

[54] **METHOD OF EXPLOSIVELY EXPANDING SLEEVES IN ERODED TUBES**

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[58] Field of Search **29/401 R, 402, 157.4, 29/421 E, 421 R; 137/15; 138/97, 98, DIG. 6**

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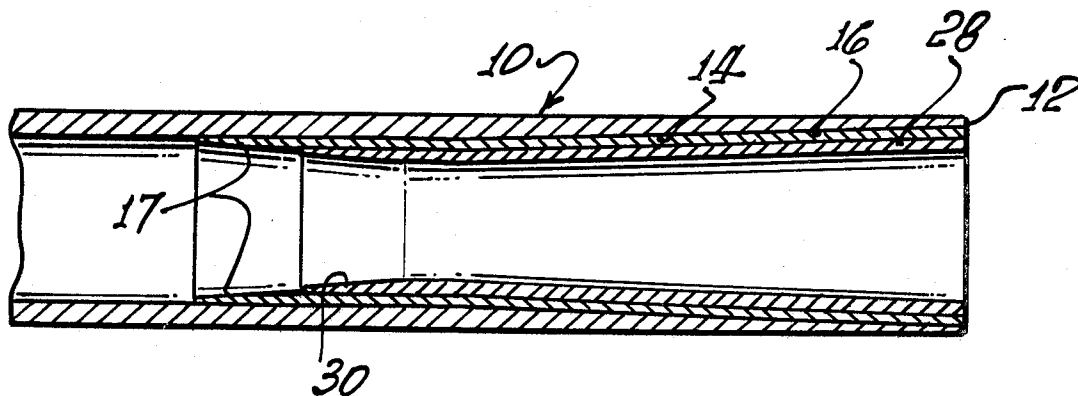
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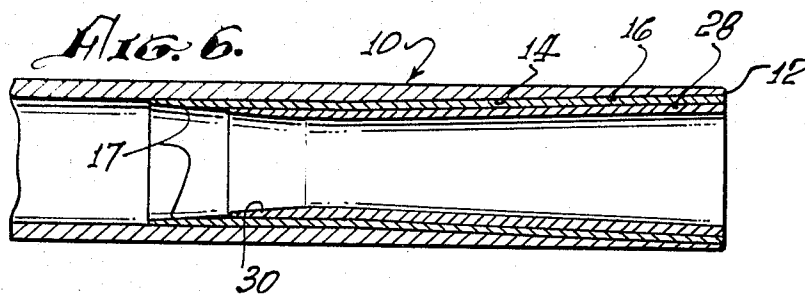
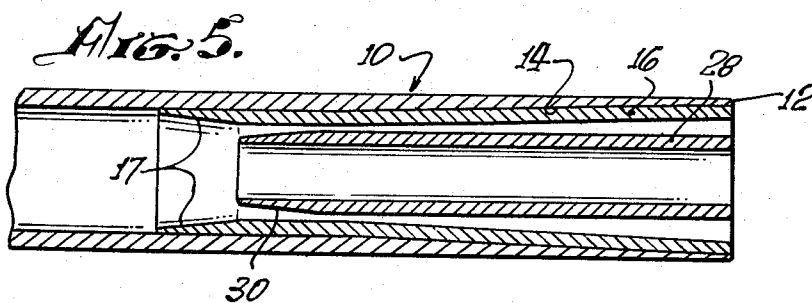
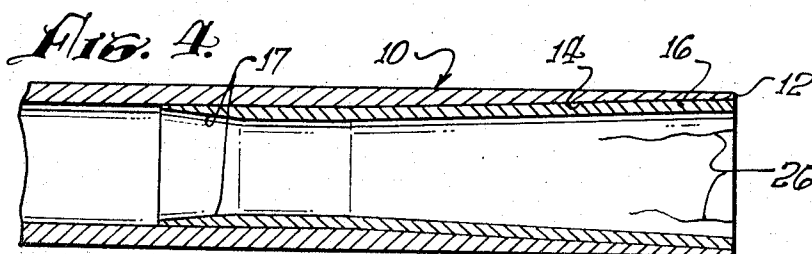
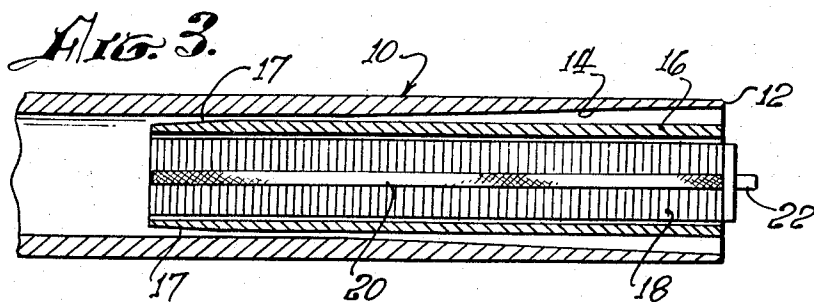
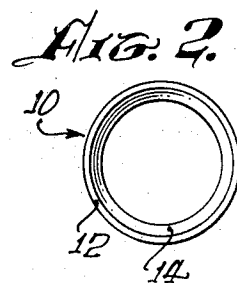
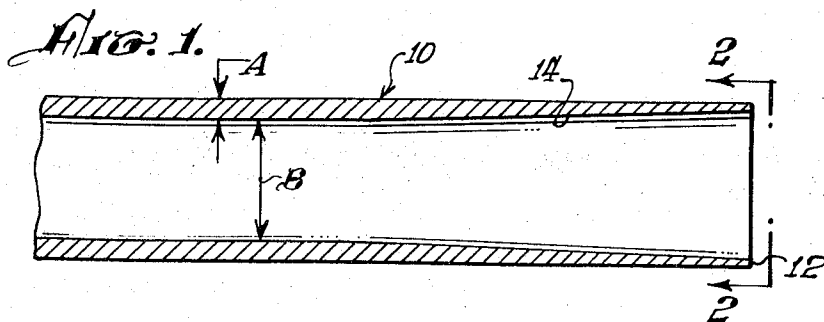
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[57] **ABSTRACT**

