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[54] **CEMENT-LINED METAL PIPE WITH IMPROVED
BOND BETWEEN PIPE AND LINING**
9 Claims, 2 Drawing Figs.

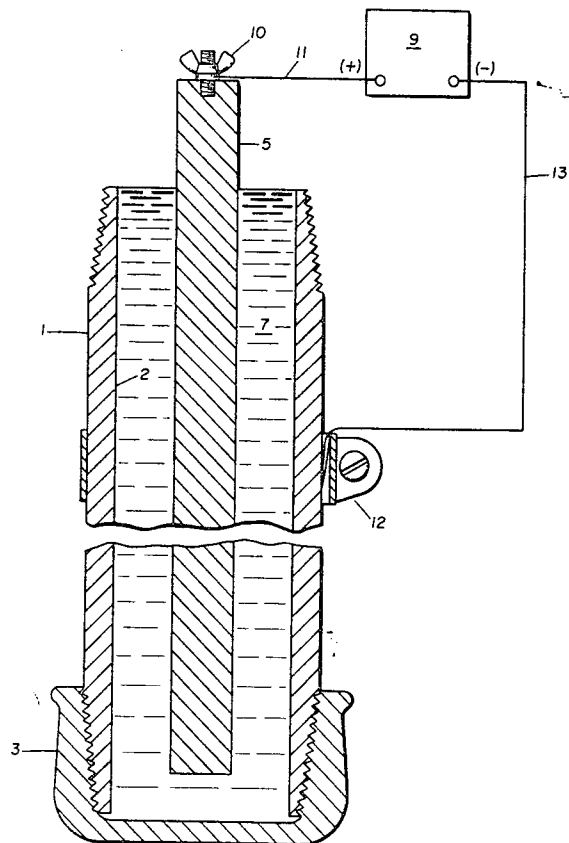
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C23b 5/56, C23f 17/00

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ABSTRACT: This specification discloses an improved cement-lined pipe and a method of roughening the interior surface of metal pipe in preparation for receiving a cement lining. The interior surface is roughened by depositing metal in the form of protrusions from an electrolytic solution by passing direct current therethrough. Cement lining may be applied to the interior surface of the pipe having protrusions formed thereon to produce a cement-lined pipe having increased bond strength between the cement and the pipe.



