PATENT SPECIFICATION (11) 1 566 378

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(21) Application No. 9012/78 (22) Filed 7 Mar. 1978 (19)

(31) Convention Application No. 784993 (32) Filed 6 Apr. 1977 in

(33) United States of America (US)

(44) Complete Specification Published 30 Apr. 1980

(51) INT. CL.[3] F16L 55/12

(52) Index at Acceptance
F2P 23F 29

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(54) PRESSURE VESSELS AND METHODS OF SEALING LEAKY TUBES DISPOSED IN PRESSURE VESSELS

(71) We, THE BABCOCK & WILCOX COMPANY, a corporation organized and existing under the laws of the State of Delaware, United States of America, of 161 East 42nd Street, New York, New York 10017, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to pressure vessels and to methods of sealing leaky tubes in pressure vessels.

This invention is especially applicable to pressure vessels in the form of sheet-and-tube type heat exchangers constructed with a large number of relatively small diameter tubes grouped in what is commonly referred to as a bundle. Heat is exchanged between a fluid passing through the tubes and a fluid in contact with the outside of the tubes. The fluids are physically separated by tubes and tube sheets, with one tube sheet being located at each end of the tube bundle. It is becoming common practice to seal off a leaky tube in this type of heat exchanger by employing an explosive activated plug in the form of a hollow metal body that is inserted at each end of the tube to be sealed. The plug contains a shaped explosive charge and a detonator which can be set off from a remote location to detonate the charge and thereby expand the plug body against the tube surface with an impact of sufficient force to weld the plug to the surrounding tube surface and form a fluid tight seal therebetween.

Some difficulty has been encountered with explosive welding in this type of heat exchanger where the closeness of the tubes is such that tubes adjacent to the leaky tube, and the tube sheet ligament therebetween, may be significantly distorted by the explosive forces released during detonation of a sealing plug in the leaky tube.

According to a first aspect of the invention there is provided an arrangement comprising a pressure vessel, first and second tube sheets transversely arranged in the pressure vessel, a plurality of fluid conveying tubes disposed within the vessel, the tubes each being connected at one end to the first tube sheet and at the other end to the second tube sheet, respective explosive activated plugs capable of insertion into the respective ends of a leaky tube, means for detonating the explosive in plugs inserted into the ends of the leaky tube to weld each plug to the surrounding tube wall to thereby seal the ends of the leaky tube, and means for supporting the tube sheets and the ends of the tubes adjacent to the leaky tube during detonation of the explosive, the supporting means comprising a respective support plug capable of insertion into each end of each said adjacent tube.

According to a second aspect of the invention there is provided a method of sealing a leaky tube disposed in a pressure vessel, the tube being one of a plurality of fluid conveying tubes each having one end connected to a first tube sheet arranged transversely within the vessel and each having the other end connected to a second tube sheet arranged transversely within the vessel, the method comprising the steps of inserting a respective explosive activated plug into each end of the leaky tube, inserting a respective support plug into each end of each tube adjacent to the leaky tube, detonating the explosive in the explosive activated plugs to weld each plug to the surrounding tube wall thereby sealing the ends of the leaky tube, and removing the support plugs from said adjacent tubes.

An embodiment of the invention described hereinbelow reduces distortion of the adjacent tubes and the tube sheets when the explosive activated plugs are detonated.

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

Figure 1 is a section elevational view of a once-through vapour generator unit embodying the invention;

Figure 2 is a sectional plan view taken along line 2-2 in Figure 3;

Figure 3 is a sectional elevational view taken along line 3-3 in Figure 2;

Figure 4 is a detail view of a support plug inserted into the end of a tube;

Figure 5 is a section plan view taken along line 5-5 in Figure 4;

Figure 6 is a further detail view of the support assembly;

Figure 7 is a detail view of an actuator seen along one of two arcuate sides thereof;

Figure 8 is a detail view of an actuator seen along one of two flat sides thereof;

Figures 9 and *10* are detail views of a wedge; and

Figure 11 is a detail view of a tool for driving the actuator towards and away from the tube.

Figure 1 illustrates a heat exchanger in the form of a once-through vapor generating unit 10 comprising a vertically elongated cylindrical pressure vessel 11 closed at its opposite ends by an upper head member 12 and a lower head member 13. The vessel 11 is transversely divided by upper and lower tube sheets 14 and 15, respectively. The upper tube sheet 14 is integrally attached to the vessel 11 and the upper head member 12 and forms, in combination with the upper head member 12, a fluid inlet chamber 16. The lower tube sheet 15 is integrally attached to the vessel 11 and the lower head member 13 forms, in combination with the lower head member 13, a fluid outlet chamber.

