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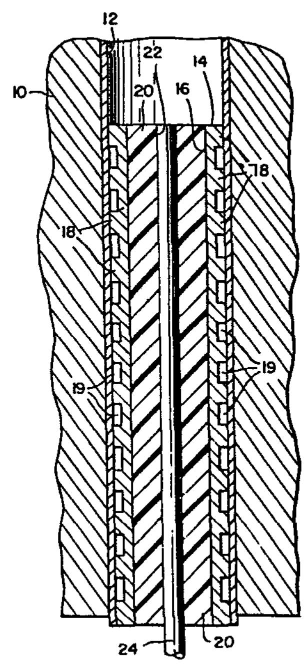
## (54) Explosively activated assembly for repairing heat exchange tubes.

(57) The invention relates to the repair of heat exchange tubes and is directed at an explosive activated assembly having a sleeve (14) which is inserted into an end of the tube (12) to be repaired and has a plurality of projections (18) extending from the outer surface thereof. A force-transmitting member (20) extends within a bore (22) formed in the sleeve (14) and contains an explosive member (24) so that, upon detonation of the explosive member (24), the force-transmitting member (20) and the sleeve (14) are expanded radially outwardly to drive the projections (18) against the tube (12).

FIG. 2.

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# EXPLOSIVELY ACTIVATED ASSEMBLY FOR REPAIRING HEAT EXCHANGE TUBES

This invention relates to an assembly for repairing a heat exchange tube and, more particularly, to such an assembly utilizing an explosively activated sleeve.

Many current designs of heat exchangers feature the use of a large plurality of heat exchange tubes supported by a tube sheet and adapted to receive primary fluid which is passed in a heat exchange relationship with a secondary fluid flowing over the tubes. During the lifetime of such a heat exchanger, a number of heat exchange tubes often fail within the area of the tube confined by the tube sheet due to erosion, corrosion, intergranular attack, and other causes. This could allow the normally separated fluids to come into direct contact with each other and thus diminish the efficiency of the unit.

The most simple manner of dealing with these type of failures is to disable the particular heat exchange tube in question i.e., to close it off at both ends in the vicinity of the tube sheet or sheets. This has been done in the past, for example, by welding plugs in the respective ends of the tubes. However, this requires relatively good access to the tubes and results in a weld bead that could become corroded and fail. Mechanically driven plugs have been suggested, but these are also not without problems since they are difficult to install with any consistency and have a relatively low pullout strength.

Both of these techniques, even if successful, compromise the efficiency of the heat exchanger due to the attendant disablement of the tube.

Although it has been suggested to insert a repair sleeve into the tube, major problems exist, including the lack of adequate pressure sealing and the possibility of compromising the axial strength of the tube should it become completely severed in the damaged region.

It is therefore an object of the present invention to provide an explosively activated repair assembly for a heat exchange tube which restores the tube to full use.

It is a further object of the present invention to provide an assembly of the above type which utilizes a sleeve which is explosively activated into engagement with the heat exchange tube.

It is a still further object of the present invention to provide a repair assembly of the above type in which a pressure-tight seal and substantial axial strength are insured.

Toward the fulfillment of these and other objects, the assembly of the present invention includes a sleeve disposed within the tube to be repaired and having an internal bore and an outer diameter slightly less than the inner diameter of the tube. A force-transmitting member extends within the bore and an explosive extends within the force-transmitting member. A plurality of projections are formed on the outer surface of the sleeve and are adapted to extend in close proximity to the inner surface of the tube. The projections overlap the explosive so that, upon detonation of the latter, the force-transmitting member is expanded radially outwardly against said sleeve to expand said sleeve radially outwardly and drive the projections into said tube.

