

Sept. 14, 1943.

F. S. DENNEEN ET AL
PROGRESSIVE HEAT TREATING

2,329,188

Filed June 19, 1941

4 Sheets-Sheet 1

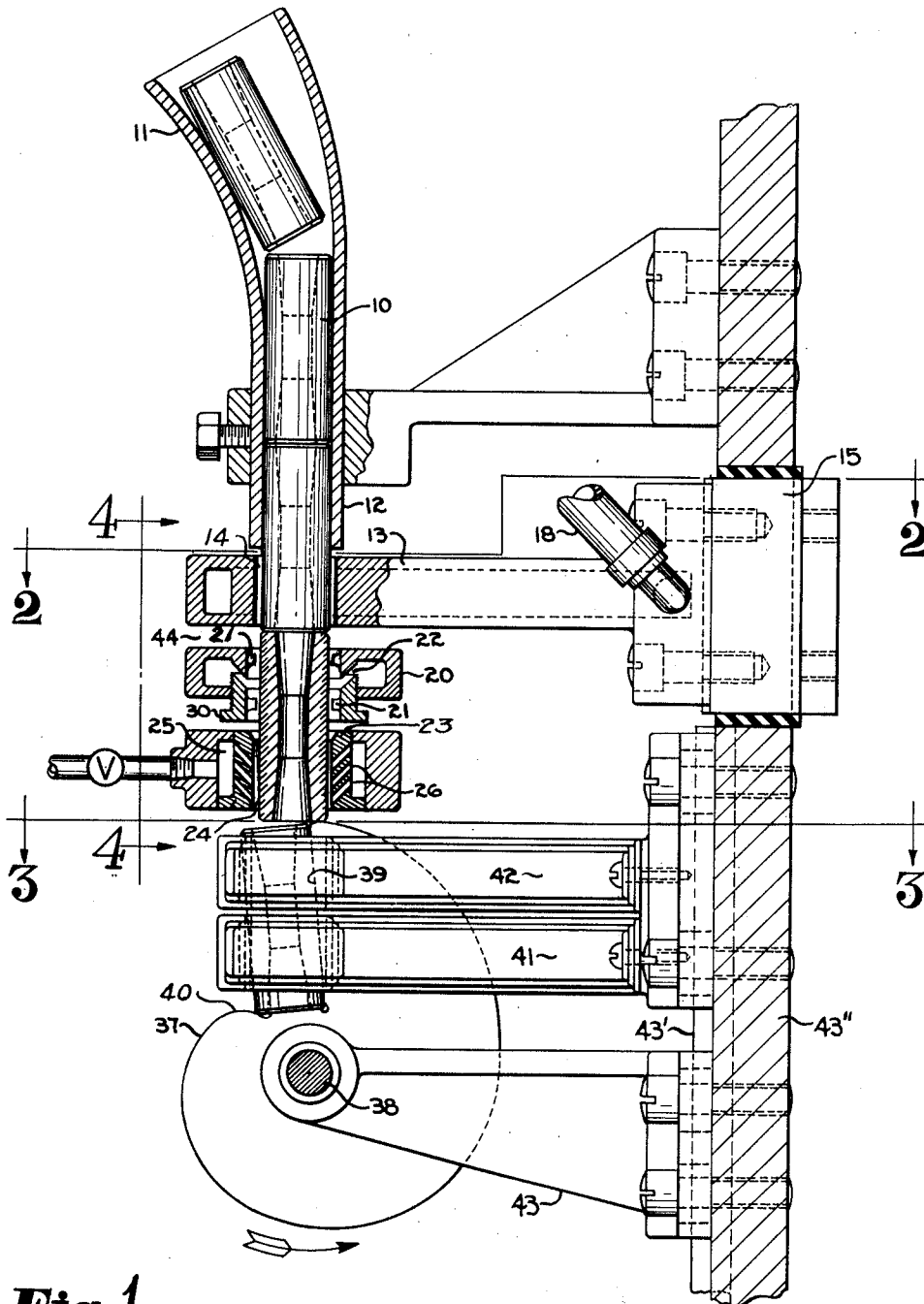


Fig. 1

