April 28, 1942. H. E. SOMES 2,281,333

PROGRESSIVE HEAT-TREATING APPARATUS

Filed June 8, 1939 3 Sheets-Sheet 1

Fig. 1.

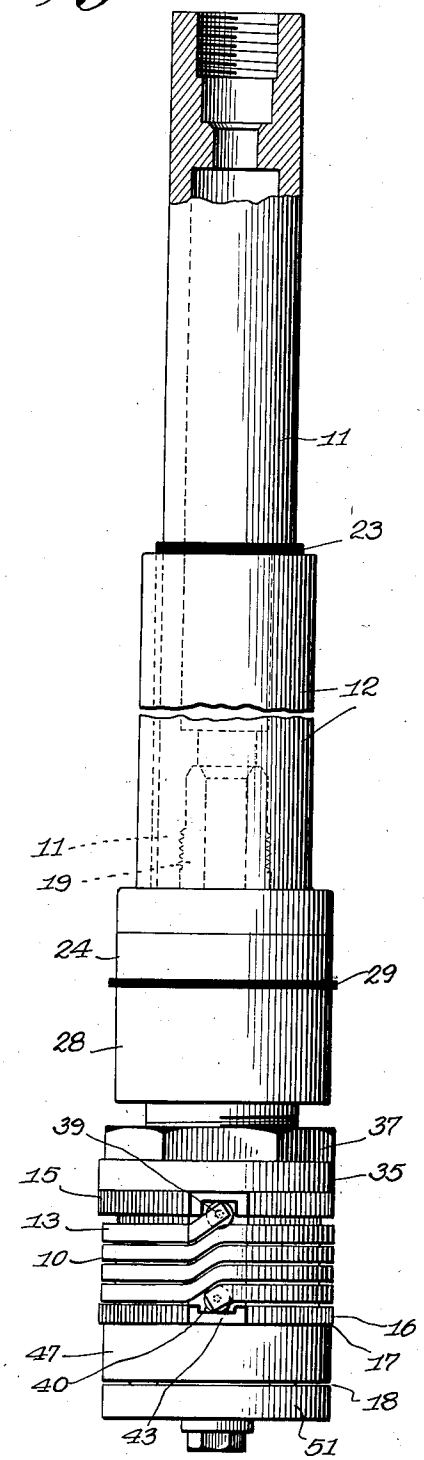
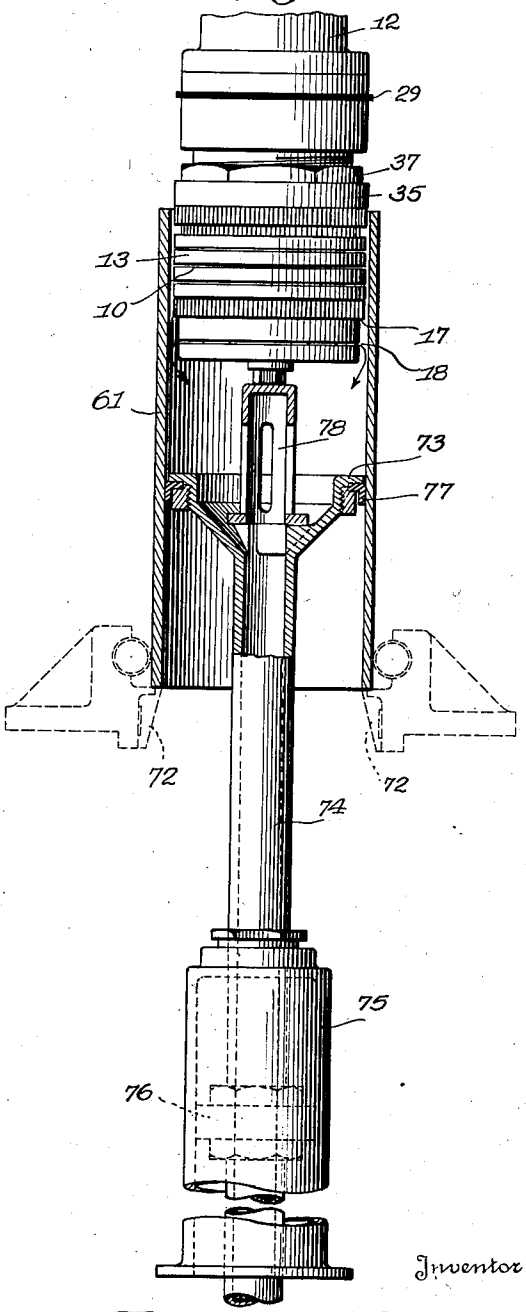


Fig. 5.