The method comprises explosively expanding a first metallic sleeve into engagement with a severely eroded section of a tube and thereafter explosively expanding a second metallic sleeve of approximately the same diameter as the first sleeve into engagement with the first sleeve to cover cracks formed in the first sleeve due to excessive expansion of portions of the first sleeve resulting from the erosion-produced, tapering of the inner wall of the tube.

10 Claims, 6 Drawing Figures





METHOD OF EXPLOSIVELY EXPANDING SLEEVES IN ERODED TUBES

BACKGROUND OF THE INVENTION

This invention relates to the expansion of metal sleeves in tubing and, more particularly, it relates to the explosive expansion of steel sleeves in heavily-eroded tubes.

Tubes such as those employed in heat exchangers and the like are subject to severe erosion from the fluids flowing therethrough. Such erosion is particularly severe at and adjacent to the ends of such tubes with the erosion generally diminishing with distance into the tubes. Usually, the erosion extends about 4 inches into the tube. Because of the change in the severity of the erosion with distance into the tube, the inner surface of the tube is given a conical or trumpet shape with the internal diameter of the tube increasing as the end of the tube is approached.

In the case of tubes which are not severely eroded, steel (or other metal) sleeves can be expanded into the ends of the tubes by rolling or explosive means. However, when this is attempted on severely eroded tubes, the sleeves crack because the ends of the sleeves adjacent to the ends of the tubes are expanded beyond their yield points. As a result, badly eroded tubes have had to be completely replaced. This, of course, is very expensive because of increased labor and material costs, and unit down time.

An alternative to replacement is to expand sleeves having an outer taper which approximates the taper of the eroded section of the tube. However, this method is very expensive because of the high cost of forming tapered tubing, particularly when that tubing has to be tailored to each application.

SUMMARY OF THE INVENTION

This invention is a method for expanding erosion-resistant metal sleeves into severely-eroded tubes. This is accomplished by inserting a first metallic sleeve into a tube within the eroded section of the tube and explosively expanding this sleeve into engagement with the tube. Although the sleeve will fracture in the region where it has to expand the most, this is overcome by inserting a second metallic sleeve into the first, expanded sleeve and explosively expanding the second sleeve into engagement with that region of the first sleeve that fractured. The second sleeve has substantially the same thickness and outside diameter as the first sleeve, but is of shorter length since it can only be inserted part way into the first sleeve which, when expanded into the tube, has a trumpet shape opening toward that end of the tube into which the sleeves are inserted.

A principal advantage of this invention is that even heavily eroded tubes can be re-used for many years, instead of being replaced, so that a substantial cost saving is realized. Furthermore, this method is relatively inexpensive since it employs standard tubing for the sleeves.

