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No. 10-121741-00004-0000

Fecha: 2011-11-08 17:29:37 Dep. 2020 DIR.NUEVASCR
Tra. 11 PATENTEIYII Eve: 379 FASENACIONALII
Act. 329 CTOINFORMACION Folios: 42

Trámite : 011

Evento : 379

Actuación : 329

Referencia : Expediente No. 10.121.741
Asunto : Solicitud de patente para: **CAÑOS DE ACERO RECUBIERTOS CON CONCRETO O MORTERO MOLDEADOS A PRESIÓN Y MÉTODOS DE FABRICACIÓN DE LOS MISMOS**
Solicitante : **AMERON INTERNATIONAL**
Fecha solicitud : 1° de octubre de 2010

1. Yo, Luz Clemencia de PÁEZ, obrando como apoderada de la sociedad solicitante en el asunto identificado en la referencia, presento con este escrito los documentos citados por el examinador en el trámite de la solicitud estadounidense No. 12/061,263 del 2 de abril de 2008, de la cual se reivindicó prioridad en el trámite de la Solicitud Internacional No. PCT/US2009/039091 correspondiente a la presente fase nacional.

2. Solicito a ese Despacho considerar estos documentos al momento de realizar el examen de patentabilidad de la solicitud de patente de la referencia.

Señor Director,

LUZ CLEMENCIA DE PÁEZ

C.C. No. 35.456.344 de Usaquén

T.P.A. No. 23.555

COLO-17910-841-001-2
JGGWGGID-204131WPC17910
No. M-2011-204131WGG

NIT. 860.041.367-3

PATENT

P.V. No. 826.990

No. 1.264.614

International classification

B 28 c - F 06 /

Prestressed composite pipe and the manufacturing process for this pipe.

Mr. MAURICE ALFRED ALEXANDRE SADOULET, a resident of (The Rhône) France.

Application filed on May 12, 1960, at 4:07 p.m., in Paris.

Issued under an order dated May 15, 1961.

(Official Gazette of Industrial Property, No. 25 for 1961.)

(Issuance of this patent was deferred pursuant to article 11, § 7
of the law dated July 5, 1844, as amended by the law of April 7, 1902.)

The use of concrete lining in steel pipes has been known for a long time. Of all known protective coatings, this concrete lining has the advantage of providing a very smooth skin whose surface improves in quality with use, and of giving excellent protection to the metal, even in a very thin sheet, against corrosive damage by the liquids the pipe carries, especially water. As a result, the thickness of a steel pipe with such a lining theoretically only has to be great enough to withstand the strains put upon it with no need for excess thickness that can be "sacrificed" to future corrosion. In addition, liquids flow better since there is no risk that protuberances, corrosion tubercles or oxide nodules will form on the metal, causing relatively significant hydraulic head loss.

However, its protection of the metal is really effective only if there are no cracks in the concrete; this means the steel pipe itself must not exceed an ultimate stress roughly equal to that allowed by the tension of the reinforcements in reinforced concrete, which is much lower than the steel pipe's load carrying capacity without permanent deformation. Consequently, either the steel pipe must be strengthened externally with a thick layer of reinforced concrete or the pipe's thickness must be greater than that required for the internal pressure it must bear.

Another possibility, which is the purpose of this invention, is to create simultaneous radial and axial prestressing of the concrete lining by placing the steel pipe itself under tension in both of those directions. As long as the stresses caused throughout the pipe by the internal pressure of the liquid it carries or by the various dynamic stresses

to which the pipe is subject while in use are less intense than the initial prestressing, the concrete will work in compression and therefore cannot crack.

We see, then, that the pipe's steel shell can be used without risk at a much higher maximum load and can therefore withstand greater pressures and tensions, while still being thinner. With this approach, the amount of material used is minimized and the cost price of a composite pipe is thus decreased to a large extent.

In this invention, the prestressed composite pipe includes an integral steel pipe, possibly end collars reinforced by creating joints via welding or any other process; and primarily to protect it against corrosion, this steel pipe is equipped with a radially and axially prestressed concrete lining, and then with cladding.

The invention also encompasses a manufacturing process characterized by the fact that it consists of lining the inner surface of the steel pipe with a layer of concrete in a pasty state; inserting an elastic container into this concrete lining; blocking the ends of the pipe with flanges firmly attached to the end collars of the steel pipe; filling this container with a hydraulic fluid under pressure to create significant internal radial and axial tensions in the pipe; maintaining constant pressure throughout the concrete's setting time; and then emptying the container and removing the flanges.

Several other characteristics of the invention also stand out in the detailed description below. An embodiment of the invention is depicted, as an example, in figures 1 to 7 in different phases of its manufacture.

The composite pipe includes a steel pipe 1 (fig. 1) whose ends are made an integral part of it,

for example by welding on thicker tabular collars 2 and 3, intended to facilitate and strengthen the welded joint between two contiguous composite pipes (fig. 2).

For instance, these collars take the form of a thick pipe, finished at one end by a chamfer 2a or 3a facilitating a welded joint between two contiguous pipes, and prolonged at its other end by a conical thinning part 2b or 3b, making it possible to progressively bring the open end of this pipe together with that of steel pipe 1. All types of steel pipes can be used, particularly those made by seamless rolling or those made by sheet rolling and by longitudinal or helical welding. The steel pipe is as thin as is allowed by the specific characteristics of the metal, by the internal pressure it must withstand and by the safety factor that was chosen, while collars 2 and 3 are thicker to allow for very sturdy butt welds; moreover, these collars can be shaped in different ways depending on the type of joint used, the type that can be dismantled or the type that cannot, in connecting two contiguous pipes.

In addition, the composite pipe includes a concrete lining 4 that adheres directly to the steel pipe (fig. 3). The thickness of this lining is determined according to the rules adopted for calculations for reinforced concrete. This concrete is put in place and pressed against the steel pipe, either by vibration in a metal mold or, preferably, by what is known as the centrifugation process, or, in fact, by any other appropriate technique.