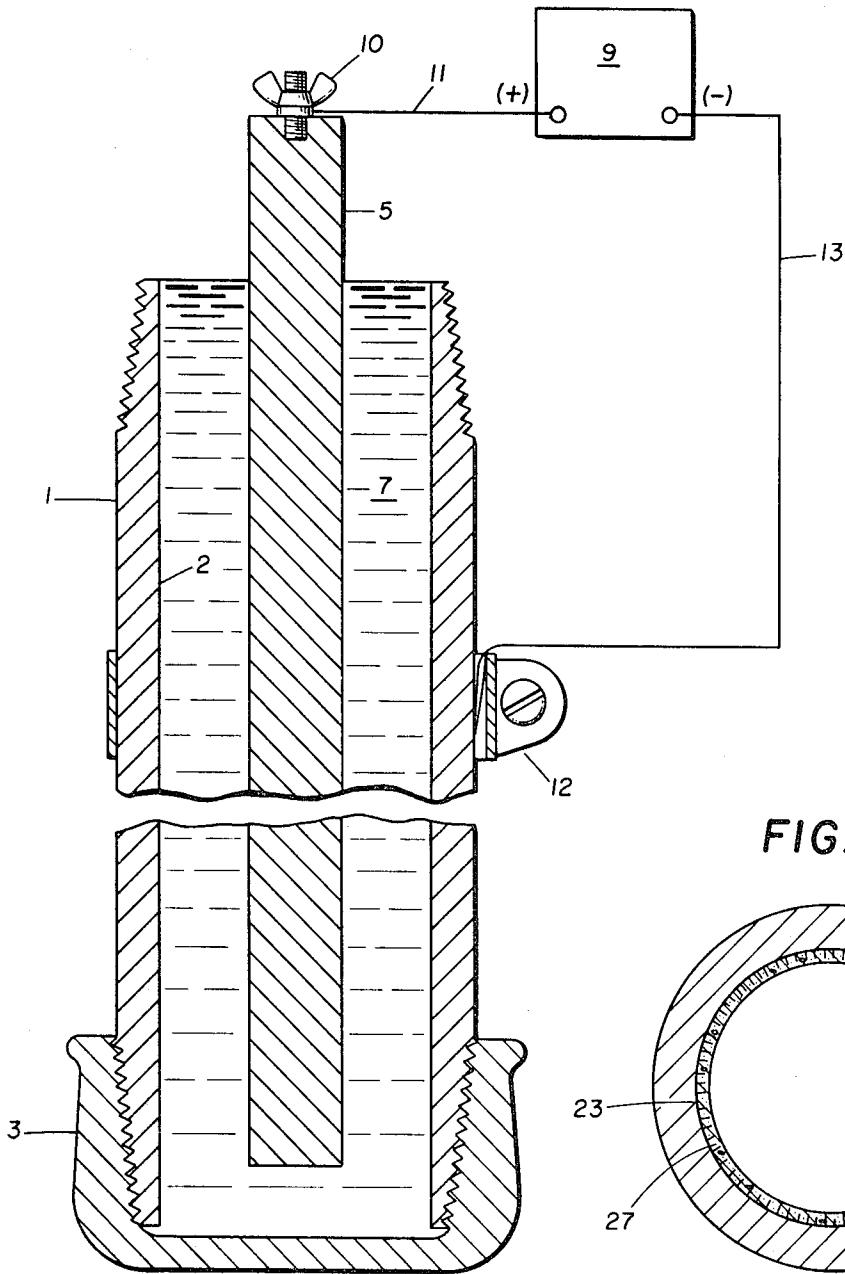
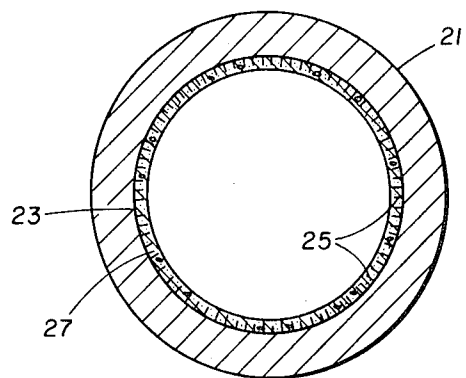


FIG. 1

FIG. 2



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CEMENT-LINED METAL PIPE WITH IMPROVED BOND BETWEEN PIPE AND LINING

BACKGROUND OF THE INVENTION

This invention is related to cement-lined pipes and to the treatment of the interior surfaces of metal pipes in order to provide a strong bond between such surfaces and internal cement linings.

Current practices of treating the interior surface of metal pipe prior to lining it with cement vary from no prior treatment whatsoever to sandblasting the interior surfaces of the metal pipe. Improvement in the strength of the mechanical bond of cement lining to metal pipe can be made by treating the interior surface of the metal pipe prior to forming cement lining therein. This is particularly true when grease, rust, or scale is present on the untreated interior surface of the metal pipe. The mechanical bond is further improved when this cleaning is done by sandblasting because this treatment roughens the interior surface of the pipe in addition to removing foreign matter therefrom. Even so, the bond between cement lining and metal pipe is sometimes weakened or broken by, for example, differential movement therebetween. Such movement may be caused by temperature changes since metal pipe and cement have different coefficients of expansion. In U.S. Pat. NO. 3,287,801 to Kenneth A. Blenkarn there is disclosed a technique for avoiding this differential movement by establishing internal upsets at the ends of the pipe. Blenkarn also discloses an alternative method for avoiding this differential movement by compressing the pipe during casting so that when the casting pressures are released, longitudinal expansion of the pipe will equal that of the lining.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided a method of roughening the interior surface of metal pipe to be cement lined. Direct electric current is passed through an electrolytic solution of metal ions in contact with the interior surface of the pipe. The current is passed between the interior surface of the pipe and an electrode which is positive with respect to the interior surface for a time sufficient to form protrusions of a height of at least 0.002 inch on the interior surface.

Preferably the electrolytic solution is selected from the class consisting of ferrous sulfate, ferrous acetate, ferrous ammonium sulfate, ferrous chloride, and ferrous thiocyanate. A potential difference within the range of 2 to 12 volts is imposed between the electrode and the pipe, with the electrode forming the anode and the pipe forming the cathode. Under this applied potential a direct current within the range of 0.1 to 1.0 ampere per square inch is passed through the electrolyte for a time period within the range of 50 minutes to 5 minutes, respectively, and protrusions are formed on the interior of the pipe. A cement lining may then be formed about the interior surface of the pipe.