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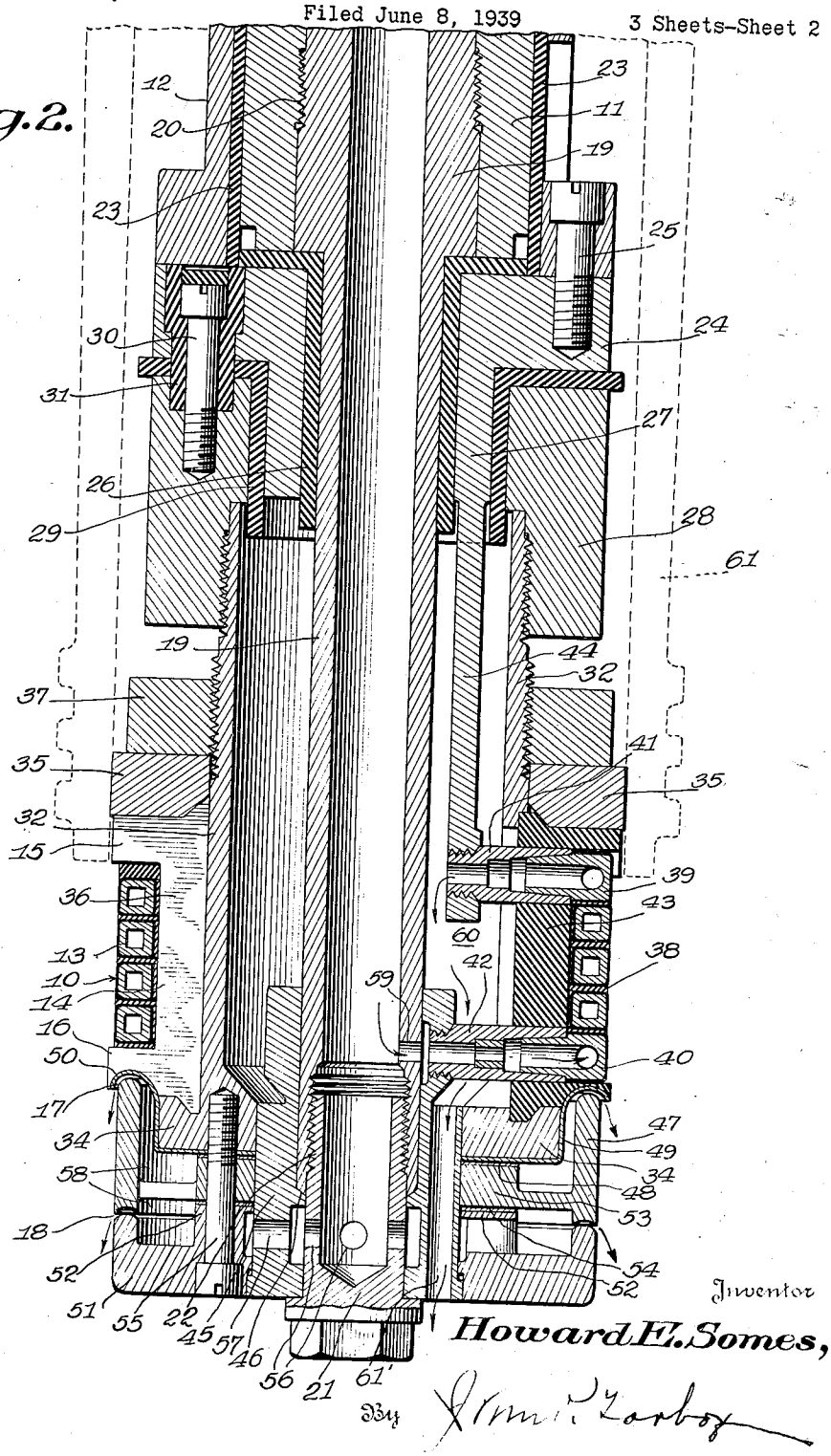
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PROGRESSIVE HEAT-TREATING APPARATUS

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Fig. 2.



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PROGRESSIVE HEAT-TREATING APPARATUS

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Fig. 3.