The composite pipe is, moreover, given cladding to protect against corrosion, and this may consist of bituminous or asphaltic insulating material reinforced with Hessian cloth, asbestos or glass wool; this cladding is then treated according to a technique known as "cathodic protection."

As specified in this invention, the resulting composite pipe is prestressed in two preferential directions: expanding radially and lengthening axially. As a result, the concrete lining works in compression; i.e., this happens under good conditions, if the stresses created in these two preferential directions by the piezometric and dynamic excess loads that the composite pipe is subjected to by the liquid it carries, as well as the external stresses, are less intense than the initial stresses.

As specified in this invention, the manufacturing process for the prestressed composite pipe is illustrated by figures 1 to 7, which depict basic phases.

The pipe 1 is taken to the first work station for the placing and welding of end

collars 2 and 3 (fig. 2); then the pipe is transported by some appropriate device, on rollers, for instance, to a second work station (fig. 3) where an even coat of concrete is deposited on its inner surface, and once this has been pressed, it becomes the lining 4. Note that the lining extends the whole length of the steel pipe 1, but that its ends, whether straight or at an angle, are nonetheless slightly separated from the ends of collars 2 and 3. In this way, subsequent welding of the sleeves of two contiguous composite pipes can be easily carried out end to end on the outside and, possibly, the inside, since the space between these contiguous pipes' linings 4 can be filled in, after installation, with a cement mortar joint, at which point the resulting conduit can be passed to the next worker. At this second station, the concrete can be deposited and pressed into place using any appropriate technique, namely by vibration in a metal mold or, preferably, by centrifugation.

Before the setting of the cement occurs, the so-called primitive pipe is taken to another work station (fig. 4 and 5) where this cement will be prestressed. To that end, a container 5, made of elastic material such as rubber, butyl, etc. is inserted into the pipe. This container is equipped with a filling nozzle 6 intended to link the container's inner chamber 7 to an external hydraulic fluid circuit 8. Then, the ends of the primitive pipe are blocked by thick flanges 9 and 10 attached firmly to steel pipe 1, for example using temporary electric welding or any other equivalent mechanical means. As an example, these flanges may be shaped as depicted in figures 4 and 5. Sticking out from them on one of their surfaces is a flanged ring 11 that could extend the corresponding collar 2 or 3 to allow a temporary joint weld 12; and this border is separated by a gap 13 for a center drilling 14 through the aforementioned collar and abutting against the concrete lining 4.

One of the end flanges, 10 for example, holds the filling nozzle 6 for the container 5; this nozzle is equipped with a connector 15 that allows quick attachment of the circuit 8 to the inner chamber 7. This circuit, which preferably will use water as its hydraulic fluid, includes a valve 16, supporting two passageways, which is attached to connector 15 by piping 17 equipped with a pressure tap associated with a pressure gauge 18. The valve allows selective connection of the container 5 either to the facility's water supply system, which, if unavailable, can be replaced by a high capacity pump operating at low pressure to force water in from a tank, or to a low capacity pump 20 operating at high pressure; the

valve can, moreover, isolate the aforementioned container 5 from both of these sources.

First, once the flanges 9 and 10 are firmly anchored on the primitive pipe, one sets the valve 16 to open a connection between the water supply system 19 or high capacity pump and the container 5 to fill the latter with water under low pressure. Second, once filling is complete (fig. 5), one sets the valve 16 to disconnect the supply system 19 and instead connect to the high pressure pump 20. As soon as the pressure gauge 18 indicates that the desired pressure has been attained, one closes the valve 16.

The pressure in the chamber 7 transmitted by the concrete and by the flanges has the effect of creating radial and axial tensions in the steel pipe equal to the planned intensity, since the pressure shown on the pressure gauge 24 is that established by the calculation to obtain the desired prestressing.

The pressure is maintained inside the container 5 throughout the concrete's setting time, whose duration is fixed by the standards adopted for prestressed concrete. When the target date is reached, one opens the valve 16, one empties the container 5, and then one removes the end flanges 9 and 10, for example by flame cutting with an oxyhydrogen torch if they were welded. Now that the external stresses that the primitive pipe was subject to are gone and now that the concrete has reached a suitable sturdiness, this pipe is in a state of equilibrium such that the aforementioned concrete is prestressed radially and axially; figures 5 and 6 clearly show that these prestressings run directly opposite to the internal tensions on the pipe when subjected to hydraulic pressure and to the stresses of longitudinal tension that the pipe may have to withstand when in use.

The resulting pipe is then taken to a final work station for cladding with insulating material 21, already described, for protection against corrosion. Obviously this station can be placed elsewhere in the production line, such as between the stations illustrated in figures 2 and 3 or figures 3 and 4.

Various additional modifications can be introduced to the embodiment and the manufacturing process depicted and described in detail above. In particular, if the axial prestressing created by the hydraulic fluid under pressure is insufficient, one can very well implement an additional device that applies traction to the steel pipe, as drawn in dotted and dashed lines in the diagram in fig. 5; this device would consist of a fixed stop 22 on one of the flanges, 10 for example, and a hydraulic

cylinder 23 pulling on the other flange, which would therefore be 9.

SUMMARY

The invention consists of:

I. A prestressed composite pipe, characterized by the fact that it includes an integral steel pipe, possibly end collars reinforced by creating joints via welding or any other process; and primarily to protect it against corrosion, this steel pipe is equipped with a radially and axially prestressed concrete lining, and then with cladding for insulation.