DESCRIPTION OF THE DRAWING

FIG. 1 is a sectioned view taken along a portion of the length of a tube illustrating the inner wall produced by erosion.

FIG. 2 is a full end view of the tube of FIG. 1 taken in the direction 2—2 of FIG. 1.

FIG. 3 is the same view as FIG. 1 but further illustrates the positioning of a first sleeve and explosive-containing insert within the tube.

FIG. 4 is the same view as FIG. 1 and it shows the first sleeve expanded against the tube.

FIG. 5 is the same view as FIG. 4 and further shows the positioning of a second sleeve within the tube.

FIG. 6 is the same view as FIG. 4 and further shows the second sleeve expanded into engagement with the first sleeve.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1, the numeral 10 designates a highly eroded tube, e.g., a carbon steel tube, which has a nominal or non-eroded thickness "A" which is usually on the order of 0.040 in. to 0.150 in. for heat exchanger tubes. However, due to erosion, the thickness of the tube 10 can decrease by about 0.045 in. at the end 12 of the tube 10. This decrease in thickness generally occurs along a length of about 4 in. for heat exchanger tubes so that the inner surface 14 of the tube 10 becomes highly tapered as shown by FIG. 1 and FIG. 2. As used herein, the term "highly eroded tube" means a tube in which erosion has produced an internally-tapered surface which defines a bore section which is too large to permit explosive expansion of a cylindrical sleeve which is receivable by the non-eroded portion of the tube, without fracturing.

To provide the tube 10 with a new inner surface or liner, a sleeve or ferrule 16 is formed from, preferably, an erosion-resistant metal such as stainless steel. The sleeve 16 has the same cross-sectional shape as the tube 10. In general, the O.D. and thickness of the sleeve 16 are selected so that the sleeve will expand beyond its plastic limit, but will not expand beyond its yield strength limit in that part of the tube 10 having an original I.D. of B. This is well-known in the art and does not constitute a part of this invention. Hereinafter, the term "explosively expandable sleeve" will be used to designate a sleeve having a diameter and thickness such that the sleeve can be explosively expanded against a parallel surface, such as that section of the inner tube wall having a nominal diameter, without fracturing. Preferably, the sleeve 16 has an O.D. which is less than, but substantially equal to the nominal I.D. of the tube 10 so that the sleeve 16 is slidably received by the tube 10 along its non-eroded length.

The length of the sleeve 16 is selected so that it will extend inwardly from the end 12 of the tube 10 to a point beyond the end of the tapered section of the tube wall 14 as shown in FIG. 2. That is, the sleeve 16 extends from the tube end 12 into the portion of the tube having a nominal I.D. of B. This, inter alia, ensures that the eroded section will be completely covered by the sleeve 16.

The outer surface of the sleeve 16 is preferably provided with an annular taper 17 extending from the inner end of the sleeve for a distance of about 0.5 in.—1 in. This taper 17 is reversed by the explosive expansion of the sleeve 16 and appears on the interior surface of the sleeve 16. This serves to fair the sleeve wall into the tube wall to improve fluid flow past the tube/sleeve innermost juncture. Additionally, the outermost end of the sleeve 16 may be flaired to ensure that the eroded area adjacent to the end 12 of the tube 10 is covered when the sleeve 16 is expanded.

After the sleeve 16 is positioned within the tube 10, a force-transmitting insert 18 such as is described in U.S. Pat. No. 3,411,198, issued Nov. 19, 1968 and U.S. Pat. No. 3,503,110, issued Mar. 31, 1970, and containing an explosive 20 positioned within the sleeve 16 as shown in FIG. 3. A detonator 22 is placed in direct contact with the explosive 20 as shown in FIG. 3, to initiate detonation of the explosive. When the latter occurs, the sleeve 16 is expanded into engagement with the inner wall 14 of the tube 10 as shown in FIG. 4.

The sleeve 16 expands against that portion of the inner wall 14 having a nominal diameter B and for some distance along the inner wall 14 towards the tube end 12 without fracturing. However, in the region adjacent to the tube end 12, the sleeve 16 is caused to expand beyond its yield strength limit due to the tapering of the inner wall 14. This expansion produces fracturing or cracks 26 (FIG. 4) in the sleeve 16.

