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Cantrell et al.

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[54] **EXPLOSIVELY WELDED PLUG FOR LEAKY TUBES OF A HEAT EXCHANGER AND METHOD OF USING THE SAME**

[75] Inventors: **Roger E. Cantrell; Louis A. Sturiale,** both of Tampa, Fla.

[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

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[52] **U.S. Cl.** **29/470.1,** 29/479, 102/1, 138/89, 228/3

[51] **Int. Cl.** **B23k 21/00**

[58] **Field of Search** .....29/479, 470.1, 421 E, 486, 29/497.5; 228/3; 102/1, 26; 220/66; 138/89

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Primary Examiner—J. Spencer Overholser
Assistant Examiner—Ronald J. Shore
Attorney—A. T. Stratton et al.

[57] **ABSTRACT**

A plug for a leaky tube of a heat exchanger, the plug being weldable to the leaky tube by a shock wave propagated by an explosive charge disposed within the plug and a method of plugging a leaky tube by explosively welding the plug to the leaky tube.

10 Claims, 3 Drawing Figures

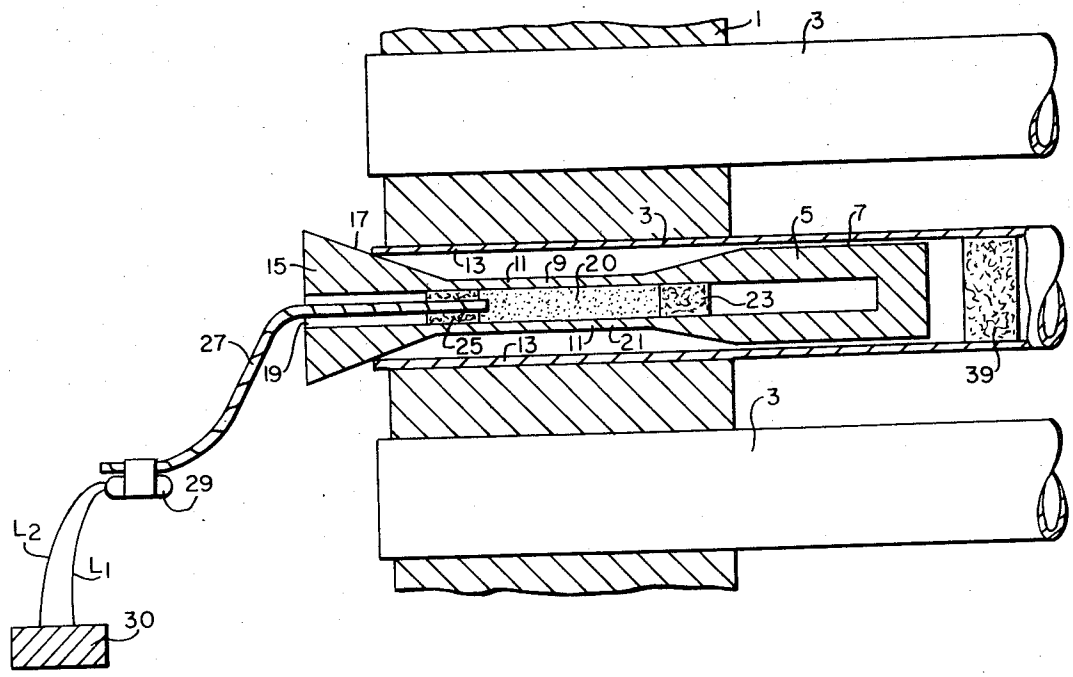


FIG. 1

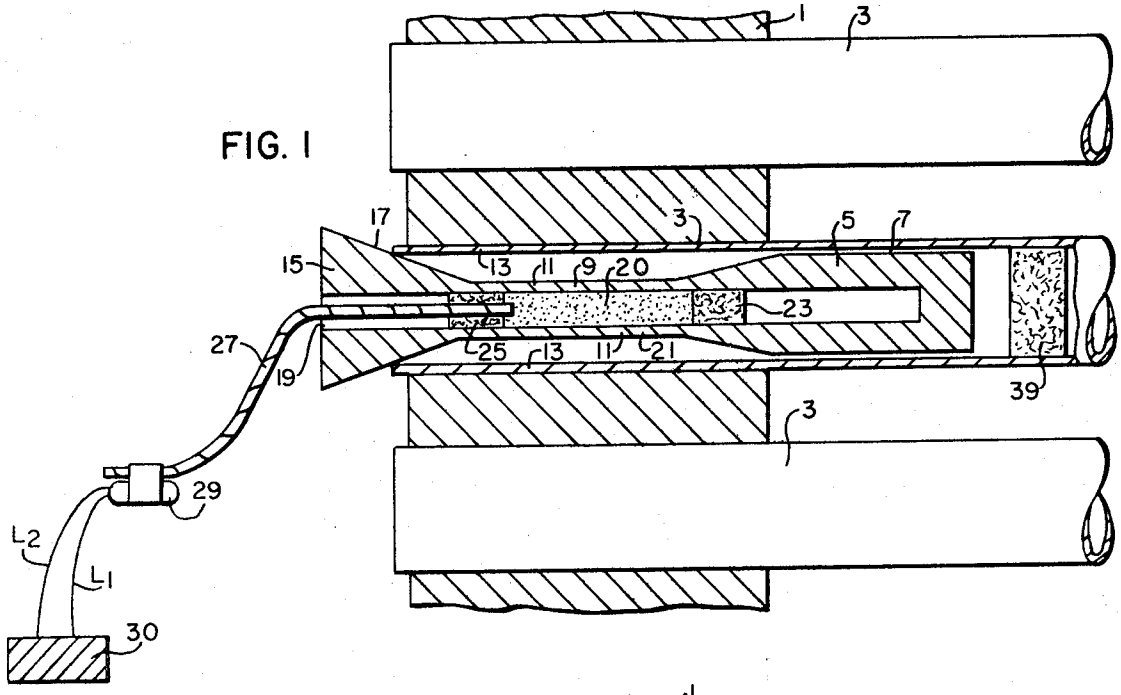
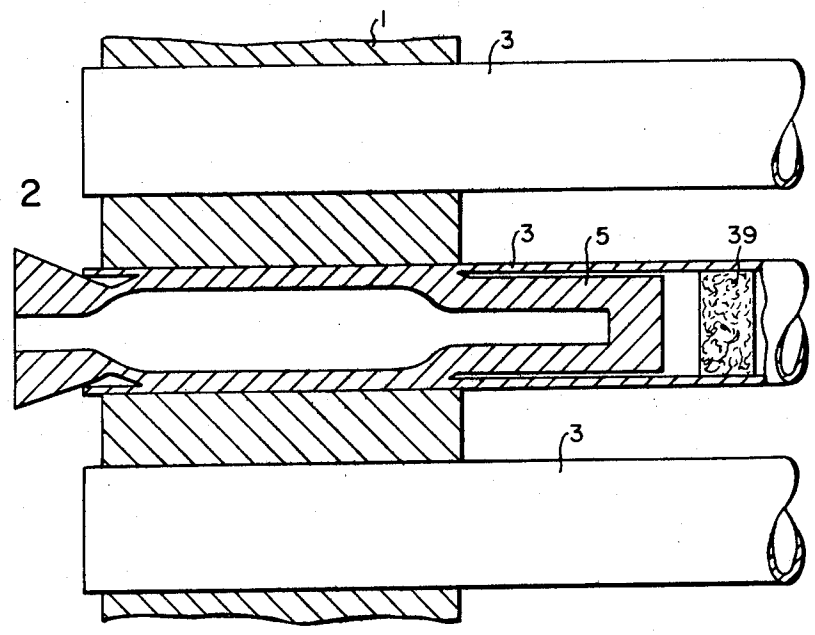


FIG. 2



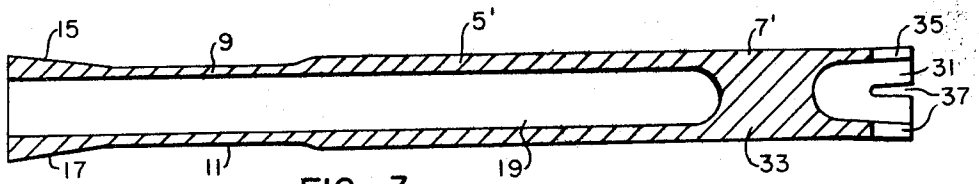


FIG. 3

EXPLOSIVELY WELDED PLUG FOR LEAKY TUBES OF A HEAT EXCHANGER AND METHOD OF USING THE SAME

BACKGROUND OF THE INVENTION

This invention relates to a method and plug for plugging a leaky tube in a heat exchanger and more particularly to a plug which is explosively welded to the inside diameter of the tube and a method of utilizing such a plug.