II. A manufacturing process for the prestressed composite pipe, remarkable particularly for the following characteristics, considered separately or in combination:

1. The process consists of lining the inner surface of the steel pipe with a layer of concrete in a pasty state; inserting an elastic container into this concrete lining; blocking the ends of the pipe with flanges firmly attached to the end collars of the steel pipe; filling this container with a hydraulic fluid under pressure to create significant internal radial and axial tensions in the pipe; maintaining constant pressure throughout the concrete's setting time; and then emptying the container and removing the flanges;

2. The process consists of lining the inner surface of the steel pipe and pressing the fresh concrete into place through centrifugation;

3. The process consists of connecting the inflatable elastic container to an external circuit that distributes hydraulic fluid under pressure; the connection is controlled by a valve, making it possible to isolate this container throughout the concrete's setting time;

4. The process consists of connecting the two-way valve either to a high-capacity pump or to the facility's water supply system, or else to a high pressure pump;

5. The process consists of seeking to increase the concrete's axial prestressing by securing the pipe's closure flanges not only against the action of the elastic container filled with hydraulic fluid under pressure, but also against the action of a press that tends to push these two flanges further apart;

6. The process consists of attaching the flanges and the steel pipe by means of a temporary weld, and flame cutting them off after the concrete has been prestressed;

7. The process consists of covering the outer surface of the steel pipe in cladding that insulates

[1.264.614]

— 4 —

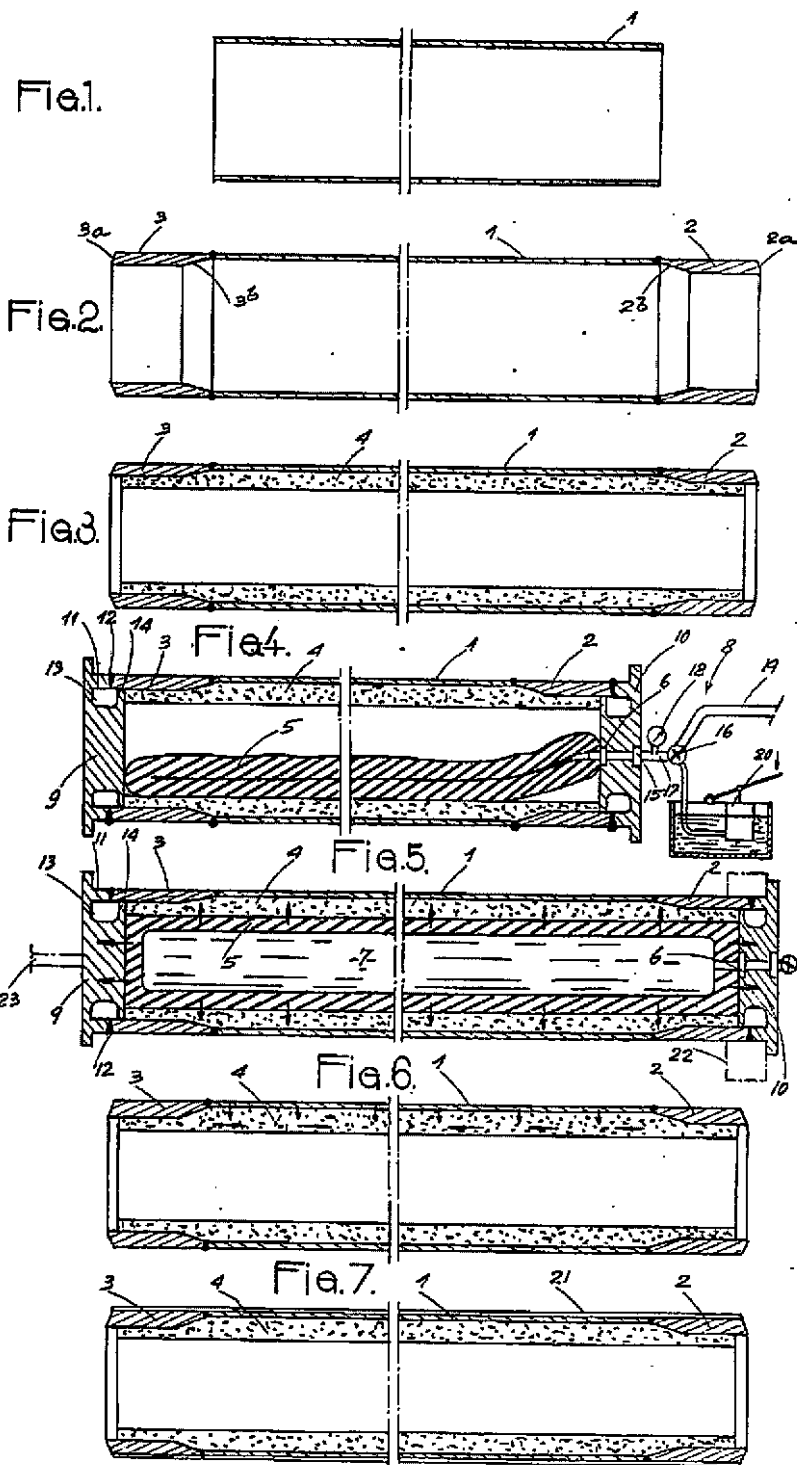
it and protects it from corrosion; this cladding with bituminous or asphaltic material is reinforced with

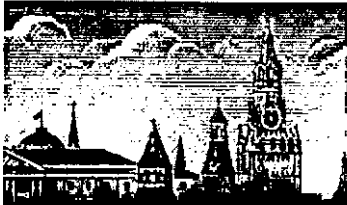
Hessian cloth, asbestos or glass wool and finished with cathodic protection.

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CERTIFICATE OF TRANSLATION

February 12, 2010

To Whom It May Concern:

Enclosed please find the French into English translation of French Patent N° 1.264.614 titled "Prestressed composite pipe and the manufacturing process for this pipe", for an invention by Mr. Maurice Alfred Alexandre Sadoulet, for Connolly Bove Lodge & Hutz LLP. The translation was performed by a native speaker of the target language, professional translator. The translation was subsequently edited by another native speaker of the target language, professional translator. The information the translation contains is accurate and correct.

Sincerely,

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US005791378A

United States Patent [19]

Stephens

[11] Patent Number: 5,791,378

[45] Date of Patent: *Aug. 11, 1998

[54] METHOD FOR GROUTING PIPE LINERS

[76] Inventor: Patrick J. Stephens, 1276 Chuckanut Dr., Bellingham, Wash. 98225

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,241,993.

[21] Appl. No.: 495,346

[22] Filed: Jun. 27, 1995

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 111,392, Aug. 25, 1993, Pat. No. 5,427,154.

