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(54) **Radially expanding tubular members.**

(57) In order to radially expand a tubular member (12), an apparatus (10) is disposed therein. The apparatus (10) comprises first and second spaced apart end caps (16, 18) rigidly connected to each other by a post (20). An expandable bladder (22) is fixed to each end cap (16, 18) and extends around the post (20) to define an annular space (24). A propellant is disposed in the annular space (24) and ignition means (32, 34) is associated with the propellant. The propellant is of the type which burns rapidly to generate large amounts of gas for expanding the bladder (22) and thus radially expands the tubular member (14) which is disposed around the bladder.

EP 0 131 466 A2

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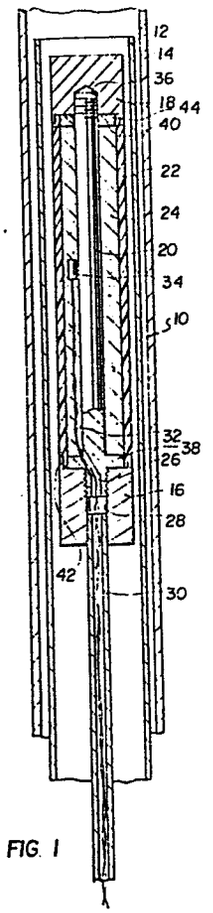


FIG. 1

RADIALLY EXPANDING TUBULAR MEMBERS

The present invention relates in general to the repairing, installing or otherwise manipulating of tubular members and, more particularly, to apparatus for and methods of radially expanding tubular members or tubes.

When installing or repairing tubes or tubular members, it is often advantageous to manipulate and shape the tubes or tubular members from within the tubes.

In nuclear-fueled vapour generators, a repair process is known whereby a tubular member is placed inside a steam generator tube and expanded near its end. A brazed joint is then made to sealably fix the tubular member within the steam generator tube. The previous method for accomplishing this was to use a hydraulic expander to expand the tubular member in the joint area prior to brazing. This process proved to be too slow and cumbersome thereby limiting the number of tubes which could be repaired in a given period of time. This was especially disadvantageous with regard to nuclear steam generators since the longer repair time resulted in an increase in nuclear radiation exposure for personnel making the repairs.

A method of and apparatus for hydraulically expanding tubing is known from US Patent No. US-A-4 195 390 (Amen). An expandable bladder is mounted between end caps connected to each other by a tie rod situated within the bladder. Hydraulic pressure is internally supplied to the bladder to expand the bladder and a surrounding tubular member. However, as noted above, hydraulic expansion is much too slow, particularly in a nuclear radiation environment. Furthermore, external pressure sources are required, which adds to the time necessary in operating the apparatus disclosed in US-A-4 195 390.

More rapid expansion techniques are known which utilise propellant or explosive charges. US Patent No. US-A-3 287 947 (Frantz et al), for example, discloses a tube flaring technique utilising an explosive charge to outwardly flare the end of a tube. US Patent No. US-A-3 876 233 (Schmedding et al) discloses an automatic pipe coupling device which uses a propellant for effecting a wedging action to move two parts with respect to each other.

According to the invention there is provided apparatus for radially expanding a tubular member, the apparatus comprising a first end cap, a second end cap spaced from the first end cap, a post rigidly connected between the end caps for connecting the end caps to each other, and an expandable bladder connected between the end caps and extending around the post, characterised in that the bladder defines a space with the post, a propellant is contained within the space, and ignition means is associated with the propellant for igniting the propellant to generate gas and radially expand the bladder.

The invention also provides a method of radially expanding a tubular member, comprising positioning in the tubular member an apparatus having spaced end caps fixed to each other by a post with an expandable bladder connected between the caps and around the post, and expanding the bladder to thereby expand the tubular member, characterised in that the bladder defines a space with the post, a fast burning propellant, which upon ignition generates large quantities of gas, is provided in the space, and the propellant is ignited to expand the bladder and at least a portion of the tubular member.

The present invention thus provides a method of and apparatus for rapid expansion of tubular members. The apparatus is preferably so designed that all of the set up work is done outside of the immediate repair area. This is particularly useful for nuclear radiation environments where exposure should be reduced to a minimum.

