Jan. 7, 1941. E. C. LEONHARDY 2,228,139

LINING TUBES

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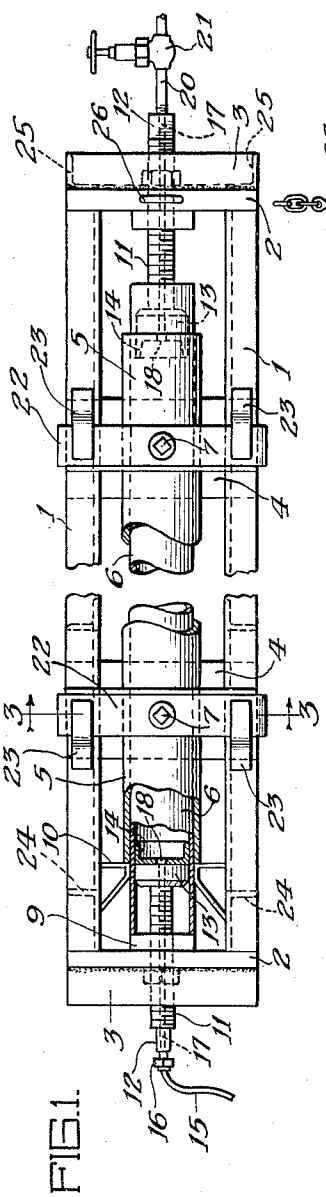


FIG. 1.

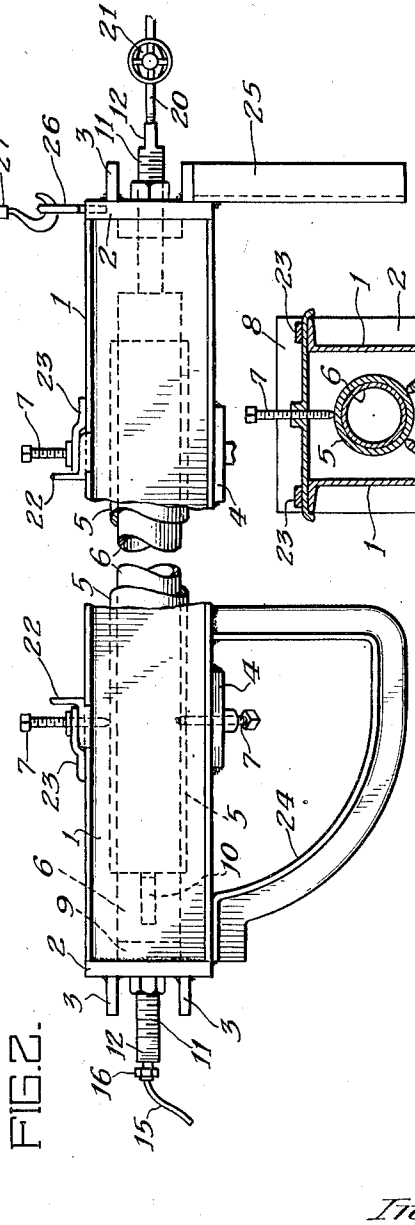


FIG. 2.

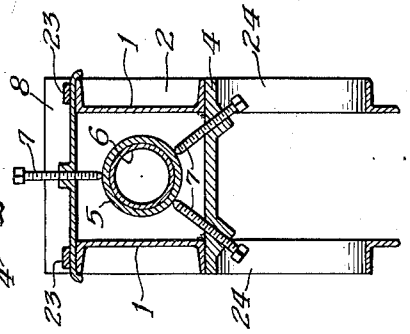


FIG. 3.

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LINING TUBES

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2 Claims. (Cl. 153—79)

The invention particularly relates to an improved method and means of expanding relatively ductile or thin wall liners into tubular metallic elements of greater tensile strength by the application of internal fluid pressure to the liner while the latter is in place in said tubular element.

