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

A method and apparatus for locating a sleeve within a surrounding tube and pressure-tightly sealing the sleeve within the tube to repair leaks in the tube. The sealing method utilizes dual elongated pressurizable tools. The first tool device includes a housing having a reduced-diameter forward extension portion attached to a front cylinder, and containing a rear piston. The front cylinder, is attached to a collet having multiple radially expandable fingers and contains a front piston attached to a tapered mandrel which is axially movable within the fingers, and has a forward tapered nose portion to facilitate inserting the tool into a tube. The rear piston is attached to the front piston by an elongated rod. By pressurizing the tool front piston by a hydraulic fluid pressurizing unit, the mandrel is forced forward through the collet fingers to expand the fingers against the sleeve and thereby expand the sleeve tightly into the tube to form the seal joint. After withdrawing the tool from the tube, the tool rear piston is similarly pressurized to retract the front piston and attached mandrel back through the collet expandable fingers to reset the tool prior to its further use. The second 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is pressurized and moved forward to release the compression on the expander unit rings, so that the tool can be easily withdrawn from the expanded sleeve and tube and inserted into another sleeve and tube for repeated usage.

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## METHOD OF APPARATUS FOR EXPANDING AND SEALING A SLEEVE INTO A SURROUNDING TUBE

This invention pertains to method and apparatus for expanding and sealing a tubular sleeve into a surrounding tube. It pertains particularly to expanding and pressure sealing opposite ends of a close-fitting metal sleeve within a surrounding tube, and to dual pressurizable tool devices which are used for remotely accomplishing such sealing.

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 3,470,724 to Gregg discloses a pipe end forming machine which utilizes an external holding collet to hold a tube end and a central tapered arbor which is pushed through a forming collet to locally expand the tube end. U.S. Patent 3,829,948 to Miller et al discloses an apparatus for expanding tubes into a tubesheet using an expandable collet. 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 has apparently not provided a method and self-contained tool devices for remotely expanding a close-fitting tubular sleeve into a surrounding tube quickly and conveniently, so as to provide a pressure-tight joint therebetween. The prior art evidently does not disclose pressurizable tool devices 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. However, a tube repair method for inserting an elongated close-fitting metal sleeve into a tube and radially expanding and pressure sealing each end of the sleeve to the tube inner wall by using improved elongated pressure-operated tool devices has now been developed according to the present invention. Also, special pressurizable tools have now been developed according to the present invention for repairing such leaking tubes by inserting a tubular metal sleeve into the tube, then inserting the tools in sequence into the sleeve and radially expanding the sleeve to seal the sleeve pressure-tight to the tube and to the tubeplate.

The present invention provides a method for expanding opposite ends of a sleeve into a surrounding tube. Specifically, the invention provides a method for utilizing a first elongated tool device for remotely expanding the forward end of a close-fitting sleeve into a surrounding tube. The method includes the steps of inserting an elongated close-fitting tubular sleeve into a tube so as to extend past any opening or rupture in the tube, then inserting the elongated extension portion of the tool into the sleeve and its surrounding tube, so that collet fingers of the tool are located near the forward or inner end of the sleeve. Next, the tool front piston is pressurized so as to force a tapered mandrel attached to the piston forward end through a plurality of radially expandable collet fingers, so as to expand the fingers radially outwardly against the inner surface of the sleeve and also expand the sleeve firmly against the tube inner wall, so as to provide an interference fit and seal therebetween. The tool front piston is further pressurized to force the mandrel further forward through the collet fingers to contact a reduced diameter portion of the mandrel so as to retract the fingers, after which the

tool is withdrawn from the sealed sleeve and tube. Finally, a rear piston of the first tool device is pressurized to retract the mandrel rearwardly through the collet fingers to its original position to reset the tool ready for a new cycle of operation for the tool device.

This invention also includes a method for expanding the rear end of the 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 second tool forward end is first inserted into the elongated metal sleeve which is positioned within the rear 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.

This invention also includes a first or inner sealing elongated tool device adapted for remotely expanding a sleeve into a surrounding tube to provide a pressure-tight seal therebetween. The first or front sealing tool device includes a housing and an elongated forward extension portion attached to a front cylinder containing an axially movable piston pressurizable through a first port in the housing. The front cylinder is attached to an expandable collet having a plurality of radially movable fingers located at its forward end. A tapered mandrel attached to the piston forward end has an enlarged diameter at its rearward end, and is arranged to be moved by the front piston axially forward through the collet to expand the collet fingers radially outwardly against the inner wall of the sleeve into which the tool is inserted. The collet fingers force a localized portion of the sleeve radi-

ally outwardly until it contacts the tube, and then radially expands both the sleeve and tube together, to radially outwardly form a positive lock and seal joint between the sleeve and the tube.

The mandrel also has an oppositely tapered reduced diameter portion located adjacent the rear end of the mandrel, so that upon further mandrel forward movement the reduced diameter rear end portion permits the collet fingers to retract radially inwardly. Such retraction of the collet fingers permits the tool device to be withdrawn from the tubular sleeve and the surrounding tube to which the sleeve has been sealed.

The tool housing extension portion also has a rear cylinder containing an axially movable piston which is rigidly connected to the front piston by a central connecting rod, and is pressurizable through a second port in the housing. Following withdrawal of the tool device from a tube, pressurizing the rear piston in the tool housing will move the mandrel rearwardly through the collet fingers to its original position, so as to reset the tool ready for repeated usage.

The invention also includes a second or rear end sealing pressurizable tool device for use in effectively repairing leaking tubes in heat exchangers. The tool is adapted for being inserted into a close-fitting sleeve located within a tube for expanding the sleeve and tube firmly into an opening in a tubesheet of the heat exchanger.

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 preferably 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 be-

ing preferred because of its desirable high pressure characteristics.

This invention advantageously provides a method for effective repair for corroded or ruptured tubes and thereby avoid expensive and time consuming rebuilding or replacement of the heat exchanger. It also advantageously provides dual elongated tools for carrying out the sealing method, the first tool being an elongated tool device which is adapted for being inserted into a close-fitting sleeve and tube in a heat exchanger and expanding the sleeve into the tube to provide a leak-tight seal therebetween.

