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(54) **Method of apparatus for expanding and sealing a sleeve into a surrounding tube.**

(57) A pressurizable tool for locating a sleeve within a surrounding tube and pressure-tightly sealing the sleeve within the tube to repair leaks in the tube. The tool includes a housing containing an axially movable piston and a forward reduced diameter portion and having an elastic expander unit for inserting into the sleeve and tube in a tubesheet. The expander unit consists of at least two elastic rings composed of an elastomer material and each having a chamfer provided at the outer edge of the unit forward and rear faces. By pressurizing a port at the housing front end, the piston is moved rearwardly to axially compress and expand the expander rings radially outwardly sufficiently to expand the sleeve firmly into the tube and provide a pressure-tight seal therebetween. Following such expansion of the sleeve, the piston is pressurized and moved forward to release the compression on the expander unit rings, so that the tool can be easily withdrawn from the expanded sleeve and tube and inserted into another sleeve and tube for repeated usage.

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This invention pertains to method and apparatus for expanding and sealing a tubular sleeve into a surrounding tube.

Tubes used in tubular type heat exchangers, particularly tubes in air preheaters used in fossil fuel fired steam power plants for preheating the combustion air against hot flue gases, often develop leaks after several years service due to metal corrosion, erosion or fatigue and require repair or replacement. Such tube leaks are usually located near the tube plate, but can occur anywhere along the tubes. Because replacement of tubes in such heat exchangers is quite expensive, particularly for large heat exchangers containing 10,000-50,000 tubes, and requires considerable outage time for a plant, a method and special tool devices for reliably repairing such tubes quickly and inexpensively in a dusty environment has been added.

Various methods and devices for remotely expanding tubes into surrounding plates or tubesheets are known in the prior art. For example, U.S. Patent 2,319,216 to Dewald discloses a pull-type tapered tube expander for expanding heat exchanger tubes into a tubesheet utilizing direct contact between a tapered wedge surface and the tube inner wall. U.S. Patent 4,182,152 to Vaill et al discloses a grid sleeve bulge tool used for securing internal guide tubes to an outer sleeve and grid. Also, U.S. Patent 4,471,643 to Champoux et al discloses a tool adapted for pulling a tapered mandrel through a sleeve to secure together abutting workpieces. Also, U.S. Patent 4,068,372 to Kamohara et al discloses a tube expander for anchoring tubes in a tube plate of a heat exchanger, and utilizes a cylindrical shaped elastic medium to be expanded by axial compression utilizing a rod inserted through the medium and back up rings. U.S. Patent 4,387,507 to Kelly discloses apparatus and method for radially expanding tubes for anchoring within a tubesheet by using primary and secondary expander rings. U.S. Patent 4,418,457 to Mueller discloses another apparatus for expanding a tube into a tubesheet opening and for controlling the tube expansion by axial location of elastomer washers relative to the tubesheet. Also, U.S. Patent 4,567,631 to Kelly discloses another apparatus for expanding tubes into tubesheets using a plurality of elastomer expander rings loaded by axial compression.

The known prior art has various deficiencies, and evidently does not disclose a pressurizable tool device adapted for conveniently and rapidly expanding a close-fitting metal sleeve firmly against a tube in a tubeplate, and which can withstand repeated cycles of use and can also be easily withdrawn from the expanded sleeve.

U.S. Patent 4069573 describes a device for expanding a repair sleeve against a tube comprising a single annular elastomeric plug which is axially compressed between a fixed and a movable stop to cause radial expansion thereof.