In many industries, tubular elements employed as conduits for various materials or as reaction or contact zones are subjected to different conditions of corrosion, erosion, oxidation and the like about their internal and external surfaces and in many instances no single metal or metallic alloy is suitable for both the internal and external conditions to which the same tube is subjected. A typical example of the occurrence of this condition is in heating corrosive fluids to relatively high temperatures and/or at higher superatmospheric pressure. Metals and metallic alloys which will resist most forms of corrosion are readily available, although rather expensive in many cases, and various steel alloys, the most commonly used of which is probably nickel-chromium steel, will successfully resist extremely high temperature and pressure conditions. However, the alloys suitable for high temperature and pressure conditions are by no means resistant to all forms of corrosion. In such instances, the use of a liner or double wall tube is indicated, the outer tube or wall, which comes in contact with the heating medium, being relatively thick and/or resistant to high temperature and pressure conditions, while the other wall or liner may be relatively thin and composed of an alloy which resists the corrosive conditions to which it is exposed.

In problems of the type above mentioned, the difficulty resides in uniting the thin wall, non-corrosive liner with the thicker external walls of the tube in such a manner that heat may be readily transferred through both walls. When an air-space or pocket is left between the liner and the thick wall tube, the flow of heat is retarded at this point and will result in poor heat transfer efficiency and relatively hot and relatively cold spots or zones along the tube walls. The advantage of using relatively thin wall liners is readily apparent, since, as previously stated, the cost of non-corrosive and metallic alloys is usually high. A painted, sprayed or baked enameled surface of corrosion-resistant material applied to the tube has been successful in a few instances, particularly where external corrosion or electrolysis is encountered, but as applied to lining the internal surface of relatively small elongated tubular elements it is extremely difficult to obtain an impervious, uniform surface and even then is not satisfactory for all conditions.

Various methods and means of expanding relatively thin liners into tubes have been proposed and tried. One of the methods heretofore used involved inserting a liner in the tube and then forcing or drawing a tapered plug through the liner to expand the same to contact with the walls of the tube. Special devices for rolling or beating the walls of the liner to expand the same against the tube have been tried. The present inventor has been engaged in work of this nature for some time and his experience is that the failure of these previous methods to achieve entirely satisfactory results resides primarily in the eccentricity and non-uniform thickness of the steel and steel alloy tubes available. These tubes are manufactured to a close tolerance on external diameter, but the manufacturing methods employed necessitate a tolerance of some 25% over the specified minimum wall thickness. Tubes of the same heat or batch will vary considerably in wall thickness and the wall thickness of each individual wall tube may vary throughout its length and about its circumference. Spiral depressions are often found in the internal walls due to the use of a rotating mandrel in drawing the tube. It is virtually impossible to beat, roll or otherwise expand the liner by mechanical means in such a manner that it will conform to the non-uniform condition of the internal walls of the tube, particularly in the relatively long and relatively small diameter tubes ordinarily employed. I have found, however, that by applying a high internal fluid pressure to the liner, while the latter is in place in the tube, it may be expanded to substantially the exact contour of the tube walls despite irregularities and any eccentricity of the tube. I preferably employ a relatively incompressible liquid such as water or oil for this purpose, but air or other compressible fixed gas may be utilized within the scope of the invention.

I have utilized the method and means specified by the invention, of expanding liners into tubes by the application of internal fluid pressure, with a high degree of success, both from the standpoint of economy and final results. The process is much more rapid than previous methods and involves the use of only relatively simple and inexpensive equipment upon which there is a minimum of wear and replacement.

The accompanying diagrammatic drawing illustrates one specific form of apparatus in

which the method of lining tubes provided by the invention may be accomplished and the following description of the apparatus illustrated includes a description of its operation.