The second 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 dual 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 exchangers, such as air preheaters in fuel fired steam power plants.

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

Fig. 1 shows a perspective elevation view of a portion of heat exchanger containing a plurality of tubes, and a pressurizable first tool device used for expanding a sleeve into leaking tubes of the heat exchanger;

Fig. 1A shows an enlarged partial sectional view of a sleeve expanded within a tube and tubesheet of the heat exchanger to provide a seal joint for the tube;

Fig. 2 shows a longitudinal cross-sectional broken view of the elongated tool device inserted into a sleeve in a tube, with the mandrel and collet fingers in their initial normal unexpanded position relative to the sleeve;

Fig. 3 shows a cross-sectional view of the tool housing taken at section 3-3' of Fig.2;

Fig. 4 shows a partial cross-sectional view of the tool after being pressurized, with the collet fingers being in an expanded position within the sleeve and tube;

Fig. 5 shows a partial cross-sectional view of the tool showing the mandrel moved to a forward position to retract the collet fingers, and thereby permit withdrawal of the tool from the sleeve and tube.

Fig. 6 shows a perspective elevation view of a heat exchanger position containing a plurality of tubes, and the second tool device used for expanding a sleeve into a tube in a tubesheet of the heat exchanger;

Fig. 6A shows an enlarged view of a sleeve after being expanded into a tube and tubesheet of the heat exchanger;

Fig. 7 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;

Fig. 8 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

Fig. 9 shows a partial sectional view of the rod and expander ring unit of the tool.

As generally shown in Fig. 1, a vertical tubular heat exchanger 10 has a plurality of tubes 12 which have been expanded at their lower ends into tubesheet 13. Some of the tubes 12 contain ruptures at 12a which are to be repaired by inserting an elongated close-fitting tubular sleeve 14 into each tube past the rupture 12a, and locally expanding the sleeve at 15 against the inner wall of the tube 12 so as to repair the rupture 12a by providing a pressure-tight joint at each end of the sleeve 14, as is shown in greater detail by Fig. 1A. Such tube repair joint 15 at the tube inner end is made by using a special first elongated tool device 20 according to the present invention. The sleeve lower end is subsequently sealed pressure-tightly to the tube by using another tool, such as described by a co-pending application.

As shown by Fig. 2, the elongated first tool device 20 includes a housing 22 which has an elongated cylindrical-shaped front portion 23 having a reduced diameter so as to be inserted within sleeve 14, and both are then inserted within tube 12. An adapter 24 is threadably attached to the forward end of extension portion 23 by threaded joint 23a, and outer spacer tube 26 is threaded onto the other end of adapter 24 by threads 25.

A cylinder assembly 28 is threadably attached at 27 to the forward end of spacer tube 26. Cylinder assembly 28 includes a collet 30 which is threaded at 29a onto the forward end of a cylinder 29. Collet 30 has at least three radially expandable fingers 31. The forward end of each collet finger 31 has an outwardly enlarged portion 31a shaped so as to contact and force an adjacent portion of sleeve 14 radially outwardly against tube 12, so as to deform the sleeve firmly into the tube and thereby provide a pressure-tight seal therebetween.

The cylinder 29 has a cylindrical bore 29b, which contains a piston 34 having a seal ring 35

and an elongated front portion 34a. The piston front portion is threadably attached at 34b to an elongated mandrel 36 having an outer surface 36a, which is tapered rearwardly so as to have an enlarged diameter at its rearward end. The tapered surface 36a is located adjacent a reduced diameter portion 37 and oppositely tapered portion 37a provided at the rear end of the mandrel 36. A tapered nose piece 38 is threadably attached at 39 to the forward end of the mandrel 36, to facilitate inserting the tool assembly 20 into the sleeve 14 and tube 12, as is generally shown in Fig. 2.

An elongated inner space tube 40 also extends between the adapter 24 and cylinder assembly 28 and is pressure sealed to the adapter 24 by a seal ring 41, and is sealed to cylinder assembly 28 by seal ring 43. The front piston 34 is pressurized and moved forward by fluid pressure being applied at sleeve expansion port 48 in housing 22, which port is connected to piston 34 by an annular longitudinal passageway 47 provided in housing extension 23 and connecting annular passageway 47a located between the inner spacer tube 40 and a connecting rod 46 as described below.

Located within the rear end portion of the tool housing 22 is a second cylindrical bore 42 containing an axially movable rear piston 44 containing a seal ring 45. The rear piston 44 is attached by a central elongated connecting rod 46 extending through the inner spacer tube 40 and is attached to near the forward piston 34. The front side of rear piston 44 is pressurizable through a longitudinal passageway 49, which is flow connected to piston retracting port 50 of housing 22. The rear end of housing 22 is closed by a plug 52 attached by threaded joint 53. Also if desired, reduced fluid pressure can be applied at port 54 to the rear side of piston 44, to augment the pressure applied through port 48 and passageway 47 to piston 34 and force mandrel 36 forward through the collet fingers 31. The relative locations of sleeve expansion port 48 and piston retraction ports 50 are shown by Fig 3.

The tool device forward extension portion 23 and cylinder assembly 28 is made to have whatever smaller diameter is needed to be easily inserted into a snug-fitting sleeve 14 within tube 12, and to have a length sufficient to pressure seal the inner end of the sleeve 14 to the tube at joint 15. The tool housing 22 outside diameter may be 2-3 inches, and the tool total length may be 4-8 feet. The tool is usually made about 6 feet long and its extension portion have a reduced outside diameter so as to slidably fit inside a close-fitting sleeve in a 1-2 inch diameter tube. The taper of the mandrel 36 is made relatively small, so as to limit the axial force necessary by piston 34 to force the collet fingers 31 radially outwardly to expand the sleeve

14 firmly into tube 12. The radial force required at the ringer end portion 31a is determined by the diameter, wall thickness and yield strength of both the sleeve 14 and tube 12 and the deformation need to produce pressure-tight seal 15. The total radial force and the coefficient of friction between the mandrel surface 36a and collet fingers 31 determines the axial force needed from piston 34 to drive forward the mandrel 26. The amount of taper for mandrel surface 36a may vary between about 0.050-0.065 inch diameter per inch length of the tapered mandrel. The mandrel outer surface 36a is usually coated with material having low coefficient of friction, such as molybdenum disulfide to minimize the friction between the tapered mandrel and the collet fingers.