A plurality of straight tubes 18 arranged to form a tube bundle extend vertically between the upper and lower tube sheets 14 and 15 and penetrates through both tube sheets to interconnect the fluid inlet chamber 16 with the fluid outlet chamber 17.

A cylindrically shaped shroud member 19 surrounds the bundle of tubes 18 and extends upwardly from a plane located above the lower tube sheet 15 and terminates at a plane located below the upper tube sheet 14. The shroud member 19 cooperates with the vessel 11 to form an annular shaped compartment therebetween. The compartment is divided into inlet and outlet passageways 21 and 20 by an annular plate 22 welded about its outer edge to the vessel 11 and around its inner edge to the shroud member 19.

During normal operation of the vapor generating unit 10, primary coolant received from a pressurized water reactor or a similar source, not shown, is supplied to the upper chamber 16 through an inlet nozzle 24. The primary coolant gives up heat to a secondary fluid during passage through the tubes 18 and is discharged from the lower chamber 17 through an outlet nozzle 25. A feed fluid is admitted through an inlet nozzle 26 and is constrained by the plate 22 to flow downwardly in the passageway 21, and hence into the open lower end of the shroud member 19. The feed fluid is heated and vaporized by heat transfer through the tubes 18 for the primary coolant. The vapor thus produced, which can be either saturated or superheated depending upon the amount of heat exchange, passes out of the open upper end of the shroud member 19 and into the passageway 20, for exit through an outlet nozzle 27.

It should be recognized that there are a large number of tubes 18 in the entire bundle within the vapor generating unit 10. Consequently, it is common practice to overcome a leak in any given tube by merely sealing off the interior of such tube by plugging the ends at the tube sheets 14 and 15. In this manner, a given tube which has developed a leak is isolated and effectively removed from the flow path for the primary coolant passing through the interior of the tubes. The remaining tubes of the bundle continue to act in the normal manner to provide heat exchange as desired. As is common practice, the leaky tube is sealed off by employing an explosive activated plug in the form of a hollow metal body that is inserted into the end of the tube to be sealed, and which contains a shaped explosive charge and a detonator that can be set off from a remote location to detonate the charge and thereby expand the plug body against the tube surface with an impact of sufficient force that it creates a zone of metallurgically bonded metal contact between the plug and surrounding tube surface, which zone extends completely around the circumference of the plug body and along an axial length portion thereof intermediate its ends.

Since the construction and arrangement of the tubes 18 with respect to the tube sheets 14 and 15 is generally the same, it is deemed sufficient to describe sealing of a leaky tube 18A in conjunction with the upper tube sheet 14.

Referring now to Figures 2 to 10 wherein like reference numerals designate like or corresponding parts throughout, there are shown support plugs 29 inserted in the tube sheet ends of the tubes 18 situated adjacent to the leaky tube 18A. Each of the support plugs 29 comprises a pair of wedges 30 and a wedge like actuator 31.

Each of the wedges 30 is formed with an arcuate side 32, generally matching the

inner contour of the tube 18, and a flat side 33. The arcuate side 32 includes a shoulder portion 34 at one end thereof and a tapered portion 35 at the other end. The wedge 30 is axially tapered along its flat side 33 in the direction of the shoulder portion 34.

The actuator 31 has a major axial portion thereof formed with a pair of opposing flat sides 36 interconnected by arcuate sides 37, and includes a frusto-conical member 38 at one end thereof and a threaded stub 39 at the other end. The large end of the member 38 abuts a pair of ledges 40 extending laterally along the flat sides 36. A shoulder portion 41 is formed between the flat sides 36 and the threaded stub 39. Each of the actuator flat sides 36 has a portion 42 which is axially tapered in the direction of the frusto-conical member 38.

In order to seal the leaky tube 18A, an explosive activated plug 43 as disclosed in U.S. Patent 3,590,877 is positioned within the tube sheet ends of the tube 18A, as shown in Figure 3 with respect to the upper tube sheet 14. Each of the support plugs 29 is assembled by positioning the tapered ends 35 of the wedges 30 on the ledges 40 and placing the tapered sides 33 of the wedges 30 against the oppositely tapered portions 42 of the actuator 31. The assembled support plug 29 is then inserted into one of the tubes 18 adjacent to the tube 18A. The support plug 29 is preferably positioned, as shown at Figure 2, with one of the wedges 30 abutting tube 18 along the wall portion facing the tube 18A. The shoulder portion 34 abuts against the tube end face and prevents further axial movement, thereby ensuring that the wedges 30 remain positioned within the tube sheet ends of the tube 18. The actuator 31 is then driven further into the tube 18 thus expanding the wedges 30 radially outwardly against the surrounding wall of the tube 18 for the support thereof and of the tube sheet 14.

After the explosive plug 43 has been detonated and the body of the plug 43 has consequently been autogeneously welded to the surrounding tube wall thereby sealing the end of the tube 18A, the actuator 31 is driven out thus releasing the wedges 30 and permitting the support plug 29 to be removed from the tube 18.