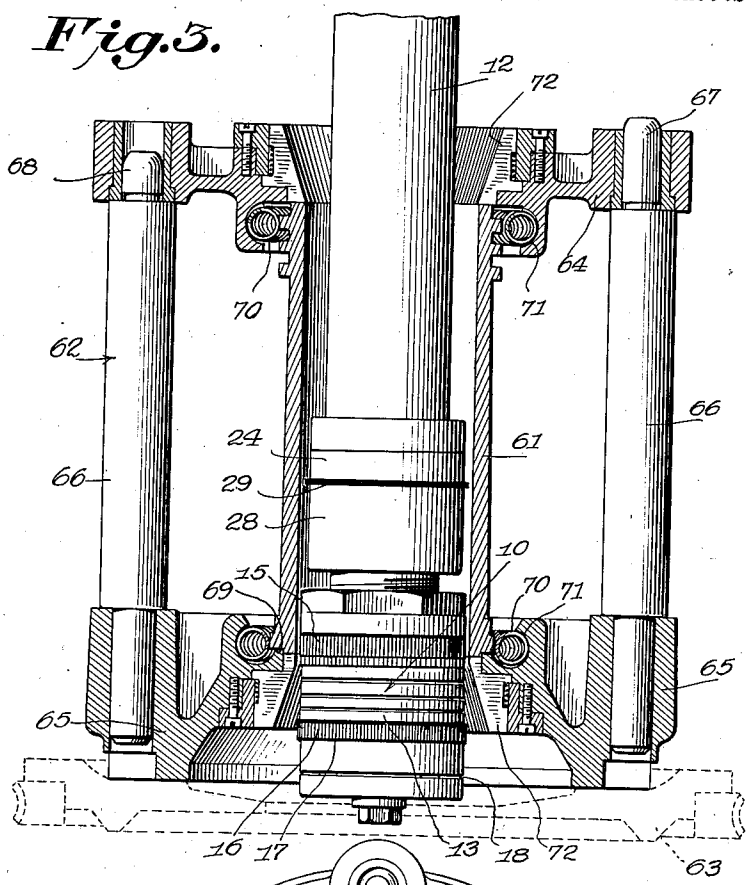
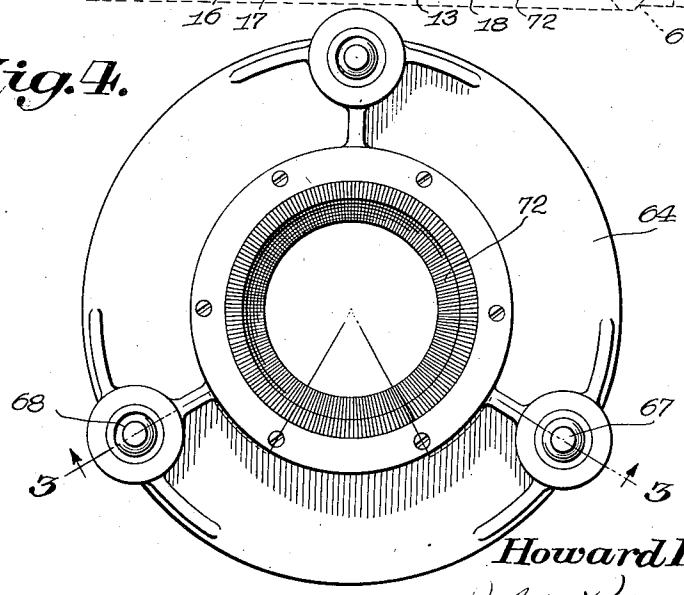


Fig. 4.



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UNITED STATES PATENT OFFICE

2,281,333

PROGRESSIVE HEAT TREATING APPARATUS

Howard E. Somes, Detroit, Mich., assignor to Budd Induction Heating, Inc., Philadelphia, Pa., a corporation of Michigan

Application June 8, 1939, Serial No. 277,996

11 Claims. (Cl. 266—4)

The present invention relates in general to induction heating and in particular to means for the differential heat treatment of interior portions of hollow objects, an important purpose being the hardening or tempering of such portions of objects of a material hardenable by heat treatment such as various ferrous alloys.

A primary object of the invention is the provision of an improved apparatus for heat treating relatively long hollow cylindrical objects, such as cylinder sleeves for internal combustion engines, in increments progressing continuously from end to end, and an improved induction heat treating head and cooperating work holder and quenching means for carrying out such method in an induction heat treating machine, preferably a machine of the type shown and described in my copending application Serial No. 164,320 filed September 17, 1937, for Induction heat-treating apparatus.

A more specific object is the provision of means whereby the localized internal heating of cylinders, such as mentioned above, to or beyond the hardening temperature may be accomplished with minimum clearance without danger of contact between the heating head and the adjacent walls of the work piece, or danger of seizure of the heating head by the work upon inward local expansion or upsetting of the inner wall portion of the work piece due to heating.

Among other objects are: Attainment of extreme close proximity of progressive heating and quenching zones; improvement in rapidity and uniformity of quenching; improvement in efficiency of quenching, and improvement in the mechanical structure of induction heat-treating heads making possible the construction of heads of relatively small diameter without sacrifice of energy carrying capacity, strength and efficiency.

While many features of the invention are essentially electrical, certain others are not limited in their application to electrical heating but are applicable to and advantageous with other kinds of heating.

Various other objects and advantages of the invention will become apparent upon a perusal of the following specification and the drawings accompanying the same.

In the drawings:

Fig. 1 is an elevation of the induction heat-treating head and mounting shaft therefor;

Fig. 2 is an elevation in vertical axial section on a large scale of the induction heat-treating head per se and its connection with the mounting shaft;

Fig. 3 is a small scale vertical axial section on line 3—3 of Fig. 4 showing the work holder and work piece in operating position with the heat-treating head in starting position;

Fig. 4 is a top plan view of Fig. 3;

Fig. 5 is a diagrammatic elevation, partly in section, showing the induction heat-treating head, work piece and quenching element in cooperative relation.

Referring to the drawings in detail and first to Fig. 1, this shows a complete, replaceable heating tool element comprising in general the induction heat-treating head 10 carried by a hollow tool shaft 11 which latter and the insulated conductor sleeve 12 serve as electrical terminals for the heat-treating head. This assemblage of mounting shaft carrying the conducting sleeve and heat-treating head constitutes a unitary tool element capable of use in a suitable machine assemblage providing suitable means for effecting relative sliding and rotational movement between the tool element and a work-piece with suitable sliding contact means for supplying current to the heat-treating head through the concentric shaft and conducting sleeve, such as the machine assemblage shown and described in my aforesaid application. The tool element is thus interchangeable with other tool elements varying in form according to the work to be done but substantially identical as to the form and proportions of the mounting shaft and conducting sleeve. The heat-treating head 10 comprises an energizing or inducing coil or winding 13 formed of a hollow tubular conductor having its terminals electrically connected one to the tool shaft 11 and one to the insulated conducting sleeve 12, and provided with a hollow cylindrical core 14 of magnetic material having flange like pole pieces 15 and 16 extending radially outwardly across the top and bottom ends of the coil. At the bottom of the bottom pole piece 16 substantially at the outer edge thereof is formed an annular downwardly and outwardly directed spray nozzle opening 17 in the form of a continuous annular slot for directing an annular spray or jet of quenching fluid downwardly and outwardly from the lower peripheral edge of the bottom pole piece. A second spray nozzle opening 18 also in the form of a continuous annular opening or slot is situated below the nozzle opening 17 and also has its outlet portion directed downwardly and outwardly.