Housing 22 has a shoulder 22a which is sized to fit within tube 12 and against the end of sleeve 14. Also, a spacer piece 51 is provided attached to the front end of housing 22. During use of tool 20, the forward end of spacer piece 51 is placed against the front face 13a of tubesheet 13 to facilitate proper location of the enlarged portion 31a of collet fingers 31 relative to the inner end of sleeve 14 to produce real joint 15.

The tool device is usually made of high strength alloy steel, with the mandrel 36 being made of hardened high carbon tool steel. The number of collet fingers 31 will vary with the diameter of the collet and sleeve 14. For example, for a sleeve outside diameter of 1.4 inch 6 collet fingers have been used, and for a sleeve outside diameter of 2.9 inches 12 collet fingers have been used.

The method steps for using the tool devices of this invention include first placing an elongated tubular sleeve 14 onto the forward end of tool 20, then inserting the tool 20 and sleeve 14 into a tube 12 which is to be repaired, as shown in Figs. 1 and 2. The first tool 20 ports 48 and 50 are connected by suitable high pressure hoses to a hydraulic pressurizing unit (not shown). The spacer ring 51 attached to the tool housing 22 forward end is abutted against the face 13a of tubesheet 13. Also, shoulder 22a of housing 22 serves to force forward the sleeve 14 and properly axially locate the sleeve within the tube 12 for forming joint 15 therebetween.

After inserting the tool 20 within a sleeve 14 and properly locating the sleeve 14 within the tube 12, the tool 20 is first pressurized at sleeve expansion port 48 to 3500-4500 psig hydraulic pressure so as to move forward piston 34 and tapered mandrel 36 and force collet fingers 31 radially outwardly against the sleeve 14 and tube 12, and then further radially expand the sleeve and tube together outwardly and form a positive lock and seal 15 between the sleeve and tube, as is shown by Fig. 4.

Further forward movement of mandrel 36 through collet fingers 31 permits the fingers to automatically retract into the mandrel reduced diameter portion 37, as shown by Fig. 5. The tool 20 is then withdrawn from the expanded sleeve 14 and tube 12, after which port 50 is pressurized using a hydraulic fluid at 3500-4500 psig pressure to move the rear piston 44 rearwardly and thereby recock the tool by withdrawing the tapered mandrel 36 from the collet fingers 31 to the initial position as shown by Fig. 2.

As is generally shown by Fig. 6, 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 Fig. 6A. Such tube repair is provided by inserting a special tool 120 into the sleeve and radially expanding the sleeve 114 against the tube 112 according to the present invention.

As shown in Fig. 7, 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 por-

tion 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  $\alpha$  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 Fig. 9.

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, and fits snugly within a sleeve 114 of a tube 112, and the tool forward portion length is usually 6-12 inches depending upon the tubesheet thickness. The tool is suitably made of high strength alloy steel.

In the method for using the second 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 Figs. 6 and 7. 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 con-

ected by suitable hoses to a hydraulic pressurizing unit (not shown). The housing front port 124 is then pressurized such as to about 2000 psig 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 Fig. 8.

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 examples of a tool and tube configuration, which should not be considered as limiting the scope of the invention.

#### EXAMPLE 1

A sleeve to tube expander first tool device according to the invention is constructed and utilized for pressure-tight sealing the inner end of sleeves into tubes of an air preheater in a power plant. The heat exchanger and tool device have the following typical dimensions and characteristics.

Tube inside diameter, in.	1.834
Sleeve length, in.	78
Sleeve outside diameter, in.	1.800
Sleeve inside diameter, in.	1.634
Tool length, in.	83
Tool housing outside diameter, in.	2.5
Front piston diameter, in.	1.31
Rear piston diameter, in.	0.56
Number of collet fingers	10
Pressure on front piston, psig	4000
Pressure on rear piston, psig	4000

During use, the tool device forward extension end is first inserted into an elongated metal sleeve provided in a tube of the heat exchanger, and the tool is pushed forward against the tubesheet so that the tool collet fingers are positioned near the front or inner end of the sleeve. The tool front piston is pressurized by a hydraulic fluid pressurizing unit connected to the tool, and the tapered mandrel is forced forward to expand the collet

fingers and expand the sleeve firmly against the tube and then expand the tube and sleeve together radially outwardly, thereby forming a positive lock and seal between the sleeve and tube. This pressurizing and sleeve sealing step usually takes 10-15 seconds time. Next, the tool is withdrawn from the sleeve and tube, after which the tool rear piston port is pressurized by the pressurizing unit, and the mandrel withdrawn through the collet fingers to reset the tool and prepare it for its next cycle of use. This procedure is repeated for each tube being repaired in the heat exchanger using the method of the invention.

#### EXAMPLE 2

A sleeve to tubesheet expander second 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.	1.834
Sleeve outside diameter, in.	1.800
Sleeve inside diameter, in.	1.634
Tool length, in.	8
Tool housing outside diameter, in.	4
Piston diameter, in.	3.25
Expander rings outside diameter, in.	1.625
Expander ring length, in.	.50
(Each of two rings)	
Piston operating pressure, psig	2000

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 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, 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, using the method of the invention.

## Claims

1. A method for remotely expanding and sealing a tubular sleeve into a surrounding close-fitting tube to provide a seal joint therebetween using dual elongated pressurizable tool devices, the method comprising:

(a) inserting an elongated tubular sleeve into a tube, said sleeve having a length extending past any ruptures in the tube;

(b) inserting an elongated pressurizable first tool device into said sleeve and aligning radially expandable collet fingers of the tool near the forward end of the sleeve, then pressurizing the tool to expand said fingers outwardly against the inner surface of the sleeve and thereby expand the sleeve forward end firmly against the tube wall and forming a seal therebetween, then withdrawing the first tool from the sleeve and tube;

(c) inserting a second pressurizable tool device into said sleeve, said second tool including a housing containing an axially movable piston and having an elastic expander provided near the rear end of the sleeve;

(d) pressurizing said second tool device to move its piston rearwardly to axially compress the elastic expander unit and radially expand the sleeve rear end firmly against the tube wall and forming a seal therebetween; and

(e) withdrawing said second tool device from the sleeve and surrounding tube.

