METHOD OF EXPLOSIVELY PLUGGING A LEAKY METAL TUBE IN A HEAT EXCHANGER TUBE BUNDLE

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 7.

FIG. 5.

FIG. 6.

FIG. 8.

FIG. 9.

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METHOD OF EXPLOSIVELY PLUGGING A LEAKY METAL TUBE IN A HEAT EXCHANGER TUBE BUNDLE

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Filed May 25, 1967, Ser. No. 641,381

Int. Cl. B22d 19/10; B25p 7/00

U.S. Cl. 29—401

4 Claims

ABSTRACT OF THE DISCLOSURE

This invention provides an explosive plugging device for insertion into a leaky metal tube of a heat exchanger bundle to plug the tube. The invention has been proposed to a method of explosively welding a metallic plugging device having an explosive charge to a metal tube by detonating the charge with a detonation initiator to peripherally expand the plug into welding association with the tube.

BACKGROUND OF THE INVENTION

The invention relates to a method and device for plugging leaky tubes in heat exchangers of the type and shell type and has for an object to provide a method and device of the type that provides a positive, metallurgically bonded seal that is leak-proof when exposed to pressurized fluids, and that is relatively safe and expeditious to employ in all types of tube and shell type heat exchangers such as condensers, feed water heaters and steam generators.

Heat exchangers of the above type are employed to transfer heat from one fluid to another and are usually provided with a bundle of tubes, the open ends of which extend through a suitable tube sheet disposed within a suitable channel head to which one of the fluids is directed for circulation through the tubes. The tube bundle and tube sheet are encompassed by a shell structure through which the other fluid is circulated in a manner to pass over the outer surfaces of the tubes. One of the fluids is hotter than the other, hence during operation the cooler fluid is heated by transfer of heat from the hotter fluid, and vice versa.

Usually one or both of the fluids are pressurized and, to prevent intermingling of the two fluids, the ends of the tubes are welded or otherwise sealingly secured to the tube sheet.

However, in operation, a tube may spring a leak through its wall or a leak may develop at the tube-to-tube sheet seal, thereby causing undesirable flow of the more highly pressurized fluid into the lower pressure fluid and contamination or adulteration of the lower pressure fluid.

Many solutions have therefore been proposed to block or plug such a leaky tube at both ends, thereby to inactivate the tube and terminate such leakage. Such solutions have usually involved mechanically expandable plugs for insertion in the leaky tube. Such solutions necessarily required a workman to be in close proximity with the tube in order to make such repair and entail working entirely within the channel head, in the larger industrial heat exchangers of the types mentioned above. Also, such prior plugging arrangements were subject to incipient leakage leading to corrosion and eventually catastrophic failure after prolonged service.

SUMMARY

Briefly, one aspect of the invention resides in the provision of an explosive plugging device for insertion into a metal tube to plug said tube by explosively welding of the plugging device to the tube. In accordance with the invention the plugging device comprises a cylindrical body formed to be slidably inserted into the tube and having a solid cylindrical portion to block the flow of fluid and a hollow cylindrical portion containing an explosive chemical charge which is detonated by a suitable explosive initiator to peripherally expand the hollow cylindrical portion into violent abutment with the inner wall of the tube with attendant "welding" or "metallurgical bonding," thereby effecting a positive leak-proof seal.

Explosive welding techniques are generally known in the welding art and many schemes have been employed or proposed to solve specific problems in the manufacture of heat exchange apparatus, as indicated in C. C. Simons and R. J. Carlson patent application No. 467,444, filed June 25, 1965, now Pat. No. 3,409,869, and R. J. Carlson, C. C. Simons and R. L. Bradford patent application No. 488,670, filed Sept. 20, 1965 and now Pat. No. 3,402,970. Both of these applications are assigned to the same assignee as this invention and more fully describe the phenomena attendant in explosive welding.