A pressurizable tool for expanding a sleeve into a surrounding tube in a tubesheet, in accordance with the invention, comprises a housing having a cylindrical axially bore, a piston axially movable within the housing bore and attached at its forward end to an elongated rod, the rod having a retainer nut threadably attached onto its forward end, and an elastic expander unit encircling the rod, the expander unit containing at least one elastomer ring, movement of the piston rearwardly in the housing axially compresses the elastic expander unit so as to radially expand the expander unit firmly against the sleeve and expand the sleeve tightly against the tube in the tubesheet, characterised in that the housing contains a front port connected to the bore, in that the tool includes a closure plate having a forward portion inserted into the cylindrical bore, and containing a rear port connected to the bore, in that the expander unit is between the housing and the retainer nut, pressurisation of the housing front port moving the piston rearwardly to axially compress the expander unit against the housing and in that the expander unit includes a plurality of elastomeric rings and has a chamfer at an outer edge of the unit front and rear end faces, the chamfer extending from the outer edge toward the centre of the ring forming the end face by a radial distance equal to 15-30% of the radial thickness of the ring.

The tool is capable of effectively repairing leaking tubes in heat exchangers and is particularly suitable for use at the rear end of the sleeve.

The tool device is adapted for being inserted into the close-fitting metal sleeve within the tube for radially expanding the sleeve into the tubesheet to provide a pressure-tight seal therebetween. The tool utilizes elastomer expander rings which are each contoured to include a chamfer at the outer corners of the forward and rear faces of the seal ring unit to provide efficient radial expansion without undesirable extrusion and achieve long useful life for the rings. Such effective tube repair avoids expensive rebuilding or replacement of heat exchanges, such as air preheaters in fuel fired steam power plants.

In a particularly preferred embodiment, the tool includes a housing having a cylindrical longitudinal bore and containing a front pressurizable port connected to the bore, and a housing closure plate containing a rear pressurizable port. A housing adapter flange having a reduced diameter portion sized to fit within the tube end is provided at the forward end of the housing to facilitate locating the tool relative to the sleeve

and tubesheet. The housing cylindrical bore contains a piston axially movable therein, which piston is attached at its forward end to an elongated rod having an adjustable retainer nut threadably attached thereon. An elastic expander unit comprising at least two elastic expander rings or washers is provided encircling the rod between the housing flange and the adjustable retaining nut. The front and rear expander rings each have a chamfer provided at the front outer corner of the front ring and the rear outer corner of the rear ring adjacent the retainer nut and housing flange, respectively, to minimize radial outward extrusion of each ring during repeated pressurization cycles during use of the tool.

The expander rings are composed of an elastic elastomer material which retains its elasticity through many high compression and depressurization cycles during use of the tool. Useful ring materials include polyurethane, nylon, teflon and synthetic rubber, with polyurethane elastomer being preferred because of its desirable high pressure characteristics.

This invention also includes a method for using the tool device for expanding an end, particularly the rear end, of a close-fitting metal sleeve firmly into the tube into the tubeplate or tubesheet such as in a heat exchanger, to provide a pressure-tight interference fit between the sleeve outer surface and the tube inner surface. In the method, the tool forward end is first inserted into the elongated metal sleeve which is positioned within the near end of a tube in a heat exchanger. The tool forward end including the retainer nut, elastic expander ring unit, and housing adapter flange forward portion are inserted fully into the sleeve, after which the housing front port is pressurized so as to move the piston rearwardly and axially compress the elastic expander rings and thereby expand them radially outwardly against the sleeve. Such expansion also expands the rear end portion of the metal sleeve radially outwardly firmly against the inner surface of the tube, which is already sealed pressure-tight within the tubesheet. The resulting joint made by the tool forms a rear pressure-tight seal between the sleeve and the damaged tube, which was previously pressure-tightly rolled into the tubesheet opening during original manufacture of the heat exchanger.

Following such expansion of the elastic expander rings and the sleeve against the tube, the housing forward port is depressurized and the rear port is pressurized so as to move the retainer nut forward and release the axial pressure on the elastic rings. The tool is then withdrawn from the expanded sleeve and tube, and is inserted into another sleeved tube where the procedure is repeated as desired.

