# United States Patent [19]

**Legate et al.**

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[54] **METHOD OF LINING METAL PIPES**


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[51] **Int. Cl.** ............................................ **B23k 21/00**
[58] **Field of Search**..... 29/421 E, 470.1, 486, 497.5 72/56



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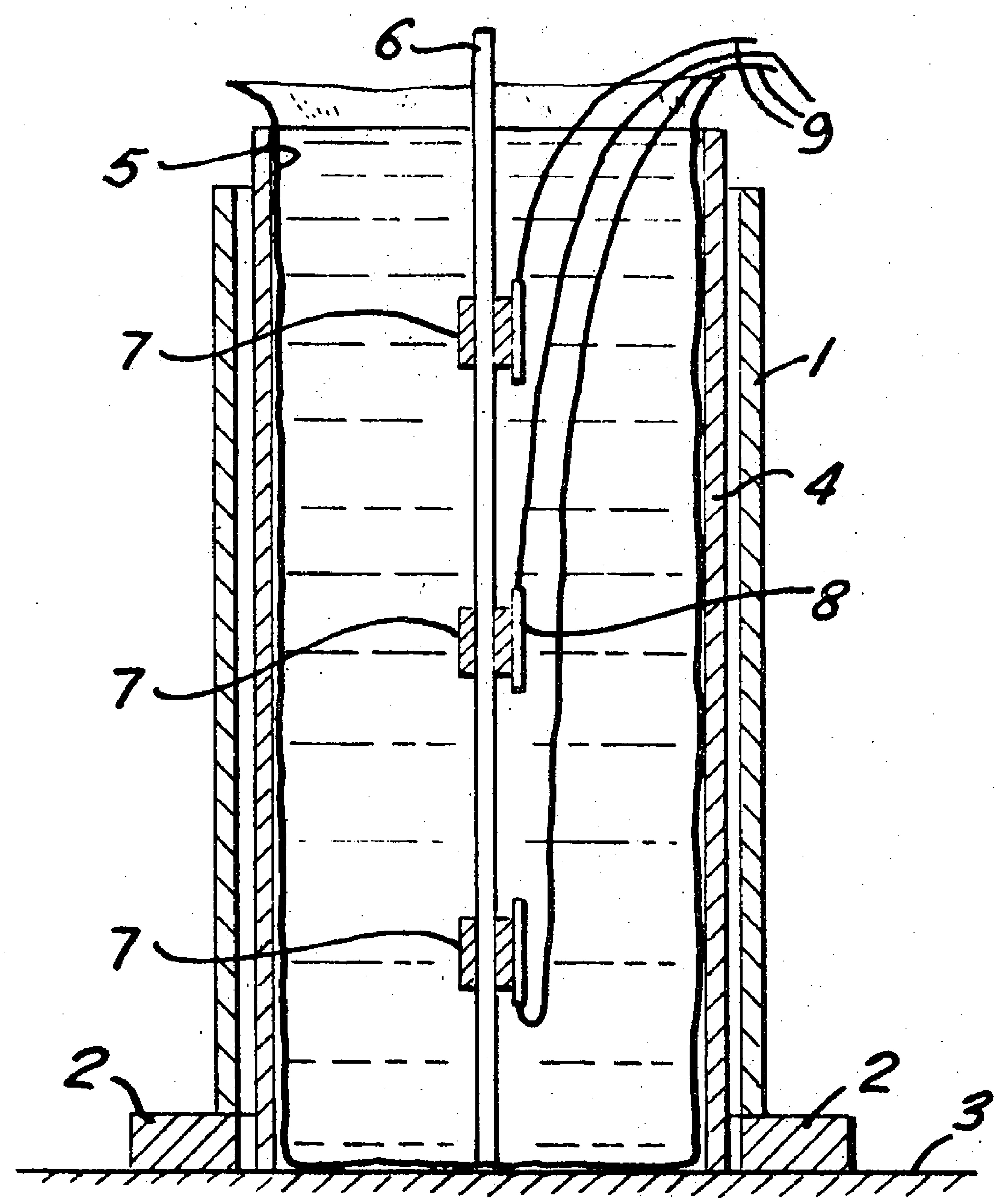
[57] **ABSTRACT**

A method for internally lining metal pipes involving the explosive forming or expansion of a metallic liner against the internal surface of a pipe in a gaseous atmosphere without the necessity for heavy evacuation equipment or dies.

The method may be used to provide a pipe with an inner corrosion-resistant lining of, for example, copper or copper alloys. The liners can be removed or replaced by new liners in situations where it is inconvenient or uneconomic to replace the whole component.