[51] Int. Cl.⁶ F16L 55/18

[52] U.S. Cl. 138/98; 138/97; 264/269

[58] Field of Search 138/97, 98, 105, 138/140; 264/36, 269; 156/94, 294; 405/150.1, 150.2, 154, 155, 156; 106/625, 672, 677, 678, 681, 682

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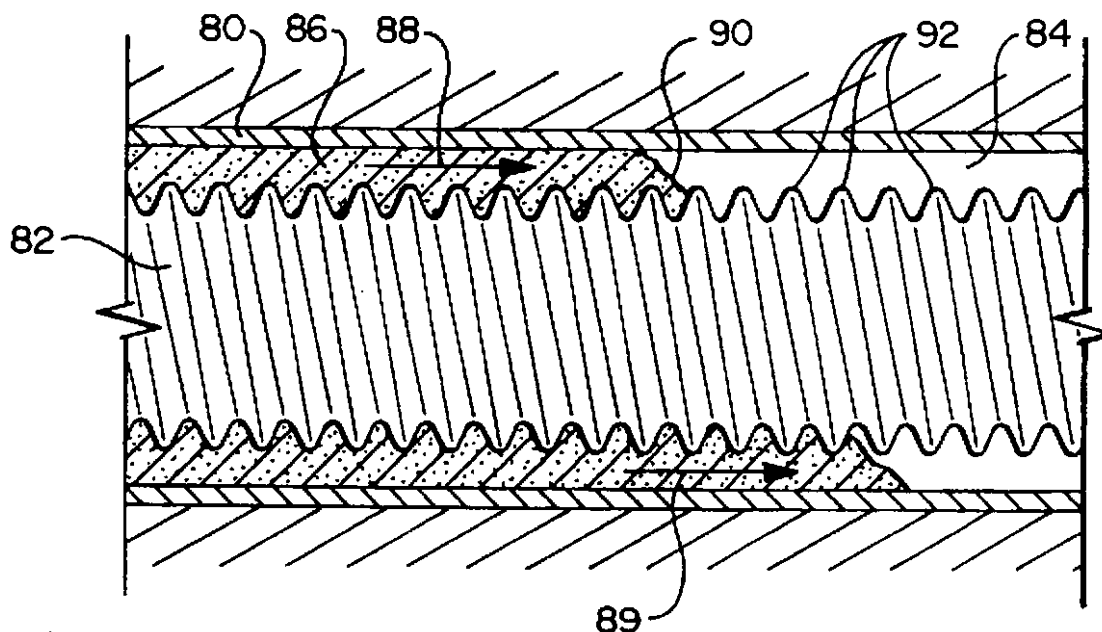
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Primary Examiner—Patrick F. Brinson
Attorney, Agent, or Firm—Todd N. Hathaway

[57] ABSTRACT

A pumpable cement grout and method for use thereof for grouting liner pipes. The pumpable cement grout is a mixture of a hydraulic cement, water in an amount sufficient so that the water-to-cement ratio of the grout is from about 0.60 to about 1.00 by weight, and pregenerated aqueous foam in an amount sufficient to adjust the wet density of the grout to a value of from about 48 to about 72 pounds per cubic foot. The pressure at which the grout is injected into the cavity is maintained at or below a predetermined maximum pressure, so as to avoid collapsing the liner pipe.

22 Claims, 2 Drawing Sheets



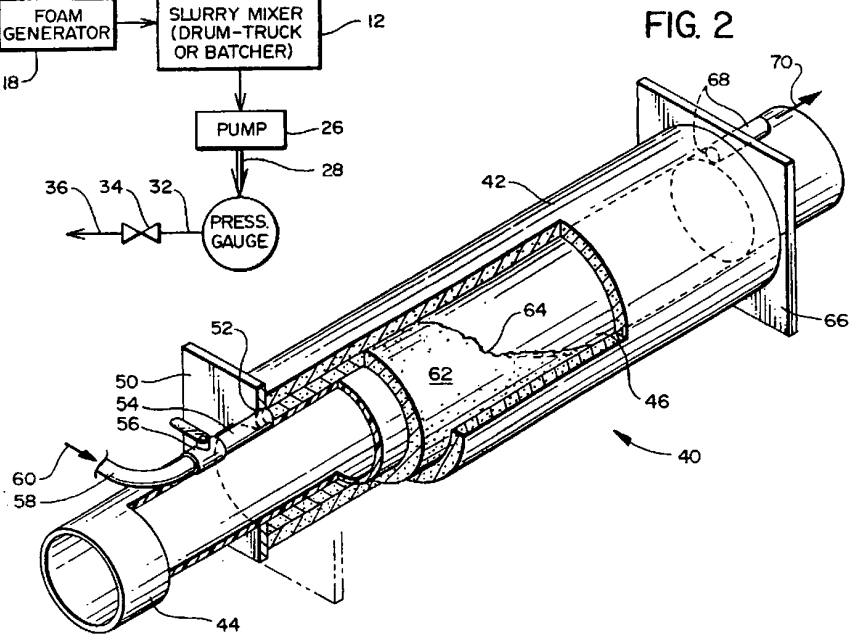
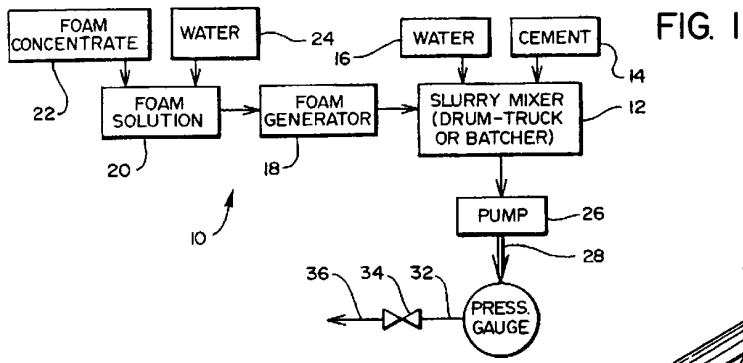