The invention will be described by way of example and with reference to the accompanying drawings, in which:-

Figure 1 shows a perspective elevation view of a heat exchanger portion containing a plurality of tubes, and a tool device in accordance with the invention which is for expanding a sleeve into a tube in a tubesheet of the heat exchanger;

Figure 1A shows an enlarged view of a sleeve after being expanded into a tube and tubesheet of the heat exchanger;

Figure 2 shows a longitudinal cross-sectional view of the tool inserted into a sleeve and tube in a tubesheet with elastomer expander rings in a normal unexpanded position relative to the sleeve;

Figure 3 shows a partial longitudinal cross-sectional view of the tool and tube with the expander rings and sleeve in an expanded position in the tube; and

Figure 4 shows a partial sectional view of the rod and expander ring unit of the tool.

As is generally shown by Figure 1, a vertical tubular heat exchanger 110 has a plurality of tubes 112 with their lower ends being expanded tightly into a lower tubesheet 113. Tube ruptures 112a in some of tubes 112 are to be repaired by inserting a sleeve 114 into each damaged tube and locally expanding the sleeve outer surface against the inner wall of tube adjacent the tubesheet 113, so as to provide a pressure-tight seal at the lower end of the tube 112, as shown in greater detail by Figure 1A. Such tube repair is provided by inserting a special tool 120 into the sleeve and radially expanding the sleeve 114 against the tube 112.

As shown in Figure 2, the pressurizable tool device 120 includes a housing 122 having a cylindrical longitudinal bore 123 and containing a pressurizable front port 124 connected to the bore. Housing 122 encloses a piston 126 axially movable in bore 123 and containing an outer seal ring 125. The housing 122 rear end is closed by a head plate 128, which has a forward portion 128a inserted into bore 123 and is attached to housing 122 by a plurality of bolts 128b and is pressure-sealed to the housing bore 123 by outer seal ring 127. Head plate 128 is pressure-sealed around a rear extension portion 126a of the piston 126 by inner seal ring 129, and contains pressurizable rear port 138 flow connected to bore 123.

The piston 126 forward end is threadably attached 126b to an elongated rod 130, which is pressure-sealed to housing 122 by O-ring 131. Rod 130 forward portion 130a has a reduced diameter and extends through an adapter flange 132, which is removably attached to the front face of the housing 122 by a plurality of threaded screws 133. Adapter flange 132 includes a front portion 132a having a reduced diameter which is sized to fit within a tube 112 into which a close-fitting sleeve 114 is to be expanded, so as

to contact the rear end of the sleeve 114 and axially locate the sleeve relative to the tube 112 and tubesheet 113. Threadably attached to the forward end 130a of rod 130 is a retainer nut 134, which may be tapered to facilitate inserting the nut and tool into a tube and sleeve 114.

Located between the adapter flange front portion 132a and nut 134 is an expander unit 136 containing 2-4 contoured elastic expander rings 136a, 136b, etc. The rings are made of an elastic material which is capable of withstanding repeated high compression loading without causing permanent deformation of the rings. Useful elastic materials for rings 136 include polyurethane, nylon, teflon, and synthetic rubber, with polyurethane elastomers being preferred because of its desirable elasticity characteristics and being able to withstand numerous use cycles without permanent deformation Polyurethane elastomer has desirable characteristics of being substantially solid under normal unpressurized conditions and having similar to a hydraulic liquid when highly pressurized. Polyurethane elastomer also has a memory characteristic of being able to return to substantially its original shape after a high compressive pressure has been removed. A suitable preferred material is polyurethane elastomer XPE-10 obtainable from Polaroid corporation.

The expander ring unit 136 is preferably provided as two annular rings or washers 136a and 136b which preferably have equal thickness. A chamfer 137 is provided at the forward outer corner of edge of front ring 136a and at the rear outer corner or edge of rear ring 136b, and serve to retard or prevent permanent enlargement of the ring at that location due to the repeated axial loadings and high compression required for the rings during use. The chamfer 137 has an angle a of 30-60 degrees with the face of the ring, and has a radial dimension d equal to 20-30% of the radius of the ring, as shown in Figure 4.