**10 Claims, 6 Drawing Figures**

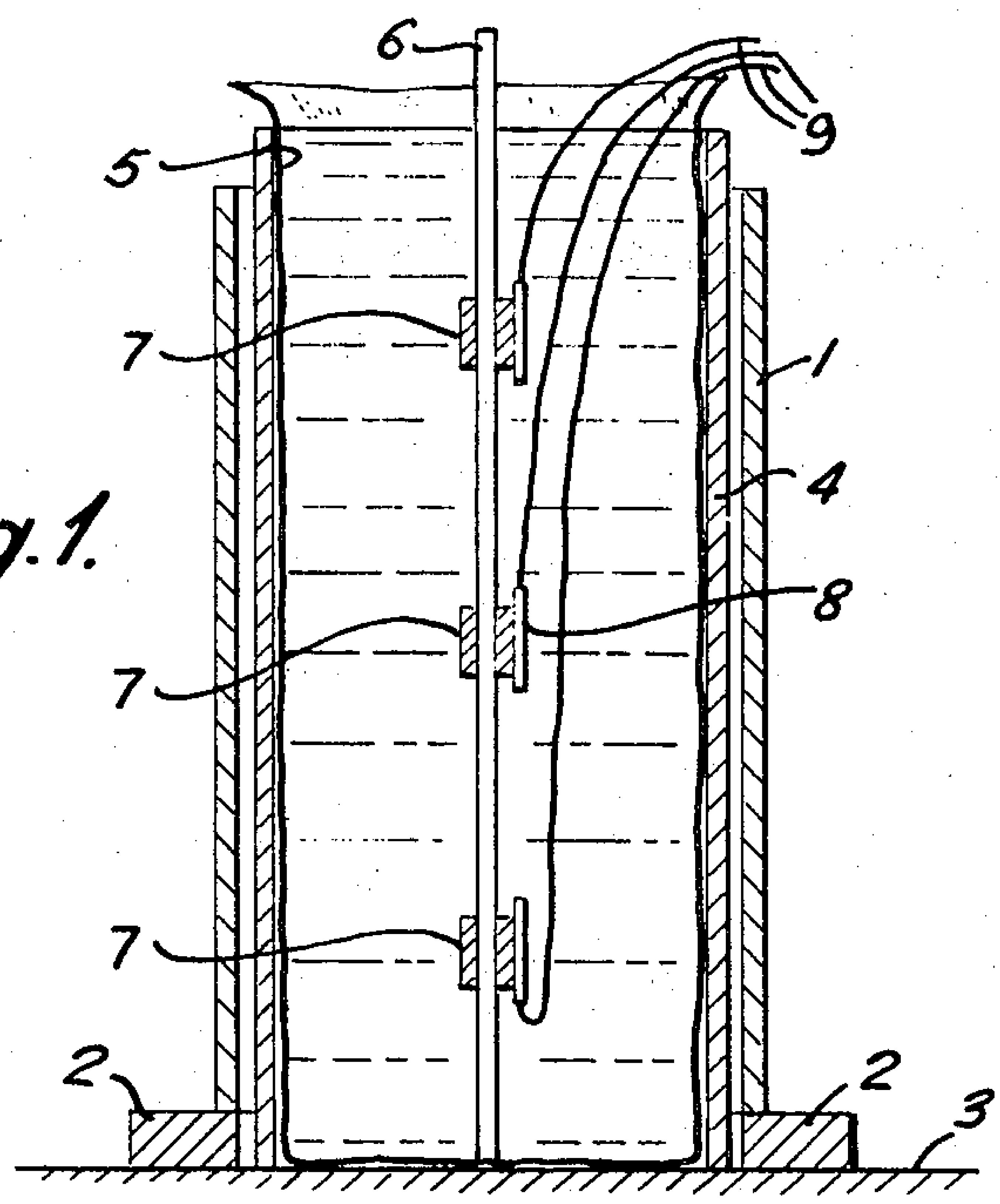



Fig.1.

Fig.2.

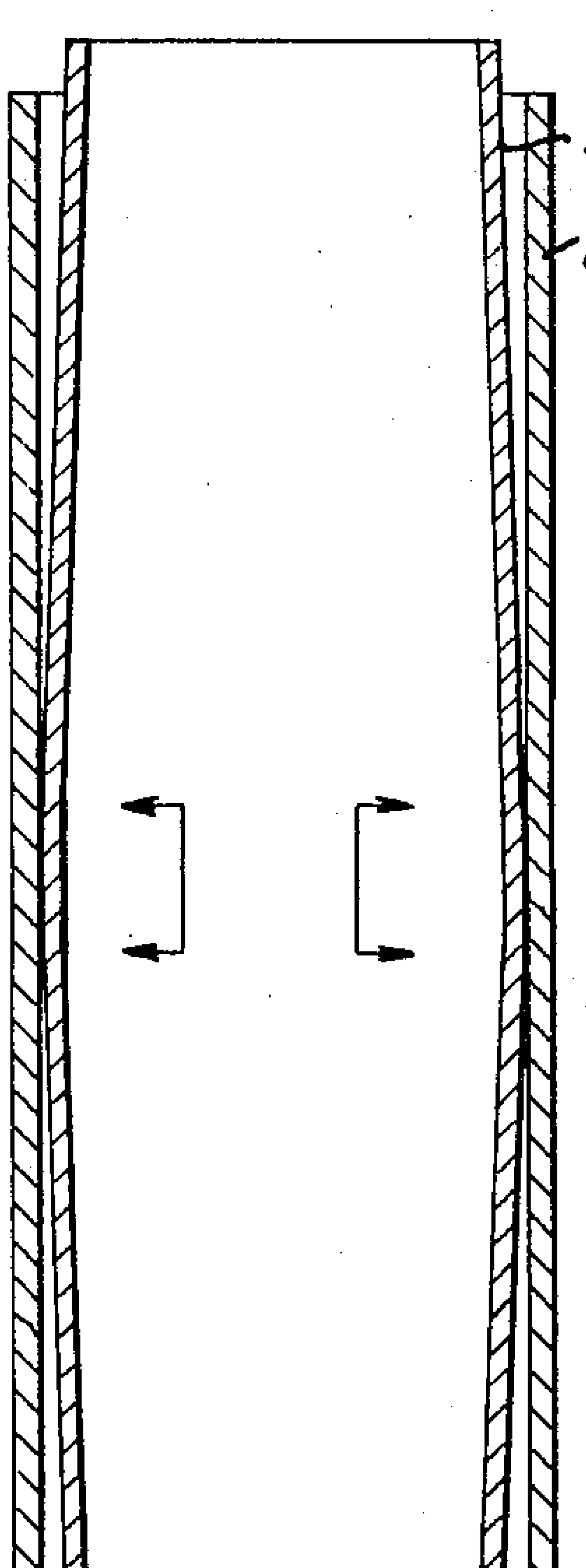



Fig.3.