2. A method for remotely expanding a tubular sleeve forward end into a surrounding tube to provide a seal joint therebetween using an elongated expander tool device, comprising:

(a) inserting an elongated tubular sleeve into a tube;

(b) inserting an elongated tool device into said sleeve and aligning radially expandable collet fingers of the tool near the forward end of said sleeve;

(c) pressurizing a front piston in said tool device and forcing an axially movable tapered mandrel attached to the piston forward end through the collet expandable fingers, so as to radially expand said fingers outwardly against the inner surface of the sleeve and thereby expand the sleeve firmly against the tube;

(d) further pressurizing the front piston to force the mandrel further through the collet fingers and thereby retracting the collet fingers;

(e) withdrawing the tool device from the expanded sleeve and tube; and

(f) pressurizing the tool rear piston to retract the mandrel rearwardly through the collet fingers and reset the tool for further use.

3. A method according to claim 2, wherein the tool front piston is pressurized to 3500-4500 psig pressure for expanding the collet fingers and sleeve.

4. A method according to claim 2, including pressurizing the rear side of the rear piston to additionally force the mandrel forward against the collet fingers.

5. A method according to claim 2, wherein the tool rear piston is pressurized to 3500-4500 psig pressure to retract the mandrel through the collet fingers.

6. A pressurizable tool adapted for expanding a sleeve rear end into a surrounding tube in a tubesheet, comprising:

a housing having a cylindrical axially bore and containing a front port connected to the bore;

a closure plate having a forward portion inserted into said cylindrical bore, and containing a rear port connected to said bore;

a piston axially movable within said housing bore, said piston being attached at its forward end to an elongated rod, said rod having a retainer nut threadably attached onto its forward end; and

an elastic expander unit encircling said rod between said housing and said retainer nut, said expander unit containing a plurality of elastomer rings and having a chamfer provided at the outer edge of the expander unit front and rear faces, whereby pressurizing the housing front port moves said piston rearwardly in the housing to axially compress the elastic expander unit against the housing so as to radially expand the expander unit firmly against the sleeve into the tube in the tubesheet.

7. A tool according to claim 6, wherein said closure plate is attached to said housing by a plurality of fastener bolts and is pressure-sealed to said housing and piston by outer and inner O-ring seals.

8. A tool according to claim 6, wherein said piston has a rearward projection which extends through said closure plate and is pressure sealed to the plate.

9. A tool according to claim 6, wherein an adapter flange is rigidly attached to said housing front end, said flange having a front portion adapted to fit inside a tube and contact an end of the sleeve.

10. A tool according to claim 6, wherein said expander unit consists of a two rings having equal thickness, with each ring having a chamfer with a radial dimension equal to 15-30% of the ring radius.

11. A tool according to claim 6, wherein said expander unit rings are composed of polyurethane elastomer.

12. A pressurizable tool adapted for expanding a sleeve rear end into a surrounding tube in a tubesheet, comprising:

a housing having a cylindrical axial bore and containing a front port connected to the bore;

a closure plate having a forward portion inserted into said cylindrical bore and containing a rear port connected to said bore;

a piston axially movable within said housing cylindrical bore, said piston having a rearward extension which extends through said closure plate and is attached at its forward end to an elongated rod, said rod having a retainer nut threadably attached onto its forward end;

an adapted flange rigidly attached to the front end of said housing encircling said rod, said adapter flange having a front shoulder portion sized to fit inside a tube and contact the rear end of the sleeve; and

dual elastic expander rings provided encircling said rod between said housing adapter flange and said retainer nut, said expander unit containing dual rings each having a chamfer located at the outer edge of the front and rear faces, whereby pressurizing the housing front port moves said piston rearwardly in said housing to axially compress the elastic expander unit against said housing adapter flange, so as to rapidly expand the expander rings firmly against the sleeve into the tube in the tubesheet.

13. An elongated first tool device adapted for remotely expanding a tubular sleeve forward end into a surrounding tube, comprising:

(a) a housing having first and second ports provided therein, said housing having a forward extension portion which is attached to a front cylinder;

(b) a collet attached to said front cylinder at its forward end, said collet having at least three radially expandable fingers located at the collet forward end;

(c) a front piston axially movable within said front cylinder, said front piston being connected to an elongated tapered mandrel having an enlarged diameter at its rearward end and an adjacent longitudinally extended reduced diameter portion, said mandrel being axially slidable in said collet and connected to a front guide portion;

(d) a rear cylinder located within said housing and containing a rear piston which is rigidly connected to said front piston by a centrally located rod extending therebetween; and

(e) an elongated tube centrally disposed around said rod, said tube being arranged for supplying fluid pressure from said first housing port to the rear end of said front piston, said housing having said first port flow connected to the rear end of the front piston and second port flow connected

to the forward end of the rear piston, whereby the tool forward extension portion can be inserted into a tubular sleeve and the front piston pressurized to move forward the tapered mandrel so as to radially expand the collet fingers against the sleeve and thereby expand the sleeve firmly into a tube to seal the sleeve into the tube.

14. A tool according to claim 13 wherein a spacer ring is attached to the forward end of said housing for axially locating said collet within the sleeve.

15. A tool according to claim 13 wherein said front cylinder is threadably attached to said housing forward extension by an elongated spacer tube to provide for adjustment of the tool length.

16. A tool according to claim 13 wherein said front guide portion is a tapered nose piece having an outer diameter slightly less than that of the collet and is rigidly attached to the forward end of said tapered mandrel.

17. A tool according to claim 13 wherein said mandrel forward portion has a diametral taper of 0.050-0.065 inch per inch of mandrel length.

18. A tool according to claim 13 wherein said housing contains an auxiliary rear port connected to the rear side of said rear piston, so as to additionally force the mandrel forward against said collet fingers.