This tool device front extension portion is made to have a diameter slightly smaller than the sleeve for easy insertion into the rear end of the sleeve provided within a tube in a tubesheet. The tool extension portion length is made sufficient to extend past the tubesheet thickness and locate the expander rings unit 136 within the tubesheet thickness. The tool expander ring outside diameter is usually 1.0-2.0 inches (2.5-5.0 cm), and fits snugly within a sleeve 114 of a tube 112, and the tool forward portion length is usually 6-12 inches (15.0-30.0 cm) depending upon the tubesheet thickness. The tool is suitably made of high strength alloy steel.

In the method for using the tool device for expanding a close-fitting metal sleeve into a tube in a tubesheet so as to provide a pressure-tight interference fit therebetween, the tool forward end portion is first inserted into sleeve 114 provided in a tube 112 within a tubesheet, as shown in Figures 1 and 2. The front face of adapter flange 132 is usually placed against the exposed end of tube 12 and the front flange extension portion 132a is usually positioned substantially in alignment with the front face of tubesheet 113. The tool is connected by suitable hoses to a hydraulic pressurizing unit (not shown). The housing front port 124 is then pressurized such as to about 2000 psig (14×10^6 N/m^2) hydraulic pressure, so as to move the piston 126 rearwardly and axially compress the elastic expander ring unit 136, thereby radially expanding the sleeve 114 pressure-tightly against the tube 112, as is shown by Figure 3.

After expanding sleeve 114, the tool housing front port 124 is depressurized and the rear port 138 is pressurized, which moved forward the piston 126 and the retainer nut 134 so as to release the axial loading pressure on expander ring unit 136. The tool device 120 can now be easily withdrawn from the tube, and inserted into another tube for further cycles of use for sleeve expansion into tubes. It has been found that the front expander ring 136a loses its resiliency first because of its loading and higher compression and greater deformation and is replaced after about 20-30 cycles of use. After another 20-30 cycles of use, both rings 136a and 136b are replaced with new expander rings by removing retainer nut 134.

This invention will be further described by the following example of a tool and tube configuration, which should not be considered as limiting the scope of the invention.

A sleeve to tubesheet expander tool device according to this invention is constructed and used for expanding and tightly sealing a sleeve rear end into a tube in a tubesheet of heat exchanger. The tool device and heat exchanger have the following typical dimensions and characteristics:-

Tube inside diameter, in (cm)	1.834	(4.658)
Sleeve outside diameter, in (cm)	1.800	(4.572)
Sleeve inside diameter, in (cm)	1.634	(4.150)
Tool length, in (cm)	8	(20)
Tool housing outside diameter, in (cm)	4	(10)
Piston diameter, in (cm)	3.25	(8.26)
Expander rings outside diameter, in (cm)	1.625	(4.128)
Expander ring length, in (cm) (Each of two rings)	0.50	(1.27)
Piston operating pressure, psig (N/m^2)	2000	(14×10^6)

In use, the tool forward extension portion is first inserted into a metal sleeve provided in a tube of the heat exchanger, so that the expander rings are positioned in lateral alignment with the tubesheet of the heat exchanger. The tool front port is pressurized to 2000 psig (14×10^6 N/m^2) by a suitable hydraulic pressurizing unit connected to the tool, which drives the piston rearwardly and compresses and expands the expander rings and swages the metal sleeve radially outwardly against the tube within the tube sheet. Then the tool housing front port is depressurized and the rear port is pressurized to 2000 psig (14×10^6 N/m^2), which moves forward the piston to release the axial force on the expander rings and permits the tool device to be withdrawn from the sleeve and tube. This procedure is repeated for each tube repaired.

As described hereinabove, the tool device is particularly suitable for the expansion of the lower or rear end of a sleeve. It will be appreciated, however, that it may be employed equally successfully to expand the inner or forward end of the sleeve. However, another tool device having a collet with multiple radially expandable fingers may be used for this purpose, the two tool devices being used in conjunction to seal both ends of a repair sleeve to a tube as is described in co-pending European Patent Application 88306743.1/0309078.