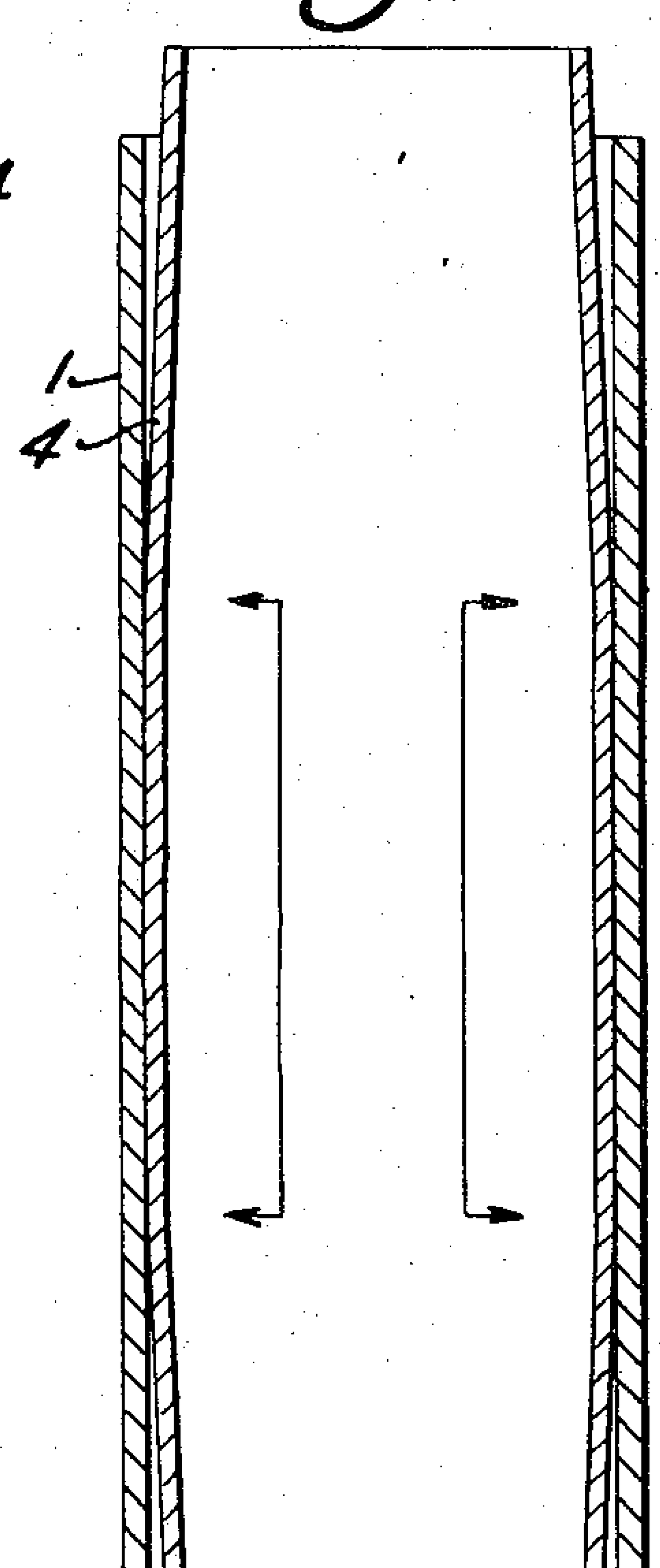
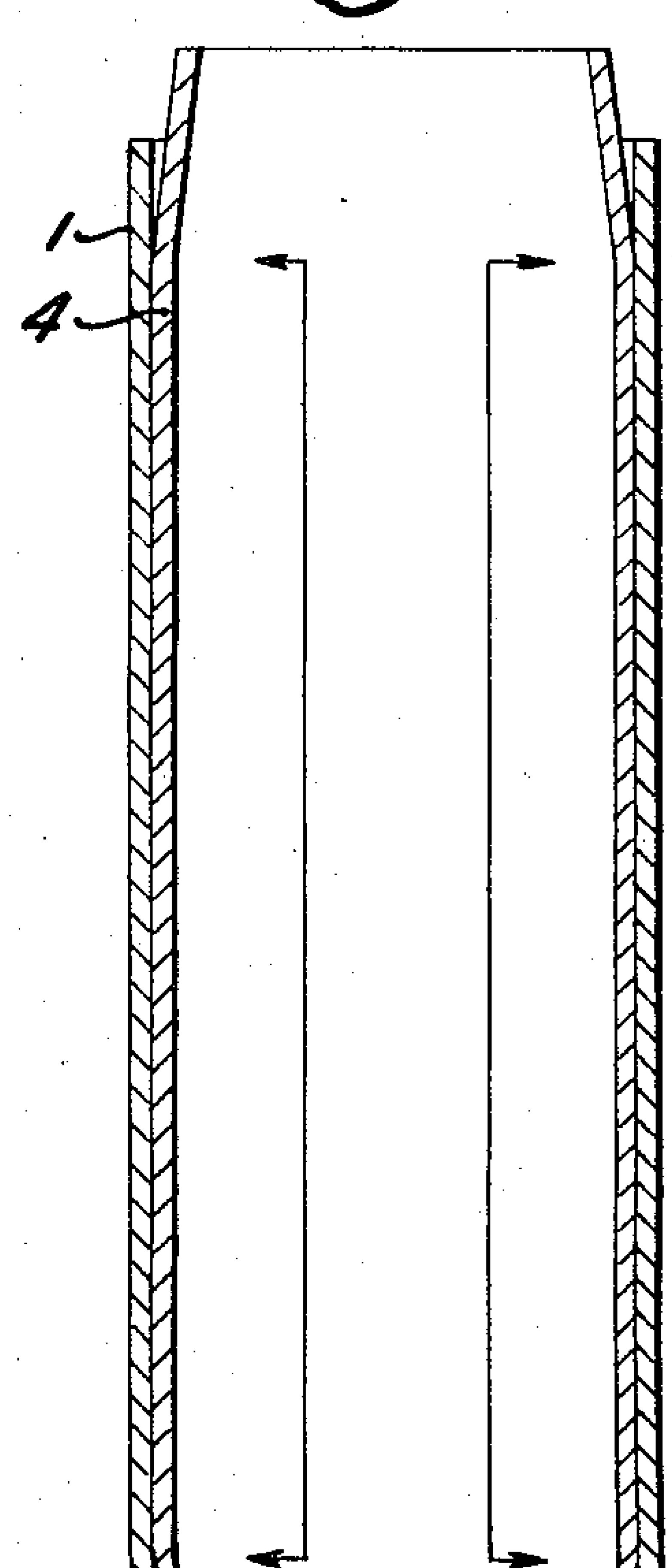



Fig.4.