The above brief description, as well as further objects, features and advantages of the present invention will be more fully appreciated by reference to the following detailed description of the presently preferred but nonetheless illustrative embodiment in accordance with the present invention when taken in conjunction with the accompanying drawings in which:

Fig. 1 is a partial fragmentary, front elevational view of a plurality of heat exchange tubes supported by a tube sheet of a typical heat exchange apparatus and depicting the repair assembly of the present invention in one of the tubes;

Fig. 2 is an enlarged, partial, longitudinal sectional view taken along the tube of Fig. 1 having the repair assembly of the present invention inserted therein; and

Fig. 3 is an elevational view, on a reduced scale when compared to Fig. 2, of a sleeve utilized in the assembly of Fig. 2.

Referring to Fig. 1 of the drawings, the reference numeral 10 refers in general to a tube sheet which can form a portion of a heat exchanger having a plurality of heat exchange tubes 12. The ends of the tubes 12 shown in the drawings are mounted to one side of the tube sheet 10 and extend through openings in the tube sheet in communication with the area extending to the other side of the tube sheet. Only a portion of the tube sheet 10 and the tubes 12 are shown in the interest of clarity, it being understood that the heat exchanger would also include a vessel enclosing the tube sheet and having suitable inlets and outlets for a primary heat exchange fluid and a secondary heat exchange fluid. According to a typical arrangement of this type, the tubes would be U-shaped with both ends of each tube extending through the tube sheet 10. The heat exchanger would include a partition, or the like, so that the primary heat exchange fluid would enter the tubes through one end from an area below the tube sheet as viewed in Fig. 1, pass through the tubes in a heat exchange relation with the secondary fluid passing through the vessel above the tube sheet, and exit through the other ends of the tubes to the area below the tube sheet.

The assembly of the present invention is shown inserted into one of the tubes 12 to be repaired and is better shown in Fig. 2. The assembly includes a sleeve 14 extending into the end of the tube 12, as shown in Fig. 2. The length of the sleeve 14 is selected so that it spans the damaged portion of the tube which, for the purpose of this example, will be assumed to be a portion of the tube confined within the tube sheet 10. The sleeve 14 has a central bore 16, and is fabricated from a suitable metal which preferably is identical to the metal forming the tubes 12, which can be carbon steel or an alloy such as carbon-nickel.

A plurality of spaced circular projections 18 are formed on the outer surface of the sleeve for its entire length. Preferably, the projections 18 are formed as a result of a plurality of circumferential, axially spaced annular grooves 19 being machined into the outer surface of the sleeve 14 as better shown in Fig. 3. The projections 18 extend to the inner surface of the tube 12 with just enough clearance to permit insertion of the sleeve 14 into the tube. The spacing of the grooves 19 and their axial length are such that the latter is substantially equal to the axial length of the projections 18.

A cylindrical force-transmitting member 20, which can be fabricated from a thermoplastic hardenable resin of a conventional composition, is disposed within the bore 16 of the sleeve 14 and extends coextensive with the sleeve 14 within the tube 12.

The member 20 has an axially extending central bore 22 which receives a cord-like explosive member 24 extending for the entire length of the member 20 and projecting outwardly from the lower ends of the latter member and the sleeve 14. The explosive member 24 contains a predetermined number of grains of explosive uniformly disposed along the axis of the member and embedded within a fiber or plastic body. The projecting portion of the explosive member 24 can be connected to a detonator cap (not shown) which can be connected, in a conventional manner, to a remotely located electric detonator, or the like.

Upon detonation of the explosive member 24 in the manner described above, the shock wave of the detonation is transmitted in a radial direction, via the member 20, to the sleeve 14, forcing the sleeve and therefore the projections 18 against the inner wall of the tube 12. Due to the very high pressure which acts for a very short time, the sleeve is expanded to a diameter greater than the inner diameter of the tube 12. As a result, the projections 18 coin, or emboss, into the inner tube surface and function to secure the sleeve within the tube, to disrupt possible leak paths and to develop a relatively high leak resistance and axial strength. The result is a restoration of the tube 12 to an as-new condition, notwithstanding the fact that the damage to the tube could have been of a magnitude to cause its complete failure.