Claims

1. A pressurizable tool adapted for expanding a sleeve into a surrounding tube in a tubesheet, comprising a housing having a cylindrical axially bore, a piston axially movable within the housing bore and attached at its forward end to an elongated rod, the rod having a retainer nut threadably attached onto its forward end, and an elastic expander unit encircling the rod, the expander unit containing at least one elastomer ring, movement of the piston rearwardly in the housing axially compresses the elastic expander unit so as to radially expand the expander unit firmly against the sleeve and expand the sleeve tightly against the tube in the tubesheet, characterised in that the housing (122) contains a front port (124) connected to the bore (123), in that the tool (120) includes a closure plate (128) having a forward portion (128a) inserted into the cylindrical bore (123), and containing a rear port (138) connected to the bore (123), in that the expander unit (136) is between the housing (122) and the retainer nut (134), pressurisation of the housing front port (124) moving the piston (126) rearwardly to axially compress the expander unit (136) against the housing (122) and in that the expander unit (136) includes a plurality of elastomeric rings (136a, 136b) and has a chamfer (137) at an outer edge of the unit front and rear end faces, the chamfer extending from the outer edge toward the centre of the ring (136a, 136b) forming the end face by a radial distance equal to 15-30% of the radial thickness of the ring.

2. A tool as claimed in Claim 1, wherein the closure plate (128) is attached to the housing (122) by a plurality of fastener bolts (128b) and is pressure-sealed to the housing (122) and piston (126) by outer and inner O-ring seals (127, 129).

3. A tool as claimed in either Claim 1 or Claim 2, wherein the piston (126) has a rearward projection (126a) which extends through the closure plate (128) and is pressure sealed to the plate (128).

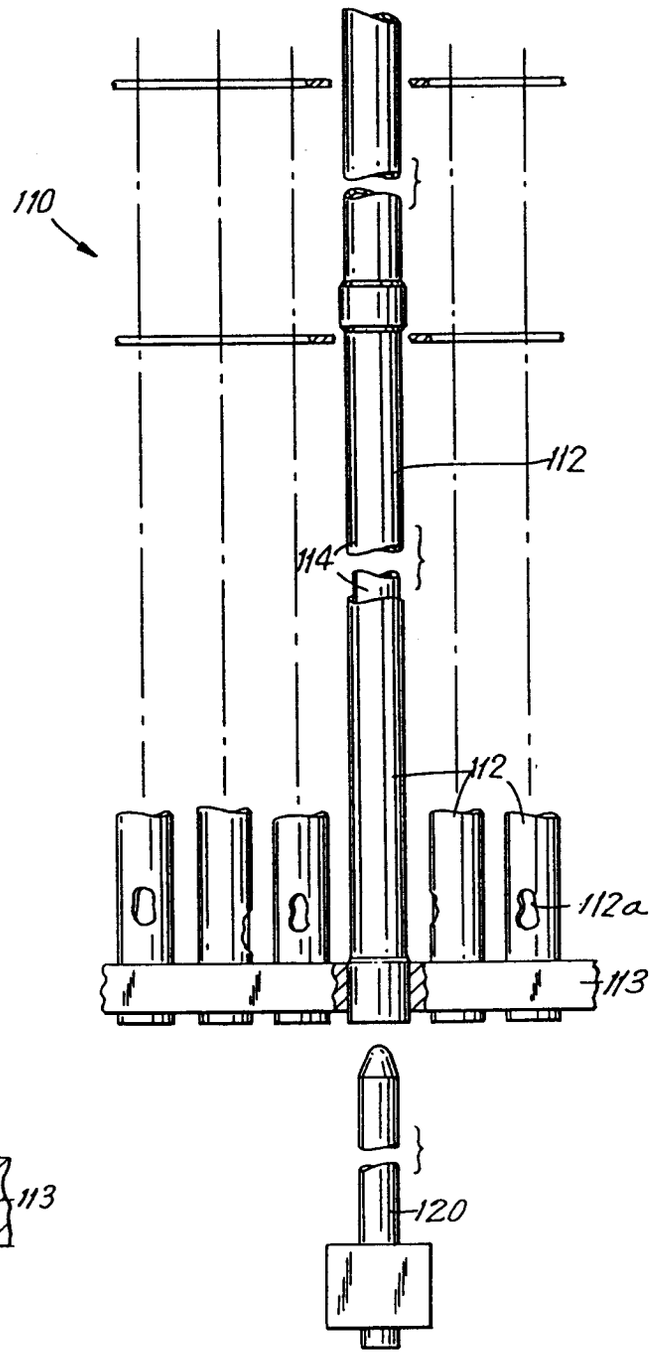
4. A tool as claimed in any preceding Claim, wherein the housing (122) has a forward reduced diameter portion sized to fit within the tube (112) and contact a rear end of the sleeve (114).