FIG. 3

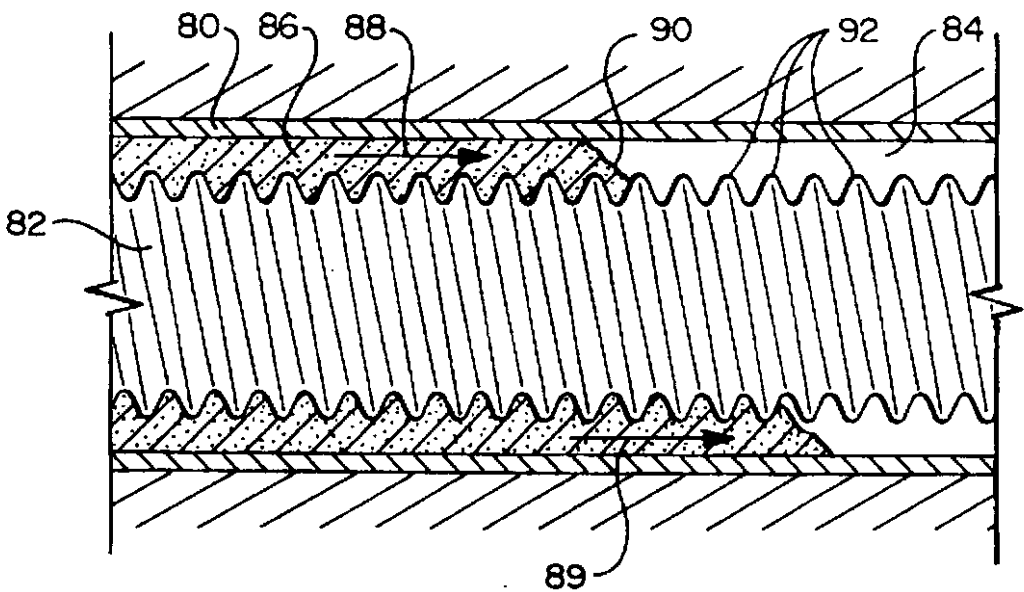


FIG. 4

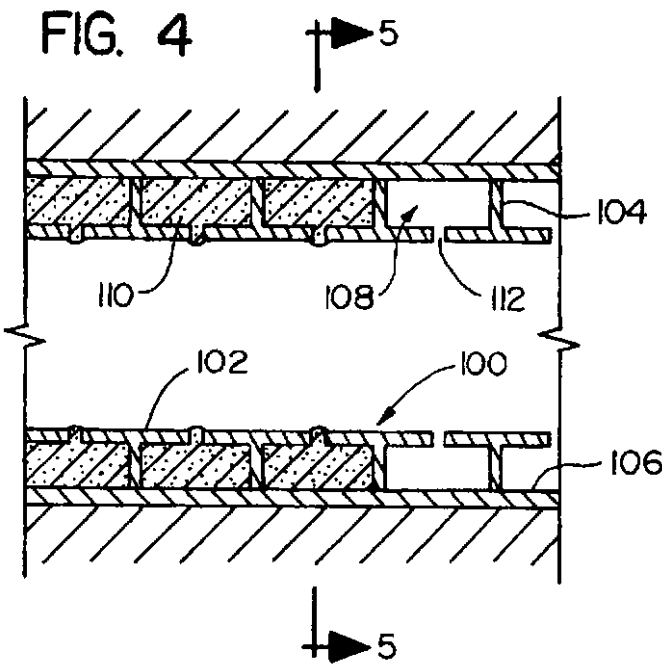
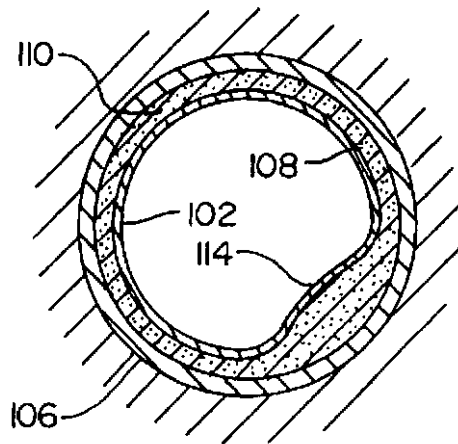


FIG. 5
PRIOR ART



METHOD FOR GROUTING PIPE LINERS

This is a continuation-in-part of application(s) Ser. No. 0 8/111,392 filed on Aug. 25, 1993 now U.S. Pat. No. 5,427, 154.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to cement grouts and methods for use of the same. More particularly, the present invention relates to a pumpable cement grout for grouting of annular cavities.

2. Background Art

Much of the infrastructure of modern society is in need of repair or upgrading, or, at the least is in need of means for reducing the frequency of such repairs. For example, it is well known that a great many sewer systems throughout the United States and elsewhere are greatly in need of frequent repair.

One relatively new and effective technique that has been used for upgrading sewer systems involves relining existing concrete sewer lines with plastic liner pipe, such as high density polyethylene (HDPE) pipe. The plastic liner is inserted into the sewer line, and is pulled or jacked longitudinally through the sewer line into place. In order to fit within the concrete sewer line, the plastic liner pipe must have an outside diameter which is smaller than the inside diameter of the concrete sewer pipe, so as to provide clearance between the two. An annular cavity is thus formed between the pipe and liner. However, it is undesirable for the liner pipe to be very much smaller in diameter than the sewer pipe, lest the capacity of the upgraded sewer system be adversely affected. Accordingly, plastic liner pipes are typically installed so that there is adequate, but minimal clearance between the outside of the liner pipe and the interior surface of the sewer pipe; in a typical installation, the radial clearance (i.e., the radial extent of the annular gap) may range from about 3 inches to less than 1 inch.