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4 Sheets-Sheet 2

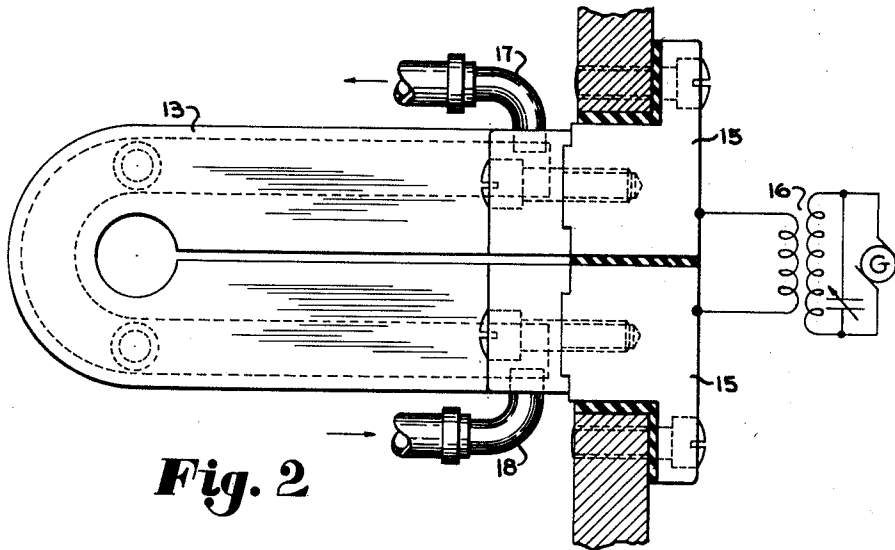


Fig. 2

Fig. 3

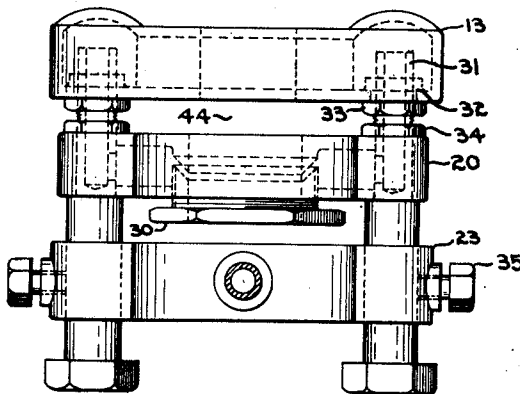
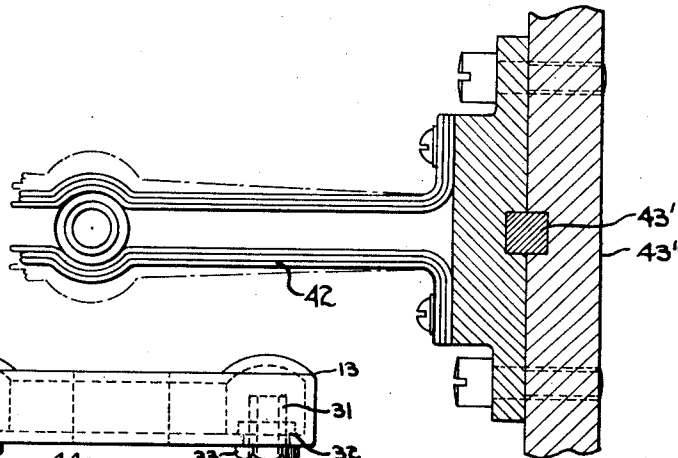