The heating head 10, as a whole, is slightly tapered downwardly so that the outside diameter of the lower core-flange or pole piece 16, is slight-

ly less than that of the upper pole piece of flange 15, their peripheral surfaces, preferably, being slightly tapered, forming continuations of a common conical surface, so that the mean diameter of the outer peripheral surface of the flange 16 will be smaller than that of the flange 15. For example, in the present embodiment where the work piece is an engine cylinder sleeve of 4¼ inches inside diameter, the diameter of the lower edge of the lower flange 16 is approximately $\frac{1}{16}$ of an inch less than that of the upper edge of the top flange 15 the top flange having a mean clearance sufficient to insure against actual contact with the work. It is this slight taper from top to bottom, that is, a slight taper in a direction opposite to that of the direction of movement of the head relative to the work piece during operation, which makes possible the use of a minimum clearance between the heat-treating head and the work piece with assurance against contact with the walls of the work piece due to inward expansion which reaches its maximum near the trailing edge of the heating element.

The various parts are assembled onto the tool shaft 11 by means of a hollow tubular supporting element 19 threaded at 20 into the lower end of the hollow shaft 11, and carrying at its lower end a shouldered retaining head 21, the retaining head being threaded into the lower end of the supporting element 19 at 22. Mounted on the outside of the shaft 11 is a conducting sleeve 12 insulated from the shaft by an intervening sleeve 23 of insulating material. At its lower end the conducting sleeve 12 is flanged outwardly and abuts a terminal ring element 24 to which it is secured in electrical contact by means of suitable countersunk bolts such as 25, the terminal ring element 24 being insulated from the shaft 11 and the tubular mounting element 19 by the intervening bushing element 26 of insulating material. The ring element 29 is provided with a downward, tubular extension 27 about which is carried an annular mounting flange element 28 insulated from the terminal ring element 24 and its tubular extension by a bushing 29 of insulating material and mechanically secured to the ring element 24 by suitable countersunk bolts such as 30 insulated from the ring element 24 by an insulating bushing 31.

Threaded into the lower end of the mounting flange 28 is a hollow cylindrical core support 32, carrying at its lower end an outwardly extending, core-mounting flange 34. Between this flange and a clamping ring 35 are clamped in place about the core support 32 a series of inwardly tapered radial laminations 36 arranged in close contact to form the hollow cylindrical core element 14, the clamping ring 35 being held in clamping engagement with the top end of the laminations by a suitable clamping nut 37 threaded on to core support 32.

The coil element 13 composed of one or more convolutions of a hollow conductor is wound about the laminated core 36 in the recessed portion between the upper and lower flanges 15 and 16, suitable insulation 38 being provided between the convolutions of the coil and between the coil and the core. The upper and lower terminals of the coil are provided with terminal elements 39 and 40, respectively, which connect with terminal extensions 41 and 42, respectively, extending inwardly through the hollow core 14 and insulated from the latter by means of a sector-shaped insulating plug 43 of the same contour in vertical section as the laminations so as to take the place of the laminations where the terminal extensions pass through the core, as will be clear from Figs. 1 and 2. A conducting extension element 44 extending downwardly from the terminal ring element 24 as part of the latter, establishes electric connection between the sleeve conductor 12 and the terminal extension 41 of the upper end of the inducing coil 13, the terminal extension 41 being threaded into the conducting extension 44. The terminal extension 42 is threaded into the manifold member 45 in electrical contact therewith, so that electrical connection is established between the lower terminal extension 42 and the tool shaft 11, through the manifold member 45 and the tubular support 19. The purpose of the manifold 45 is to effect an even distribution of the quenching fluid from the interior of the hollow supporting element 19 to the spray nozzle. The manifold 45 is held in position on the end of the tubular mounting element 19 by means of the shoulder on the retaining head 21 and the abutting relation between the shoulder 46 within the manifold member and the lower end of the tubular support 19.

The nozzle structure comprises an intermediate nozzle section 47 mounted about the manifold element 45 and provided with an abutment ring portion 53 arranged to be clamped upwardly against the lower end face of the flange 34 on the core support 32 through the intermediation of an adjusting shim or shims 48 and the intervening, inwardly extending flange of a thin spun metal lining element 49 covering the lower surfaces of an annular recess 50 in the lower core flange 16. Also mounted about the manifold element 45 below the intermediate nozzle section 47 is a bottom nozzle ring 51, provided with an abutment ring portion 52 arranged to be clamped against the bottom surface of the abutment ring 53 of the intermediate section through the intermediation of an adjusting shim or shims 54. This clamping of the nozzle sections against each other and against the bottom of the tubular mounting element 19 is effected by means of suitable countersunk cap screws such as the cap screw 55 threaded into the lower end of the tubular core support 32.