With the bladder and its end caps positioned within the tubular member, the propellant can be ignited to radially expand the tubular member, for any desired purpose. The propellant-actuated device can thus be utilised to expand repair tubing within a vapour generator tube of a nuclear-fuelled vapour generator. The invention is, however, also useful for expanding tubing into other elements such as tube sheets, support plates, headers and the like. The invention can also be used for expanding tube plugs and producing special tube configurations.

A preferred apparatus and method embodying the invention and described hereinbelow are simple in design, rugged in construction, economical to manufacture and easy to implement.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawing, in which:

Figure 1 is a sectional view of a propellant-actuated apparatus embodying the invention, shown with a tubular member to be expanded within a vapour generator tube;

Figure 2 is a view similar to Figure 1, showing the apparatus an instant after the propellant has bee ignited; and

Figure 3 is a view similar to Figure 2, showing the apparatus after the propellant has been spent and the expanding gases have been vented for withdrawal of the apparatus from the now-expanded tubular member.

The drawing shows apparatus 10 for radially expanding a tubular member 12 which, for example, may be repair tubing for a vapour generator tube 14 of a nuclear vapour generator (not shown).

The apparatus 10 comprises a first end cap 16, a second end cap 18 and a central post or tie rod 20 rigidly connected to both caps and holding them in a spaced relationship. In the usual vertical orientation of the vapour generator tube 14, the first end cap 16 would form a lower end cap and the second end cap 18 would form an upper end cap.

A flexible, resilient bladder 22 is fixedly connected between the caps 16 and 18 and extends around the post 20 to form a space 24, which is preferably annular. A propellant is provided in the space 24 to partially or fully fill the space.

Access is had to the space 24 through an ignition port 26 formed in one end of the post 20. The port 26 communicates with a bore 28 of the cap 16. A positioning rod 30 may be fixed to the cap 16, for example by press fitting or by threading an end of the rod 30 into the bore 28. This facilitates the positioning of the apparatus 10 in the tubular member 12 at a desired position.

Ignition means is provided in the form of an electrical wire 32 and an ignitor 34. The wire 32 may be supplied through a central bore of the rod 30, the bore 28 and the port 26. Alternative known ignition means may also be provided, which may or may not require mechanical access to the space 24 through the port 26.

The end of the post 20 containing the port 26 is threaded into the bore 28 and the opposite end is threaded into a blind bore 36 of the cap 18.

To properly support and hold the bladder 22 so that it closes the space 24, except for the port 26, the post 20 may include a flange 38 or may be surrounded by a separate ring 40 which bears against the inner surface of

the bladder 22 adjacent its ends. The caps 16 and 18 are provided with sleeve extensions 42 and 44, respectively, to support the outer end surfaces of the bladder 22.

In operation, the apparatus is positioned as shown in Figure 1.

Upon igniting the propellant, which is preferably fast burning, voluminous amounts of gas are generated thereby creating high pressure to rapidly expand the bladder 22, and a surrounding portion of the tubular member 12, as shown in Figure 2.

Once the propellant is exhausted the gases may be vented, for example through the ignition port 26. The bladder 22 collapses, as shown in Figure 3, and the apparatus 10 can then be removed.

The tubular member 12 is thus expanded in the vapour generator tube 14, in a rapid and secure manner, and with a minimum of on site exposure to nuclear radiation.

In comparison with the known hydraulic method of expanding tubing, the present apparatus and method can expand a tubular member within 10 to 15 milliseconds, as opposed to a period of about 5 minutes as required by the hydraulic technique. This is particularly significant where a large number of vapour generator tubes must be repaired in an environment exposed to nuclear radiation.

Another advantage of the present method and apparatus is cleanliness. While this is not generally a problem for the hydraulic expansion technique, it can be a problem in other expansion techniques which require lubricants or produce undesirable or harmful waste products. The propellant used with the present method and apparatus is totally contained within the bladder 22 and the generated gases can be vented to a location outside of the expansion area. Thus, there is no tube contamination, which would pose problems to subsequent brazing and could leave undesirable products within the tube or on the tube surface, possibly leading to future tube degradation.