Fig. 4

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4 Sheets-Sheet 3

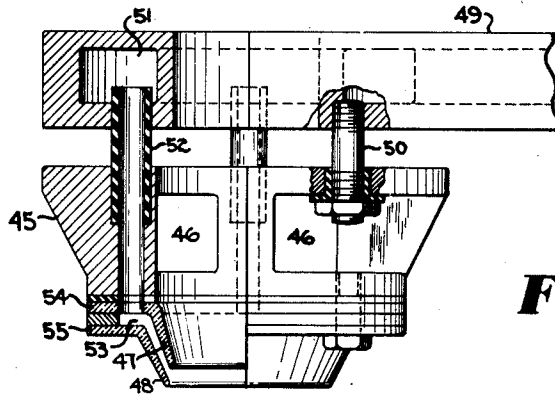


Fig. 6

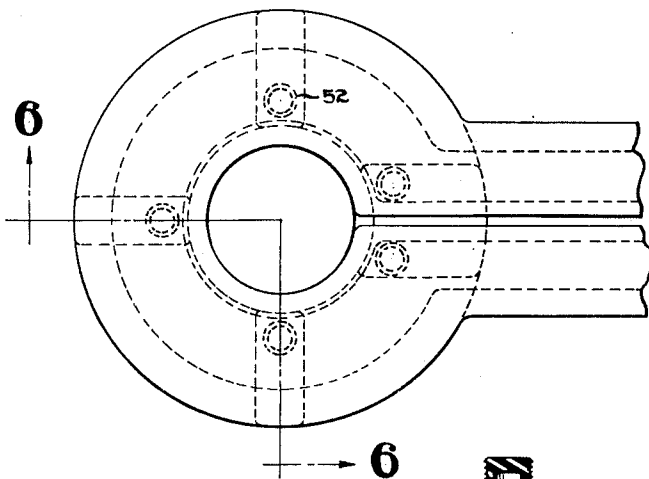


Fig. 5

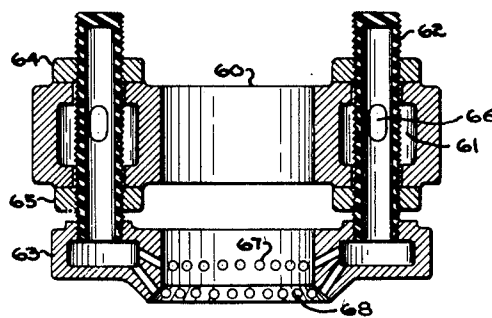


Fig. 7

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4 Sheets-Sheet 4

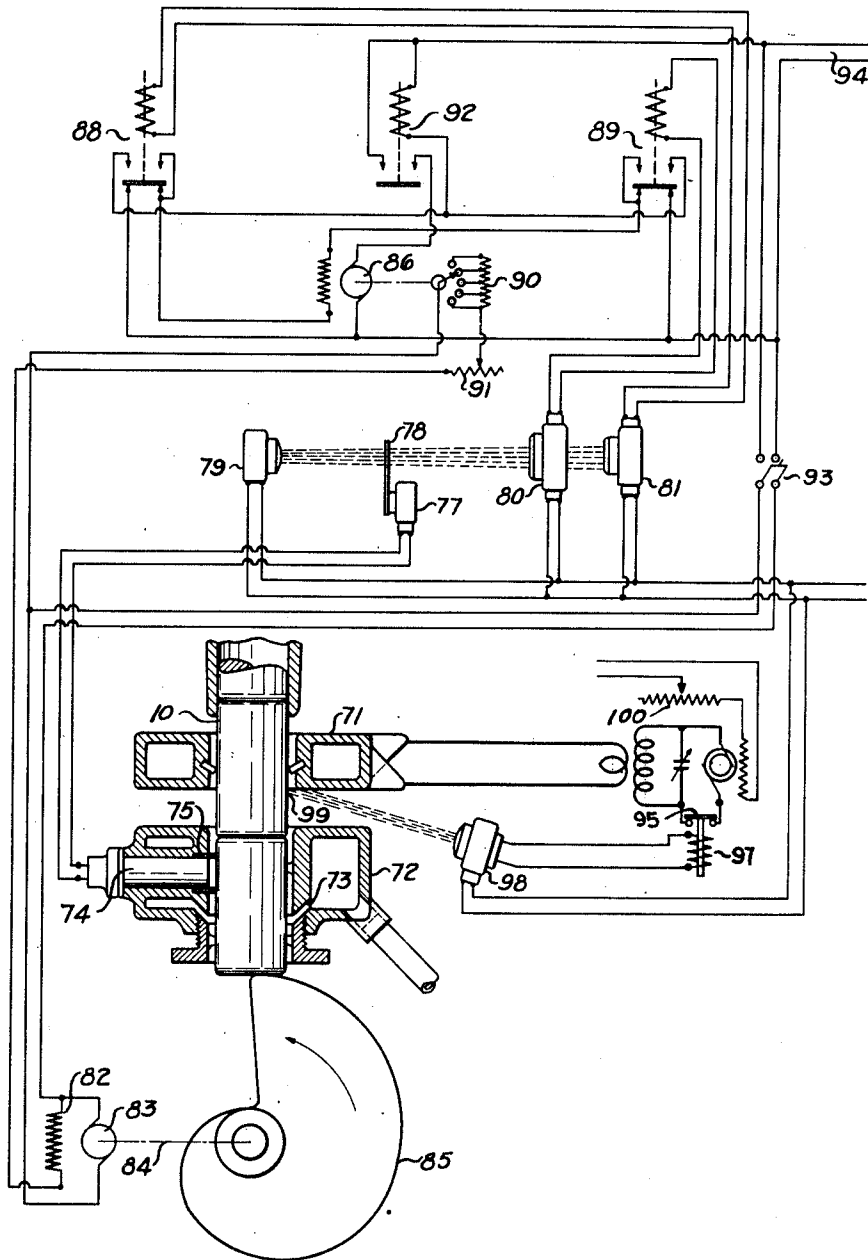


Fig. 8

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UNITED STATES PATENT OFFICE

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PROGRESSIVE HEAT TREATING

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Application June 19, 1941, Serial No. 398,726

12 Claims. (Cl. 266—4)

This invention relates to apparatus for progressively heating articles and is particularly adapted to the heat treatment of a series of articles in relatively rapid succession.

