Nov. 2, 1971 R. J. COLLINS ET AL 3,616,807

DEVICE FOR QUENCHING ELONGATED INDUCTIVELY HEATED WORKPIECES

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FIG. 1

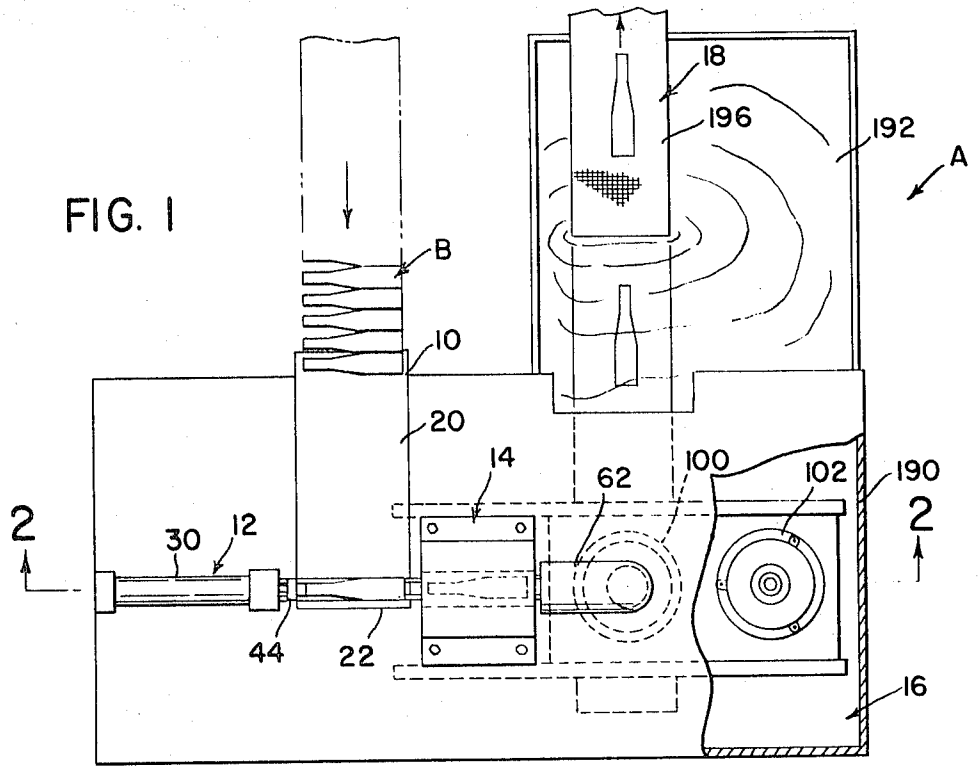
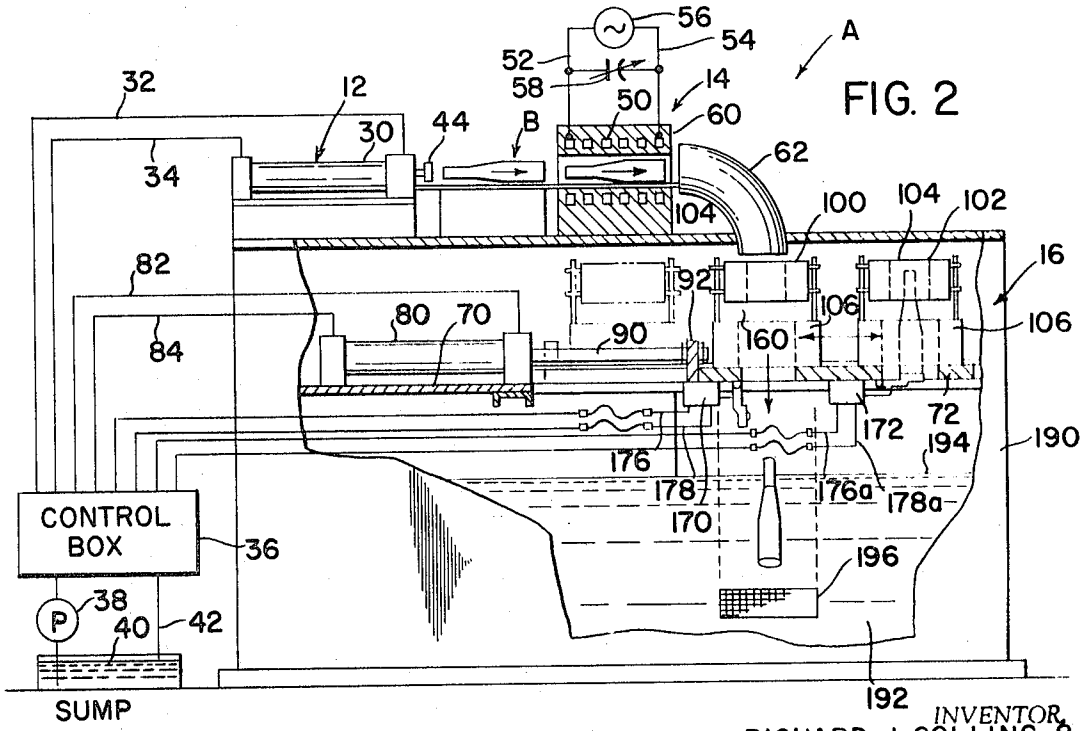