Any tool that would include some means for threadably engaging it with the actuator stub 39, might be employed to driven the actuator 31 towards and away from the supported tube. However, a preferred tool is one such as shown in Figure 11. The preferred tool 44 comprises a guide rod 45 having an internally threaded end 46 for engaging the actuator stub 39 as shown in Figure 4 and includes a pair of axially spaced disks 47 and 48 weldably mounted on the guide rod 45, and a hand-operated ramming cylinder 49 slidably mounted on the rod 45 intermediate the disks 47 and 48. The cylinder 49 is moved to strike the disk 47 when it is desired to drive the inserted actuator 31 toward the supported tube so as to expand the wedges 30 radially outwardly against the surrounding tube wall, thus providing the required tube wall and tube sheet support. Conversely, the cylinder 49 is moved to strike the disk 48 when it is desired to drive the actuator 31 away from the tube 18 thereby releasing the wedges 30 to allow removal of the support plug assembly from the supported tube.

WHAT WE CLAIM IS:-

1. An arrangement comprising a pressure vessel, first and second tube sheets transversely arranged in the pressure vessel, a plurality of fluid conveying tubes disposed within the vessel, the tubes each being connected at one end to the first tube sheet and at the other end to the second tube sheet, respective explosive activated plugs capable of insertion into the respective ends of a leaky tube, means for detonating the explosive in plugs inserted into the ends of the leaky tube to weld each plug to the surrounding tube wall to thereby seal the ends of the leaky tube, and means for supporting the tube sheets and the ends of the tubes adjacent to the leaky tube during detonation of the explosive, the supporting means comprising a respective support plug capable of insertion into each end of each said adjacent tube.

2. An arrangement according to claim 1, wherein said support plug includes means for expanding it radially outwardly against the surrounding tube wall.

3. An arrangement according to claim 2, wherein the expanding means of each support plug includes an elongate member having tapered sides.

4. An arrangement according to claim 3, wherein each support plug includes a pair of wedges, each wedge having a tapered side engaging a corresponding tapered side of the associated said elongate member.

5. An arrangement according to claim 4, wherein each of the wedges has an arcuate side generally matching the inner contour of a said tube to be supported thereby.

6. An arrangement according to claim 4 or claim 5, wherein the elongate member has ledges formed at one end thereof for facilitating the insertion and removal of the wedges from a tube supported thereby.

7. An arrangement according to claim 1, substantially as herein described with reference to the accompanying drawings.

8. A method of sealing a leaky tube disposed in a pressure vessel, the tube being one of a plurality of fluid conveying tubes each having one end connected to a first tube sheet arranged transversely within the

vessel and each having the other end connected to a second tube sheet arranged transversely within the vessel, the method comprising the steps of inserting a respective explosive activated plug into each end of the leaky tube, inserting a respective support plug into each end of each tube adjacent to the leaky tube, detonating the explosive in the explosive activated plugs to weld each plug to the surrounding tube wall thereby sealing the ends of the leaky tube, and removing the support plugs from said adjacent tubes.

9. A method according to claim 8, including the step of expanding each inserted support plug radially outwardly against the surrounding tube wall for the support thereof and of the tube sheet during detonation of the explosive.

10. A method according to claim 9, wherein each support plug comprises an elongate tapered member and a pair of tapered wedges, and wherein the step of expanding each inserted support plug includes driving the associated elongate member against the wedges and into the support tube.

11. A method according to claim 10, wherein the step of removing the support plugs from the supported tubes includes driving the elongated members out of the supported tubes.

12. A method of sealing a leaky tube disposed in a pressure vessel, the method being substantially as herein described with reference to the accompanying drawings.

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Printed for Her Majesty's Stationery Office,
by Croydon Printing Company Limited, Croydon, Surrey, 1980.
Published by The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.

