United States Patent

[11] 3,590,877

[72] Inventors Phillip M. Leopold
Alliance, Ohio;
Louis A. Sturiale, Irwin, Pa.

[21] Appl. No. 761,273
[22] Filed Sept. 20, 1968
[45] Patented July 6, 1971
[73] Assignee The Babcock & Wilcox Company
New York, N.Y.

[54] EXPLOSIVE-ACTIVATED PLUG
4 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** 138/89, 29/421, 138/97, 138/103
[51] **Int. Cl.** F16l 55/10
[50] **Field of Search** 138/114, 89, 97, 103, 108; 29/421

[56] **References Cited**

UNITED STATES PATENTS

3,491,798	1/1970	Beshara	138/93 X
311,149	1/1885	Stevens	138/108 X
2,214,226	9/1940	English	138/97 X
3,126,918	3/1964	Eaton	138/114 X
3,263,323	8/1966	Maher	29/421 E X
3,290,770	12/1966	Silverman	29/421 E
3,292,253	12/1966	Rossner	29/421 E
3,358,349	12/1967	Rosen	29/421 E X
3,364,561	1/1968	Barrington	29/421 E X

Primary Examiner—Herbert F. Ross
Attorney—J. Maguire

ABSTRACT: A plug which can be inserted into a tube and containing a shaped explosive charge which is detonated to expand the plug against the surrounding tube surface with an impact that effects a circumferential weld bond between the plug and tube surface to seal the tube.