Another aspect of the invention resides in a method of explosively welding a plugging device of the above type in a leaky tube of a tube and shell heat exchanger. Briefly, the method comprises insertion of a plugging device of the above type into the leaky tube within the length of the tube confined in the tube sheet but preferably in close proximity with the open end of the tube and detonating the explosive charge to effect the peripheral welded seal. The detonation is effected preferably from a position external of the heat exchanger channel head, thereby rendering the method inherently safe for personnel, especially in repairing nuclear power steam generators.

The above method is subject to modification involving chamfering of the end of the tube and adjacent tube sheet and emplacement of the plugging device in flush relation with the surface of the tube sheet, so that, on detonation of the explosive charge, a portion of the plugging device is expanded into the flared opening formed by the chamfering.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an axial sectional view of a typical heat exchanger of the tube and shell type prepared for the plugging of a leaky tube, in accordance with the invention;

FIG. 2 is an enlarged axial sectional view of an explosive tube plugging device in accordance with the invention;

FIG. 3 is an enlarged fragmentary axial sectional view illustrating the plugging device in inserted position within a leaky tube of the heat exchanger shown in FIG. 1, in preparation for sealing by welding;

FIG. 4 is a view similar to FIG. 3 but illustrating the tube and plug after welding;

FIG. 5 is a fragmentary axial sectional view illustrating another leaky tube condition;

FIG. 6 is a view similar to FIG. 5 but illustrating preparation of the tube and tube sheet for plugging;

FIG. 7 is a view similar to FIG. 2 but illustrating a further plugging device modification;

FIG. 8 is a view illustrating the modified plugging device of FIG. 7 inserted in the prepared tube of FIG. 6, in preparation for welding; and

FIG. 9 is a view similar to FIG. 8 but illustrating the tube and plug after welding.

DESCRIPTION OF THE INVENTION

Referring to the drawings in detail, in FIG. 1 there is shown a typical heat exchanger 10 of the tube and shell type comprising the usual components, as follows: a bundle of tubes 12 of the hairpin type having their opposite end portions 14 and 15 extending through a suitable tube sheet 16.
As illustrated, the tube sheet 16 may be of the clad type, including a relatively thick plate portion 17 of one type of metal and a relatively thin clad layer 18 of a different type of metal. As more fully explained in F. X. Brown and L. K. Poole Pat. 3,257,710, issued June 28, 1966, and assigned to the same assignee as this invention, the metal for the clad layer 18 may be selected for weld compatibility with the metal of the tubes 12, to permit welding of the tube end portions 14 and 15 to the tube sheet 16, as more clearly shown at 19 in FIG. 3.

The tube bundle 12 is enclosed by a tubular shell structure 20 disposed in fixed sealing abutment along its peripheral end portion with the tube sheet 16 and joint therewith forms an inlet chamber 21. The shell 20 has a fluid inlet opening 22 and a fluid outlet opening 23 communicating with the chamber 21.

A channel head 24 having a partition 25 is disposed in fixed peripheral sealing abutment with the opposite face of the tube sheet 16 and jointly therewith forms an inlet chamber 26 in communication with the tube end portions 14 and an outlet chamber 27 in communication with the tube end portions 15. The channel head 24 has a fluid inlet opening 28 communicating with the chamber 26 and a fluid outlet opening 29 communicating with the chamber 27.

In operation, as well known in the art, pressurized fluid at one temperature is admitted to the channel head chamber 26 through the inlet 28 and directed through the bundle of tubes 12 to the chamber 27 and thence directed through the outlet 29. A second fluid at a different temperature and pressure is directed into the chamber 21 through the inlet 22 and thence into the outlet 23. During its flow across the outer surfaces of the tubes 12, heat is exchanged between the two fluids with resulting heating of one fluid and cooling of the other.

In order to prevent a greater degree of permeable effect of different fluids at different pressures, it is desirable, and in many cases imperative, to prevent intermingling of the two fluids. This is especially so in heat exchangers such as steam generators employed in nuclear turbine power plants, since the fluid flowing through the tubes 12 is usually a hotter fluid and has been heated in the nuclear reactor, and therefore may contain some radioactivity.