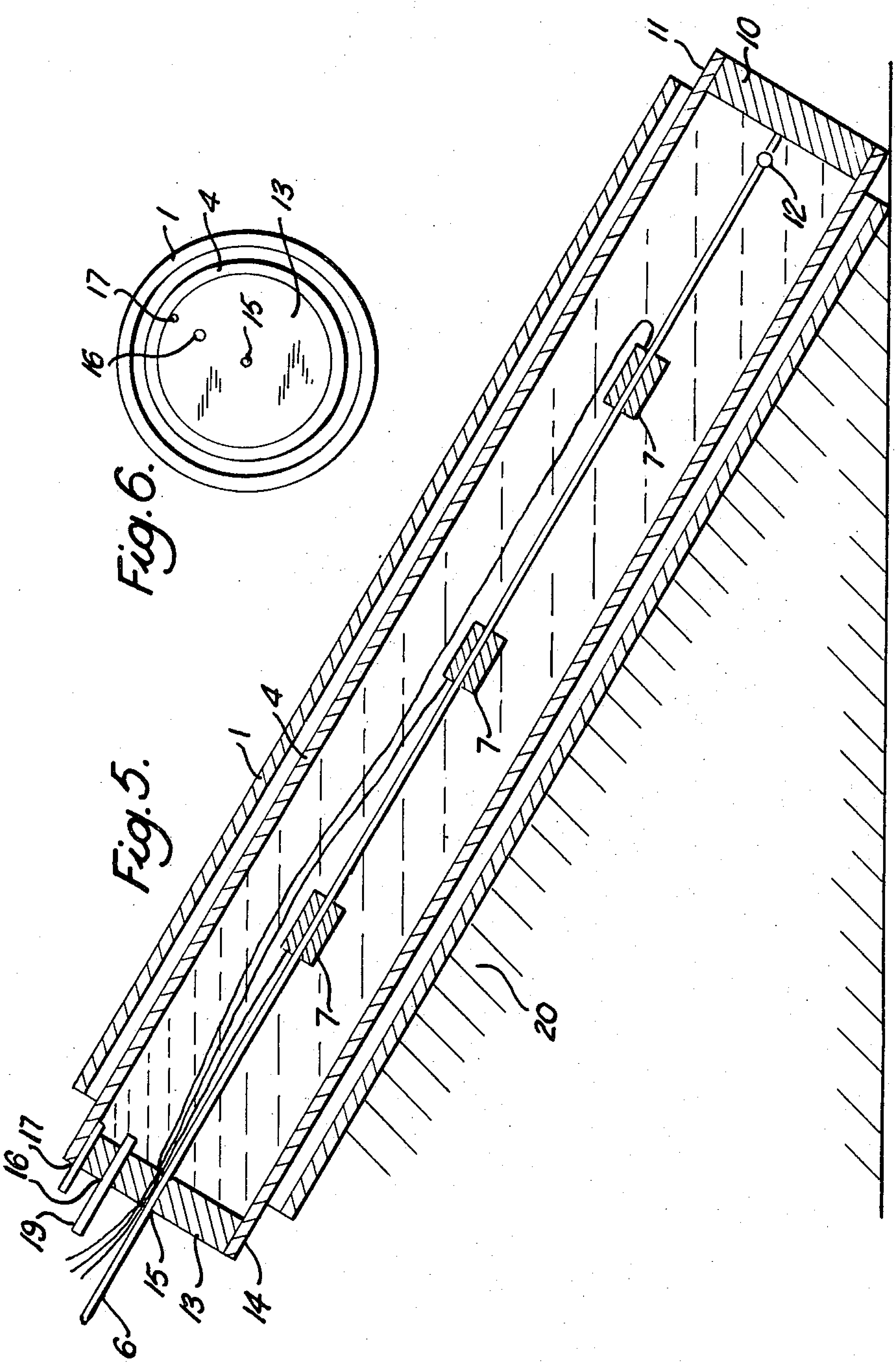



Fig. 6.

Fig. 5.

# METHOD OF LINING METAL PIPES

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method for lining metal pipes. In particular the method involves the explosive forming or expansion of a liner against the internal surface of a pipe to form a tight mechanical bond between the outer surface of the liner and the internal surface of the pipe.

2. Description of the Prior Art

Explosive forming techniques have been used to form shaped metallic articles and in the cladding of metal pipes. In the known, stand-off explosive forming technique the shock wave produced by the detonation of explosive can be transmitted for some distance through water to a workpiece in a period of a few microseconds thus deforming the workpiece. The velocity of the shock wave is dependent on the amount of explosive used. This initial energy impulse was responsible for the majority of the deformation but the low-amplitude tail of the shock wave only contributed slightly to the final deformation of the workpiece.

In British Patent Specification No. 925,422 there is disclosed a method of forming a metallic article by placing a metal blank over the contoured surface of a mould, the mould and blank being completely immersed in a fluid, positioning an explosive charge in the fluid and detonating the explosive charge so that the shock wave produced causes the metal to conform to the shape of the mould. This specification also indicates that a cylindrical member may be trued by using a split die, a fluid transmission medium and an axially disposed line of explosive charges. These techniques had the disadvantages that heavy equipment in the form of dies and evacuation apparatus were necessary.

British Patent Specification No. 1,020,912 is concerned with a method of fabricating multi-layer vessels from a plurality of single-layer shells which may be applied to the expansion of an inner liner into tight engagement with an outer cylindrical vessel by means of a shock wave produced by an axially-situated explosive charge. However this method does not solve the problem of removing the air from the space between the liner and the cylinder. Further the explosive charge is situated such that a uniform shock wave is directed against the shell which is subjected to the same pressure at every point. There is a real danger therefore of air pockets being trapped between the liner and the cylinder resulting in undesirable weak places in the lined cylinder.