FIG. 2



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DEVICE FOR QUENCHING ELONGATED INDUCTIVELY HEATED WORKPIECES

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FIG. 3

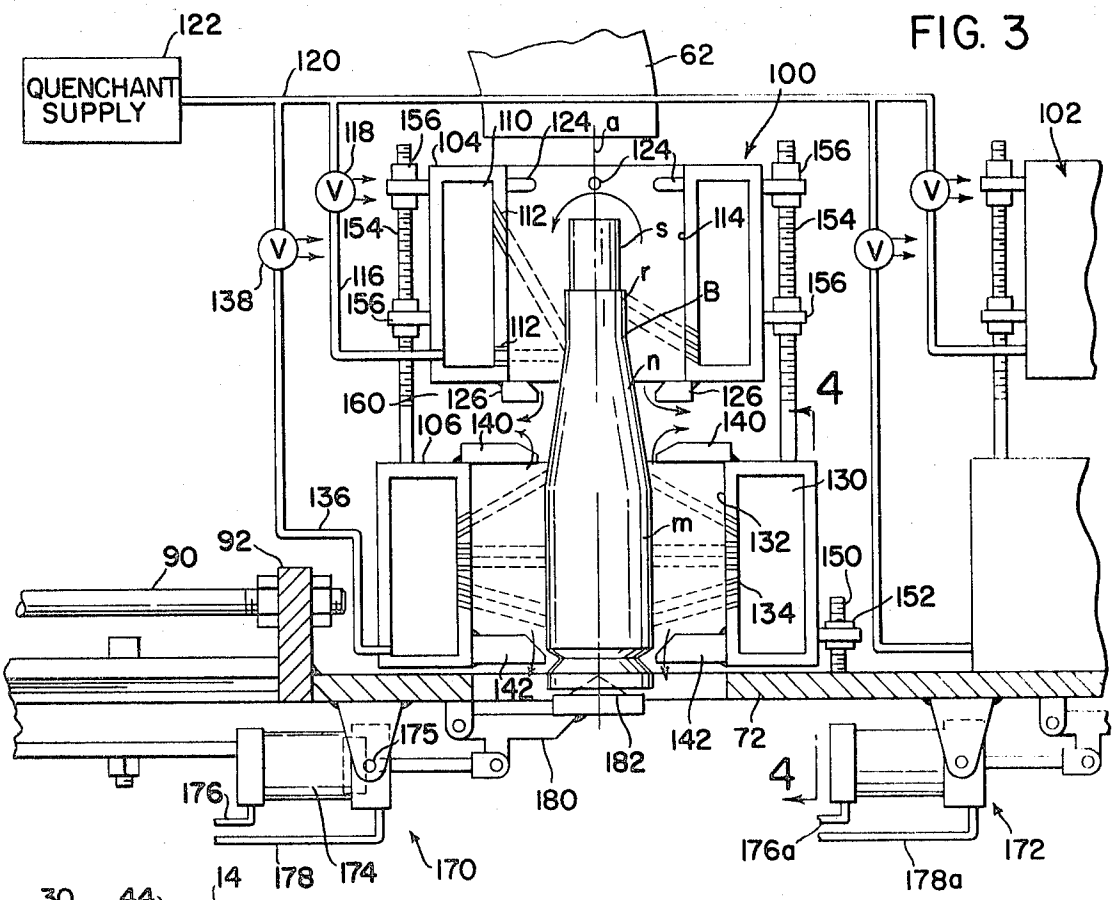


FIG. 4

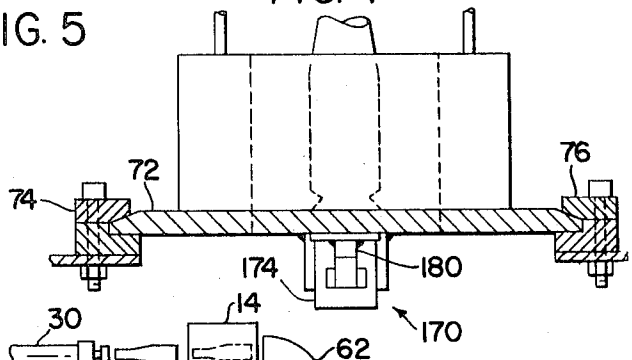


FIG. 5

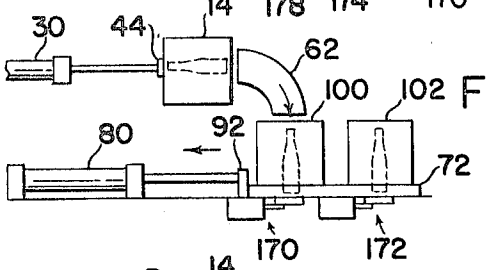


FIG. 6

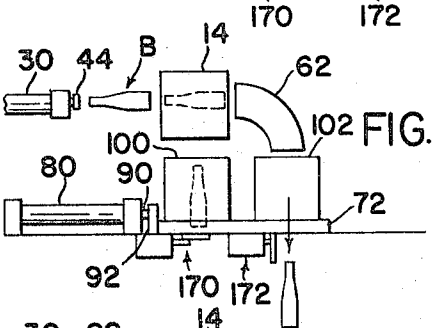


FIG. 7

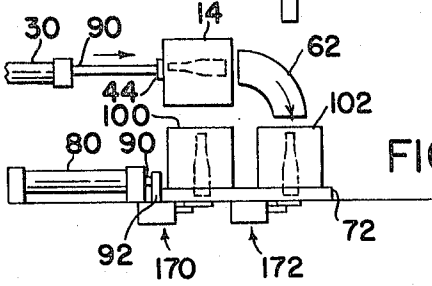
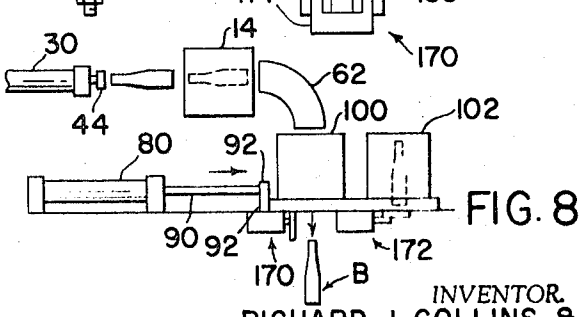


FIG. 8



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3,616,807

DEVICE FOR QUENCHING ELONGATED INDUCTIVELY HEATED WORKPIECES

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U.S. Cl. 134—199 7 Claims

ABSTRACT OF THE DISCLOSURE

A device for quenching an inductively heated, elongated workpiece having at least two axially spaced portions of different cross-sections. The device includes two separate quench bodies having internal dimensions generally matching the two separate portions of the workpiece and a space between the bodies to allow quenchant to flow through this space for more uniform quenching of the two different dimensioned portions of the workpiece.

This invention relates to the art of quenching an inductively heated workpiece and more particularly to a device for quenching an elongated, inductively heated workpiece having axially spaced portions of different cross-sections.

The invention is particularly applicable to quenching a short axle shaft having two cylindrical portions separated by a conical portion, and it will be described with particular reference thereto; however, it should be appreciated that the invention has much broader applications and may be used in quenching various inductively heated, elongated workpieces. Indeed, certain aspects of the inventing are applicable to heating an elongated workpiece having a substantially uniform cross-section throughout its length.