In another aspect of this invention there is provided a new and improved cement-lined conduit. This conduit comprises a metal pipe, a cement lining disposed adjacent the interior surface of the pipe, and a plurality of electrolytically deposited protrusions on the interior surface of the pipe extending into the cement lining to effect a bond between the cement lining and the interior surface of the pipe.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal cross section of a pipe containing an electrolyte and an electrode therein which illustrates apparatus for roughening the interior surface of metal pipe by forming protrusions thereon; and

FIG. 2 is a transverse cross section of the pipe of FIG. 1 showing protrusions formed on the interior surface.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In carrying out this invention protrusions are electrolytically deposited on the interior surface of metal pipe by passing direct electric DC current through an electrolytic solution of metal ions in contact with the interior surface of the pipe. The direct current is passed through the electrolytic solution between an anode and a cathode (interior surface of the pipe) for a sufficient time to form protrusions of a height of at least 0.002 inch on the interior surface.

It has been recognized in the electroplating art as indicated in the STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS, McGraw-Hill Book Company, Tenth Edition, Section 23-58 that the tendency to form rough deposits or protrusions, sometimes called "trees" or "whiskers," on the cathode, i.e. the article being plated, can be reduced by the use of a solution of good conductivity. The formation of protrusions is a common defect which plaques most plating operations. These protrusions are undesirable from a visual standpoint because they reduce the brightness or smoothness of the article being plated and from a corrosion standpoint because they reduce the resistance to corrosion of the article being plated.

In accordance with this invention these protrusions are utilized for beneficial purposes. They are deposited on the interior surfaces of metal pipe to adapt it for receiving a cement lining whereby the bonding strength between the pipe and cement is increased. Thus, a new and improved conduit is provided which is particularly useful for carrying corrosive fluids.

More particularly, and with reference to FIG. 1, there is shown a metal pipe 1 closed at one end by a cap 3. An elongated shaft or a bayonet electrode 5 is positioned within the pipe and is surrounded by an electrolytic solution 7 containing metal ions. A DC voltage source 9 is imposed between electrode 5 and pipe 1. Conductor 11 connects the positive terminal of source 9 to electrode 5, and conductor 13 connects the negative terminal of source 9 to pipe 1. Thus, the electrode 5 becomes an anode and pipe 1 becomes a cathode. Conductors 11 and 13 may be connected to electrode 5 and pipe 1 by any suitable means and are illustrated as being connected by a bolt 10 and clamp 12, respectively. A sufficient current is passed through the electrolytic solution for a long enough time to form protrusions of a height of at least 0.002 inch on the interior surface 2 of metal pipe 1. After forming the protrusions on the interior surface 2 of pipe 1, the pipe is dismantled from the apparatus used in forming the protrusions. Pipe 1 is now in condition to be cement lined. Preferably it is washed however to remove any excess solution from interior surface 2 prior to lining it with cement. A cement lining may then be formed about interior surface 2 of pipe 1 by conventional cement lining means.

The protrusions should be deposited to a height of at least 0.002 inch in order to provide for a good bond between the interior surface of the pipe and a subsequently applied cement lining. It usually will be preferred to limit the protrusions to a height of no more than 0.02 inch in order to ensure that the protrusions are adequately covered by the cement lining. This will avoid corrosion which might otherwise result if the protrusions should extend through the cement lining and be exposed to corrosive fluids within the conduit. In addition, experiments carried out with regard to the invention and described in detail hereinafter indicated that a protrusion height of 0.02 inch is sufficient to form a bond between a cement lining and metal surface which is stronger than the cement itself. Thus, protrusions of a height greater than 0.02 inch are generally unnecessary in this respect.

The anode used in carrying out this invention is preferably a bayonet-type electrode. With such an electrode, a uniform current density can be simultaneously imposed over the entire inner surface of the pipe. This allows a plurality of protrusions to be formed on the inner surface of the pipe in a minimum amount of time. However, it is to be understood that other types of electrodes may be used. For example, a point elec-

trode may be drawn along the interior of the pipe or even positioned outside of the pipe particularly when the pipe length is short.