Figure 1 of the drawing is a plan view of the apparatus with a tube and liner in place ready to be expanded, with portions of the apparatus, tube and liner shown in cross-section. Figure 2 is a side-elevation of the apparatus illustrated in Figure 1. Figure 3 is a cross-sectional view of the apparatus illustrated in Figures 1 and 2, with the tube and liner in place, this view being taken along the plane indicated by line 3—3 in Figure 1.

A frame for receiving a tube and holding it during the liner expanding operation is provided and comprises side-members 1 which are standard steel channels with their web spaced apart to provide an opening therebetween for the tube and liner and with their ends welded to heavy steel plates 2. The end plates 2 are reinforced, in the case here illustrated, by transverse metal plates 3 extending across the width of plates 2 and welded to the latter. The channel side members 1 are transversely braced by one or more steel plates 4 spanning the space therebetween and welded to one flange of each of the channels, the opposite side of the frame being left open so that the tube and liner may be readily inserted and removed therefrom.

The tube 5, in which liner 6 has been inserted before placing the same in the frame, is held in place, in the particular case here illustrated, by suitable set screws 7, the ends of which engage tube 5 at spaced points about its circumference. Two of the set screws 7, in this particular instance, extend through and are threaded to each of the plates 4, while the set screws on the opposite side of the frame extend through and are each threaded to an angle member 8. Members 8 are releasably engaged with the top flanges of channel members 1 by means of lugs 23 welded to the latter. As will be apparent from the drawing, members 8 are removable from the assembly when a tube and liner is to be placed within or removed from the frame.

A lug 9, which is attached to or integral with one of the plates 3, acts as a stop for one end of the liner 6 and the adjacent end of the outer tube 5 abuts suitable stops 10 attached to channels 1 at a spaced distance from lug 9, the liner being preferably somewhat longer than tube 5 and extending beyond the opposite ends of the latter, since the length of the liner will be considerably decreased by its circumferential expansion.

Screws 11, one of which is disposed at each end of the frame, extend through and are threaded to the adjacent end plate 2. The outer end of each of these screws is flattened, as indicated at 12, to receive a wrench for adjusting the same. A metal plug 13 which closely fits and is adapted to slide into liner 6 is provided at the inner end of each of the screws 11. By providing adjusting means, such as screws 11, compensation for tubes of varying lengths is obtained so that plugs 13 may be properly located within the liner with reference to the ends of tube 5. This adjustment is not an essential feature of the invention since the tubes to be lined may be cut to uniform length before being inserted in the frame, in which case the position of plugs 13 may be fixed by attaching each of them to a rod, bar or shaft rigidly attached to the adjacent end plate 2. It is also entirely within the scope of the invention to mount the plug 13 adjacent stops 10 in fixed relation thereto in the manner above described and employ an adjustable screw 11 at the opposite end of the frame. Preferably, plugs 13 are located by either adjustable or fixed means so that the inner face of each plug is substantially flush with the adjacent end of tube 5.

To prevent the leakage of fluid from the liner when pressure is applied, pliable cups 14 of leather, rubber, or other suitable material are provided for insertion into the opposite ends of the liner. These cups may be separate from or attached to plugs 13 and are backed up by the latter and tightly expanded against the interior surface of the liner walls when pressure is applied within the liner.

A suitable high pressure pump or compressor of any desired well known form, not illustrated, supplies fluids under high pressure to the space within the liner between cups 14 through a relatively small and preferably flexible tube 15 which is capable of withstanding the pressure employed. This tube is connected to the outer end of one of the screws 11 by connector 16 and communicates through opening 17, extending through this screw 11 and plug 13, and through opening 18 in cup 14 with the space in liner 6 between cups 14. As internal pressure is applied to the liner by operation of the pump or compressor, the liner gradually expands and contacts the inner surface of the walls of tube 5, the flanges of cup 14 expanding with the liner and keeping the pressure zone tightly sealed.