As a non-limitive example of the dimensions and spacing of the projections 18 formed on the sleeve 14 according to the present invention, the projections 18 can have an axial length (measured in a direction parallel to the axis of the sleeve) of approximately .06 inches, and a thickness (corresponding to the depth of the corresponding groove) of .02 inches. The spacing between the projections is equal to their axial length (.06 inches) and, after the explosion, the projection emboss into the inner tube surface for a distance of approximately .002 inches.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention therein.

CLAIMS:-

1. An explosively activated assembly for repairing a tube in a tube sheet, said apparatus comprising a sleeve disposed within said tube and having an internal bore and an outer diameter slightly less than the inner diameter of said tube, a force transmitting member extending within said bore, explosive means extending within said force-transmitting member, and a plurality of projections extending from the outer surface of said sleeve and adapted to extend in close proximity to the inner surface of said tube, said projections overlapping said explosive means so that, upon detonation of said explosive means, said force transmitting member is expanded radially outwardly against said sleeve to expand said sleeve radially outwardly and drive said projections into said tube.

2. The assembly of claim 1 wherein said projections extend for the entire length of said sleeve.

3. The assembly of claim 1 wherein the length of said force-transmitting member is equal to the length of said sleeve.

4. The assembly of claim 1 wherein after said expansion, said projections emboss into the inner surface of said tube.

5. The assembly of claim 1 wherein said projections have a rectangular cross section.

6. The assembly of claim 1 wherein said projections are formed by forming a plurality of spaced annular grooves in the outer surface of said sleeve.

7. The assembly of claim 6 wherein the axial length of each projection is substantially equal to the axial length of each groove.

8. The assembly of claim 1 wherein each of said projections extends continuously around the outer surface of said sleeve.

FIG. 1.

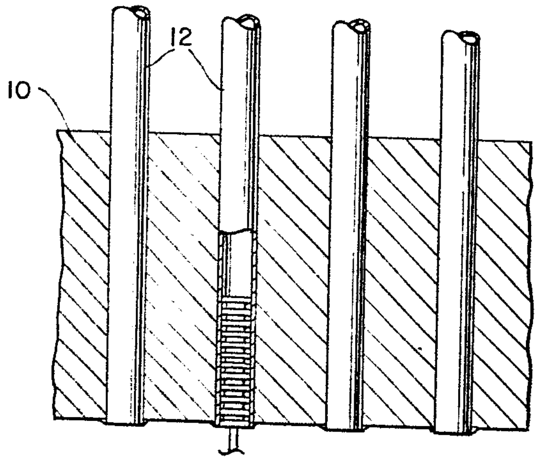


FIG. 2.

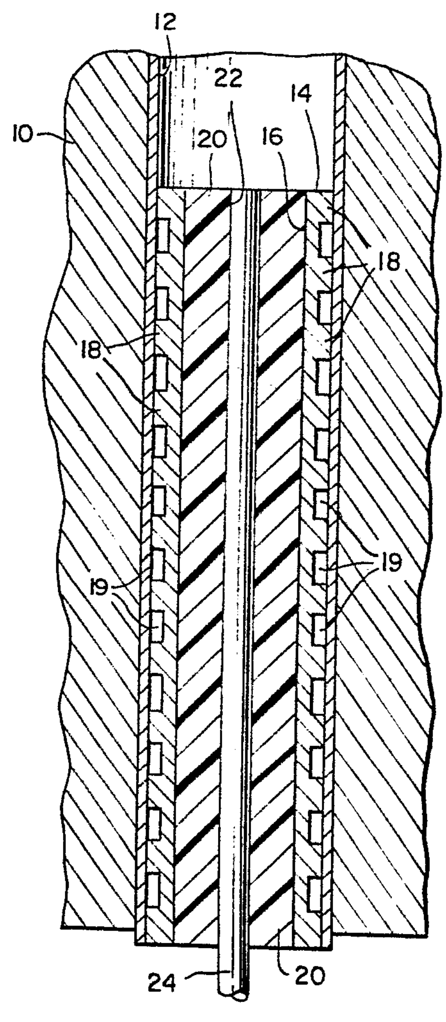


FIG. 3.