves immediately after leaving said heating means, said cylindrical shell cooperating with said cylindrical exterior surface of said body in providing an annular space surrounding said body; means for tangentially introducing a quenching medium into said annular space; and means for forcibly withdrawing said quenching medium from that end of said annular space furthest from said heating means.

11. In a device for heat-treating a length of pipe without application of excessive pressure to the surface thereof, the combination with a heating means, of: a cylindrical shell adjacent said heating means and through which the heated pipe moves for rapid quenching, said cylindrical shell cooperating with the cylindrical periphery of said pipe in defining an annular space; and means for introducing a stream of quenching medium into said annular space in a direction to not impinge at a steep angle against the peripheral surface of said pipe thereby preventing distortion thereof, said means including a nozzle means directing a stream of quenching medium tangentially into said annular space toward said cylindrical shell whereby said stream impinges against said cylindrical shell rather than against said pipe and is deflected by said cylindrical shell to flow circumferentially around said pipe in contact with the periphery thereof.

12. A combination as defined in claim 11 in which said pipe is perforated, and including means reducing the pressure inside said pipe to draw said quenching medium through said perforations.

13. In a device for heat-treating a long perforated pipe, the combination with a heating means through which the pipe is moved, of: a shell through which said pipe moves after leaving said heating means; and means forcibly moving a quenching medium through the perforations of said pipe from said shell into the interior of said pipe, said last-named means including means for introducing quenching medium into said shell and means for reducing the pressure inside said pipe to draw said quenching medium thereinto.

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