Quenching fluid is supplied to the nozzle from a suitable source of supply through the channel within the hollow tool shaft 11 and the tubular supporting element 19 to the interior of the hollow retaining head 21 in which the fluid is distributed through ports 26 in the retaining head and ports 57 in the manifold distributing element 45 to the distributing chamber 58 in the nozzle structure, from which the quenching fluid is ejected downwardly and slightly outwardly of the nozzle through the restricted annular openings 17 and 18. The quenching fluid sprayed through the channel in the tubular supporting element 19 also acts as a coolant for the inducing coil 13 to which it is supplied through a port 59 in the wall of the supporting tube element 19 and the central opening or channel in terminal extension 42 and terminal 40 at the lower end of the coil. The coolant passing upwardly through the coil 13 passes out through the upper terminal of the coil by way of a channel in the terminal element 39 and terminal extension 41 into the outlet chamber 60 from which it passes downwardly and out through the bottom of the nozzle by way of outlet ports, one of which is shown at 61 and of which there may be several spaced around the inner portion of the nozzle

between the ports 57. It is to be understood, of course, that the quenching and cooling fluid will be supplied at such a volume and pressure that the back pressure built up in the chamber 58 due to the restricted flow through the nozzle openings, will be sufficient to force the cooling fluid through the coil at the velocity desired.

Cooperating with the heat-treating head just described, for holding work piece 61 in proper position for heat treatment by the heat-treating head, I provide the work holder structure 62 shown in Figs. 3 and 4, arranged to be supported in any suitable manner such as on a rotary support 63 like that shown and described in my aforesaid copending application. The work holder comprises a pair of upper and lower annular holding elements 64 and 65, respectively, held in vertical spaced relation by spacing columns 66 supported in the lower holding element 65. These spacing columns are provided at the upper ends with reduced dowel portions on which is removably mounted the upper holding element 64, one of the dowel elements such as 67 being longer than the remainder such as 68 so that the upper holding member 64 may be raised clear of the shorter dowels and swung to one side on the longer dowel without complete removal from the holder structure, to facilitate loading and unloading the holder as will be described hereinafter. Inasmuch as the upper and lower holding elements 64 and 65 are substantially the same in structure and function, a detailed description of one, for example, the lower one will suffice. Thus, each is provided with an end abutment ring 69 for engagement with the ends of the work piece 61, the upper and lower abutment rings 69 bearing against the opposite ends of the work piece under weight of the upper holding element 64 to hold the work piece against axial displacement. To clamp the cylindrical work piece 61 centrally of the holder against radial displacement, each work holder ring element is provided with a toroidal shaped spiral spring 70 nested in an annular recess 71 and arranged to bear radially inwardly against the adjacent outer portion of the work piece. To increase the resiliency of the spring 70 in resisting reduction in space between the work piece and the back of the recess 71, the convolutions instead of being formed symmetrically to the radius of the toroid may be given a slight angular bias with relation to such radius so that radial compression of the toroid may take place by an increase of such bias rather than by direct radial compression of the convolutions. Countersunk in each of the annular holding elements is a cylindrical extension element 72 built up of tapered, radial laminations having one end portion arranged to overlap an end of the work piece in close proximity thereto so as to form an extension of the work piece extending away therefrom in a general axial direction but flared outwardly away from the inner surface of the cylindrical work piece and extending an axial distance from the end of the work piece sufficient to substantially enclose the heat-treating head in positions beyond the ends of the work piece, as shown in Fig. 3. To load the work holder, the upper annular holding element 64 is raised above the short dowels 68 and swung about the long dowel 67 to one side of the machine whereupon the work piece may be set down on to the lower abuttment ring 69 with the lower end embraced by the lateral clamping spring 70 after which the upper holding element 64 may be swung back over the work piece into axial alignment therewith and set down upon the upper end of the work piece over the short dowels 68 with the upper abuttment ring 69 bearing upon the upper end of the work piece under weight of the ring element 64 with the upper toroidal spring 70 bearing radially against the upper sides of the work piece.

With the parts thus proportioned and arranged, it will be seen that the heat-treating head may be moved through the work piece from a position below the lower end of the work piece surrounded by an end extension 72 of low permeability, to and out of the upper end of the work piece through the upper end extension 72 of low permeability. The end extensions forming, in effect, continuations of the work piece, avoid end effects in the treatment of the work piece by the heat-treating head, and in addition to this, because of their low permeability, tend to avoid abrupt change in the inductive reactance of the heat treating head during its movement into and out of the ends of the work piece. A function of the flared form of the extension members 72 is to vary the reluctance of the end extension and thereby compensate for the difference in permeability between the work piece and such extension members.