Heat treating a series of similar articles in a progressive manner is well known in the art, but limiting and accurately controlling such heat treatment to definite surface zones of varying forms and depths and accomplishing the heat treatment of the articles in rapid succession for mass production, has not been accomplished successfully heretofore. In the manufacture of articles such as piston pins it is often desired to have the entire outer cylindrical surface zone hardened, but it is important that this zone be so limited in depth that the wall of the pin is not hardened entirely thru at those points where the wall is thin and that the depth of the hardened zone be of generous and ample proportions where the wall is thick and where the greatest amount of bearing wear occurs.

The chief object of our invention has been to provide apparatus for successively hardening to varying depths the surface zones of a series of articles. Another object has been to provide means for accomplishing such hardening in rapid succession. A further object has been to provide automatic temperature controlled means for controlling the rate of movement of the articles during heating and quenching. Other objects will become apparent from the following description.

With the above and related objects in view, the said invention consists of the means hereinafter described together with the steps employed in using this or similar means, which means and steps are particularly pointed out in the claims. The annexed drawings and the following description set forth in detail certain means and one mode of carrying out the invention, such disclosed means and mode illustrating, however, but one of various ways in which the principle of the invention may be used.

In the annexed drawings:

Figure 1 is an elevation partly in section showing the preferred form of our apparatus.

Figure 2 is a section taken substantially at 2—2 of Figure 1.

Figure 3 is a section at 3—3 of Figure 1.

Figure 4 is an elevation and indicated at 4—4 of Figure 1.

Figure 5 is a plan view showing a modification of the inductor shown in Figure 2.

Figure 6 is a section substantially on line 6—6

of Figure 5 showing both inductor and quench ring.

Figure 7 is a further modification of the inductor and quench ring.

Figure 8 is a schematic illustration, showing a temperature responsive control mechanism applied to the apparatus of Figure 1.

Referring now to Figures 1, 2, 3 and 4 of the drawings, the parts to be hardened, and which may assume a variety of forms, are illustrated by the piston pins 10 which are delivered by gravity from the adjustable chute 11 thru the guide tube 12 to the inductor 13 thru which they pass with suitable clearance as indicated at 14. Current of suitable frequency is supplied to this inductor from bus bars 15 usually connected to a transformer such as 16. Cooling fluid supplied by lines 17 and 18 regulates the temperature of the inductor. The current in the inductor produces heating currents which flow peripherally, chiefly in that part of the outer surface zone of the pin which is within the inductor. As increments of the pin emerge from the inductor they have been heated to or above hardening temperature. The pin in moving downwardly enters the quench ring 20 which is provided with lugs or radial projections 21 to assist in holding the pin in line as it passes downwardly. Quench ring 20 is provided with a peripheral passage 22 located at such distance from the inductor as to delay the quenching until the temperature of the pin has dropped to the desired level in its downward travel, and at such angle as to sweep away any pockets of steam or other gas which tend to form on the surface of the pin. As the pin continues to descend it enters guide ring 23 which is provided with axial flutes as at 24 and with a quench chamber 25 from which additional quenching fluid is delivered thru orifices 26 onto the pin to complete the quenching. Valve V controls the delivery of quenching fluid to chamber 25.

The amount of quenching fluid and the pressure of this fluid when it is projected against the pins is controlled by the opening of passage 22. This opening is regulated by adjustable ring 30 which is threaded into the body of the quench ring 20. Not only is the amount of quenching fluid regulated, but the distance from the inductor to the point where this fluid impinges against the pins is controlled. This is accomplished by regulating the distance of the quench ring 20 from the inductor. The quenching fluid is supplied to the quench ring by the inductor which in turn is supplied by lines 17

and 18, this fluid in passing first thru the inductor prevents any harmful rise in its temperature as pointed out above. The quenching fluid is delivered to the quench ring from the inductor by means of the hollow screws or studs 31 shown more clearly in Figure 4. These hollow screws not only serve as means to deliver the quenching fluid to the quench ring, but serve as means to regulate the axial positions of both quench rings 20 and 23. The screws 31 are threaded into the inductor as at 32 and are held in adjusted positions by jam nuts 33. Rings or nuts such as 34 hold quench ring 20 at the correct level and set screws 35 support the lower quench ring 23. The parts of both upper and lower quench rings are usually made of non-conducting material, such as micarta, to eliminate the use of special bushings and other insulators. Passages are provided in the sides of the screws 31 to deliver the quenching fluid into the annular chamber of ring 20.