In the production of short axle shafts of the type usually having two cylindrical portions separated by a conical portion and a terminal threaded portion, the shaft is first forged and machined to substantially the desired dimensions. To provide a hardened outer surface, the shafts are passed one-after-the-other through a solenoid type induction heating coil. By known induction heating principles, this process increases the temperature adjacent the surfaces of the axle shaft to a temperature sufficiently high for subsequent quench hardening. In the past, the quenching was often accomplished by dropping the heated axle shaft into a quench tank filled with an appropriate quenchant. Since this process caused steam pockets adjacent the surface of the shaft, uniform quenching was not always obtained. In addition, there was no accurate control over the rate of quenching. To overcome these difficulties, it has been suggested to provide a vertically extending cylindrical quench unit into which the inductively heated axle shaft was located. Apertures on the internal surface of the quench unit directed quenchant in small jets against the surface of the shaft. The quench unit was vertical to assist the outflow of quenchant. After the shaft was quenched to a desired degree, the shaft was then introduced into a quench tank for final cooling. This arrangement did provide a more uniform and controlled quenching of the outer surface of the axle shaft; however, certain difficulties were experienced.

When using a quench body surrounding an axle shaft having two cylindrical portions separated by a conical portion, a nonuniform turbulence was created at the surface and quenchant impinging upon the cylindrical surfaces often moved along the conical surface and formed

a barrier between this surface and quenchant impinging thereon. Since the quenchant from the cylindrical surfaces was heated due to heat transferred from the heated axle shaft, this quenchant barrier produced certain areas of heat insulation which prevented uniform quenching of the conical surface on the shaft, as well as certain areas of the cylindrical surfaces. Even though this phenomenon is more pronounced when quenching an elongated workpiece having different cross-sections at various portions, it still occurs when quenching elongated workpieces wherein the quenchant directed against the workpiece, from a vertical, surrounding quench body, creates turbulence and flows along the surface. In this instance a heat barrier can form to prevent uniform quenching at all areas along the outer surface of the elongated workpiece.

These and other disadvantages encountered when using a vertical, elongated encircling quench body for quenching an elongated workpiece by impinging streams of quenchant against the workpiece are overcome by the present invention which relates to an improved quenching device that reduces the deleterious effects of turbulent flow along the surface of the workpiece which forms a heat barrier.

In accordance with the present invention, there is provided a device for quenching an inductively heated elongated workpiece having axially spaced first and second portions with different cross-sections. This device comprises means for locating the workpiece along a selected axis, a first quench body surrounding the first portion of the workpiece and a second quench body surrounding the second portion of the workpiece with the first and second bodies being spaced along the axis to define a transversely extending opening therebetween for the radial outward flow of quenchant coming from the two spaced quench bodies.

By providing two separate quench bodies, separated by an opening, or an elongated quench unit having an opening intermediate its ends, quenchant flows against the workpiece surface and is, then, reflected radially outward from the heated surface. The opening allows this spent quenchant to flow from the quench unit instead of remaining in the unit. This reduces the amount of quenchant which is forced to flow along the surfaces of the workpiece. The pressure of the incoming quenchant coacting with the surface upon impingement provides an impetus for the outward flow of quenchant through the opening separating the two quench bodies or through an intermediate opening in the quench unit.

In accordance with another aspect of the present invention, the two quench bodies spaced along the axis of the workpiece may be provided with quenchant at different pressures. This regulates the amount of quenchant and the impinging energy of the quenchant jets or streams at the different axially spaced heated portions of the workpiece. Consequently, the amount of quenching can be controlled according to the demands of the particular surfaces being quenched.

In accordance with still a further aspect of the present invention, two separate quench units formed of axially spaced quench bodies may be mounted upon a shuttle movable between two positions so that a heated workpiece remains in a particular quenching unit for a prolonged time determined by the time programmed into the shuttle for shifting between the two positions.

The primary object of the present invention is to provide an encircling quenching device for an elongated workpiece which device reduces the flow of heated quenchant along the workpiece surface during the quenching operation.

Another object of the present invention is the provision of an encircling quenching device for an elongated

workpiece which device includes an intermediate opening for the outflow of quenchant.