A further advantage of the present method and apparatus over the prior art is that it requires far fewer auxiliaries. In the simplest form, a power supply need only be connected to the ignition wires. Unlike the hydraulic technique, the present method and apparatus do not require pumps, water supplies, piping, pressure recorders or electronic controls.

As opposed to roller type expanders, the present method and apparatus do not produce a damaged layer of material on the tube surface, thereby eliminating future corrosion problems which can result from such damage.

In addition to repairing nuclear-fueled vapour generators, the present method and apparatus can be utilised in any type of heat exchanger and with other types of material. Also, the apparatus and method can be used with practically any diameter tubing and can make an expansion of any desired length.

Exemplary materials for the bladder consist of polyurethane or similar substances having the requisite resiliency.

Exemplary materials for the propellant charge are smokeless gunpowders having the requisite burning rate. Smokeless gunpowders usable in the present method and apparatus include the materials sold under the trademarks HI-SKOR and designated as 700-X by E.I. DuPont de Nemours & Co., Inc., and HERCULES 2400 by Hercules Incorporated.

CLAIMS

1. Apparatus for radially expanding a tubular member (12), the apparatus (10) comprising a first end cap (16), a second end cap (18) spaced from the first end cap (16), a post (20) rigidly connected between the end caps (16, 18) for connecting the end caps to each other, and an expandable bladder (22) connected between the end caps (16, 18) and extending around the post (20), characterised in that the bladder (22) defines a space (24) with the post (20), a propellant is contained within the space (24), and ignition means (32, 34) is associated with the propellant for igniting the propellant to generate gas and radially expand the bladder (22).

2. Apparatus according to claim 1, wherein the space (24) is annular and extends around the post (20).

3. Apparatus according to claim 1 or claim 2, wherein the post (20) includes flange means (38, 40) disposed within the space (24) adjacent the caps (16, 18), the caps (16, 18) have sleeve portions (42, 44) surrounding the flange means (38, 40), and end portions of the bladder (22) are fixed between the sleeves and flange means.

4. Apparatus according to claim 1, claim 2 or claim 3, wherein the first cap (16) includes a bore (28) extending therethrough, the post (20) being fixed within the bore (28) and having an ignition port (26) connecting the bore (28) with the space (24).

5. Apparatus according to claim 1, claim 2 or claim 3, wherein a positioning rod (30) is fixedly engaged with the first cap (16), the rod (30) has a longitudinal bore therein, the ignition means comprises a pair of wires (32) extending through the longitudinal bore, the post (20) has an ignition port (26) therein connecting a bore (28) of the first cap (16) with the space (24), the pair of wires (32) continues through the ignition port (26) to the space (24), and the ignition means further comprises an ignitor (34) connected to the wires (32).

6. A method of radially expanding a tubular member, comprising positioning in the tubular member (12) an apparatus (10) having spaced end caps (16, 18) fixed to each other by a post (20) with an expandable bladder (22) connected between the caps and around the post, and expanding the bladder (22) to thereby expand the tubular member (12), characterised in that the bladder (22) defines a space (24) with the post (20), a fast burning propellant, which upon ignition generates large quantities of gas, is provided in the space (24), and the propellant is ignited to expand the bladder (22) and at least a portion of the tubular member (12).