Accordingly, if leaks should occur in the tubes, it is present practice to interrupt operation of the heat exchanger 10 and plug both ends 14 and 15 of a tube 12 that is leaking.

In accordance with the invention, there is provided an explosive plugging device 30, as best shown in FIG. 2, for insertion into a tube 12 that is leaking through a rupture 31 in the tube wall as indicated in FIG. 3, and a method of plugging the leaky tube in a positive leak-proof manner.

The plug device 30 is of symmetrical circular cross-section about its longitudinal axis A—A and includes a metallic body member 33 preferably formed of metal having weld compatibility with the tube metal, and of generally thinible form having one end portion 34 of solid cylindrical shape and an opposite end portion 35 of hollow cylindrical shape jointly forming an axial cavity 36 of cylindrical shape. As shown in FIGS. 2 and 3 the solid portion 34 is of such a diameter as to permit a slidably fit with the tube end 14 to be plugged, while the hollow portion 35 is of smaller diameter than the solid portion and extends along the tube wall thickness of the tube.

More specifically the solid portion 34 is on the order of about .002" smaller diameter than the internal diameter of the tube end 14, while the hollow portion 35 is on the order of about .030"-.050" smaller diameter than the diameter of the solid portion 34 to provide an annular clearance or space S of about .015"-.025" from the internal wall of the tube end 14.

Within the cavity 36 there is received an explosive chemical charge 37 of cylindrical shape and provided with an axial opening 38. The charge 37 is preferably of integral or cast form and extends axially about 50% of the length of the cavity. The charge may be of any suitable high detonation velocity, explosive material for example, TNT (trinitrotoluene) or PETN (pentaerythritol tetranitrate) and of such axial length and cross-sectional area as to provide about 6 grams per square inch (of cross-sectional area) of such explosive.

An end cap member 40 of any suitable plastic material having an axial opening 41 extending therethrough is provided with an inner end portion 42 of a diameter to be snugly received in the cavity 36 and maintain the charge 37 in position and an outer end portion 43 of the same diameter as the outer diameter of the tube end portion 14.

An electrical detonation initiator 44 of cylindrical form and having a pair of external lead wires 45 is slidably received in the registering axial openings 41 and 38 and extending through the charge 37 into endwise abutment with the end wall of the cavity 37.

The explosive plug device 30 is inserted into the tube end portion 14 to the fullest extent permitted by abutment of the end portion 43 of the cap member 40 with the end of the tube portion 14. Accordingly, the body member 33 and the explosive charge 37 are properly positioned within the tube portion in the optimum position indicated in FIG. 5.

The lead wires 45 are then connected to a supply of electrical current and energized to fire the initiator 44, which, in turn detonates the explosive charge 37. As the charge 37 is detonated, its explosive forces explosively expand the hollow end portion 35 of the body in peripherally outward direction across the annular stand-off space S into impinging abutment with the inner wall of the tube portion 14, as shown in FIG. 4. The velocity of radially outward movement of the end portion 35 is of sufficient magnitude to metallurgically bond or explosively weld the periphery of the hollow end portion 35 to the inner periphery of the tube and provide a seal that is leak-proof and reliable, even when subjected to fluid pressure, as incurred in operation of the heat exchanger.

Any refuse remaining in the cavity 36 from the detonated explosive, the plastic cap member 40 or the initiator 44 may be easily removed.

The opposite end portion 15 of the leaky tube may be plugged in the same manner described above to completely isolate the tube from the system.

In FIG. 5, there is shown the tube end portion 14a, similar to the tube end portion 14 shown in FIGS. 3 and 4, and extending through the tube sheet 16. In this case the tube has not been ruptured, but the annular tube-to-tube sheet weld joint 19 has incurred a small break causing a leakage flow path 31a to be established between the outer surface of the tube and the tube sheet, so that fluid in the chamber 21 and the fluid in chamber 26 may intermingle.