Yet another object of the present invention is the provision of an encircling quenching device for an elongated workpiece which device includes at least two quench bodies spaced axially to produce an opening through which the quenchant passes during the quenching operation.

These and other objects and advantages will become apparent from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a top view illustrating, somewhat schematically, an apparatus utilizing the present invention;

FIG. 2 is a cross-sectional view taken generally along line 2—2 of FIG. 1;

FIG. 3 is an enlarged cross-sectional view showing, somewhat schematically, the preferred embodiment of the present invention;

FIG. 4 is a cross-sectional view taken generally along line 4—4 of FIG. 3; and,

FIGS. 5–8 are schematic views illustrating the operating sequence of the apparatus illustrated in FIGS. 1 and 2.

Referring now to the drawings, wherein the showings are for the purpose of illustrating a preferred embodiment of the invention only, and not for the purpose of limiting same, FIGS. 1 and 2 show a hardening apparatus A for surface hardening an elongated workpiece, such as short axle shafts B. As primary components, the hardening apparatus includes an input conveyor **10**, a feeding device **12**, an induction heating coil **14**, a quenching device **16**, and an output conveyor **18**. The workpiece is fed into the hardening apparatus where it is first inductively heated and then quench hardened to provide the necessary hardness along the surface of the workpiece.

Referring now to the conveyor **10**, it includes an inclined ramp **20** terminating in an abutment **22**. The axle shafts B are fed, in series, along the ramp to the abutment where they are forced through the apparatus by the feeding device **12**. This device could take a variety of structural embodiments; however, in accordance with the illustrated embodiment, it includes a cylinder **30** having hydraulic control lines **32**, **34** which are communicated with a hydraulic control valving unit **36**. The operation of the control unit does not form a part of the present invention; therefore, it is schematically illustrated and a variety of control units could be used to accomplish the functions which are hereinafter described. As is schematically illustrated, the control unit is connected by a pump **38** with a reservoir **40** of hydraulic fluid. Also, a sump line **42** is illustrated as a means for relieving pressure on various lines controlling the cylinder **30** and the other cylinders hereinafter to be explained. Cylinder **30** includes a pusher rod **44** which, when extended pushes the axle B into the induction heating coil **14** where it is inductively heated for subsequent quench hardening.

Referring now more particularly to the induction heating coil, as illustrated, this coil is a solenoid type including a multi-turn water cooled coil **50** having input leads **52**, **54** which are connected across the output of a power source, schematically represented as generator **56**. As is common in the induction heating art, an adjustable power factor correcting capacitor **58** is connected across leads **52**, **54** for adjusting the power factor of the heating station. In accordance with normal practice, the coil is encapsulated by insulating material **60** to form a rigid, fixed asssembly having an opening directly opposite to the pusher rod **44**. When an axle is forced into the coil by the pusher rod **44**, it is inductively heated for subsequent hardening. At the same time, a previously heated axle is forced into a chute **62** having a downwardly directed output generally aligned with axis *a* as shown in FIG. 3. This axis defines the feeding position, or feeding point, for the quenching device **16**.

The present invention is directed toward an improvement in the quenching device which relates to a means for directing quenchant against the workpiece in a manner to provide uniform quenching of the workpiece surface. In accordance with the preferred embodiment of the present invention, the quenching device **16** includes a fixed support plate **70** on which a shuttle **72** is reciprocally mounted for movement in a longitudinal direction. As shown in FIG. 4, guideways **74**, **76** are used to guide the shuttle **72** as it is reciprocated, in a manner to be explained later. A hydraulic cylinder **80** having control lines **82**, **84** connected to control unit **86** is used for reciprocating the shuttle **72** by using a reciprocal rod **90** connected onto the shuttle by a bracket **92**. Movement of the rod **90** in accordance with hydraulic pressure within lines **82**, **84** shifts the shuttle **72** between a first position shown in solid lines in FIG. 2 and a second position shown in phantom lines in FIG. 2. The shuttle mounts upwardly extending quench units **100**, **102**, each of which is substantially identical; therefore, only the quench unit **100** will be described in detail. This description will apply equally to the quench unit **102**.