The DC voltage source used in carrying out this process is normally a storage battery, a direct current generator, or a rectified alternating current. The battery delivers "pure DC," that is DC with no ripple. Both generators and rectifier units deliver a pulsating unidirectional current, colloquially referred to as "DC with a ripple." Thus, the direct current may be either a pulsating or steady current.

In any given electrolyte metal system, the weight of the material deposited, and thus the height of the protrusions formed, may be determined quantitatively by Faraday's Laws of Electrolysis which state that the amount of a substance liberated from a solution by electrochemical action is proportional to the quantity of electricity passed, and that the amounts of different substances liberated by the same amount of electricity are proportional to their chemical equivalent weights. Thus, in effect, the height of the protrusions formed increases as the product of the current density at the cathode and the duration of the current application increases.

The anode which is immersed in the electrolytic solution is made of the metal being deposited, or of an inert material. If the anode is of the same metal as that being deposited, it dissolves in the electrolytic solution, thus replenishing the metal content of the solution. Of course by employing a suitable sacrificial anode the ions deposited to form protrusions may be supplied by the anode.

Preferably, the electrolytic solution will include ions of the metal of which the pipe is formed. With these solutions it has been found that the protrusions formed of the metal ions develop extremely strong bonds with the metal pipe. However, satisfactory bonds develop when using electrolytic solutions which include ions of a metal different from the metal of the pipe. For example, when forming protrusions on iron pipe, the electrolytic solution may comprise ions of nickel, copper, cadmium, zinc, or chromium.

In a preferred embodiment of this invention, the electrolytic solution is selected from the class consisting of ferrous sulfate, ferrous acetate, ferrous ammonium sulfate, ferrous chloride, ferrous thiocyanate, and mixtures thereof. A voltage of from 2 to 12 volts is applied by voltage source 9 for a period of time of from 50 minutes to 5 minutes. This produces current flow within the range of 0.1 to 1.0 ampere per square inch through an electrolytic solution having a typical conductivity and forms protrusions on interior surface 2 of pipe 1. More specifically, 2 volts may be applied for 50 minutes or 12 volts for 5 minutes or any comparable combination of voltage and time.

In a further preferred embodiment of this invention, the electrolytic solution 7 is comprised of ferrous sulfate and current of about 0.4 ampere per square inch is passed through the solution for 20 minutes. This results in forming protrusions on the interior surface 2 of the pipe of a sufficient height to adapt the pipe for receiving a cement lining to ensure a strong bond between the pipe and cement lining. Thereafter, a cement lining may be formed about interior surface 2 by conventional cement-lining techniques.

In another aspect of this invention, shown in cross section in FIG. 2, a product is formed which has utility for transporting corrosive fluids. More particularly this product is a conduit comprising a metal pipe 21 having an interior surface 23 and having formed thereon a plurality of electrolytically deposited protrusions 25 of a height of at least 0.002 inch. A cement lining 27 is disposed adjacent the interior surface of the pipe and in contact therewith. The protrusions extend into the cement and effect a bond between the cement lining and the interior surface of the pipe.

In laboratory experiments relative to the invention, protrusions were electrolytically deposited on one face of each of two 1-inch cubes of steel that had been cleaned by sanding with No. 600 sandpaper and degreased with benzene and acetone. The protrusions were grown by passing 0.4 ampere per square inch of DC current for 20 minutes between an elec-

trode (anode) and the cubes (cathode) through a 0.5 molar solution of ferrous ammonium sulfate $[\text{FeSO}_4(\text{NH}_4)_2 \text{SO}_4 \cdot 6 \text{H}_2\text{O}]$ containing 0.1 molar HCl. This treatment produced a deposit of iron in the form of protrusions of a maximum height of 0.02 inch over the surfaces of the cubes. Each surface was then coated with a 1/16-inch layer of cement comprised of 40 percent Portland type 1 cement, 60 percent Ottawa sand combined with sufficient water to produce a buttery consistency. The two coated surfaces were then butted together to form a 1/2-inch-thick cement joint. The joint was cured at room temperature (about 75° F.) for 60 days at 100 percent relative humidity. The joint was then tested for tensile strength in a machine equipped to measure tensile stress to ± 2.5 p.s.i. The cement joint failed at 320 p.s.i. tensile stress. The failure occurred through the cement itself rather than at the cement steel interface as occurred in other samples tested and described below.