When the surfaces of two metals are caused to come into contact with a high relative velocity and with an included angle of collapse, the interacting surfaces will become welded together. This type of welding has been utilized to provide cladding for low alloy steels and other metals with some type of metal which is difficult to weld by conventional methods due to their physical or chemical properties, such as aluminum, stainless steel or tantalum. Explosive welding generally employs a cold bonding, plastic flow phenomenon, which allows a large number of similar or dissimilar metals to be strongly bonded together without elaborate surface preparation.

Tubular heat exchangers are utilized to transfer heat between two fluids in processes in which it is undesirable to mix the fluids. Occasionally one of the tubes springs a leak due to corrosion or due to latent defects in the tube. Because it is very difficult or almost impossible to replace a leaky tube without disassembling the heat exchanger, the ends of the leaky tube are generally plugged by driving plugs of some type into the tube. The simplest plug being a tapered bar, which is driven into the tube with a hammer and seal welded thereto. However, to drive such plugs there must be sufficient room to swing the hammer and make a seal weld and a workman must remain in close proximity to the tube and tube sheet for an extended period of time in order to properly seal the plug. While this time is not extremely long, it becomes critical, when the area is radioactive as in plugging nuclear steam generator tubes so that some extremely rapid method such as explosive welding is advantageous. For additional information relating to plugging tubes with explosive devices reference may be made to U.S. Pat. No. 3,555,656 by Francis X. Brown and Samuel Wismer, Jr., assigned to the same assignee.

SUMMARY OF THE INVENTION

In general a plug for an end of a leaky tube of a heat exchanger made in accordance with this invention is formed from a metal capable of being welded to the tube by a shock wave propagated by an explosive charge. Such a plug comprises a forward portion adapted to center the forward end of the plug in the tube, a central portion having an outer peripheral surface formed to provide generally equal spacings between the peripheral surface and the tube, a rear portion having a frustoconical shape adapted to center the plug within the tube and position the plug relative to the end of the tube and a central cavity having an axial opening which extends through the rear portion and the central portion of the plug and partially into the forward portion. An explosive charge is disposed in that portion of the cavity adjacent the center portion of the plug and a detonating cord is in communication with the explosive charge to detonate the explosive charge and explosively weld the plug to the tube. This invention also includes a method of utilizing such a plug to seal off one end of a leaky tube.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of this invention will become more apparent from reading the following detailed description in connection with the accompanying drawings, in which:

FIG. 1 is a partial sectional view of a heat exchanger tube sheet showing a plug made in accordance with this invention before being explosively welded to one end of a leaky tube;

FIG. 2 is a partial sectional view of a heat exchanger tube sheet showing the plug explosively welded to the end of a leaky tube; and

FIG. 3 is a sectional view of a modified plug.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings in detail, FIG. 1 shows a heat exchanger tube sheet 1 having a plurality of tubes 3 extending therethrough. A plug 5 is disposed in the end of the central tube so that it may be explosively welded thereto. The plug is shown to comprise a forward portion 7 having a diameter slightly less than the diameter of the tube 3 to generally center the forward portion 7 of the plug 5 in the tube; a central portion 9 having a neckdown section having a peripheral surface 11, which is generally spaced an equal distance from the surface 13 of the tube 3; and a rear portion 15 having a frustoconical peripheral surface 17 which centers the rear portion of the tube 3 and positions the plug 5 relative to the end of the tube so that the center portion of the plug is adjacent the tube sheet 1.

An axial bore 19 provides a cavity, which extends through the rear and central portion 15 and 9, respectively, and partially into the forward portion 7.

An explosive charge 20, such as TNT (trinitrotoluene), PETN (pentaerythritol tetranitrate) or SWP-1 (an explosive manufactured by Trojan-US Powder Co. of Allentown, Pa. and others, is disposed in the cavity 19 adjacent the central portion 9, which has a relatively thin wall 21 of uniform thickness. The explosive charge 20 is contained by wadding 23 and 25. The forward wadding 23 blocks the forward portion of the cavity 19 and the rear wadding 25 blocks the rear portion of the cavity 19 confining the explosive charge to the central portion of the cavity 19.