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Sheet 1

FIG. 1

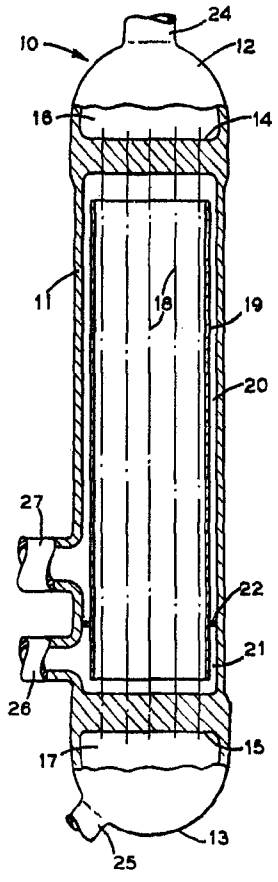


FIG. 2

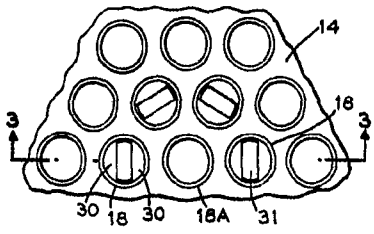


FIG. 3

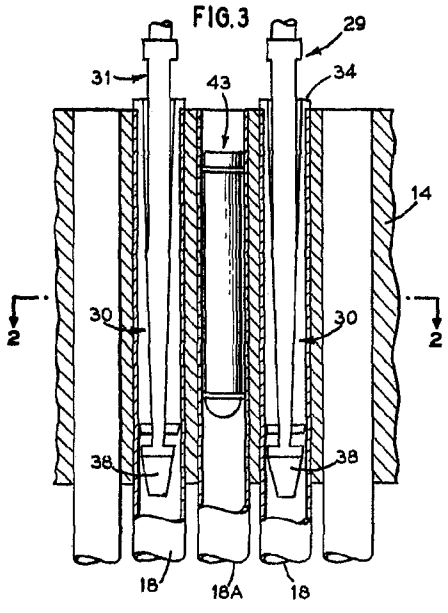
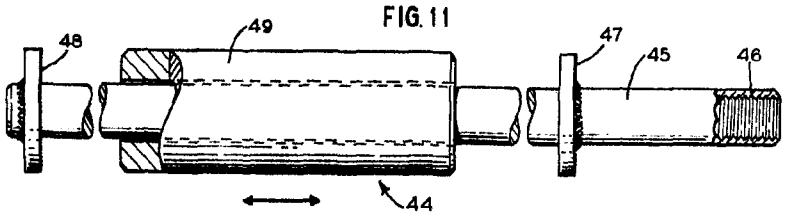


FIG. 11



1566378 COMPLETE SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 2

FIG. 8

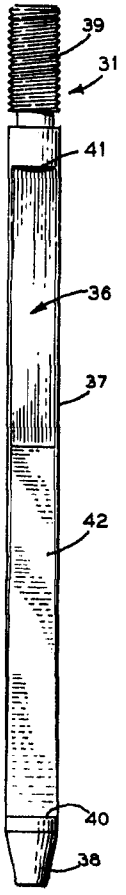


FIG. 7

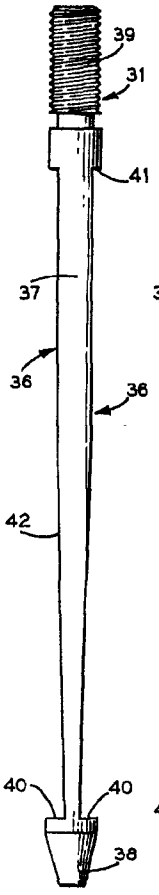


FIG. 6

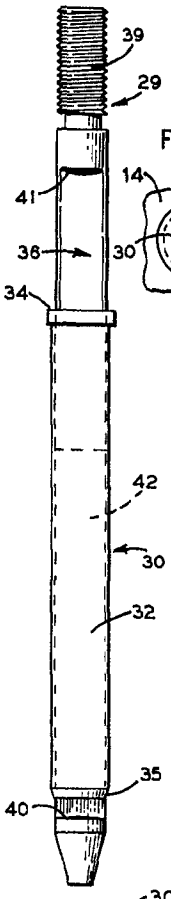


FIG. 5

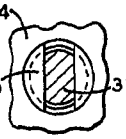


FIG. 4

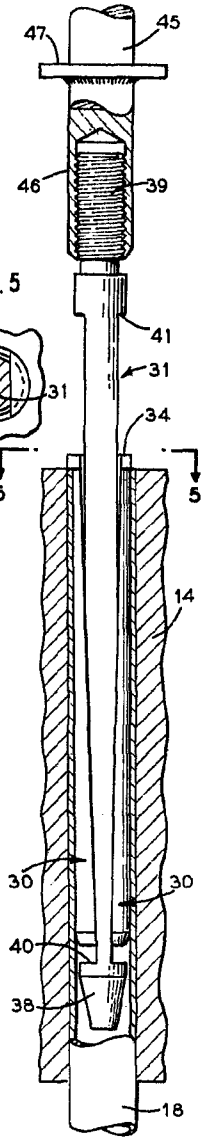


FIG. 9

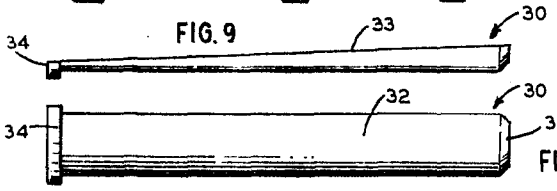


FIG. 10