Once the plastic liner pipe has been pulled or jacked into place, it is usually desirable to fill the annular space between the pipe and liner with grout to protect the liner from future damage. The potential for such damage may exist, for example, when the old concrete pipe is badly deteriorated and there is a danger that portions of the wall of the pipe may fail. A material which has been found suitable for such protective grouting is concrete grout which, in conjunction with the inexpensive plastic liner pipe, provides the potential for old sewers to be rehabilitated with minimal excavation and cost. However, the inside diameters of concrete sewer pipes typically range in size from about 60 inches down to 15 inches or less, and so direct access to the interior of the sewer line by personnel and construction equipment is usually difficult or impossible; this precludes the possibility of grouting of the pipe liner by means of the conventional cement grouting techniques which are used for backfilling large tunnels and similar structures, which typically involve boring holes through the wall of the tunnel at a multiplicity of points along the length of the tunnel, and then injecting cement grout through the holes and into each local area of the cavity about the tunnel.

Because of this inability to apply proven, conventional techniques, grouting of plastic sewer liners has been attempted by injecting a cement grout into the annular cavity at a first point along the pipe so that the grout flows longitudinally through the cavity towards a second point along the pipe. However, a very serious problem has been

encountered when attempting to use this technique because the plastic liner pipe itself is typically unable to resist the significant external pressures which are exerted by the injected concrete grout. As noted above, the space between the plastic liner pipe and the existing sewer pipe is typically small; hence, it is typically very difficult to maintain a low grout pressure when pumping the grout longitudinally through the annular cavity. Unfortunately, the plastic liner pipe can easily collapse under even relatively low pressures, some pipes being unable to withstand external pressures as low as 3 pounds per square inch (psi). For example, a plastic liner pipe which is commonly used for lining sewer pipe is high density polyethylene (HDPE) pipe having a wall thickness of SDR 32.5 (where SDR is the ratio of outside diameter-to-wall thickness). HDPE pipe having a wall thickness of SDR 32.5, while able to contain significant internal pressures, has a tendency to collapse within one day if subjected to an external pressure in excess of 4 psi. Another, less commonly used size of HDPE pipe has a wall thickness of SDR 26, and tends to collapse when subjected to an external pressure in excess of 8 psi. Such external pressure maximums can easily be exceeded when attempting the longitudinal injection techniques described above using conventional cement grouts. The conventional cement grouts generally exhibit fairly high viscosities, and relatively high injection pressures are thus required to force the grouts along the annular cavity. Furthermore, as the grout moves through the annular cavity, the grout tends to hydrate (i.e., bind or set up), particularly if the concrete sewer pipe and/or plastic liner are dry, thus compounding the difficulty of maintaining a low grout injection pressure; also, in many cases the plastic liner may be ribbed or corrugated, and the increased external surface area of this pipe tends to compound the hydration factor, as well as add increased friction.

These problems become critical when long distances are encountered between sequential injection points, in other words, when the individual runs to be grouted between access points are fairly long. This is often the case in conventional city sewers, where the distance between access points provided by manholes is often on the order of 300-500 feet or more. In some such cases, the contractors performing such grout work (using conventional cement grouts), have resorted to the expedient of drilling access holes vertically through the pavement and soil overlying the sewer pipe so as to provide additional grout injection points, which is obviously a costly and time-consuming makeshift approach. But, if the plastic liner collapses during the grout injection, the consequences may be catastrophic for the job. Not only is the flow of sewer water through the sewer line blocked by such a collapse, which may cause an overflow, but it may also be necessary to excavate and replace the entire section of sewer line in which the liner is collapsed, at great expense.

As was noted above, the problem of high grout pressures often develops in installations where the annular clearance between the pipe and liner is relatively tight, e.g., in a range of about 3 inches or less, and also in small-moderate diameter installations. However, similar problems can sometimes develop in large or very large diameter installations, and also where there are relatively large annular clearances. For example, synthetic pipe liners are available in the 10 foot diameter range, and 30 foot plus diameter water/sewer lines are in existence. As a general rule, however, the larger the diameter of the liner, the lower the external pressures which it can withstand. Moreover, when grouting very large diameter installations, fluid loss from the grout can reach very high levels owing to the large surface areas involved.

Accordingly, even though the annular clearance may be very great, the development of excessive grout pressures and the resultant collapse of the liner can be a very real problem in such installations, even when using straight-sided liner pipe.

An analogous problem can develop when using certain liner systems which have buttresses or flanges which extend around the outside of the synthetic liner pipe so as to support the liner within the original conduit. An example of a liner system of this type is that which is available under the trademark "T-LOCK" from the Danby Company. A simplified example of a liner 100 of this general type is shown in FIG. 4. As can be seen, this comprises the liner pipe 102 having outwardly extending flanges 104 about its outer surface, which extend to and engage the inner wall of the conduit 106. Each of the flanges 104 extends around the perimeter of the liner pipe, so that a series of annular voids 108 are formed between the liner and the conduit.

The voids 108 must be filled with grout 110 to complete the installation, as is shown in FIG. 4, with injection ports 112 being provided in the liner pipe 102 for this purpose. As the grout flows in a generally circumferential direction through the long annular chambers or channels 108, hydration and fluid loss problems may develop. Also, the actual weight of the grout itself becomes an important factor: As can be seen in FIG. 5, when using prior art grouts to fill the cavities 108, the weight of the grout 110 increases the external pressure on the lower sides and bottom of the liner pipe 102. As a result, these areas tend to collapse inwardly, forming large, inwardly extending blisters or "puckers" 114. If substantial, such inward collapse of the liner pipe can ruin the installation.

Although the particular type of liner system which is shown in FIGS. 4-5 is a notable example of this problem, owing both to the injection pressures which develop in the annular cavities and the relative sensitivity of the particular liner pipe to external pressures, it will be understood that this same kind of problem can in some cases develop when using more conventional, straight-sided liner pipes, particularly when quite large conduits/liners are involved.

Accordingly, there exists a need for a grout material for grouting plastic sewer liners and the like, and a method for the use thereof, which is both effective and inexpensive, yet which reduces the possibility of collapse of the plastic liner pipe during grouting of the liner in the sewer line, particularly when using a ribbed or corrugated liner. Furthermore, there exists a need for such a grout material and method for use thereof which employs a fluid yet lightweight grout material which will reduce or eliminate the problem of the weight of the grout itself causing excessive external pressures on the lower and bottom portions of liner pipes.