A detonating cord or Primacord 27, such as a 25 or 50 grain per foot Cordeau detonating cord extends through the rear wadding 25 and is in contact with the explosive charge 20. A blasting cap 29 is taped to the detonating cord 27 and electrically connected to an electric blasting machine 30 via conductors L1 and L2. The electrical blasting machine 30, when activated, will detonate the blasting cap 29 to ignite the detonating cord 27 and detonate the explosive charge 20 which propagates a shock wave.

The peripheral surface 11 of the central portion 9 of the plug 5 is disposed an equal distance from the tube 3 so that the shock wave propagated by the detonation of the explosive charge will progress from adjacent the rear portion 15 of the plug 5 to adjacent the forward portion 7 of the plug 5. This causes expansion of the

central portion 9 of the plug 5 to initiate adjacent the rear portion 15 and progress to the forward portion 7 in such a manner that the peripheral surface 11 of the central portion 9 of the plug 5 will progressively contact the inner surface 13 of the tube 3 at sufficiently high velocity so that there is plastic flow at the interface of the surfaces as they come into contact to provide a weld between these surfaces. The weld thus formed is strong and essentially free of voids and inclusions of foreign material, due to a jetting effect caused by the rapid collapse of the included angle between the interacting surfaces as the expansion of the thin wall portion 21 of the plug progresses.

FIG. 2 generally shows the shape of the plug 5 after it is explosively welded to the tube 3.

FIG. 3 shows a modification of the plug shown in FIG. 1. In the modified plug 5', the center and rear portions 9 and 15 respectively are generally the same as the center and rear portions of the plug shown in FIG. 1. However, the forward portion 7' in the modified plug has a bore 31 extending partially therein from the forward end thereof. Thus, leaving a solid metal plug 33 between the cavity 19 and the bore 31. The wall 35 of the bore 31 has kerfs 37 spaced girthwise thereon to permit end segments of the wall 35 to be flared outwardly to provide leaf springs for centering the plug 5' within the tube 3 and holding the plug in position prior to detonating the explosive charge. The rear portion 15 of the plug 5' has a frustoconical peripheral surface so that the plug may be made to a nominal size and yet centered accurately in tubes having openings which vary several thousandths in diameter to provide generally uniform spacing between the central portion 9 of the plug 5' and the tube 3 to locate the plug relative to the end of the tube and firmly hold the plug in place prior to explosively welding it to the tube.

A method of plugging a leaking tube utilizing a plug made in accordance with this invention comprises the following steps;

identifying and marking the ends of the leaking tube;

cleaning inside one end of the leaking tube to a depth of approximately 3 to 4 inches;

inserting a clean dry felt pad 39 into the end of the tube, pushing it to a depth slightly in excess of seven inches to provide a temporary plug or dam to prevent water from seeping into the plugging area prior to explosively welding the plug 5 to the tube 3;

cleaning the plug 5 to remove all grease and foreign material;

forming wadding 23 for the forward portion 7 of the plug by rolling masking tape into a cylinder, which fits snugly into the bore 19 of the plug 5;

inserting the wadding 23 into the bore 19 until it is slightly past the central portion 9 of the plug 5 approximately 2.4 inches into the plugs as shown in FIG. 1;

weighing out a predetermined amount of explosive material 20;

placing the explosive material 20 in the bore 19 of the plug 5;

lightly tapping the forward portion 7 of the plug 5 on a table top to settle the explosive;

cutting a length of detonator cord 27 sufficiently long to extend from the leaking tube 3, out a manway and to a position where the blasting cap 29 may be detonated outside of the heat exchanger;

forming wadding 25 for the rear portion 15 of the plug 5 by wrapping masking tape about 3/32 inches from one end of the detonating cord 27;

inserting the tape wadding 25 and detonating cord 27 into the bore 19 of the plug 5 so that the detonating cord 27 comes into contact with the explosive charge 20;

cleaning the outer peripheral surface of the plug 5;

coiling the detonating cord 27 so that it can be held in one hand with the plug 5 and passed through a manway opening into the heat exchanger;