Referring now to FIG. 3, axle shaft B includes a cylindrical first portion *m*, a conical second portion *n*, a cylindrical third portion *r* and a terminal nose *s*. Portions *m* and *r* have different cross-sections, as does the conical portion *n*. Quench unit **100** includes axially spaced quench bodies **104**, **106**. Referring first to quench body **104**, it includes an internal chamber **110** for liquid quenchant, aperture means **112**, taking the form of spaced holes, extending between cylindrical surface **114** and the internal chamber **110**. The aperture means direct streams of liquid quenchant from the chamber **110** onto the outer surface of the axle B adjacent the conical second portion and the cylindrical third portion. As illustrated, the aperture means or holes **112** may be formed at a variety of angles to direct quenchant in the proper angle against the surface of the axle shaft. Indeed, the apertures can all have the same direction or different directions. The cylindrical surface **114** generally corresponds with the upper portion of the axle B so that the optimum impingement force and direction can be used in bringing the liquid quenchant into contact with the upper portion of shaft B. Liquid quenchant is provided by conduit **116** through a pressure valve **118** having an input connected with supply **120** of pressurized quenchant supply **122**. For guiding the axle B through body **104**, there are provided upper cylindrically spaced guide pins **124** and lower cylindrically spaced guide lugs **126**. A variety of other structure could be used for allowing the axle shaft B to fall centrally through the space defined by surface **114**, into the position as illustrated in FIG. 3.

Referring now to the quench body **106**, it includes an internal chamber **130** having an inwardly facing, cylindrical surface **132** generally matching the first portion *m* of the axle B. Aperture means **134** are communicated with the internal chamber **130** for directing a liquid quenchant against the portion *m* of axle B. A conduit **136** supplies quenchant through a valve **138** connected with supply line **120**. The valves **118**, **138** can be adjusted so that the pressure within the internal chambers **110**, **130**, respectively, can be different to create a different impinging force or a different volume of quenchant at the upper, and lower portions, respectively, of the axle shaft B. Upper, cylindrically spaced, guide lugs **140** and lower, cylindrically spaced, guide lugs **142** direct the falling workpiece B through the passageway defined by cylindrical surface **132** so that it may assume the general position as illustrated in FIG. 3.

A plurality of cylindrically spaced threaded rods **150**, only one of which is shown, are secured onto shuttle **72** and support the quench body **106** in a position which can be adjusted by rotating cooperating threaded nuts **152**. By changing the position of the quench body **106**, variations can be made in the amount of quenchant actually

contacting the outer surface of portions *m* and the areas of actual impingement. This provides flexibility in adjusting the quenching action effected by the lower quench body **106**. Upper quench body **104** is adjustably mounted with respect to quench body **106** by a plurality of circumferentially spaced, threaded rods **154** secured onto the quench body **106**. By rotating the threaded nuts **156** supported on the quench body **104**, the axial position of the quench body **104** with respect to the quench body **106** may be adjusted. The spacing of the quench bodies **104**, **106** provides a radially extending opening **160** between the quench bodies. An opening intermediate the ends of the quench unit, forms an essential feature of one aspect of the present invention.

In the past, a vertical, cylindrical quench body having a general length corresponding with the length of elongated workpiece was used for quenching the workpiece. By using this type of structure, a quenchant would impinge against the outer surface of the workpiece and flow therealong. This would create a heated quenchant barrier on the surface of the workpiece to interrupt or adversely affect the quenching qualities of the quench body. This was especially true when quenching an elongated workpiece having a contour similar to that found in axle shaft B. Quenchant would flow upwardly along the conical surface *n* during the quenching operation. At this surface, a substantial barrier of coolant would accumulate and be heated to a temperature which would interfere with the normal quenching operation of the quenchant being directed toward the outer surface of the workpiece. This is particularly true when steam pockets are formed by the heated quenchant. In accordance with the present invention, the intermediate opening **160** prevents the accumulation of quenchant, especially along the conical portion *n* and at the junction of the conical portion *n* and the cylindrical portion *r*. This accumulation will tend to occur even when the axle shaft is reversed in the quench unit. By providing this intermediate opening, quenchant being impinged against the surface of the workpiece is propelled outwardly through the opening **160**, as illustrated by the arrows in FIG. 3. This removal of spent quenchant in the intermediate area of the quench unit greatly reduces the incident of accumulation of quenchant at the irregular surfaces of axle B. The lugs **126**, **140** have a substantially small transverse direction so that they will not affect, to any great extent, this outflow of spent quenchant. The opening **160** is quite useful when a workpiece has an irregular surface; however, the same general principle will apply to a continuous uniform surface. The present invention is, thus, applicable to quenching a workpiece having a uniform cross-section; however, the advantages are not pronounced because there is a lesser tendency to accumulate spent quenchant along the surface of a uniformly dimensioned workpiece.