19. A tool according to claim 13 wherein said collet has 6-12 radially expandable fingers.

20. An elongated first tool device adapted for remotely expanding a tubular sleeve forward end into a surround tube to provide a seal therebetween, the tool comprising:

(a) a housing having first and second ports provided therein, said housing having a forward extension portion and a spacer piece attached at its forward end to a front cylinder;

(b) a collet attached to said front cylinder at its forward end, said collet having 6-12 radially expandable fingers located at the collet forward end;

(c) a front piston axially movable within said front cylinder, said front piston being connected to an elongated tapered mandrel having an enlarged diameter at its rearward end and an adjacent longitudinally extended reduced diameter portion, said mandrel being axially slidable in said collet and connected to a front tapered nose guide piece having a diameter slightly less than that of the collet;

(d) a rear cylinder located within said housing and containing a rear piston which is rigidly connected to said front piston by a centrally located rod extending therebetween; and

(e) an elongated tube centrally disposed around said rod, said tube being arranged for supplying fluid pressure from said first housing port to the rear end of said front piston, said housing having said first port flow connected to the rear end of the front piston and said second port flow connected to the forward end of the rear piston, whereby the tool forward extension portion can be inserted into a tubular sleeve and the front piston pressurized to move forward the tapered mandrel so as to radially expand the collet fingers against the sleeve and thereby expand the sleeve firmly into a tube to seal the sleeve into the tube.

21. A method for radially expanding a sleeve rear end in a surrounding tube in a tubesheet, comprising:  
inserting a tool device into a close-fitting sleeve to be expanded in a surrounding tube, said tool device including a housing containing an axially movable piston and having an elastic expander unit provided at the housing forward end;  
pressurizing the tool to move said piston rearwardly and axially compressing the expander unit so as to radially expand the expander unit and sleeve firmly against the inner wall of the tube to produce a pressure-tight seal therebetween; then  
pressurizing the tool to move the piston forwardly to release the axial compression from the expander unit and contract the expander unit; and  
withdrawing the tool from the expanded sleeve and tube within the tubesheet.

22. A method according to claim 21, wherein the expander unit includes a forward and rear elastomer ring, and the forward ring is discarded after at least each 20 cycles of use and both rings are discarded after at least 40 cycles of use.

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Neu eingereicht / Newly filed  
Nouvellement déposé