inserting the plug 5 in the end of the leaking tube 3;

pushing the plug into the tube until the frustoconical surface 17 adjacent the rear end of the tube 3 contacts the tube;

ascertaining that there is no electrical source in the manway area which could prematurely ignite the detonating cord 27;

shoring the lead wires L1 and L2 adjacent the blasing machine 30;

fastening an electrically ignited blasting cap 29 to the detonating cord 27 by taping it thereto with masking tape;

connecting the lead wires L1 and L2 to the blasting cap 29;

removing the short from the other end of the lead wires L1 and L2, checking that all personnel are out of the heat exchanger and away from the vicinity of the blasting cap 29;

firing the blasting cap 29 to ignite the detonating cord 27 and detonate the explosive 20 to explosively weld the plug 5 to the tube 3;

inspecting the explosively welded plug 5 in the same manner as a fusion welded plug would be inspected.

The other end of the leaking tube together with other leaking tubes would be plugged in a similar manner. Such plugs may be welded to the tubing very rapidly and they also lend themselves to be inserted into leaky tubes by remote control equipment, which is used to service heat exchangers utilized with nuclear reactors and associated steam generators.

What we claim is:

1. A plug for an end of a tube, said plug being formed of a material capable of being welded to said tube by a shock wave propagated by an explosive charge, said plug comprising

three integral portions,

a forward portion having means for centering said forward end of said plug within said tube,

a central portion of reduced cross section having an outer peripheral surface formed to provide generally equal spacing between said surface and said tube, and

a rear portion having a gradually increasing cross section to provide means for centering said rear portion of said plug in said tube and for positioning the plug relative to said end of said tube,

a central cavity formed by an axial opening of generally constant cross section and extending completely through said rear portion and said center portion and partially into said forward portion,

an explosive charge disposed in a portion of said cavity adjacent said center portion of said plug,

wadding disposed in said cavity to keep said explosive charge adjacent said center portion, and

means for detonating said explosive charge.

2. A plug as set forth in claim 1, wherein the material of the plug is essentially the same as the material of the tube.

3. A plug as set forth in claim 1, wherein the forward portion of the plug is generally cylindrical and has a diameter slightly smaller than the diameter of the tube.

4. A plug as set forth in claim 3, wherein the forward portion of the plug has an axial opening extending inwardly from the forward end thereof and a plurality of kerfs disposed in the forward end of the plug and spaced girthwise therein, and the forward end of the plug is expanded outwardly to engage the tube for holding the plug in place prior to explosively welding the plug to the tube.

5. A plug as set forth in claim 1, wherein the rear portion thereof is frustoconical shape to provide the means for centering the rear portion of the plug and posi-tioning the plug relative to the end of the tube.

6. A plug as set forth in claim 1, wherein the central portion thereof has a thin wall of uniform thickness,

said wall being substantially thinner than the walls of the forward and rear portions.

7. A method of plugging one end of a tube utilizing a plug having three integral portions, a forward portion, which has means for centering said forward portion in said tube, a central portion of reduced cross section having an outer peripheral surface which is generally equally spaced from said tube when disposed therein and a rear portion which has a gradually increasing cross section to provide means for centering said plug in said tube and locating said plug relative to said end of said tube, and a central cavity having an axial opening of generally constant cross section extending through said rear and central portions and partially through said forward portion of said plug, said method comprising

placing a forward wadding in said cavity so that said wadding plugs the cavity in the forward portion of the plug adjacent the central portion,

placing a predetermined amount of explosive material in said cavity,

placing a rear wadding with detonating means extending therethrough in said cavity to retain said explosive in the region of said central portion of said plug,

inserting the forward end of said plug in said tube;

pushing the plug as far into the tube as it will go, and

detonating said explosive charge to explosively weld said plug to the end of said tube.

8. A method as set forth in claim 7 and further comprising cleaning the inside wall of the tube adjacent the end of the plug.

9. A method as set forth in claim 7 and further comprising inserting a temporary plug into the tube to provide a dam to prevent liquid from seeping into the area occupied by the plug prior to explosively welding the plug to the tube.

10. A method as set forth in claim 7 and further comprising cleaning the outer peripheral surface of the plug prior to inserting the plug in the tube.

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