Cooperating with the quenching nozzle openings 17 and 18 in the heat-treating head, to maintain the axial extent of the quenching zone substantially constant is a progressively movable bulkhead element in the form of a bulk head piston 73, as shown in Fig. 3. This piston is arranged to be moved up into the cylindrical work piece 61 in trailing relation to the heat-treating head by means of a hollow piston rod 74, slidable through a suitable work cylinder 75 within which it is secured to a driving piston 76 for imparting reciprocatory movement to the rod for moving the bulkhead piston into and out of the work piece. The flared form of the end member 72 at the bottom of the work holder aids in directing the bulkhead piston 73 into the lower end of the work piece without injury to the piston cup 77. To insure maintenance of a given axial spacing between the piston bulkhead and the bottom or nozzle portion of the heat-treating head, I provide a spacing element 78 carried by the bulkhead piston and arranged to abut the lower end of the heat-treating head. To permit drainage of the quenching liquid out of the space between the heat-treating head and the bulkhead piston down through the hollow piston rod, the spacing element 78 is given the form of an elongated open cage, as shown in Fig. 3. Thus, the extent of the zone of contact of the quenching fluid with the work piece is maintained substantially constant as the heating and quenching zones are progressed through the work piece, the waste quenching fluid being maintained isolated from other parts of the work piece during its passage out of the quenching zone.

A further improved feature of the present heat-treating head is the substantial symmetrical relation of the path of inducting current to the work piece accomplished through the novel construction of the coil element 13 whereby the end convolutions of the coil are made to lie in a plane at right angles to the axis for substantially a complete convolution which results in the production of a heated zone in the work piece terminating axially in planes at substantially right angles to the axis of the coil. This is of

special utility in combination with the circular quenching jets in the nozzle arranged to direct the quenching fluid against the work piece in a plane at right angles to the axis in that it brings the plane of the trailing end of the heated zone in the work piece in parallelism with the plane of the beginning of the quenching zone, thus, resulting in uniformity of quenching.

With the jets of quenching fluid directed downwardly from the nozzle openings 17 and 18 as shown and described, they act as shielding diaphragms preventing the quenching fluid from passing upwardly around the heat-treating head, and at the same time, because of their pressure and velocity, permit the existence of some pressure within the quenching chamber between the nozzle and the bulkhead piston, should it seem desirable, which condition may be brought about by suitable regulation of the drain and input to maintain the desired pressure, the velocity of the jets being maintained sufficient to prevent a backing up of the quenching fluid past the heat-treating head. With the structure shown and described the surface being quenched is thus made part of the wall of a channel filled or substantially filled with the cooling fluid or liquid flowing at high speed and, if desired, under high pressure, as distinguished from the usual situation where the cooling fluid is splashed or sprayed against the surface being cooled.

By arrangement of the upper nozzle channel 17 within the lower flange or pole piece 16 to form an annular jet issuing substantially directly from the outer lower edge of the lower pole piece 16, the zone of initial contact of the quenching fluid with the work piece is brought into extremely close proximity to the trailing end of the heated zone which is the hottest portion of the heated zone. It is further to be pointed out that an advantage of the arrangement whereby cooling fluid is directed through the hollow conductor of the coil 13 from bottom to top, that is in the direction of the progression of travel of the coil relative to the work piece, is that the part of the coil which is presented to the hottest portion of the progressing heated zone is first to receive the cooling fluid. Also, because the coil is intended to travel upwardly through the work piece with the result that it is the lower terminal of the coil which is presented to the hottest part of the heated zone, this terminal is the one selected for connection with the tool shaft 11, which latter together with the work piece, during operation, will lie in electrocal contact with a suitable support or frame element not shown, whereby that portion of the coil presented to the hottest part of the work where arcing would ordinarily most likely occur, is maintained at substantially the same potential as the work piece.

In the use of the apparatus above described, for carrying out a preferred method of heat treatment, it being assumed that the tool shaft 11 and work holder 62 are mounted for relative axial and rotary motion in any known or other suitable manner which, for example, may be like that shown in the aforesaid prior application, the tool shaft 11 is moved downwardly to pass the heat treating head 10 down through the work piece 61 to a position just below the lower end of the work piece where the heat-treating head will be surrounded by the lower, low-reluctance extension element 72. In this position, the inducing coil of the heat-treating head is energized from a suitable source of high frequency current supplied to the coil by way of the tool shaft 11 and insulated sleeve 12 through means of suitable contact brush elements which may be of any known or other suitable form, for example, that shown in the aforesaid application. The path of the energizing current may be traced from the tool shaft 11, through tubular supporting element 19, terminal extension 42, terminal element 40, lower end of inducing coil 13, through the inducing coil to the upper terminal element 39, terminal extension 41, conducting extension 44, conducting flange 24, back to the source by way of the insulated conducting sleeve 12.

The heat-treating head thus energized, and for the moment below and outside of the cylindrical work piece 61, is, as will be seen from Fig. 3, surrounded by the low reluctance extension element 72 whereby its inductive reactance is maintained at a desirable degree. Immediately upon energization of the inducing coil, the heat-treating head is moved upwardly and out of the top end of the work piece preferably at a uniform rate of travel, the energizing current being cut off after the inducing coil passes upwardly out of operative relation with the work piece. Preferably, the energizing current is cut off before the inducing coil leaves the upper low reluctance extension element, so as to prevent complete removal of the coil from the surrounding medium of low reluctance and consequently prevent sudden reduction of the inductive reactance of the coil element. Thus, in known manner, heating currents are generated in the work piece occupying a field in proximity to the heat-treating head which field of current occupancy and the resulting heated zone is progressed upwardly through the work piece with the upward movement of the heat-treating head, the trailing end of the heated zone being the hottest at any one moment due to its relatively longer exposure to the influence of the heat treating head.