To drop the workpiece from the quench units **100**, **102**, there are provided releasing means **170**, **172**, respectively. These releasing means each include a cylinder **174** pivotally mounted at **175**. Hydraulic control lines **176**, **178**, for unit **100** and **176***a*, **178***a* for unit **102**, actuate the cylinders **174** to pull pivot arms **180** downwardly. The pivot arms include upwardly extending centers **182** for engaging a center recess for workpiece B. As the workpiece drops through the quenchant, it is guided to a position wherein the center **182** holds the workpiece substantially upright. The force of the quenchant against the surface of the workpiece assists in holding the workpiece in the upright position. When a workpiece is sufficiently quenched within one of the quenching units, the releasing means is actuated to drop the workpiece into a tank **190** filled with a liquid quenchant **192** to an upper level **194**. This removal of the workpiece takes place at axis *a* which is vertically aligned with an inclined conveyor belt **196** for directing the quenched workpiece from the apparatus A.

Referring now to FIGS. 5–8, another aspect of the present invention is illustrated. This aspect of the present invention is accomplished by the reciprocation of shuttle **72** on which the separate quench units **100**, **102** are mounted. Referring to FIG. 5, shuttle **72** is in its first position and workpieces are in units **100**, **102**. The workpiece in unit **102** has been quenched for a time greater than the workpiece in unit **100**. At this time, the workpiece in unit **100** has just started its quenching operation. Another workpiece has just been forced into the induction heating coil **14**. Control unit **36** then retracts pusher rod **44** as shown in FIG. 6 and it also shifts the shuttle **72** by cylinder **80** into the second position. Thereafter, releasing means **172** is actuated by the control unit **36** and drops the workpiece from quench unit **102**. This empties unit **102** and allows the workpiece within unit **100** to be quenched by the inward flowing of quenchant. Thereafter, releasing means **172** is closed, as shown in FIG. 7. Pusher rod **44** then forces another workpiece into coil **14**. This drops a workpiece into the previously emptied quenching unit **102**. During this time, the workpiece within unit **100** is continuing its quenching operation. Pusher rod **44** is then retracted so that another workpiece falls into the feeding position. This is shown in FIG. 8 wherein the control unit **36** actuates releasing means **170** to empty the unit **100**. Thereafter releasing means **170** is shifted again to the closed position and a workpiece is forced from the coil **14** by an incoming workpiece shifted by pusher rod **44**. This is shown in FIG. 5. The sequence is then repeated. As can be seen, the workpieces are quenched for a substantially longer period of time than the heating cycle within the coil **14**. It has been found that this provides a more uniform quenching of the workpieces over a system wherein the quenching was accomplished by dropping the workpiece directly into the quenchant bath or into an encircling quench unit whose cycle is controlled by the heating cycle for the workpiece. If desired, the quenchant may be turned on and off to further control the timing of the quenching operation to a time less than the cycle time for the shuttle **72**; however, this is not necessary. It is appreciated that a greater length of quenching time could be accomplished by providing more than two quench units and having a multiple position shuttle as distinguished from a two position shuttle.

Having thus described our invention, we claim:

1. A device for quenching an inductively heated, elongated workpiece having axially spaced first and second cylindrical portions, said first portion having a transverse cross-section substantially different from the transverse cross-section of said second portion, said device comprising: means for locating said workpiece coincidentially to a selected axis; a first quench body having a workpiece receiving passage defined by a first generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface and communicated with said chamber for directing quenchant from said chamber toward said axis; means for mounting said first quench body around said first portion of said workpiece; a second quench body having a workpiece receiving passage defined by a second generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface of said second body and communicated with said chamber of said second body for directing quenchant from said chamber in said second body toward said axis; means for mounting said second quench body around said second portion of said workpiece; and said first and second bodies being spaced along said axis to define a transversely extending opening therebetween for the radial outward flow of quenchant from said first and second bodies and said first and second cylindrical surfaces having different diameters generally matching said first and second portions, respectively.