FIG. 1

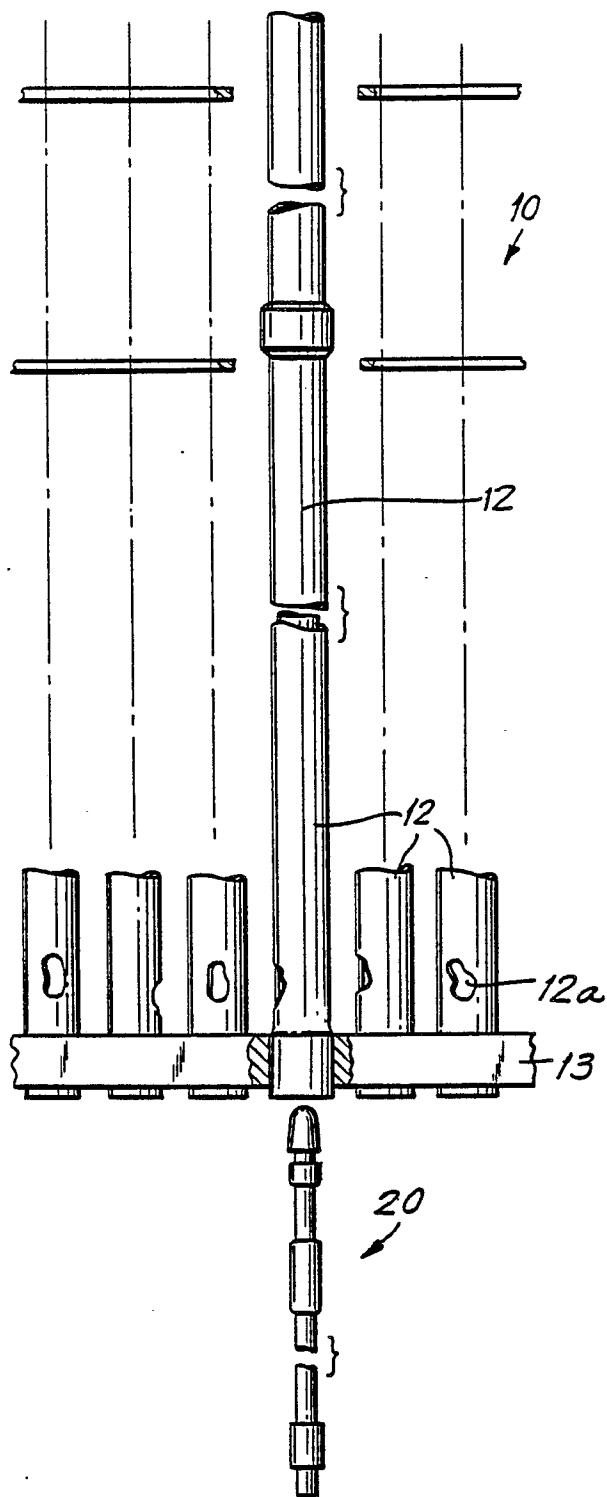


FIG. 1A

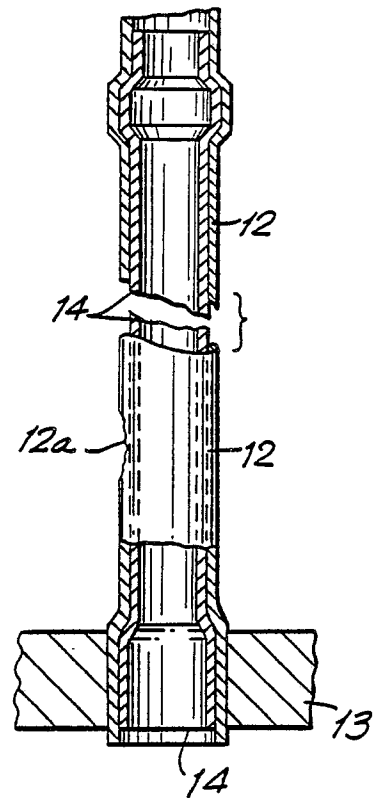
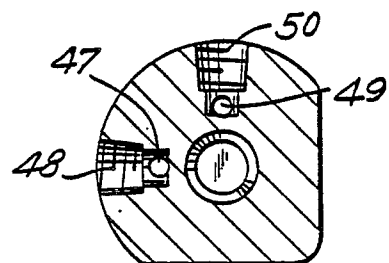
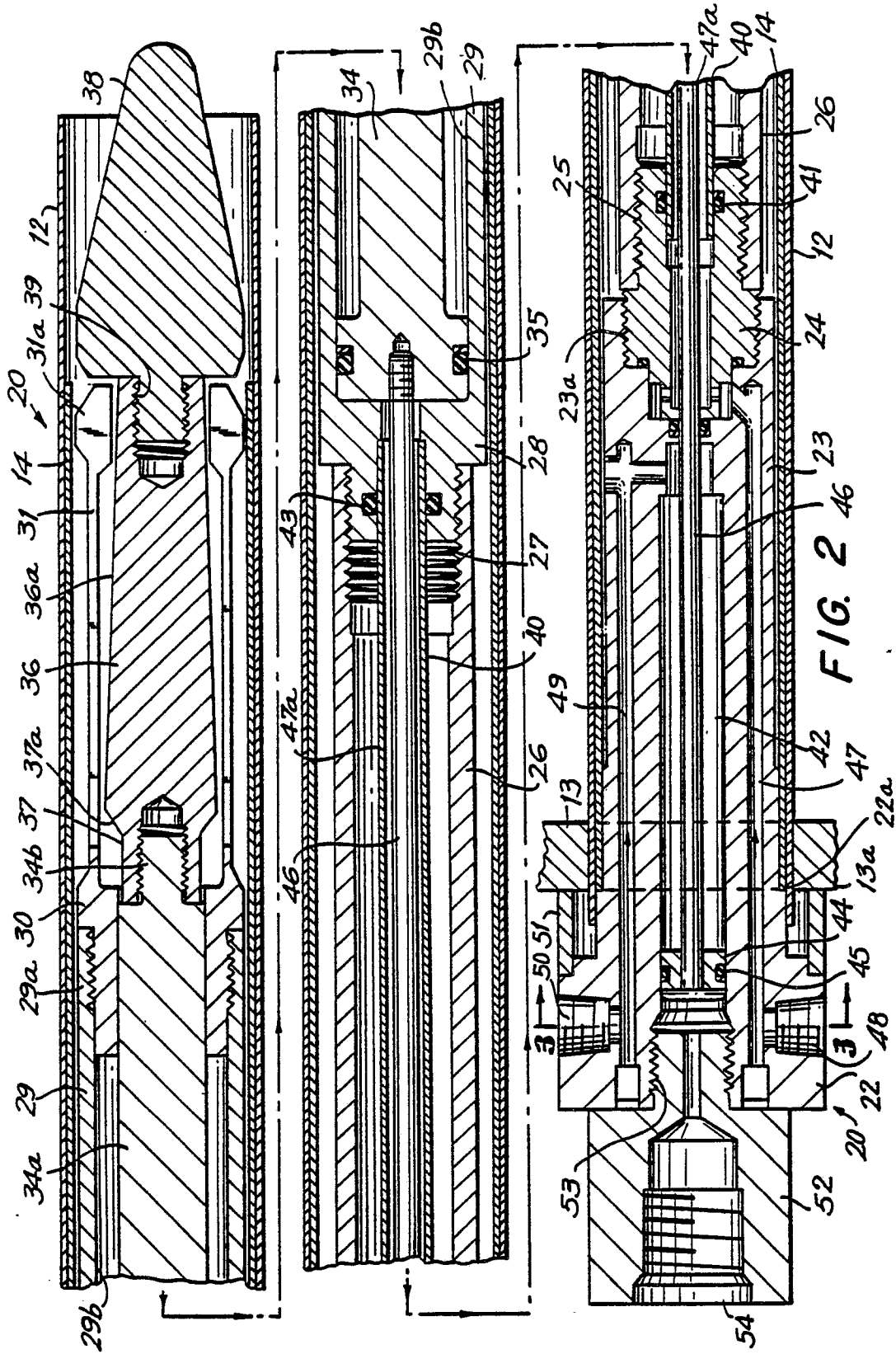