U.S. Pat. No. 3,036,374 discloses an explosive forming method by which a liner may be expanded against the inside wall of a hollow metal cylinder. This technique requires a restraining die to prevent distortion of the cylinder due to the firing of the single explosive charge. However this method does not appear to be controllable to any desired extent and as can be seen from FIG. 9 the result of the method is the formation of a "semi-metallurgical" bond between the two metals. There appears to be some degree of diffusion of one metal into the other metal and it seems unlikely that a metal lining bonded in such a way could be removed easily and without damage to the outer tube as is often required.

The interdiffusion of the two metal layers may be prevented by the method disclosed in U.S. Pat. No. 3,314,139 in which a third element as a transition layer is inserted between the two metal layers to be bonded. However in practice this method also requires the evacuation of the space between the surface to be bonded and are reinforcing die.



None of the prior art methods therefore are able to provide an effective explosive forming method for the lining of metal pipes without the necessity for reinforcing dies and heavy equipment. Furthermore it has been found necessary to remove the air from the space between the liner and the pipe before the firing operation is carried out. This has usually involved evacuation of the space and required a considerable amount of extra equipment.

The present invention overcomes these disadvantages.

## SUMMARY OF THE INVENTION

The invention provides a method for internally lining a metal pipe said method comprising (i) positioning a metallic liner inside a pipe in a gaseous atmosphere, (ii) maintaining the volume within the liner full of a liquid, (iii) setting up at least three explosive charges in the liquid along the central axis of the pipe and (iv) simultaneously firing the explosive charges, the explosive charges being located such that initially the liner forms a tight mechanical bond with the pipe in the central region of the pipe.

After the initial firing the liner usually forms a tight mechanical bond with the pipe approximately half-way along its length.

Subsequent firings may be carried out to drive the gas from between the liner and the pipe so that the liner forms a tight mechanical bond with the pipe along the length of the pipe.

An advantage of the present invention is that the gas between the liner and the pipe is progressively driven out as the firing proceeds so that no gas is traped.

The tight mechanical bond which is formed between the liner and the pipe is not a fusion or welding of the two metals at the interface nor an entry of one metal into the other. The mechanical tightness of the bond is such that the lined pipe behaves as a unitary body under working conditions such as thermal expansion and other mechanical treatments. Under certain conditions the mechanical bond may result in greater thermal or electral conductance from one metal to the other.

The liquid in which the explosive charge or charges is set and fired is a liquid which must be physically and chemically relatively stable to the firing of explosive charges. Water is the preferred liquid.

Conveniently, the preparation steps include prefabricating a liner, for example by welding, the liner having generally the internal contours of the structural component or complex shape to be lined, cleaning and brightening the internal surface of the structural component or complex shape, and cleaning and brightening the outer surface of the liner. The liner is normally of a metallic material, for example, copper and copper alloys, titanium, tantalum, aluminum and alloy steels.

Good results have been obtained in the method of the present invention when three explosive charges were used at each firing. The three explosive charges are positioned along the central axis of the pipe and are detonated simultaneously. The tail waves of the shock waves produced by the detonations are caused to intermingle or interact with one another so that they rebound from one another and by doing so remain powerful for a longer duration than if a single central charge were used. The charges at each end of the line of explosive charges course a buffer effect of the shock waves. The resulting turbulence produced drives the air in the space between the liner and the pipe outwards so that none is trapped between the bonded liner and pipe. After several firings, during which all the air between the liner and pipe is driven outwards, the liner is bonded to the pipe along the whole length.

When three explosive charges are used in the initial firing operation, it is preferred that the charges positioned at each end are of equal power. The centrally-positioned charge may be of greater or less power. In the former case, the ratio of the power of the explosive charges may be, for example, 1:2½:1. However, in the case when there is a larger central charge, the reflection or buffering effect of the central charge by the two smaller charges is less than that in the alternative embodiment wherein the central charge is the smallest. In general, when the end charges are larger than the central charge, more power is directed into the central region of the pipe and less power is lost by being directed outwardly from each end of the pipe. Thus generally, less firing operations will be needed to complete the lining operation if the end charges have greater power than the central charge.

Conveniently the metallic liner is initially longer than the pipe to be lined and is positioned inside the pipe such that it protrudes from the pipe at each end. Liquid may be maintained inside the liner during the firing operation by a flexible, liquid-proof bag, conveniently made from a plastics material, for example polyethylene. Another method of maintaining water inside the liner is to seal the end-openings of the liner with bungs, for example, wooden bungs, through which means for supplying more liquid may be fixed.

These two methods may conveniently be used when the lining operation is carried out in air. The former method may be used for internally lining a metal pipe not more than 8 feet in length. The latter method may be used to line pipes greater than 8 feet in length and in this case the pipe and liner are conveniently supported at an angle to the horizontal.

Although the present invention described herein does not usually utilise an external die or clamp, if extra reinforcement is necessary in a particular case then a split die or clamp can be set up to surround and support the pipe and liner during the lining operation. If the pipe to be lined is of such material and adequate thickness to withstand the shock waves produced during the firing operations then no further reinforcement should be necessary.

The type of explosive used is not critical. Various high explosives may be used allowance being made in the weight of explosive used to compensate for variations in power.

Good results have been obtained in the method of the present invention by using "Cordtex" detonating fuse as the explosive charges. Cordtex fuse consists of a core of P.E.T.N. (pentaerythritoltetranitrate) encased in a plastics material and can be cut easily to required lengths. It offers an easily measurable method of calculating the power of the explosive charges. Cordtex detonates at 22,000 ft/sec. and has a calorific value of 13,500 ft.lb. In the method of lining pipes lengths of Cordtex may be detonated simultaneously using I.C.I. No. 6 electric detonators activated by an electrical impulse.