5. A tool as claimed in any preceding Claim, wherein an adapter flange (132) is rigidly attached to the housing front end, the flange (132) having a front portion (132a) adapted to fit inside a tube (112) and contact an end of the sleeve (114).

6. A tool as claimed in any preceding Claim, wherein the expander unit (136) consists of two rings (136a, 136b) having equal thickness.

7. A tool as claimed in any preceding Claim, wherein the expander unit rings (136a, 136b) are composed of polyurethane elastomer.

FIG. 1



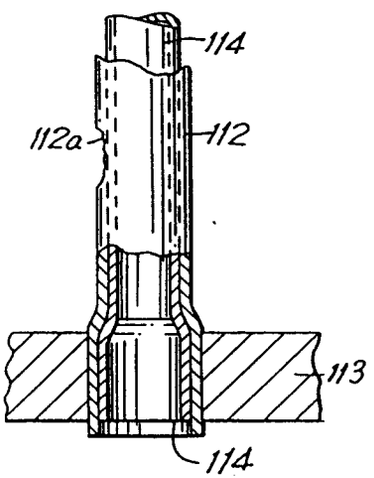
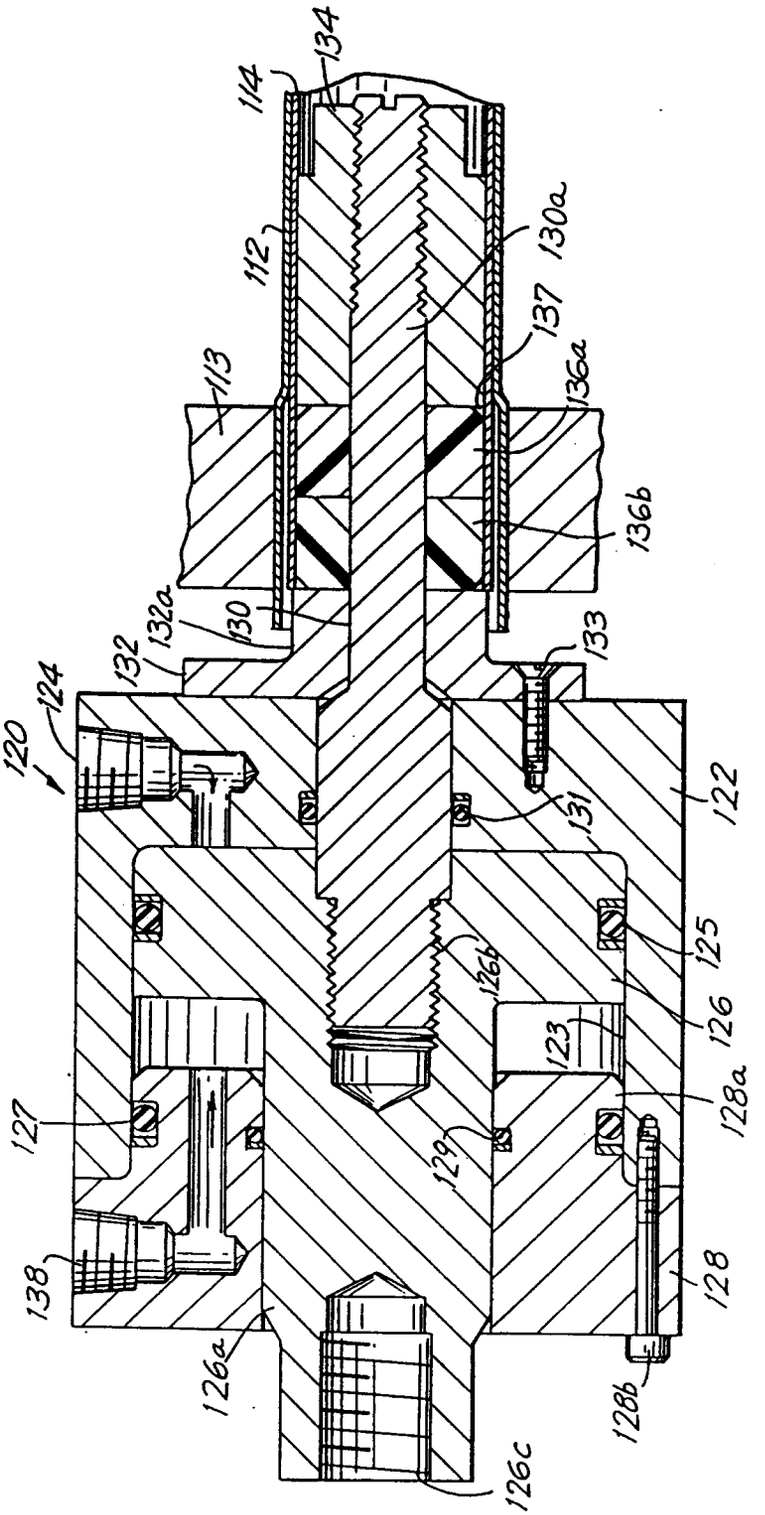