Each pin as it descends is supported by another pin which has preceded it in its downward movement. The last or lowest pin is supported by cam 37 which is formed to regulate the rate of movement of the column of pins and, as a result, the rate of travel of each pin as it passes not only the inductor but the quench rings also. Thus for a uniform supply of power to the inductor, the rate of movement will control the depth of the heated zone. It is usually possible to control the rate of movement by the form of the cam only, but in some cases a further control is provided by varying the rate of rotation of the shaft 38 on which the cam is mounted.

The bore of the piston pin is usually enlarged at both ends from a minimum diameter at its central portion leaving a greater wall thickness at its center. Since greater pressures and hence greater wear are usually imposed on the central part, it is desired to provide a hardened zone of greater depth at its center. To accomplish this, the cam 37 is so formed that the axial movement of the pin is slower as this center part passes thru the inductor 12 than while the end parts are passing therethru, thus giving more time for the induced currents to penetrate deeper and thus to heat deeper at this center part. This varying rate of travel is made such by the form of the cam as to taper out the depth of the hardened zone to the desired minimum at both ends.

As the cam continues to rotate in the direction indicated, the face 39 of the cam engages the side of the pin at its upper end and tips it into the inclined position shown while the pin continues to descend supported by the portion 40 of the cam. The supported end of the pin slides along this portion 40 which is so formed that the pin continues to descend while it is being tipped and expelled by face 39 of the cam, thus permitting the succeeding pin above to descend at the correct rate during the period of ejection. Pairs of support springs 41 and 42 serve as means for holding the pin in a substantially vertical position as it descends out of lower quench ring 23. In its lower position the lower end of the pin is held by lower springs 41 while the upper springs open under pressure of the cam acting against the upper end of the pin. As the cam continues to rotate from the position shown, the pin is carried out bodily and permitted to fall into a suitable receptacle while the pin following from above contacts the cam and continues

its downward movement in the same manner as the pin which had preceded it.

By changing cams and by changing the distance between the cam center and the lower quench ring, pins of various lengths can be heat treated.

This is accomplished by raising or lowering bracket 43 carrying shaft 38 of cam 37. The spline or key 43' serves as means for guiding the bracket. Slotted holes in the bracket for the screws holding the bracket in engagement with support 43'' permit this movement when the screws are loosened. Key 43' also serves as means for guiding the support for springs 41 and 42 which also are adjusted in some cases when cam 37 is changed or is raised or lowered.

By varying the power input to the inductor and/or the rate of rotation of the cam the depth of the heated zone and/or the linear rate of heat treating is controlled. The general arrangement of the inductor and quench rings also are radially changed to accommodate varying conditions and varying requirements in the finished product.

It is usually necessary to inspect the pins as they leave the indicator and before they enter the quench ring so as to know that they are at the right temperature when quenching begins. For that reason practically all quench rings are arranged either as to form or location so as to permit the heated parts to come into view as these parts leave the inductor. The required distance between the inductor and quench ring, such as the space 44, is usually sufficient for this purpose. In other cases it is not, and the mechanism must be so formed as to provide inspection openings.

In the modification shown in Figures 5 and 6 the quench ring comprises the support 45 having inspection ports 46 and quench discharge members 47 and 48. The annulus of quenching fluid is thus spaced at some distance from the inductor 49 altho the support may be made as narrow as required to reduce this spacing. The support with its discharge members is adjustable longitudinally of the travel of the pins or other parts thru the inductor by means of studs or screws 50. Quenching fluid is taken from chamber 51 in the inductor by means of insulating tube 52 which is slidable in the inductor and this fluid is delivered into space 53 between the flanges 54 and 55 of the quench delivery members. These delivery members may be made of any suitable metallic material, but preferably are made of heat resisting glass to render the articles visible as they approach the quenching region just at the lower edge of the outer member. The direction of the elements of the conical sheet of quenching fluid is readily changed by replacing one or both of the quench delivery members by others.

Another modification in which only one quench ring is employed is shown in Figure 7. In this arrangement the inductor 60 has an annular cooling fluid chamber 61 thru which tubular studs 62 pass for holding the quench ring 63. This quench ring has a multiplicity of passages directing quenching fluid at the desired angles against the parts being heat treated as these parts pass thru this quench ring. The quench ring is raised and lowered as desired by means of nuts 64 and 65 seating on the upper and lower faces respectively of the inductor. Passages such as 66 are provided in the tubular studs for receiving the quenching fluid so as to deliver it

to the quench ring chamber. The delivery passages from the quench ring are directed as required to insure the necessary quenching and are arranged in annular rows. The passages in the upper row 67 usually are of a different size and at a different angle than the passages 68 in the lower row and are usually staggered to distribute the quenching fluid over a greater surface of the articles being quenched.