SUMMARY OF THE INVENTION

The present invention has solved the problems cited above, and is a method for lining a conduit. Broadly, the method comprises the steps of: (a) placing a liner in the conduit so that at least one cavity is formed intermediate the conduit and the liner, an interior of the liner being maintained substantially unpressurized, and the liner having a tendency to collapse if subjected to an external pressure in excess of a predetermined maximum pressure, (b) forming a pumpable cement grout, the grout comprising hydraulic cement, water in an amount sufficient so that the water-to-cement ratio of the grout is from about 0.60 to about 1.00 by weight, and pre-generated aqueous foam in an amount sufficient to adjust the wet density of the grout to a value of from about 48 to about 72 pounds per cubic foot, (c)

pumping the cement grout into the cavity under positive pressure so that the grout fills the cavity by flowing in a direction generally along an axis thereof, and (d) maintaining the positive pressure under which the grout is pumped into the cavity between the conduit and liner at about equal to or less than the predetermined maximum pressure.

The step of forming the pumpable cement grout may further comprise the steps of determining the density of the liner, and mixing the pre-generated aqueous foam into the grout in an amount sufficient to adjust the density of the grout to a value substantially equal to or less than that of the liner, so as to avoid the liner floating on the grout to the top of the interior of the conduit.

The method may further comprise the step of directing a flow of fluid, such as water or sewage, through the liner, and the step of determining the density of the liner may comprise determining the density of the liner carrying the flow of the fluid. The flow of fluid may be backed up into the liner, so as to increase the density of the liner and to permit the density of the grout to be increased while still remaining equal to or less than that of the liner.

The method is applicable to both small diameter (60 inch or less) and large diameter (greater than 60 inch) conduits/liners. The grout may be flowed generally in the direction of the longitudinal axis of the liner, or may be flowed in a generally circumferential direction, depending upon the orientation of the cavities.

These and other features of the present invention will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram representation of apparatus for generating the pumpable cement grout of the present invention;

FIG. 2 is a perspective view of a length of concrete sewer pipe having a plastic liner pipe installed therein and being grouted in accordance with the present invention;

FIG. 3 is a longitudinal cross-sectional view of a length of concrete pipe having a spirally corrugated plastic liner pipe installed therein and being grouted in accordance with the present invention;

FIG. 4 is a longitudinal cross-sectional view of a length of concrete conduit having a type of liner pipe installed therein in which there are support flanges which extend radially from the liner pipe to engage the inner surface of the conduit, thus forming annular cavities which are filled with grout to complete the installation; and

FIG. 5 is cross-sectional view taken along line 5-5 in FIG. 4, showing the development of an inward collapse or "blister" of the liner when using heavy grout materials to fill the annular cavities in accordance with prior art techniques.

DETAILED DESCRIPTION

FIG. 1 shows a block diagram of an apparatus 10 for producing the lightweight pumpable cement grout of the present invention. Grout generating apparatus 10 comprises a slurry mixer 12, which may be, for example, a drum-truck or a conventional cement mix batcher. Slurry mixer 12 receives hydraulic cement 14 and water 16 for mixing. Cement 14 may be any suitable hydraulic cement which undergoes hydration in contact with water, and is preferably conventional portland cement. In terms of weight-per-yard, cement 14 is added to slurry mixer 12 at a rate of from about 600 pounds to about 1100 pounds per cubic yard of produced grout.

Portland cements are hydraulic cements composed primarily of hydraulic calcium silicates, and are well known to those skilled in the art; during hydration, the cement combines with water to form a stone-like mass. Hydration begins as soon as the portland cement comes in contact with water. Types I and II cement have been found to be particularly suitable for use in the present invention, and noncorrosive cement compounds should be used if the grout is to be placed in contact with corrodible materials, such as steel. Furthermore, it should be understood that cement 14 will generally be free of mineral aggregates and the like, which would ordinarily increase the density of the resulting cement grout, although such fillers may be desirable in some applications of the present invention. Sand, fly ash, and similar materials may be added in amounts which may be desired for a particular application or job (e.g., on the order of 1,000 lbs./yd.³), provided they do not take the density and weight of the grout into unacceptable ranges. Still other additives which are known to those skilled in the art may be included to enhance various characteristics of the grout mixture.

Water 16 may be any water (e.g., fresh or salt) which is suitable for causing hydration of cement 14. For applications where the resulting grout may be in contact with corrodible components, however, it is preferable that water 16 be free of chloride, sulfate, and other ions which might cause corrosion. Sufficient water 16 is added to cement 14 so that the water-to-cement ratio of the mixture is from about 0.60 to about 1.00 by weight. This water-to-cement ratio is significantly higher than that used in conventional lightweight cellular cement mixes, and this helps the pumpable cement grout of the present invention achieve a desirably low viscosity. For example, roof deck-type mixes (which are used to form lightweight cement roofs) may typically have a water-to-cement ratio of approximately 0.50; this lower water-to-cement ratio is necessary for the cement to set up before the bubble structure dissipates, but it also renders such mixes significantly more viscous than the grout of the present invention, and, consequently, the former would require excessively high pressures to inject into the annular space between the liner and sewer pipe.

Slurry mixer 12 also receives pregenerated aqueous foam from foam generator 18. Foam generator 18 may be any suitable conventional foam generation system, such as those used for the production of cellular concrete, and these are well known to those skilled in the art. Typically, such systems include positive displacement foam generating pumps having rotors for mixing liquid foam solution with air, and an example of such a system is the mechanical foam generation system supplied by Cellufoam Concrete Systems (a division of Patrick Chadwick Incorporated, 110 Pine Glen Road, Toronto, Ontario M4E 1K9) as their Model 620-114-1; other examples include batch-type systems which mix a pressurized foam solution stream with a pressurized air stream in a nozzle or column to produce the foam, and an example of this type of system is the batch-type preformed foam system supplied by The Mearl Corporation (220 West Westfield Avenue, Roselle Park, N.J. 07204) as their Model OT 10-5.