The pressure required to satisfactorily expand the liner and make it conform to irregularities in the internal surface of the tube into which it is expanded will, of course, depend upon the composition, size and strength of the liner, as well as the strength of the outer tube. A pressure in excess of the elastic limit of the liner will, of course, be required and it may also exceed the yield point of the outer tube, but should not too closely approach the elastic limit of the latter. With the foregoing in mind, the minimum and maximum limits of the actual gauge pressure most suitable may be determined by calculations based upon the diameter and wall thickness of the tubes and the known physical properties of the metals or alloys of which they are composed.

As previously stated, I preferably employ hydrostatic pressure to expand the liner, since the operation may be more quickly performed with less expense than when a compressible fluid is utilized. When hydrostatic pressure is employed the liner preferably is substantially filled with a relatively non-compressible fluid, such as water or oil, and air is vented from the liner before pressure is applied.

In numerous tests, no difficulty has been encountered with ruptured or otherwise damaged tubes or liners as a result of this method and aside from occasional replacement of the cups 14, no repairs or replacement of equipment have been required. It is worthy of note that care should be exercised to see that cups 14 are within the space enclosed by the outer tube 5. If they are allowed to project any substantial distance beyond the ends of tube 5, the liner will expand at this point and there is danger of rupturing the liner if pressures in excess of its safe working pressure are employed. Although actual failure of the liner under the pressures ordinarily employed is not likely to occur, if the cups are not properly placed expansion of the liner may cause them to creep between the liner and plug 13 and the cup may be ruptured or destroyed.

In the particular case here illustrated, the entire assembly, above described, is mounted upon legs 24 and 25 attached to opposite ends of the frame. The form of the rear legs 24, here illustrated, permits elevation of the forward end of the assembly which is advantageous in venting substantially all of the air from the liner. Since the tube and liner may ordinarily be placed in and more readily removed from the frame when the latter is in a horizontal position, it is normally retained in this position, except when venting air from the lines. In the particular case here illustrated, an eye 26 is attached to the top central portion of the forward end plate 2 for receiving the hook 27 of a chain fall or the like, not illustrated, which may be used for elevating the forward end of the assembly.

To facilitate venting air from the space within the liner between cups 14, when hydrostatic pressure is employed for expanding the liner, cup 14 and screw 11 at the forward end of the assembly are also provided with openings 18 and 17, respectively, and a tube 20 having a valve 21 or other suitable shut-off means is attached to the outer end of this screw and communicates through openings 17 and 18 with said space.

As a specific example of the operation of the process herein provided, as it may be accomplished in an apparatus such as illustrated and above described, the tube to be lined is 3⅛ inch O. C. nickel-chromium-steel tube approximately 15 feet long with a minimum wall thickness of ⅛ inch. The alloy employed for this tube corresponds to A. S. T. M. specification No. 158–37T, except that approximately 0.35% of titanium is added. This alloy is one of the class of commonly termed "stainless steel" and is advantageously used where high pressures and high furnace temperatures are encountered.

The liner employed is a 2⅝ inch O. D. tube, approximately 11 feet long with a nominal wall thickness of ⅛ inch and is composed of a copper-aluminum alloy containing from 92 to 95% copper, the remaining 5 to 8% being substantially entirely aluminum.

The outer surface of the liner is carefully wiped to remove any foreign material and, preferably, the inner surface of the steel alloy tube is swabbed for the same reason. The liner is then inserted in the outer tube and the two are set within the frame in the position shown in Figure 1 of the accompanying drawing with each end of the liner projecting at a sufficient distance from the end of the outer tube to compensate for shrinkage in the length of the liner as it expanded. The cups 14 and plungers 13 are inserted in opposite ends of the liner to approximately the position shown in Figure 1. The assembly is then up-ended, valve 21 at the high end is opened and cold water is admitted from a high pressure pump to the liner to fill the same and expel the air through valve 21. When a steady stream of water flows through valve 21, the latter is tightly closed and by continued operation of the high pressure pump the pressure within the liner is gradually increased to approximately 6,000 pounds per square inch, gauge pressure. When this pressure is reached, the pump is stopped and valve 21 is opened to relieve the pressure. Plungers 13 are then backed from the liner, the upper set screws 7 loosened, members 22 disengaged from lugs 23 and removed and the lined tube is then removed from the frame. In case cups 14 are not attached to plungers 13 or have not been forced from the liner by water expelled therefrom, they are not recovered with a packing hook or the like and the apparatus is ready to receive another tube and liner.