To cover the cracks 26 and to provide a relatively continuous inner liner surface, a second sleeve 28 is inserted within the expanded sleeve 16. The inner sleeve 28 has an O.D. and thickness which are substantially equal to those of the expanded sleeve 16. The length of the inner sleeve 28 is made to approximate the distance from the tube end 12 to the inner end of the eroded section of the inner wall 14. This usually means that some force is required to force substantially the total length of the sleeve 28 into the tube 10. In some cases, the sleeve 28 may have to be shortened slightly. The resulting forcefit ensures concentric alignment of the sleeve 28 with the longitudinal axis of the tube 10. Preferably, the inner end 30 of the sleeve initially is externally tapered to internally taper it by expansion as described with reference to the outer sleeve 16.

The inner sleeve 28 is explosively expanded into engagement with the expanded sleeve 16 using an insert as described herein with reference to FIG. 3. The result of this second expansion is shown in FIG. 6. That is, the tube 10 is provided with a liner having a double thickness extending inwardly from the tube end 12 to substantially the location along the tube length where the tube thickness is substantially that of the non-eroded tube. From that location inward to the inner end of the outer sleeve 16, the liner has a single thickness.

If the erosion is so severe that the inner sleeve 28 also cracks, a third sleeve (not shown) may be employed as described in connection with the inner sleeve 28.

This invention will be further described by the following Example.

EXAMPLE

A number of stainless steel sleeves were explosively expanded into highly eroded carbon steel tubes using the method described herein.

The tubes had a nominal I.D. of 0.435 in. which increased over a distance of about 4 in. to an I.D. at the end of the tubes of about 0.530 in. The nominal O.D. of the tubes was about 0.550 in.

The first sleeve was 6 in. long and the second sleeve was 4 in. long. Both sleeves were 0.016 in. thick and had an O.D. of 0.430 in. Additionally, both sleeves were provided with an external taper at their innermost ends of about 0.5 in. in length.

The tubes have been used in a heat exchanger for several months with excellent results.

I claim:

1. A method of providing a tube with a liner wherein said tube has a highly eroded, internally-tapered section, said method comprising the steps of:

inserting a first metal sleeve into said tube so that said first sleeve is substantially co-extensive with both said eroded section and an adjacent section of said tube having a nominal internal diameter, said first sleeve being explosively expandable against said adjacent section of said tube;

explosively expanding said first sleeve into engagement with said tube;

inserting a second metal sleeve within said first sleeve, said second sleeve characterized by being explosively expandable into engagement with said section of said tube having said nominal diameter and having a length substantially as long as is permitted by the bore defined by said expanded first sleeve; and

explosively expanding said second sleeve into engagement with said first sleeve.

2. The method of claim 1 wherein said second sleeve has an outer diameter substantially equal to that of said first sleeve.

3. The method of claim 1 wherein the outer diameter of said first sleeve is substantially equal to but less than said nominal internal diameter of said tube.

4. The method of claim 1 wherein the innermost ends of said first and second sleeves are provided with an external taper which reverses upon expansion of said inserts to provide a more continuous surface transition from said expanded second sleeve to said expanded first sleeve to said tube.

5. The method of claim 1 wherein said second sleeve is expanded beyond its yield point and wherein a third sleeve is explosively expanded into engagement with said second sleeve, said third sleeve having an outer diameter substantially equal to that of said first and second sleeves and having a length as long as that which is receivable by said expanded second sleeve.

6. The method of claim 1 wherein said sleeves comprise an erosion-resistant metal.

7. The method of claim 1 wherein said second sleeve is force-fitted into said expanded first sleeve prior to expanding said second sleeve.

8. A method of providing a tube with a liner wherein said tube has a highly-eroded, internally-tapered section, said method comprising:

inserting a first erosion-resistant metal sleeve into said tube, said sleeve being coextensive with said eroded section and with an adjacent section having a nominal diameter and having an outer diameter substantially equal to but less than said nominal diameter of said tube;

explosively expanding said sleeve into engagement with said tube to fracture said first sleeve adjacent to its end of greatest expansion;

force-fitting an end of a second erosion-resistant, metal sleeve into said expanded first sleeve, said second sleeve having a diameter and thickness substantially equal to those of said first sleeve and having a length extending from the region of said force fit substantially to said end of greatest expansion of said first sleeve; and

explosively expanding said second sleeve into engagement with said first sleeve.

9. The method of claim 8 wherein said force-fitted end of said second sleeve is externally tapered.

10. The method of claim 8 wherein the innermost end of said first sleeve and said force-fitted end of said second sleeve are externally tapered.

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