The method of the present invention may be used to provide a pipe with, for example, an inner corrosion-resistant lining and in many industrial situations there is a need for metal tubes, pipelines or vessels to be lined with metals which possess very different properties to those possessed by the pipe or tube itself. For example, it is often required that the inner surface of a pipe be resistant to corrosion from chemicals, water etc, whereas the pipe itself must have considerable strength properties. Metal pipes, therefore, which need to be strong and also corosion-resistant internally are often provided with a corrosion-resistant inner lining. The strength-bearing outer pipe is usually manufactured from inexpensive metal having sufficient thickness to provide the rigidity and strength required for the particular use of the pipe. The corrosion-resistant lining is usually manufactured from more expensive metal and need only be of a thickness sufficient to withstand the corrosion agents with which it will come into contact during use.

The liners which are fitted by the method of the present invention can be removed and replaced by a new liner in a short time. This is useful when the inner liner has worn out and it is inconvenient or uneconomic to replace the whole component. BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a longitudinal, sectional view of the components assembled for the initial firing in the lining of a short pipe,

FIG. 2 is a longitudinal, sectional diagram of the pipe and liner of FIG. 1 after the first firing,

FIG. 3 is a similar view to FIG. 2 and shows the pipe and liner after the third firing,

FIG. 4 is a similar view to FIGS. 2 and 3 and shows the pipe and liner prior to the last firing,

FIG. 5 is a longitudinal, sectional view of components assembled for the initial firing in the lining of a long pipe, and

FIG. 6 is a plan end view of the upper bung of the assembled components of FIG. 5.

FIGS. 1 to 4 illustrate the preferred procedure involved for lining a short length of pipe, that is less than 8 feet long. This procedure is described in detail below as method A. FIGS. 5 and 6 relate to an alternative procedure useful in lining longer lengths of pipe, that is longer than 8 feet.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Method A

In this method a metal pipe is lined with a metal liner which may be a drawn tube or may be prefabricated from sheet by seam welding to follow the internal contours of the pipe. The internal surface of the pipe and the outer surface of the liner are cleaned so that the metal is bright.

The pipe **1** to be lined is mounted on wooden blocks **2** on a concrete base **3** as shown in FIG. **1**. A liner **4** is inserted into the pipe **1**. The liner **4** is longer than the pipe **1** so that it protrudes a short distance, usually about 2 inches, from the pipe at each end. Generally the liner 4 has its outside diameter dimensions slightly less than the internal dimensions of the pipe 1 so that the liner 4 may be inserted easily within the pipe 1. A large polyethylene bag 5 is inserted inside the liner 4 and then filled to the top of the liner with water as the transmission medium. A long cane 6 supporting three explosive charges 7 is located in the water along the central axis of the liner 4. The ratio of the power of the explosive charges 7 and the locations of the charges 7 ensures that after the first firing the liner 4 bonds with the pipe 1 approximately half-way along its length, as shown in FIG. 2.

The cane 6 supporting the explosive charges 7 may be replaced by a chain or rope or other suitable supporting means.

Suitable detonators 8 are attached to each of the explosive charges 7. Ignition wiring 9 connects the detonators 8 to a central control, not shown. As shown in FIG. 1 the detonators attached to the central and upper charges face downwards so that the explosive force is directed towards the middle region of the pipe 1 and liner 4. The detonator attached to the lower charge faces upwards for the same reason. The explosive charges are detonated simultaneously.

After the first firing has been carried out the liner 4 is bonded to the pipe 1 in the middle as shown in FIG. 2. The arrows in FIGS. 2, 3 and 4 show the region over which the liner is bonded to the pipe. subsequent firings, usually five or six firings in all, are carried out to drive the air out from between the liner 4 and the pipe 1.

FIG. 3 shows the position after the third firing. The liner 4 is forced into a mechanical bond with the inner wall of the pipe 1. As each firing takes place the air between the liner and the inner wall of the pipe is driven out so that so air remains trapped.

FIG. 4 shows the position of the liner and pipe prior to the last firing which has more explosive at each end of the pipe to seal the ends of the liner and pipe with a bond of greater strength. The last firing may be repeated as necessary until the lining operation is completed.

The preferred ratios of the three explosive charges are listed below:

| | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st Firing | 4 | 2½ | 4 |
| 2nd Firing | 4½ | 3 | 4½ |
| 3rd Firing | 5 | 3½ | 5 |
| 4th Firing | 5½ | 3½ | 5½ |
| 5th Firing | 6 | 5 | 6 |
| 6th Firing | 6 | 5 | 6 |

When Cordtex explosive is used, the length measurements of Cordtex which are suitable for lining a pipe of 1 inches diameter are listed below:

| | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st Firing | 1 ⅛" | 15/16" | 1 ⅛" |
| 2nd Firing | 1 11/16" | 1 ⅛" | 1 11/16" |
| 3rd Firing | 1 ⅞" | 1 5/16" | 1 ⅞" |
| 4th Firing | 2 1/16" | 1 5/16" | 2 1/16" |
| 5th Firing | 2 ¼" | 1 ⅞" | 2 ¼" |
| 6th Firing | 2 ¼" | 1 ⅞" | 2 ¼" |

For a pipe which is more than one inch in diameter, the values in the above table may be taken as a suitable value for each inch of diameter of the pipe being lined.

The location of the lower explosive charge depends upon the length of pipe being lined. For a pipe of 8 feet in length the lower charge can be located approximately 18 inches from the lower end of the liner, with the upper charge 18 inches from the top of the liner. The middle charge is usually located equidistant from the upper and lower ends of the liner. The upper and lower charges can be moved to within 6 inches of the upper and lower ends of the liner respectively depending on the length of the pipe being lined. Generally, the upper and lower charges are located within 30 inches of the centrally located charge and each of these charges is equidistant from the middle charge.

Method B.

This alternative embodiment of the method is useful for lining longer lengths of pipe e.g. above 8 feet in length.