It was noted during this operation that the pump rapidly builds up a pressure of approximately 2,000 pounds but that the rate of pressure increase from approximately 2,000 to 4,000 pounds is relatively slow, the rate of pressure increase being again relatively rapid from about 4,000 to 6,000 pounds. This indicates that the actual expansion of the liner takes place between approximately 2,000 and 4,000 pounds. Micrometer measurements on the outer tube indicate that it is expanded by about 0.005 of an inch, while the full 6,000 pounds pressure is applied, but that when this pressure is released the tube returns to its normal size.

Without any particular haste or effort to establish a record, the entire tube expanding operation, above described, was accomplished in approximately 12 minutes time using a hand-operated pressure pump. Obviously, this time could be materially shortened by the use of a motor driven pressure pump. Automatic controls for opening and closing valves 21 would further reduce the time required. This compares with a time of approximately 1 hour for expanding the liner by drawing or forcing a tapered plug therethrough and a time of approximately 4 to 6 hours for expanding the liner with special beating, spinning, or rolling equipment. For large scale operations or quantity production, I contemplate the use of a frame, such as illustrated and above described, but having a multiplicity of tube compartments with header arrangements for simultaneously supplying fluid under high pressure to the interior of each of the liners so that a multiplicity of tubes may be lined in a single pressurizing operation.

I claim as my invention:

1. An apparatus for expanding liners into tubes which comprises, in combination, a relatively rigid frame for receiving said tube with the liner inserted therein, a stop at one end of said frame for the liner, another stop at the same end of the frame for said tube, said stops being spaced apart to permit the end of the liner to project from the tube, plungers attached to said frame and adapted to be inserted therein and retracted from opposite ends of the liner, means attached to said relatively rigid frame and adapted to engage the outer surface of the walls of said tube at spaced points thereon for restraining said tube in a predetermined position with respect to said plungers, said means comprising set screws mounted in spaced relation on said frame, means preventing leakage of fluid between the walls of the liner and said plungers consisting of expansible cup-shaped members upon said plungers, means for introducing fluid under pressure through one of said plungers to the space within the liner between said plungers, said means consisting of a rod mounted on one of said plungers having an opening running the length thereof and suitable means for connecting said rod opening to the pressure supply, and means for venting undesirable fluid from said liner, said means consisting of a similar rod mounted upon the other of said plungers having an opening running the length thereof.

2. An apparatus for expanding liners into tubes which comprises, in combination, a relatively rigid frame adapted to receive said tube with the

liner inserted therein, rocker supporting members mounted at the rearward end of said frame and adapted to facilitate the tipping thereof, a stop at one end of said frame for the liner, another stop at the same end of the frame for said tube, said stops being spaced apart to permit the end of the liner to project from the tube, plungers attached to said frame and adapted to be inserted therein and retracted from opposite ends of the liner, means attached to said relatively rigid frame and adapted to engage the outer surface of the walls of said tube at spaced points thereon for restraining said tube in a predetermined position with respect to said plungers, said means comprising set screws mounted in spaced relation on said frame, means preventing leakage of fluid between the walls of the liner and said plungers consisting of expansible cup-shaped members upon said plungers, means for introducing fluid under pressure through one of said plungers to the space within the liner between said plungers, said means consisting of a rod mounted on one of said plungers having an opening running the length thereof and suitable means for connecting said rod opening to the pressure supply, and means for venting undesirable fluid from said liner, said means consisting of a similar rod mounted on the other of said plungers having an opening running the length thereof.

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