2. A device as defined in claim **1** including means for shifting said bodies in a direction transverse of said axis while quenchant is flowing from said aperture means.

3. A device as defined in claim **1** including a supply of quenchant; first conduit means for connecting said supply

with said chamber of said first body; second conduit means for connecting said supply with said chamber of said second body; and control means operatively connected with said first and second conduit means for regulating independently the volume of quenchant flowing from the aperture means of said first body and the aperture means of said second body.

4. A device for quenching an inductively heated, elongated workpiece having axially spaced first and second portions, said first portion having a transverse cross-section substantially different from the transverse cross-section of said second portion, said device comprising: means for locating said workpiece coincidentally to a selected axis; a first quench body having a workpiece receiving passage defined by a generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface and communicated with said chamber for directing quenchant from said chamber toward said axis; means for mounting said first quench body around said first portion of said workpiece; a second quench body having a workpiece receiving passage defined by a generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface of said second body and communicated with said chamber of said second body for directing quenchant from said chamber in said second body toward said axis; means for mounting said second quench body around said second portion of said workpiece; and said first and second bodies being spaced along said axis to define a transversely extending opening therebetween for the radial outward flow of quenchant from said first and second bodies, including means for adjusting bodies relative to each other in an axial direction to thereby vary the axial length of said transversely extending opening.

5. A device for quenching an inductively heated, elongated workpiece having axially spaced first and second portions, said first portion having a transverse cross-section substantially different from the transverse cross-section of said second portion, said device comprising: means for locating said workpiece coincidentally to a selected axis; a first quench body having a workpiece receiving passage defined by a generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface and communicated with said chamber for directing quenchant from said chamber toward said axis; means for mounting said first quench body around said first portion of said workpiece; a second quench body having a workpiece receiving passage defined by a generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface of said second body and communicated with said chamber of said second body for directing quenchant from said chamber in said second body toward said axis; means for mounting said second quench body around said second portion of said workpiece; and said first and second bodies being spaced along said axis to define a transversely extending opening therebetween for the radial outward flow of quenchant from said first and second bodies, including means for adjusting the axial position of at least one of said quench bodies.

6. A device for quenching an inductively heated, elongated, workpiece having axially spaced first and second portions, said first portion having a transverse cross-section substantially different from the transverse cross-section of said second portion, said device comprising:

means for locating said workpiece coincidentally to a selected axis; a first quench body having a workpiece receiving passage defined by a generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface and communicated with said chamber for directing quenchant from said chamber toward said axis; means for mounting said first quench body around said first portion of said workpiece; a second quench body having a workpiece receiving passage defined by a generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface of said second body and communicated with said chamber of said second body for directing quenchant from said chamber in said second body toward said axis; means for mounting said second quench body around said second portion of said workpiece; and said first and second bodies being spaced along said axis to define a transversely extending opening therebetween for the radial outward flow of quenchant from said first and second bodies, including means for adjusting the axial position of said first body and means for adjusting the axial position of said second body.

7. A device for quenching an inductively heated, elongated workpiece having axially spaced first and second portions, said first portion having a transverse cross-section substantially different from the transverse cross-section of said second portion, said device comprising: means for locating said workpiece coincidentally to a selected axis; a first quench body having a workpiece receiving passage defined by a generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface and communicated with said chamber for directing quenchant from said chamber toward said axis; means for mounting said first quench body around said first portion of said workpiece; a second quench body having a workpiece receiving passage defined by a generally cylindrical surface coaxial with said axis, an internal chamber for receiving quenchant under pressure, and aperture means in said surface of said second body and communicated with said chamber of said second body for directing quenchant from said chamber in said second body toward said axis; means for mounting said second quench body around said second portion of said workpiece; and said first and second bodies being spaced along said axis to define a transversely extending opening therebetween for the radial outward flow of quenchant from said first and second bodies, said workpiece receiving passages each having a transverse dimension generally matching said cross-sections of said irrespective portions, said transverse dimensions beings substantially different.

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LEONIDAS VLACHOS, Primary Examiner

U.S. Cl. X.R.

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