The pipe and liner are prepared as previously described. The liner 4 is inserted into the pipe 1 and placed on a sloping trestle 20 as shown in FIG. 5. A water-tight wooden bung 10 for holding water inside the liner is forced into the lower end 11 of the liner 4. Rubber bungs or bungs of plastic material may also be used. A chain 6 carrying the explosive charges 7 is inserted inside the liner 4 and is attached to the wooden bung 10 at a centrally located ring 12. The explosives are thus located axially inside the liner. For a very long pipe more than three explosive charges may be necessary. The liner 4 is filled with water and a second wooden bung 13 is placed in the upper end 14 of the liner 4. The second bung 13 has three holes, one in the centre, one near the edge, and one located a short distance from the centre. The central hole 15 is provided so that the chain or cable 6 supporting the explosive charges 7 and the associated firing wiring can be passed through the bung 13. A water-tight seal should be provided at hole 15. The second hole 16 is provided so that more water may be supplied to top-up the water level. The hole 17 is provided for a water level bleed value 18. The positions of these holes 15, 16 and 17 are indicated on a plan of bung 13 shown in FIG. 6. A hose 19 is attached to the water entry hole 16 and the liner 4 completely filled with water. The air present in the liner between the two bungs is driven out via the bleed valve 18. When water exits via the valve 18, no air remains in the liner and the water level is flush with the inside faces of each bung.

The explosive charges are detonated in the same manner as described in Method A, the ratios of the explosive charges also being the same as in Method A. However for these longer lengths of pipe after the first four firings have been carried out and the central section of the pipe has been lined, the next three charges are moved along towards one end and subsequent firings are carried out with the ratio 6:5:6. The charges are progressively moved along towards the end and the firings are repeated until the pipe is lined from the central section to that end. Further explosive charges are then located on the other side of the central section and thereafter progressively towards the other end of the pipe, the firings being repeated with the ratio of 6:5:6 until the lining is completed.

The following Examples give further details of pipes and tubes that have been lined using the preferred procedures of Methods A and B described above.

Example 1

The procedure of Method A was used to line internally a 15inches long mild steel tube having an outside diameter of 4⅔inches and a thickness of one-fourth inches with 18 S.W.G aluminium N.S.3 tube having an outside diameter of 4 inches and being 19 inches in length.

Six firings were carried out; three explosive charges of Cordtex being used at each firing. The measurements of Cordtex used are detailed in Table **1**.

Table 1

| Firing | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st | 5⅓" | 3¾" | 5⅓" |
| 2nd | 5¾" | 4½" | 5¾" |
| 3rd | 7½" | 5¼" | 7½" |
| 4th | 8¼" | 5¼" | 8¼" |
| 5th | 9" | 7½" | 9" |
| 6th | 9" | 7½" | 9" |

After the firing procedure the aluminium liner was found to have a 3percent reduction in thickness.

Example 2

The procedure of Method A was used to line a 5 inches long mild steel tube having an outside diameter of 4½, inches a wall thickness of one-fourth inches and a 2 inches flange at one end with 18 S.W.G. aluminium N.S.3 tube having an outside diameter of 4 inches and being 9 inches in length.

Again six firings were carried out with three explosive charges of Cordtex at each firing. The measurements of Cordtex used are the same as those given in Table **1.**

The finished tube and the flange at one end of the tube were clad internally with aluminum, there being a 3 percent reduction in thickness of the aluminum liner on the tube wall and a 5 percent reduction of thickness on the flange.

Example 3

A 7½inches long Admirality brass tube having an outside diameter of 3 ⅛inches and a wall thickness of one-eighth inch was internally lined using the procedure of Method A. The liner was a 20 S.W.G. aluminum tube having an outside diameter of 3 inches and being 10 inches in length. Six firings were carried out as before; three explosive charges of Cordtex being used at each firing. The measurements of Cordtex used are given in Table 2.

Table 2

| Firing | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st | 4" | 2 13/16" | 4" |
| 2nd | 5 1/16" | 3 3/8" | 5 1/16" |
| 3rd | 5 ⅝" | 3 15/16" | 5 ⅝" |
| 4th | 6 3/16" | 3 15/16" | 6 3/16" |
| 5th | 6 ¾" | 5 ⅝" | 6 ¾" |
| 6th | 6 ¾" | 5 ⅝" | 6 ¾" |

The finished aluminum-lined brass tube was found to have a reduction in thickness of the liner of 2 percent.

Example 4

A length of mild steel tubing being 5 inches long, and having 4½ inches outside diameter and ¼ inches wall thickness had a 2 inches flange at one end similar to parent tube used in Example **2.** The procedure of Method A was again used to line the mild steel tube with 18 S.W.G. copper tube having an outside diameter of 4 inches and being approximately 9 inches in length. six firings were used; three explosive charges of Cordtex being used at each firing. The Cordtex measurements which were used are detailed in Table 1.

On the finished copper-lead steel tube and flange, a reduction in thickness of the liner of 3 percent in the tube wall and 4 percent on the flange was noted.

Example 5

Using the procedure of method A a 30 inches length of ⅜ inches thick mild steel tube spirally welded and of 30 inches outside diameter was lined with a liner of phosphorous-deoxydised copper. The liner was one-eighth inch thick and was welded into a tube using B.S.2901, C21 filler alloy, the outside diameter of the tube being 24½ inches. six firings were carried out so that the steel pipe became internally clad with copper. As before three charges of Cordtex were used at each firing. The Cordtex measurements are given in Table3.

Table 3

| Firing | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st | 31.85" | 22.9" | 31.85" |
| 2nd | 41.3" | 27.56" | 41.3" |
| 3rd | 45.9" | 32.1" | 45.9" |
| 4th | 50.50" | 32.1" | 50.50" |
| 5th | 55.125" | 45.9" | 55.125" |
| 6th | 55.125" | 45.9" | 55.125" |

On examining the finished lined steel pipe it was found that there was a 12 percent elongation of the liner and also there had been a reduction of the thickness of the liner of 6 percent to 0.118 inches.

Example 6

The procedure of Method A was used to line 12 inches length of mild steel pipeline, having an outside diameter of 12 inches and a wall thickness of one-fourth inch, with an 14 inches length of 20 S.W.G. tantalum seam-welded tube. Six firings were used according to the procedure of Method A, using three explosive charges of Cordtex at each firing. The measurements of the three Cordtex charges are given in Table 4.