Since manual control cannot be depended upon to provide the high degree of accuracy required to produce the uniform results demanded, automatic means for regulating heating and quenching are resorted to in many cases. The amount of heat imparted to the article being heat treated is controlled either by varying the rate of power being delivered during the heating interval or by keeping the delivery of power substantially constant and varying the rate of travel of the article thru the heating region, or by both. For a given rate of travel, the power input must be regulated to produce the required heating, not only as to surface temperature but as to depth of the heated zone. If the power input is fixed, the rate of travel is regulated to provide the correct temperature and depth of heated zone.

In the present case, the cam employed is of fixed form and, for a constant speed of the cam shaft, provides a definite rate of travel which may be constant or which may vary at different parts of the movement depending on the form of the cam. Regardless of the form of the cam or the power input, sufficient heat must be added to bring the surface zone to hardening temperature. To insure attaining this temperature an automatic control mechanism responsive to the temperature of the surface zone has been provided.

The mechanism for insuring automatic temperature control is shown in Fig. 8. In this figure the apparatus substantially as illustrated in Fig. 1 is provided with a temperature responsive element connected to control the movement of the article being heated and quenched. As the article 10 passes inductor 71 its temperature rises until it reaches a maximum at the point where it leaves the flux field produced by the inductor. This temperature usually is a little above the critical so that as the article enters the quench ring 72 its temperature drops gradually until the quenching region at the annular passage 73 is reached where vigorous quenching occurs due to fluid quenching medium supplied under pressure. Since different articles require different temperatures and thus different rates of travel in passing from the inductor to the quench ring, means for controlling the temperature of the article at the time it reaches the quenching passage must be provided.

Since such control is difficult to operate manually, automatic means is desirable and often necessary. To accomplish this control, a temperature responsive member such as the thermo-couple 74 is often employed. This is usually placed as closely as possible to the quenching passage since the temperature of the article at the time of quenching is the factor which determines to a major extent the results of the heat treatment. To prevent the steam or other vapors resulting from the quenching from contacting with the thermo-couple thus influencing its voltage, a shield 75 is provided to protect the thermo-couple and to lie closely enough to the article to prevent the vapors from readily passing into the space within the shield.

Since the current delivered by a thermo-couple, or by other temperature responsive devices, is usually very small, the thermo-couple is connected to a sensitive instrument such as the galvanometer shown at 77, the indicator 78 of which requires a very small moving force. By means of a light 79 and one or more photo electric cells such as 80 and 81, which are usually placed side by side, the current in the field 82 of the variable speed motor 83 is changed thus changing the speed of shaft 84 carrying feed control cam 85, the motor being connected to drive this shaft.

The indicator 78, in certain positions, serves as a shield to interrupt the passage of light from the source of illumination 79 to the photoelectric cells 80 and 81, which cells are connected through suitable relays to supply current to motor 86. The current supply to this motor controls its movement to regulate the field 82 and consequently the speed of motor 83, which motor, thru suitable gearing and shaft 84, rotates feed cam 85. Both of these motors are preferably of the direct current shunt wound type. The photo-electric cells 80 and 81 thru solenoid operated switches 88 and 89 operate to reverse the direction of motor 86 and consequently to increase or decrease resistance in rheostat 90 in the circuit of field 82 of feed motor 83. A hand operated rheostat 91 is included in this field also to serve as a preliminary adjustment for the speed of this motor. Solenoid operated switch 92 serves as means for opening the circuit supplying current to motor 86 so as to stop this motor and to thus leave the field rheostat 90 in its normal operating position when this position has once been reached.

Current is supplied to motor 83 by means of switch 93 which connects this motor to direct current power lines 94 which lines also supply current to motor 86. High frequency current of suitable power is supplied to inductor 71 by means of switch 95.

The operation of this mechanism is substantially as follows:

Connections are made as indicated on the drawing, switches 93 and 95 being closed to start feed cam 85 and to supply heating current to inductor 71. The temperature of pins 10 rapidly increases and is somewhat above the critical as these pins leave the alternating flux field of the inductor and enter quench ring 72. The temperature of these pins is indicated by the voltage of thermo-couple 74 just before the heated surface of the pin passes into the conical sheet of quenching fluid emerging from passage 73. This voltage causes operating current to pass thru galvanometer 77 and to cause the galvanometer needle 78 to move so as to pass across and interrupt the beams of light passing from source of illumination 79 to photo-electric cells 80 and 81, the end of this needle having a shielding disc or plate. In moving in one direction it interrupts the light beam passing to one of these cells and in moving in the opposite direction it will interrupt the light beam passing to the other cell. In its central position, which corresponds to the desired quenching temperature of the pin as transmitted to the galvanometer by the thermo couple 74, the needle shields light from both cells 80 and 81 simultaneously, the needle being formed so as to accomplish this shielding substantially in its central position.