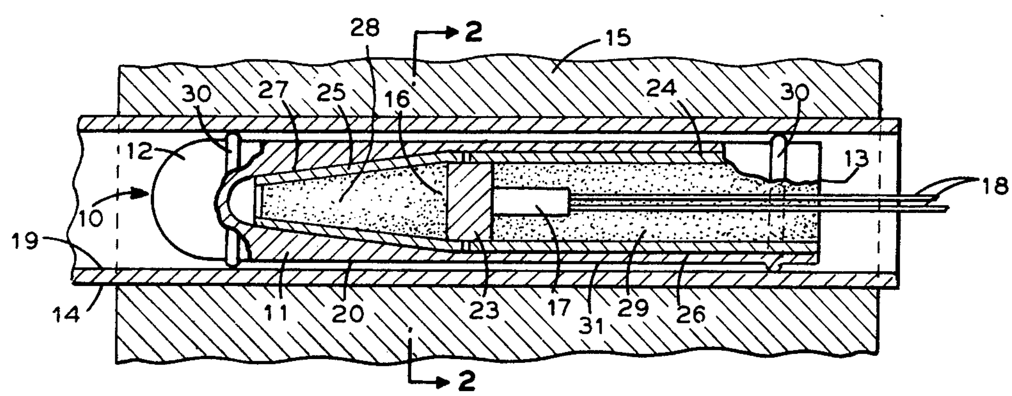


FIG. 1

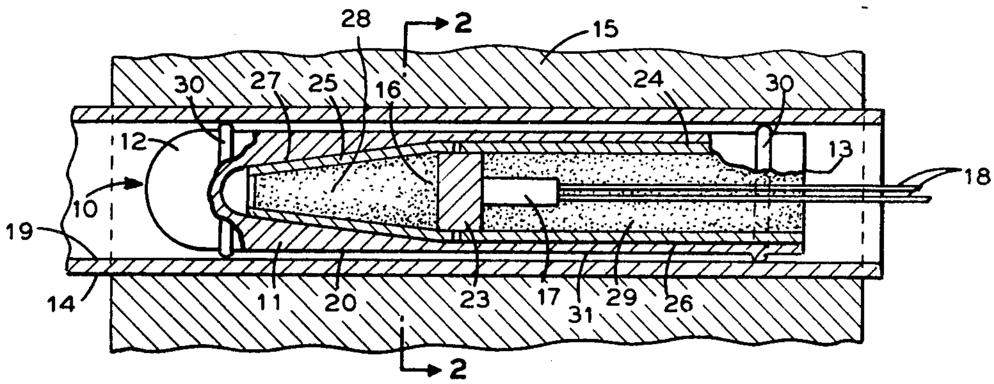


FIG.2

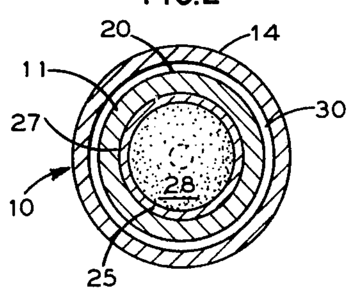
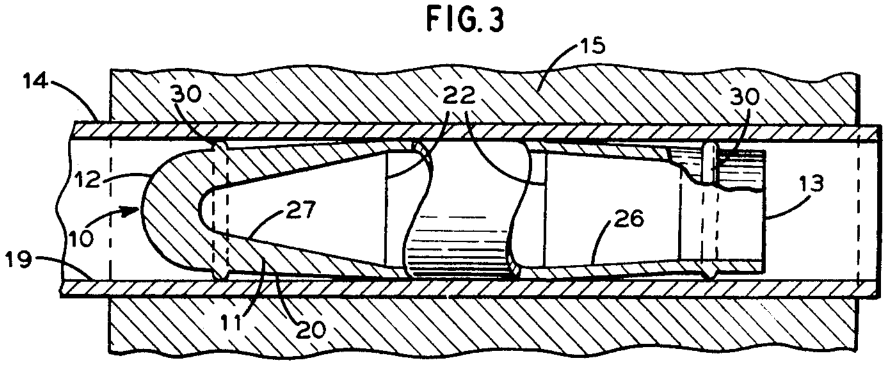


FIG.3



INVENTORS
Phillip M. Leopold
Louis A. Sturiale

BY

ATTORNEY

EXPLOSIVE-ACTIVATED PLUG

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates in general to the art of explosive welding, and more particularly to an explosive-activated metal plug which can be inserted into a tube or the like and then detonated into a sealing configuration.

In the operation of heat exchangers wherein heat transfer occurs between fluid passed through tubes and fluid in contact with the outside of tubes it sometimes becomes necessary to seal one or more tubes, in order to prevent mixing of the fluids, as in the case where the tubes develop leaks. The sealing of tubes in the past has generally been accomplished by means of mechanically expandable plugs for tubes exposed to moderate fluid pressure differentials, and by means of welded plugs for tubes exposed to high fluid pressure differentials.

Ordinarily, where a high-pressure heat-exchanger tube is to be sealed, a cylindrical plug is inserted at the tube sheet into the bore of the tube, and a weld bead is deposited around the outside and circumference of the joint between the tube and plug to form a pressuretight seal. While in many cases such tube sealing technique will be satisfactory, it has been found that fluid can sometimes penetrate along the tube-plug interface and corrode through the weld bead thereby causing leakage and necessitating extensive repairs.

Moreover, in some heat exchangers, it is relatively difficult to weld seal plugs using conventional equipment, because of space limitations.

The invention avoids these disadvantages of prior art welded plugs by employing an explosive activated plug in the form of a hollow metal body that is inserted into the bore of a metal tube to be sealed, and which 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 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.

This metallurgically bonded, or weld, zone comprises a considerably greater area of the plug surface than is possible when using the conventional seal welding just around the exposed end of the plug.

Consequently, through the use of the invention, a much more extensive area of welding of the plug to the tube can be achieved, and it will be appreciated that this explosive welding is accomplished without the need for manipulating electrodes or any other welding tools.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawing and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. 1 is a longitudinal view, partly in section, of an explosive-activated plug according to a preferred embodiment of the invention shown as inserted into a tube to be sealed and prior to detonation.

FIG. 2 is a transverse cross-sectional view of the plug and tube shown in FIG. 1 as taken along line 2–2 therein.