Table 4

| Firing | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st | 15.39" | 10.75" | 15.39" |
| 2nd | 19.4" | 12.94" | 19.4" |
| 3rd | 21.56" | 15.10" | 21.56" |
| 4th | 23.72" | 15.10" | 23.72" |
| 5th | 25.87" | 21.56" | 25.87" |
| 6th | 25.87" | 21.56" | 25.87" |

Example 7

Using the procedure of Method B, which is particularly convenient for longer lengths of pipe, a length of mild steel pipeline, 10 feet long and having an outside diameter of 6 inches and a wall thickness of one-fourth inch, was lined with copper. The copper liner was in the form of a copper tube, 3/16 inch thick, 11feet long and having an outside diameter of 5½ inches.

Three charges of Cordtex were used at each firing as in the previous examples, however the fifth firing was repeated several times, firstly towards one end of the pipe and then towards the opposite end until cladding had been completed. The Cordtex measurements are given in Table 5.

Table 5

| Firing | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st | 7.33" | 5.15" | 7.33" |
| 2ND | 9.27" | 6.19" | 9.27" |
| 3rd | 10.06" | 7.22" | 10.06" |
| 4th | 11.34" | 7.22" | 11.34" |
| 5th | 12.37" | 10.06" | 12.37" |
| | 5th firing repeated until clad. | | |

The copper-lined steel pipeline was found on inspection to have a reduction in thickness of the copper liner of 4 percent.

Example 8

A 6 inch length of stainless steel tubing was internally lined by the procedure of Method A with titanium. The stainless steel tubing had an outside diameter of 2 inches and a wall thickness of one-eighth inch. The liner was a 26 S.W.G. titanium tube 8 inches long. As in Examples 1 to 6, six firings were used to internally clad the stainless steel tubing, each of the firings consisting of a simultaneous explosion of three explosive charges of Cordtex located axially inside the liner. The Cordtex measurements are detailed in Table 6.

Table 6

| Firing | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st | 2.16" | 1.42" | 2.16" |
| 2nd | 2.40" | 1.82" | 2.40" |
| 3rd | 3.05" | 2.13" | 3.05" |
| 4th | 3.35" | 2.13" | 3.35" |
| 5th | 3.65" | 3.05" | 3.65" |
| 6th | 3.65" | 3.05" | 3.65" |

Example 9

The procedure of Method A was again used to line a mild steel pipe, 14 inches long, with cupra-nickel. The mild steel pipe has an outside diameter of 6 inches and a wall thickness of one-fourth inch. The cupra-nickel **17** liner was a 16 inches long seam-welded tube having an outside diameter of 5½ inches and a wall thickness of one-eighth inch. Six firings were carried out to complete the lining operation, there being three explosive charges of Cordtex at each firing. The Cordtex measurements are detailed in Table 7.

Table 7

| Firing | Upper charge | Middle charge | Lower charge |
|---|---|---|---|
| 1st | 7.33" | 5.15" | 7.33" |
| 2nd | 9.27" | 6.19" | 9.27" |
| 3rd | 10.06" | 7.22" | 10.06" |
| 4th | 11.34" | 7.22" | 11.34' |
| 5th | 12.37" | 10.06" | 12.37" |
| 6th | 12.37" | 10.06" | 12.37" |

Example 10

A mild steel pipe similar to that in Example 9 but only 12 inches long was lined internally with a cupra-nickel liner which was also similar to that in Example 9 but 14 inches long. The procedure of Method A was again used, six firings being used. The Cordtex measurements were the same as those used in Example 9 and detailed in Table 7.

Example 11

A mild steel sea-value vessel, 24 inches in length and having a wall thickness of one-half inch was internally lined with a cupra-nickel liner. The cupra-nickel liner was a conical, seam-welded fabrication, one-eighth inch thick and 26 inches high. The procedure of Method B was used although the sea-value vessel was only 24 inches long and the Method B procedure is considered to be of particular benefit in the lining of larger lengths of pipe.

we claim:

**1.** A method for internally lining a metal pipe said method comprising (i) positioning a metallic liner inside a pipe in a gaseous atmosphere, (ii) maintaining the volume within the liner full of a liquid, (iii) setting up at least three explosive charges in the liquid along the central axis of the pipe, (iv) simultaneously firing the explosive charges, the explosive charges being located such that initially the liner forms a tight mechanical bond with the pipe in the central region of the pipe, and carrying out subsequent firings to drive the gas from between the liner and the pipe so that the liner forms a tight mechanical bond with the pipe along the length of the pipe.

**2.** A method according to claim **1** wherein prior to positioning the liner inside the pipe, the internal surface of the pipe and the outer surface of the liner are cleaned and brightened.

**3.** A method according to claim **1** wherein the metallic liner is initially longer than the pipe to be lined and is positioned inside the pipe such that it protrudes from the pipe at each end.

**4.** A method according to claim **1** wherein the liquid is maintained inside the liner during the firing operations by a flexible, liquid-proof bag.

**5.** A method according to claim **1** wherein the liquid is maintained inside the liner by sealing the end-openings of the liner with bungs.

**6.** A method according to claim **1** wherein the liner is made from a metal selected from the group consisting of copper, one or more copper alloys, titanium, tantalum, aluminium or one or more alloy steels.

**7.** A method according to claim **1** wherein two of the initial explosive charges are of equal power and the third initial explosive charge is greater in power than the other two charges and is positioned centrally with respect to the two smaller charges.

**8.** A method according to claim **7** wherein the power of the three initial explosive charges is approximately in the ratio 1:2½:1.

**9.** A method according to claim **1** wherein two of the initial explosive charges are of equal power and the third initial explosive charge is less in power than the other two charges and is positioned centrally with respect to the two larger charges.

**10.** A method according to claim **9** wherein the power of the three initial explosive charges is in the ratio 4:2½:4.

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