For comparison purposes, several other tests were performed at the same time on samples prepared in a similar manner except for the growing of protrusions on the faces of the cubes. This data is shown in table 1.

TABLE I

Tensile Strength of Cement Steel Joints*

Surface Preparation	Strength of Adhesion, p.s.i.
Coated with clear varnish	<10
Surface covered with 0.003-0.004" rust	<10
Sanded to bright 0.003" roughness	100
Sanded to bright 0.006" roughness	160
Sanded to bright 0.009" roughness	180
Protrusions grown to a height 0.020"	320

*1" steel cubes cemented together with 1/8" mortar composed of 40 percent cement, 60 percent Ottawa sand (20-40 mesh) and cured 30-60 days at 100 percent relative humidity.

During testing, the cement steel bond failed at the steel cement interface for all cubes except the one having protrusions on the faces thereof. In the tests of these cubes, the cement itself failed at 320 p.s.i. tensile stress rather than the bond between the cement and cube face.

These tests show that greatly strengthened cement-to-metal bond develops between metal having protrusions formed thereon as contrasted to metal in conditions comparable to those normally present in pipes at the time they are cement lined. In fact, those bonds formed between cement and metal having protrusions thereon are stronger than the cement itself as evidenced by the fact that the cement failed rather than the bond during tensile stress tests.

What is claimed is:

1. In the roughening of the interior surface of a metal pipe to adapt said surface to receive a cement lining, the method comprising passing a direct electric current through an electrolytic solution of metal ions in contact with the interior surface of said pipe, said current being passed between the interior surface of said pipe and an electrode which is positive with respect to said interior surface for a time sufficient to form protrusions of a height of at least 0.002 inch on said interior surface.

2. A method of roughening the interior surface of metal pipe to be cement lined, comprising:
 putting into said pipe an electrolytic solution containing metal ions;
 inserting an electrode within said pipe; and
 imposing a DC voltage source between said electrode and said pipe with said electrode being connected to the positive terminal of said source and said pipe being connected to the negative terminal of said source wherein a suffi-

cient direct current is passed through said solution for a sufficient time to form protrusions of a height of at least 0.002 inch on the interior surface of said metal pipe.

3. The method of claim 2 wherein said electrode is an elongated shaft.

4. A method of lining metal pipe with cement, comprising: passing a direct electric current through an electrolytic solution of metal ions in contact with the interior surface of said pipe, said current being passed between the interior surface of said pipe and an electrode which is positive with respect to said interior surface for a time sufficient to form protrusions of a height of at least 0.002 inch on said interior surface; and

forming a cement lining about the interior surface of said pipe whereby the bonding strength between said pipe and said cement is increased due to said protrusions.

5. The method of claim 4 wherein said electrolytic solution is selected from the class consisting of ferrous sulfate, ferrous acetate, ferrous ammonium sulfate, ferrous chloride, ferrous thiocyanate, and mixtures thereof.

6. The method of claim 4 wherein the DC voltage source has a potential within the range of 2 to 12 DC volts.

7. The method of claim 4 wherein said current has an amplitude within the range of 0.1 to 1.0 ampere per square inch

and is passed through said electrolytic solution for a period of time within the range of 50 minutes to 5 minutes, respectively.

8. A method of lining iron pipe with cement, comprising: filling said pipe with an electrolytic solution comprised of ferrous sulfate;

inserting an electrode within said pipe;

imposing a DC voltage source between said electrode and said pipe with said electrode being connected to the positive terminal of said source and said pipe being connected to the negative terminal of said source and passing a direct current of about 0.4 ampere per square inch through said solution for about 20 minutes to form protrusions on the interior surface of said pipe; and

forming a cement lining about the interior surface of said pipe whereby the bonding strength between said pipe and said cement is increased due to said protrusions.

9. A conduit comprising a metal pipe, a cement lining disposed adjacent the interior surface of said pipe and in contact therewith, and a plurality of electrolytically deposited protrusions of a height of at least 0.002 inch on the interior surface of said pipe extending into said cement lining to effect a bond between said cement lining and the interior surface of said pipe.

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