FIG. 1A

FIG. 2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134
112
130a
137
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136a
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130
132
133
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126a
128b
126c

FIG. 3

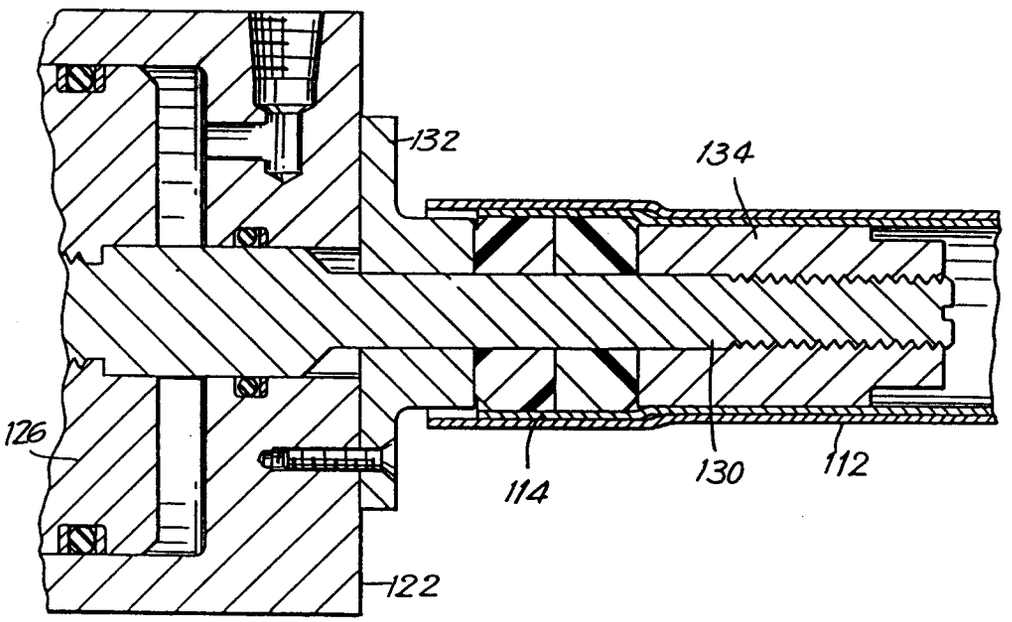

FIG. 4