FIG. 3 is a longitudinal sectional view of the plug and tube shown in FIG. 1 as seen after detonation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

In FIGS. 1 and 2 there is illustrated, by way of example, a typical explosive-activated plug 10 constructed in accordance with the invention. The plug 10 has an elongated hollow metal body 11, which is generally cylindrical in form, closed at one end 12, and open at its other end 13. In its contemplated use, the plug 10 is inserted into the bore of a metal tube 14 that is to be sealed, the end portion of tube 14 being received and retained by a tube sheet 15, as in a typical heat exchanger (not shown).

Within the hollow interior of plug body 11 is a shaped explosive charge 16 and a detonator 17. Detonator 17 is preferably an electrically operable type having lead wires 18 extending out through the open rear end 13 of plug body 11 for connection to a remote firing circuit (not shown).

The charge 16 is so distributed and arranged that when set off by the detonator 17, the resultant explosion expands the plug body 11 against the surrounding tube surface 19 with an impact that drives the exterior surface 20 of plug body 11 into metallurgically bonded contact, i.e. cold-welding fusion, with tube surface 19 over a zone 22 extending completely around the circumference of body 11 and along an axial length portion thereof intermediate the ends 12 and 13, as better seen in FIG. 3.

It has been found that such explosive welding of the plug 10 to the tube 14 results in a perfect sealing of the tube 14 and can be achieved by using an explosive charge 16 made up from a cylindrical block 23 of explosive material which is positioned axially in generally centered relation to the axial limits intended for zone 22, and in contact with detonator 17; a cylindrical sheet 24 of explosive material positioned in contiguous adjoining relation to the block 23; and a conical sheet 25 of explosive material positioned in contiguous adjoining relation to block 23 and cylindrical sheet 24.

To accommodate such charge 16 and to provide a plug 10 which will deform radially within the zone 22 and without any significant axial movement, the plug body 11 is made with a cylindrical bore section 26 extending axially inward from the open end 13, and a tapered blind bore section 27 that communicates with the cylindrical bore section 26 and tapers with increasing cross-sectional metal volume toward the closed end of plug body 11.

As can be readily noted from FIGS. 2 and 3, the plug body 11 is most heavily reinforced at its forward end 12 whereas from its center toward its rear end 13 the wall thickness of body 11 is considerably lighter. This prevents blowout at the forward end portion of plug 10, which, if it occurred, would destroy its usefulness as a sealing means for tube 14.

To maintain the conical explosive sheet 25 supported in contact with the surface of tapered bore section 27, and the cylindrical explosive sheet 24 in contact with the surface of the cylindrical bore section 26, there are respectively provided a frustoconical filler piece 28 and a cylindrical filler piece 29, both expediently made of a material such as styrofoam.

Externally, the plug body 11 is provided with a pair of radially projecting flange parts 30 that engage the tube surface 19 and serve to support the plug body 11 in a coaxial spaced relation to the tube 14 such that prior to detonation of the charge 16, a predetermined radial standoff distance is established between tube surface 19 and the cylindrical exterior surface portion 31 of body 11. The provision of such standoff distance allows the development of sufficient impact velocity along the plug surface 31 upon detonation of the explosive charge to achieve good bonding to tube surface 19.

In the course of developing the invention a prototype heat exchanger was constructed using Inconel tubes five-eighths inch O.D. by 0.035 inch wall thickness received in a 23½ inches thick AISI 1020 steel tube sheet having 0.635-inch diameter tube holes spaced 0.875 inch center-to-center. The tubes were roll expanded into the holes over a depth of three-quarters inch and then seal welded to the tube sheet.

Several explosive-activated plugs constructed substantially the same as plug 10 were tested in the prototype to determine whether the basic configuration of the plug 10 and its charge 16 would be capable of effecting a fluid pressuretight seal of a typical Inconel tube against a 3200 p.s.i. differential across the plug.

The plugs were machined from Inconel bar stock of the same alloy as that used for the tubes.