FIG. 3



Neu eingereicht / Newly filed  
Nouvellement déposé



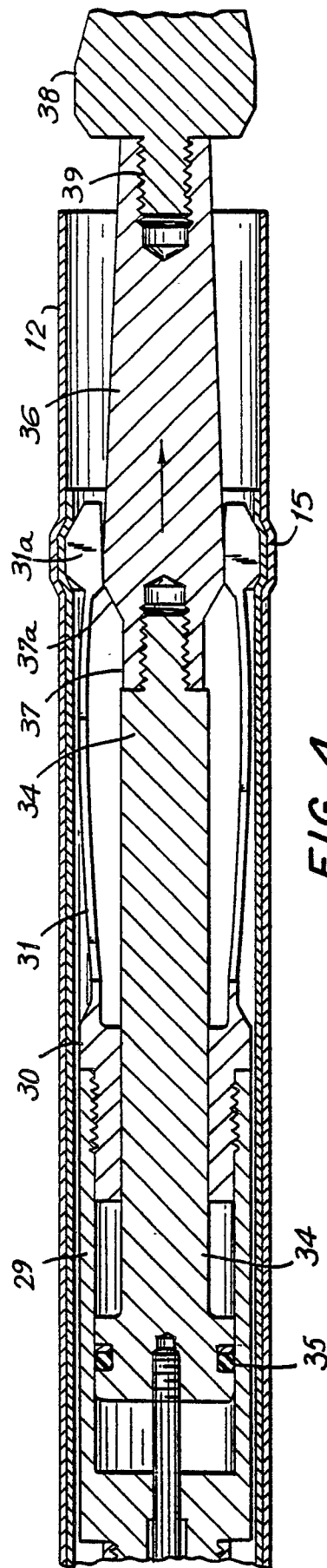


FIG. 4

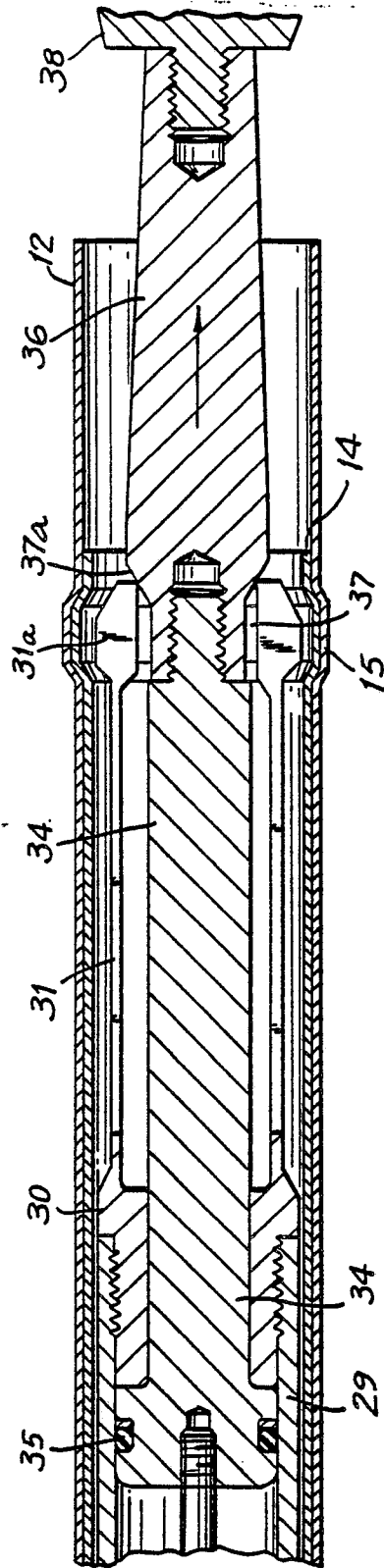


FIG. 5