Also upon energization of the inducing coil or slightly in advance thereof and while in the initial position shown in Fig. 3, cooling and quenching fluid is forced down through the hollow tool shaft 11 and hollow supporting element 19 from any suitable source of supply, not shown. The cooling fluid thus forced downwardly through the hollow supporting element 19, passes on through lateral ports 56 in the hollow retaining head 21 and distributing ports 57 in the manifold element 45 into the nozzle chamber 58 and out through the circular nozzle openings 16 and 18 from whence it is forced downwardly and outwardly in two continuous curtains of fluid. Back pressure, developed due to the restricted flow through the nozzle openings, causes the cooling fluid also to flow upwardlly through the inducing coil by way of port 59 in the wall of the tubular supporting element 19 near the lower end, and the central channels in the terminal extension 42 and terminal element 40, leaving the coil through the central channels of the terminal element 39 and extension 41 from whence the cooling fluid flows downwardly and out through the bottom of the nozzle by way of drain ports, one of which is shown at 61 (Fig. 2).

Immediately, the lower peripheral edge of the core extension 16 reaches the lower edge of the work piece, at which moment the lower end of the work piece is about at its highest temperature, the jet of cooling fluid issuing from the upper nozzle opening 17 contacts with said portion of the work piece to immediately initiate the quenching of the latter. This quenching of the inner surface of the workpiece continues as the heat-

treating head moves upwardly, the quenching effect of the jet from the nozzle opening 17 being augmented by that from the opening 18. As the heat-treating head moves upwardly through the work, it is followed by the bulkhead piston element 73 whose entrance into the workpiece is guided by the outwardly flared lower end extension 72 in the work holder, the bulkhead piston being maintained a definite distance below the heat-treating head by abutment of the spacing element 76 against the bottom of the heat-treating head. Thus, the axial length of the quenching zone is maintained at a given maximum. This progressive quenching operation is continued until and after the heat-treating head has passed beyond the upper end of the work-piece and until after the bulkhead piston reaches the top of the workpiece and energizing current has been turned off. Concurrently with the quenching operation the excess quenching fluid passes downwardly through the open spacing element 76 and the hollow piston rod 74 to a suitable waste or drain connection, not shown. Also, as previously described, the jets of quenching fluid especially the uppermost jet, because of its downward direction and high velocity operates to prevent quenching fluid from passing upwardly around the heat-treating head, and even may be maintained with sufficient pressure and velocity to permit the existence of some pressure within the quenching chamber between the nozzle and the bulkhead piston. High pressure is desirable not only because it increases the rate of interchange of quenching fluid in contact with the surface being quenched, but also increases the heat absorbing qualities of the quenching fluid.

It is to be understood that in the use of the invention herein disclosed, either the heat-treating element or the work-piece, or both may be moved to effect the required relative movement between them, and that the mere mechanical inversion necessary to change from one such form of relative movement to the other falls within the spirit of the invention and is intended to be covered by those of the appended claims specifying either of such forms of movement, in accordance with the doctrine of equivalents.

The heat head per se forms the subject matter of my divisional application Serial No. 411,851, filed September 22, 1941, and the work support including the elements 72 forms the subject matter of my divisional application, Serial No. 411,852, filed September 22, 1941.

While I have thus herein shown and described a specific embodiment and useful application of my invention for the sake of disclosure, it is to be understood that the invention is not limited to such specific embodiment and mode of application, but contemplates all such variants and modifications thereof as fall fairly within the scope of the appended claims.

What I claim is:

1. An induction head for heat-treating a hollow workpiece from the inside comprising a core support, a cylindrical radially laminated core carried by said support and surrounding the same, an induction heating coil surrounding said core, said core having extensions at each end extending radially outwardly of the ends of said coil, and a quenching fluid channel formed in the external radial face of one of said core extensions to direct a quenching fluid outwardly and axially away from said radial face.

2. An induction heating head for progressively heat-treating an inner portion of the wall of a cylindrical chamber in a body hardenable by heat treatment, comprising a supporting rod, and an inducing coil and core therefor carried by said rod, said core having a trailing end and a portion extending at said end radially outward across the adjacent end of said coil into close proximity to the wall of the chamber and a quenching fluid channel in said extending portion of said core, said channel having an outlet extending outwardly and axially away from the peripheral edge of said extending portion.

3. An induction heat treating head for progressively heat treating an inner portion of the wall of a cylindrical chamber in a body hardenable by heat treatment, comprising an inducing coil, and an annular core of magnetic material for said coil having a portion extending radially outward across an end of the coil to within close proximity to the wall of the chamber, and means for directing quenching fluid from within the annulus of said core outwardly in close proximity to the external radial face of said extending portion and axially away from said face into contact with the wall of the chamber.