As a precautionary measure against failure in the control circuits, such, for instance, as an interruption of supply of current to motor 83 and/or motor 86 which would result in serious overheating of pin 10 and possible injury to the mecha-

nism, means is provided for automatically interrupting the supply of power to inductor 71 when such overheating tends to occur. This is accomplished by opening switch 95 by means of solenoid 97, the current supply to this solenoid being controlled by a temperature responsive means such as photo-electric cell 98 which is so directed as to intercept light produced by an overheated condition of pin 10 at the point 99 where this pin leaves the inductor 71 and which is the point where maximum temperature usually occurs.

It will be understood that a photo-electric cell can be employed instead of the thermo-couple 74 when apparatus more rapidly responsive to variations in temperature than the thermo-couple is required. The rate of movement of the articles 10 is controlled by both the form of cam 85 and by its rate of rotation. Its form is changed by substituting other cams. Such other cams may not only provide different rates of travel, but provide for handling articles of different lengths. The shaft carrying the cam is readily raised or lowered along the guide key, such as 43' of Figs. 1 and 3, to accommodate such substituted cam. The cam is formed to vary the rate of movement of the article will vary the time during which succeeding parts of the article are in proximity with the inductor and will thus vary the degree of heating being accomplished. To prevent overheating of the surface metal when the normal rate of rotation of the cam lets the article move too slowly, and to prevent under heating when the rate is too fast, the thermo-couple 74 thru the light actuated relays 80 and 81 changes the rate of rotation of the cam. The variation in the rate of movement of the article will be the same as before, but will occur in longer or shorter periods of time depending on whether the speed of the shaft is decreased or increased by the relays.

In some cases the cam is formed to give a uniform rate of travel to the article and the relays serve as before to keep the surface temperatures within the prescribed limits. Variations in the depth of heating, in either case are readily controlled further by regulating the amount of power delivered to the inductor by regulating the field current of the generator such as by rheostat 100 or by other regulating means if power is supplied by some type of equipment other than the usual generator.

Other modes of applying the principle of our invention may be employed instead of the one explained, change being made as regards the structure herein disclosed and the steps employed in its use, provided the means or method stated by any of the following claims or the equivalent of such stated means or method be employed.

We therefore particularly point out and distinctly claim as our invention:

1. In a method of heat treating a metallic article, the steps comprising progressively moving the article in series with other articles, passing said article downwardly relative to an inductor and in close proximity with the inductor, controlling the rate of movement of the article by means of a supporting cam, regulating movement of the cam by temperature actuated means to control the heating, passing the article from the inductor into quenching means, regulating the distance between the inductor and the quenching means to control a drop in temperature before quenching, supplying power to the inductor at a predetermined rate, and discharging the article

by bringing a side of the cam into engagement therewith.

2. In a method of heat treating a series of metallic articles, the steps comprising progressively moving the articles in contiguous relation with each other past an inductor, supplying current to the inductor to induce heating current in the articles, controlling a rate of movement of one of the articles by the temperature of a preceding article to maintain surface temperatures of a succeeding article within prescribed limits, moving the articles into a quenching means, and adjusting a member comprising a part of the quenching means to control a stream of fluid being projected at an acute angle against a heated surface of the article.

3. In a method of hardening corresponding surface zones of a series of ferrous articles, the steps comprising advancing the series of articles downwardly by gravity past an inductor and in heating proximity with the inductor, supplying inducing current to the inductor, to heat the articles, each of the articles being supported by the article below it, controlling the movement of the lowest article to control the rate of movement of the series of articles and to cause each article to pass the inductor at a predetermined varying rate to vary the heating of each of the articles, and projecting quenching fluid against a heated part of the article and at an acute angle with the direction of movement to quench the heated zone of the article at a predetermined distance from the inductor.

4. In a method of hardening corresponding surface zones of a series of ferrous articles, the steps comprising advancing the articles downwardly by gravity past an inductor and in heating relation to the inductor, each of said articles being supported by the article below it, controlling the movement of the lowest article to permit the series of articles to descend at a predetermined rate to vary the heating of each of said articles, the movement being regulated so that the varying of the heating in one article is substantially the same as the varying of heating in another article of the series.