FIG. 6

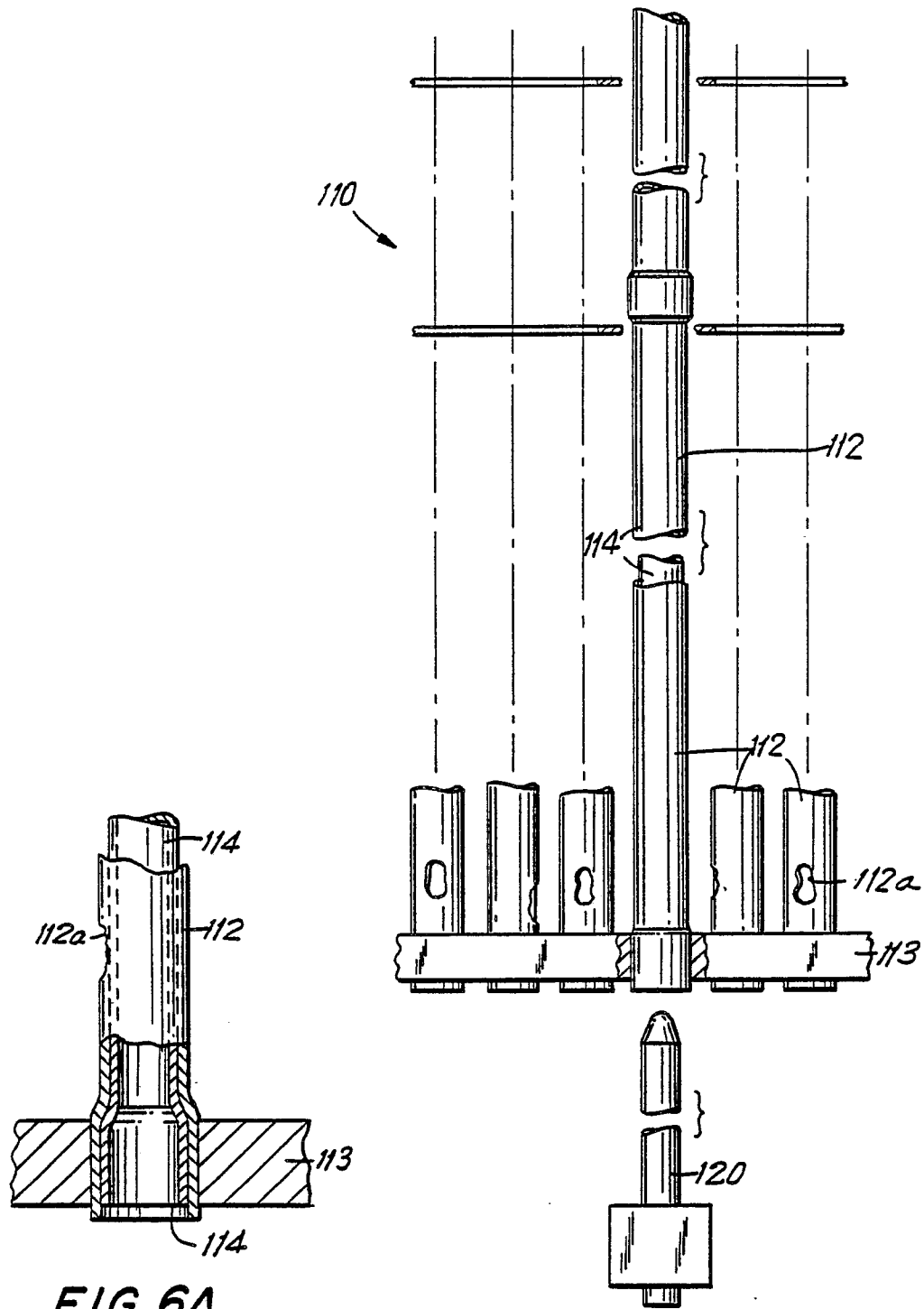


FIG. 6A

FIG. 7

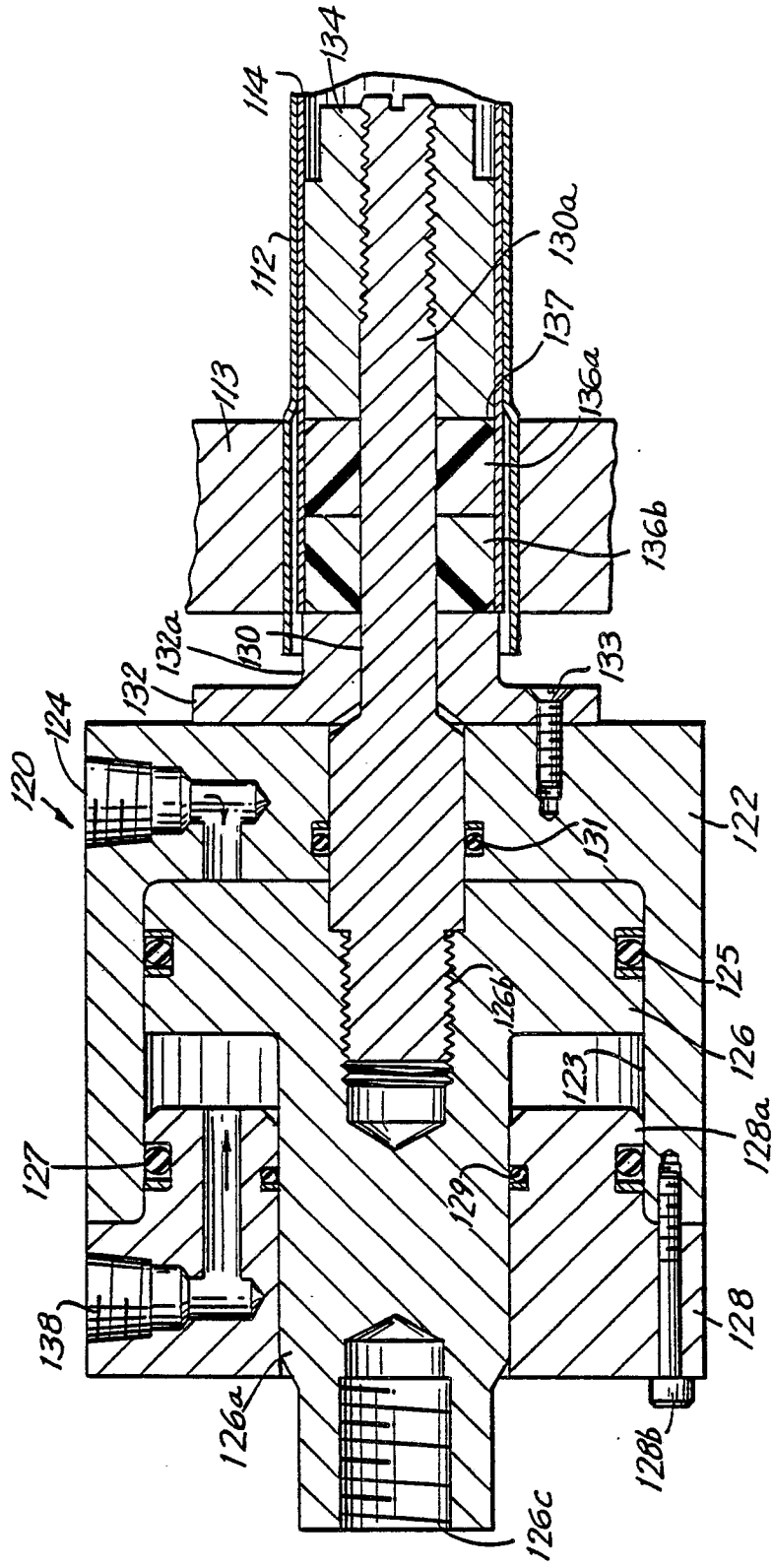


FIG. 8

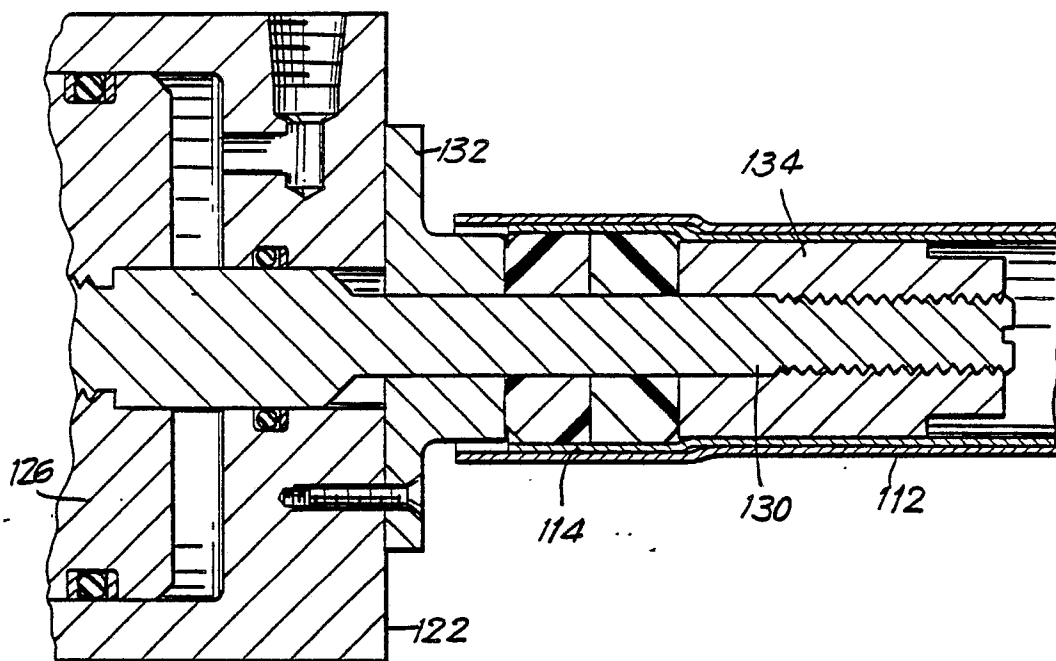


FIG. 9