4. An induction heat treating head for progressively heat treating an inner portion of the wall of a cylindrical chamber in a body hardenable by heat treatment, comprising a supporting rod, an inducing coil, a radially laminated core for said coil carried by said rod and having a trailing end, said core having a portion extending radially outwardly of the adjacent end of said coil into close proximity to the wall of the chamber, said extending portion having an annular channel in the external radial face thereof adjacent its periphery, the radially outward wall of said channel extending radially outward and axially away from said face, and a relatively thin metal lining conforming to the contour of said channel for directing quenching fluid radially outward and axially away from said core but in close proximity thereto.

5. An induction heat treating head for progressively heat treating an inner portion of the wall of a cylindrical chamber in a body hardenable by heat treatment, comprising a hollow cylindrical core support, a cylindrical core element surrounding the core support and carried thereby, an inducing coil wound about said core element, said core having a portion extending radially outwardly across one end of said coil and having an annular recess in the external radial face of said portion adjacent the peripheral edge thereof, an intermediate nozzle ring arranged to abut said support and having an annular channel opposite the wall of said recess and a second annular channel wall portion to form one wall of a second channel, an end channel ring arranged to abut a portion of said intermediate ring and to form the other wall of said secod channel, shim elements between said abutting portions, and means for clamping the rings in abutting relation with each other and said core support to fix the widths of said channels.

6. In an apparatus for heat treating by electromagnetic induction the surface of a workpiece hardenable by heat treatment and having a heating element having an inducing coil, a magnetic core for said coil, at least a portion of said core being laminated at the trailing end of said coil, a quenching nozzle, and means for effecting relative longitudinal movement between the workpiece surface and said heating element and nozzle, the improvement for cooling said core which comprises the nozzle being located contiguous

the trailing edge of said core so that the quenching fluid flowing through said nozzle is in heat exchange relation with an adjacent portion of said core and separated from said core laminations by only a thin wall of heat conductive material.

7. An induction heat-treating head for progressively heat treating the inner surface of an elongated hollow object hardenable by heat treatment, comprising an annular inducing element having a leading end and a trailing end, a core of magnetic material within said heating element in supporting relation and having an end terminating adjacent said trailing end of said inducing element, said end having an annular recess in the radial face thereof, and means associated with said recess and forming therewith an annular quenching fluid passageway for directing an annular sheet of quenching fluid outwardly and axially away from said trailing end of said inducing element.

8. An induction heat-treating head for progressively heat treating the inner surface of an elongated hollow object hardenable by heat treatment, comprising an annular inducing element having a trailing end and a leading end, a core of magnetic material within said heating element in supporting relation and having an end terminating adjacent said trailing end of said inducing element, said end having an annular recess in the radial surface thereof, means within said core forming a quenching fluid conducting passageway, and means associated with said last means in fluid communication with said passageway and forming with said recess an annular nozzle passage for directing quenching fluid outwardly and axially away from said trailing end of said conducting element.

9. An apparatus for progressively heat treating a work surface by electromagnetic induction heating and by quenching, comprising an electromagnetic inducing head, a quench head contiguous said inducing head, and means for effecting relative translation between the work surface and said heads, one of said heads having an annular quenching fluid chamber therein, adjacent portions of said heads forming the walls of a discharge passageway in receiving communication with said chamber for discharging a sheet of quenching fluid toward the work surface, said passageway being generally concave and opening axially away from said inducing head, whereby the quenching fluid may be closely juxtaposed to said induction head to provide a relatively short distance between heat and quench application.

10. An induction heat-treating head for progressively heat treating an inner portion of the wall of a cylindrical workpiece hardenable by heat treatment, comprising an inducing coil disposable in close proximity to the wall portion to be heat treated and having a trailing end, a core of magnetic material for said coil having a trailing end, means for providing relative axial movement between said coil and the workpiece to be heat treated, means for conducting quenching fluid axially within said core and thence outwardly in close proximity to said core trailing end and axially away from the trailing ends of said coil and core, and means disposable in predetermined axially spaced relation with respect to said quenching fluid conducting means and in slidable engagement with a portion of the wall portion of the workpiece quenched during heat treatment to confine the engagement of quenching fluid with such wall portion to an area of predetermined axial extent, the space between said coil and the surface area being heated at any instant being at all times in open communication with the space between said conducting means and said confining means.

11. An induction heat-treating head for progressively heat treating an inner portion of the wall of a cylindrical workpiece hardenable by heat treatment, comprising an inducing coil disposable in close proximity to the wall portion to be heat treated and having a trailing end, a core of magnetic material for said coil having a trailing end, means for providing relative axial movement between said coil and the workpiece to be heat treated, means for conducting quenching fluid axially within said core and thence outwardly in close proximity to said core trailing end and axially away from the trailing ends of said coil and core, and means disposable in predetermined axially spaced relation with respect to said quenching fluid conducting means and in slidable engagement with a portion of the wall portion of the workpiece quenched during heat treatment to confine the engagement of quenching fluid with such wall portion to an area of predetermined axial extent, the space between said coil and the surface area being heated at any instant being at all times in open communication with the space between said conducting means and said confining means, said quenching fluid confining means including conduit means for conducting the used quenching fluid away from the quenched area out of contact with previously quenched areas.

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