5. In apparatus for progressively heat treating an article, the article being adapted to be hardened by heating and quenching, a heating member and a quenching member, means for supplying power to the heating member to heat the article, means for variably controlling gravitational movement of the article in heating relationship with the heating member and in quenching relationship with the quenching member, adjustable means for supplying cooling fluid to the heating member, adjustable means connecting the quenching member to the heating member to vary spacing between the heating member and the quenching member, said means serving as a passage to conduct the cooling fluid from the heating member to the quenching member, and a passage in the quenching member to deliver the cooling fluid onto a heated surface of the article to quench said surface, said passage being directed downwardly at an acute angle with the direction of gravitational movement of the article.

6. In apparatus for progressively heat treating an article, the article being adapted to be hardened by heating and quenching, an inductor, cam means adapted to support the article and for controlling a variable downward movement of the article to cause a surface zone of the article to progressively pass the inductor in closely spaced relation thereto, means for supplying periodically

varying current to the inductor to induce heating current in the surface zone so that the surface zone will attain a predetermined temperature while the zone passes the inductor, a quenching member in spaced proximity with the inductor and disposed to quench the surface zone progressively after the said zone has passed the inductor, means for varying the space between the inductor and the quenching member to bring the quenching into timed relation with the attainment of the predetermined temperature of the zone, the said space being determined by the rate of travel of the article, and a passage in the quenching member for directing a stream of quenching fluid downwardly and against a heated surface of the article while the article passes the quenching member.

7. In apparatus for progressively heat treating a contiguous series of longitudinally extending metallic articles, a heating member, means for controlling a gravitational movement of one of the articles to control movement of all of the articles to progressively bring a surface zone of each article successively into heating proximity with the heating member, means for supplying power to the heating member to cause a rise in temperature of the surface zone, the said means for controlling the movement of the articles being formed to vary the rate of said movement to progressively change the depth of the heated zone, and means for quenching the heated zone, said means comprising a passage for quenching fluid directed toward said article, the said passage being spaced from the aforesaid heating member to provide a predetermined interval between the termination of the rise in temperature and the beginning of quenching.

8. In apparatus for progressively heat treating a metallic article, a heating member and a quenching member, means for controlling a variable gravitational movement of the article to progressively bring a surface of the article into heating proximity with the heating member, means for supplying power to the heating member to raise the temperature of a surface zone of the article, means for flowing quenching fluid into the quenching member, and an adjustable passage in the quenching member to deliver the quenching fluid onto a heated increment of the aforesaid surface in time spaced relation with the termination of a rise in temperature of the surface of the article, the fluid being delivered onto the heated increment substantially in the directions of elements of an inverted cone.

9. In apparatus for progressively heat treating an elongated ferrous article, a heating member adapted to progressively heat the article, means for controlling gravitational movement of said article past the heating member, said means comprising a cam adapted to engage an end of the article for controlling movement of the article

to vary the rate of travel of the article, and means for supplying power to the heating member to heat increments of the article as the article passes the heating member, the cam having a face adapted to engage a lateral surface of the article to eject the article from the aforesaid apparatus.

10. In apparatus for progressively heating a cylindrical article, an inductor having an opening to permit passage of the article axially there-through, means for guiding the article into said opening, guiding means for receiving the article as the article emerges from the opening in the inductor, moving means adapted to supportingly engage an end of the article, said moving means being of varying form to vary a rate of movement of the article thru the inductor to control heating, and means for supplying periodically varying current to the inductor.

11. In apparatus for hardening an elongated article, an inductor adapted to lie in spaced relation with a surface of the article, means for supplying current to the inductor to increase temperature in the article, means supporting the article, said supporting means being adapted to move uniformly and to vary the movement of the article past the inductor to regulate the increase in temperature, a quenching member lying adjacent to the inductor, the quenching member having passages adapted to deliver quenching fluid to increments of the surface of the article after the said increments have passed the inductor, a temperature responsive member lying between the inductor and the fluid supply member and being adapted to respond to the temperature of the increments of the surface of the article as the said increments approach the quenching member, and means connecting the temperature responsive member to the supporting means to change the uniform movement of the said last named means to further vary the movement of the article.

12. In apparatus for progressively heat treating an article, the article being adapted to be hardened by heating and quenching, a heating member, means for supplying power to the heating member to heat the article, supporting means for the article, said supporting means being adapted to move at a prescribed rate and to vary the rate of movement of the article while the article is in heating relation with the heating member means for changing the speed of the last named means to further vary the rate of movement, means for supplying cooling fluid to the heating member, and means for flowing cooling fluid against a surface of the article to quench the article, said means comprising a passage disposed to direct the cooling fluid against the article after the article has passed the heating member and at a predetermined distance from the heating member.

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