The above type of leaky tube may be plugged in the same manner described in conjunction with FIGS. 2—4, incl., since the explosive forces of the charge 37 are so great that a peripheral portion of the tube and 14a will be expanded into tight abutment with the tube sheet to interrupt the flow path 31a. However, a positive and reliable seal may not be obtained in every instance, since most of the explosive force may be absorbed in welding the plug body 33 to the tube.

Accordingly, in cases of leakage as shown in FIG. 5, there is provided a modified explosive plugging device 50, shown in FIGS. 7 and 8. This plugging device may be identical in all aspects to the plugging device 30, except that the end cap 51 has an outer end portion 52 of greater diameter than the end portion 43 for a purpose subsequently to be described.

As shown in FIG. 6, the preparation for plugging the tube end portion 14a comprises the step of machining away (by chamfering or countersinking, for example) a portion of the tube, the weld joint 19 and a peripheral
portion of the clad layer 18 surrounding the tube to provide an enlarged opening 53 that is flared or beveled at any suitable angle \( \alpha \). The machining is performed to a depth sufficient to cause the end 54 of the tube to terminate within the clad layer 18 and present a flush continuation of the flared opening 53.

To plug the tube end portion 14a, the plug 50 is inserted thereinto to the fullest extent permitted by the end cap 51. The end portion 52 is formed with a larger diameter than the maximum diameter of the flared opening, so that insertion of the plug is limited by abutment of the end portion 52 with the outer surface 56 of the tube sheet. Accordingly, as in the first embodiment, the plug body 57 and the explosive charge 58 are properly located in the optimum position.

After, the explosive charge is detonated, the plug body 57 is explosively deformed as shown in FIG. 9 to form an annular explosive weld or metallurgical bond between the periphery of the hollow tubular body portion 59 and the peripheral surface of the flared opening in the tube sheet, thereby effectively interrupting the leakage path 31a.

It will now be seen that the invention provides a simple, yet highly effective method and apparatus for plugging a leaky heat exchanger tube by explosively welding the plug in position.

It must be pointed out that in both disclosed schemes, the plugging device is positioned in the leaky tube within the confines of the tube sheet 16. Accordingly, the large mass of the tube sheet is effective to greatly restrain the explosive forces of the exploding charge and enhance the explosive welding effect.

Also, since the tube portion subjected to the explosive forces is not greatly enlarged in cross-section, due to the restraining effect of the tube sheet, the plugged tube may be readily removed at a later date and replaced in any conventional manner, if so desired.

It will further be seen that since the lead wires 45 may be passed through the inlet or outlet openings 28 or 29, or a suitable man-way opening (not shown), the tube plugging may be conducted in a manner safe to personnel.

We claim:

1. The method of plugging a leaky metal tube in a heat exchanger tube bundle and tube sheet structure, wherein the open ends of the tubes in the tube bundle extend through said tube sheet, said method comprising inserting a metallic plug device having an explosive charge into the opening end of said leaky tube, inserting a detonation initiator into said plug in axial juxtaposition with said explosive charge, and firing said initiator to detonate said charge in a manner to peripherally expand said plug into peripheral welding association with said tube.

2. The method recited in claim 1 and further including chamfering the open end of said leaky tube to provide a flared opening in the tube sheet surface, and positioning the metallic plug device adjacent said flared opening before detonation of the initiator, thereby to peripherally expand an annular portion of the plug device into welding association with said flared opening.

3. The method recited in claim 1 wherein the tube sheet is clad with a layer of metal having weld compatibility with the metal tubes, and the metallic plug device is formed of metal having weld compatibility with the metal tubes and/or said layer of metal.

4. The method recited in claim 1, wherein the tube sheet is clad with a layer of metal having weld compatibility with the metal tubes, and the metallic plug device is formed of metal having weld compatibility with the metal and/or said layer of metal, and including chamfering the open end of said leaky tube to provide a flared opening in said layer of metal, and positioning the metallic plug device in substantially flush relation with said layer of metal, thereby to peripherally expand an annular portion of the plug device into welding relation with said flared opening.

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U.S. Cl. X.R.

29—157.3, 157.4, 421, 470.1, 497.5