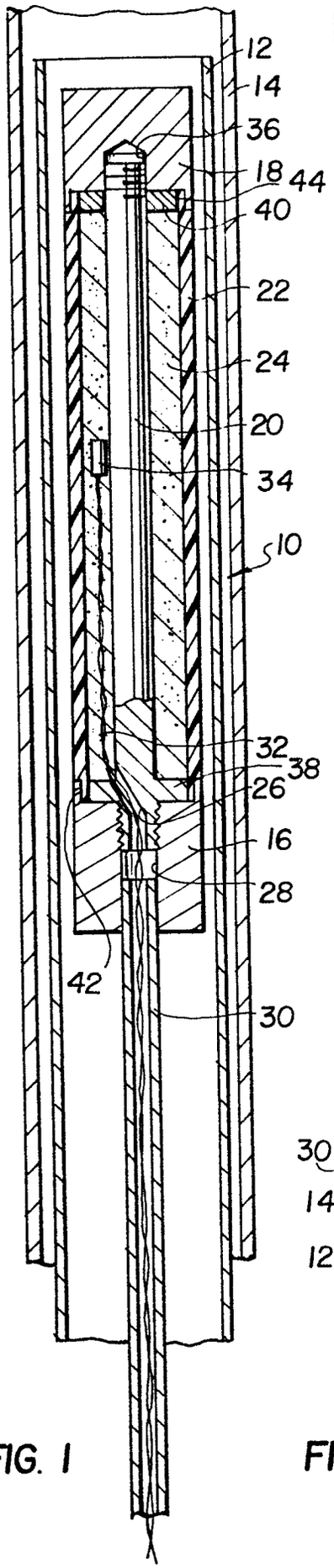


FIG. 1

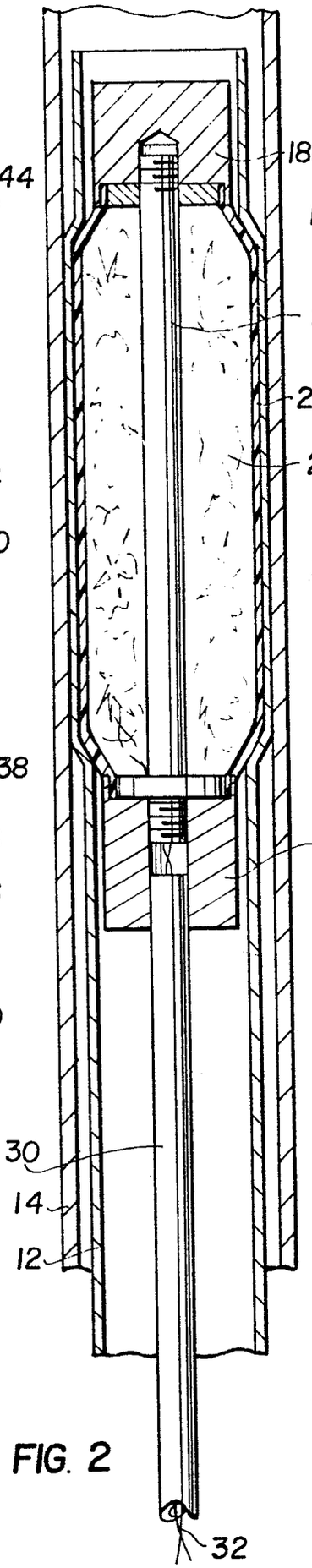


FIG. 2

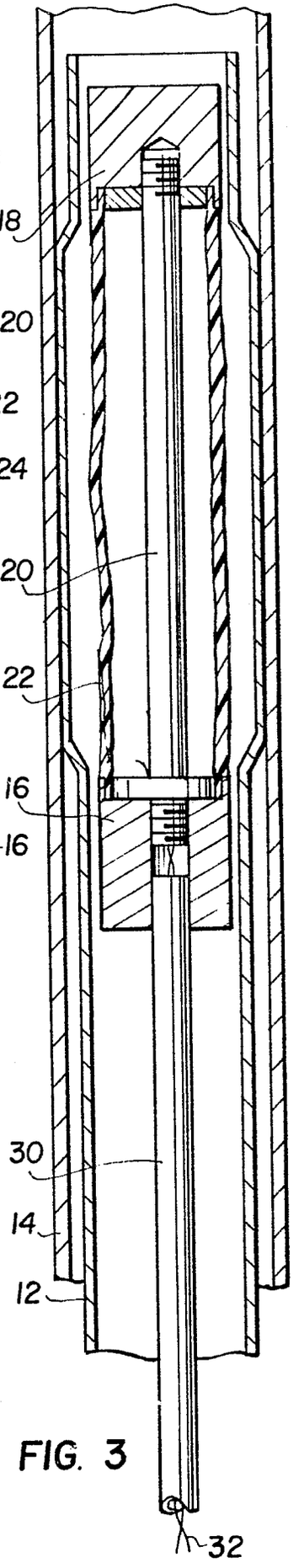


FIG. 3