In terms of the reference numbers used in describing the plug 10, the typical test plug had the following dimensions:

Overall length (closed forward end 12 to open rear end 13).—3¼ inches.
Axial length between flanges 30 centers.—2²¹⁄₃₂ inches.
Axial length from forward end 12 to forward flange 30 center.—¼ inch.
Axial length from rear end 13 to rear flange 30 center.—1¾ inches.
Axial length of cylindrical bore 26.—1¾ inches.
Axial length of conical bore 27.—1¼ inches.
Basic O.D. of plug along cylindrical surface 31.—0.520 inch.
O.D. of flanges 30.—0.545 inch.
I.D. of cylindrical bore 26.—0.450 inch.
Radius of forward termination of conical bore 27.—³⁄₃₂ inch.
Half-angle of conical bore 27.—6.5 degrees.
Inside radius of forward end 12.—0.260 inch.

In the test plugs, the explosive charge 16 was made up from Detasheet C which is a PETN-base explosive manufactured by Du Pont. The cylindrical block 23 was approximately three-eights inch diameter by three-sixteenths inch thick and weighed 4.6 grains. The cylindrical sheet 24 and conical sheet 25 portions of charge 16 were made by wrapping Detasheet around styrofoam filler pieces such as those exemplified by 29 and 28 and taping the outside of the assembled charge 16 and filler pieces 28, 29 to retain the several components in their desired relative positions. The cylindrical and conical sheets 24 and 25 were both approximately one-sixteenth inch thick and weighed 28.9 grains and 14.0 grains respectively. The detonator 17 used for each test plug was a X-549-D Minidet type manufactured by Du Pont.

To determine the effect of tube surface oxidation upon the sealing capabilities of the plugs, the Inconel tubes were first oxidized in a steam atmosphere of 900° F. for 20 days. The resultant oxide coating on the inside of the tubes is believed to be representative of the worst that would be encountered in actual heat exchanger service.

The tubes were then explosively plugged using the apparatus and method here disclosed without any further surface preparation.

Hydrostatic tests were performed on all tubes that were plugged and it was found that in each case the plugs were able to withstand 3,200 p.s.i. water pressure without encountering any leakage.

In addition, the plugged tubes were given a helium leak check using 2,000 p.s.i. helium pressure behind each plug, and again no leakage was detected.

Several of the plugged tube specimens were split longitudinally and analyzed metallographically to determine the extent of welding. The oxide layers on the tubes apparently had little or no effect on the bond. The weld bond zone was found to extend completely around the plug circumference and over an axial length portion approximately one-half inch long located /¼ inches from the rear end of the plug.

In the metallographic examination, it was noted that some slight evidence of the oxide appeared at the edges of the bond zone, as would be expected, because of the jetting action occurring during the explosive welding, which results in displacement and dispersion of surface layers along the metal interface.

While in accordance with the provisions of the statutes there is illustrated and described herein a specific embodiment of the invention, those skilled in the art will understand that changes may be made in the form of the invention covered by the claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of the other features.

What I claim is:

1. An explosive-activated plug which comprises a generally cylindrical hollow metal body open at one end and closed at the opposite end and disposed for insertion into the bore of a metal tube to be sealed, a shaped explosive charge retained within said hollow body, said explosive charge having an explosive material distributed lengthwise within said body and including a cylindrical block of explosive material, a cylindrical sheet of explosive material positioned in contiguous adjoining relation to said cylindrical block, and a conical sheet of explosive material positioned in contiguous adjoining relation to said cylindrical block, and means disposed within said body and operable from a location outside thereof to detonate said explosive charge and thereby expand said body radially outward against the surrounding tube surface with an impact energy effecting a metallurgically bonded contact between said body and surface to seal the bore, said contact being over a zone extending completely around the circumference of the body and along an axial length portion thereof intermediate said ends.

2. An explosive-activated plug as defined in claim 1 wherein said detonator means is positioned for contact with said cylindrical block of explosive material.

3. An explosive-activated plug as defined in claim 1 wherein said hollow body has a cylindrical bore extending axially inward from said open end of the body, and a blind core communicating with said cylindrical bore and tapering with decreasing cross-sectional area toward said closed end of the body.

4. An explosive-activated plug as defined in claim 3 including filler means disposed within said body to support said cylindrical sheet of explosive material in contact with the surface of said cylindrical bore, and to support said conical sheet of explosive material in contact with the surface of said tapered blind bore.