Foam generator 18 receives foam solution 20 from a mixing and storage tank, and this solution is usually a mixture of foam concentrate 22 and water 24. Preferably, foam concentrate 22 and water 24 are mixed in proportions such that foam generator 18 produces a suitable micro cellular foam having a density of about 2.40 pounds per cubic foot, although other relatively light densities of preformed foam may be used as well. Foam concentrate 22 itself is usually a suitable foam-forming surfactant material,

such as, for example, an alcohol sulfate diethanolamine salt sold under the trademark "DUPONOL" EP Surfactant by E. I. Du Pont de Nemours and Company, Inc., (1007 Market Street, Wilmington, Del. 19898). Similar suitable materials are available from The Mearl Corporation under the trademark "MEARLCEL 3532 FOAM LIQUID", from Cellufoam Concrete Systems under the trademark "WF304 Foam Concentrate", and from Elastizell Corporation of America (P.O. Box 1462, Ann Arbor, Mich. 48106) under the trademark "Elastizell EF". Another example of foam concentrate which may be suitable for some applications of the present invention is available under the trademark "MEARL GEO-FOAM LIQUID" from The Mearl Corporation. It will be noted, however, that some foam concentrates, such as the MEARL GEOFOAM LIQUID™, may contain chloride ions and other corrosive components which may limit their use in applications where the grout is to be placed in contact with steel or other corrodible components. Using the commercially available foam concentrates noted above, it has been found that a foam solution 20 comprising two to five percent by volume foam concentrate generally produces foam having suitable density (i.e., about 2.40 PCF) and stability, as well as suitable micro-bubble characteristics, and foam solution comprising about 2.5% by volume foam concentrate has been found to be particularly suitable for use in the present invention. The proportions of foam concentrate and water in the foam solution may, of course, need to be adjusted to compensate for field conditions or different concentrations of foam concentrate, so as to ensure that suitable preformed foam is generated.

The foam is then blended with the cement slurry in the mixing device 12, and the voluminous and stable micro-bubble pregenerated aqueous foam provides a multiplicity of air voids about which a subsequent cement matrix may form, thus forming a low density concrete; the foam consequently needs to have sufficient stability to maintain its structure until the cement sets to form the matrix, and the foam generation and the proportioning of the cement slurry are regulated to achieve control of the final strength and density of the grout.

After mixing the pumpable cement grout is drawn from slurry mixer 12 to pump 26, which pressurizes the grout for subsequent injection. Pump 26 discharges the grout through hose line 28 to pressure gauge 30, which permits an operator to check the injection pressure of the grout and adjust pump 26 accordingly. From pressure gauge 30, the grout passes through injection line 32 to valve 34. Valve 34 permits an operator to selectively commence and terminate injection of the grout. When valve 34 is open, the grout is discharged through injection fitting 36, as indicated by the arrow, so that it passes into the void which is to be filled by the grout.

The grout generating equipment described above with reference to FIG. 1 is normally very portable, and can be transported to a typical job site using a pickup truck.

Having described the equipment and materials suitable for generation of the pumpable cement grout of the present invention, attention is now directed to FIG. 2, with reference to which the grouting of an exemplary annular void will be described. FIG. 2 shows generally a lined sewer line 40. Sewer line 40 comprises sewer pipe 42, which may typically be a concrete sewer pipe which is in need of upgrading; as noted above, such concrete sewer pipe may typically range in size from about 15 inches up to about 60 inches in inside diameter, which, while relatively large for a sewer line, still provides inadequate space for personnel and grouting equipment to enter the pipe. A liner pipe 44 is disposed in sewer pipe 42 so that liner pipe 44 provides a replacement conduit

for the flow of sewer water which is carried by sewer line 40. Liner pipe 44, as noted above, may typically be a plastic pipe, such as an HDPE liner pipe, which tends to collapse if subjected to an external pressure in excess of a predetermined maximum. As also noted above, such liner pipe is typically placed in and then pulled or jacked through sewer pipe 42; accordingly, the external diameter of liner pipe 44 is smaller than the internal diameter of sewer pipe 42, so that an annular gap or void 46 is formed when liner pipe 44 is installed in sewer pipe 42. In typical applications, the radial extent of annular void 46 may vary from about one to about three inches.

Although the example which is described in this section in order to illustrate the present invention—i.e., a small diameter, limited access conduit and tight annular clearances—is of a kind which is notable for the difficulties which are solved by the present invention, it will be understood that the present invention is applicable to larger diameter and larger clearance installations as well. For example, as was noted above, there are very large installations (e.g., up to 10 feet or greater diameter) in which excessive grout pressures remain a serious problem, in spite of clearances typically much greater than 3 inches, owing to fluid loss, hydration and other factors, as well as the relatively diminished ability of the large diameter liners to withstand significant external pressures. Moreover, even in smaller diameter installation with relatively great clearances (e.g., on the order of one to several feet), the present invention eliminates grouting pressure problems which might otherwise have arisen, particularly when long grouting runs are involved.

A bulkhead or dam 50 is installed at a first access point along sewer line 40 so as to seal the annular gap between sewer pipe 42 and liner pipe 44. As noted above, such access points along a sewer line are typically provided by manholes, which extend downwardly from the surface to the sewer pipe, and these may be spaced along a sewer line at distances of 300 to 500 feet or more. Such access manholes are normally of adequate size so as to permit personnel and equipment to gain access to the end or portion of the sewer line at that point. Dam 50 surrounds liner pipe 44 and abuts against the exposed end of sewer pipe 42, thereby sealing the annular gap between the two. Dam 50 may be a board-like dam, as illustrated in FIG. 2, which may be constructed of wood, plastic, metal, or the like, or it may be a built-up dam of earthen materials, gravel, sand, or the like, if sufficient strength to resist the injection pressure of the grout can be so achieved. Dam 50 is provided with an injection port 52, through which an injection nozzle 54 can be inserted. Accordingly, it will be understood that injection port 52 establishes communication between the surface and the annular cavity 46 between the pipes. It will also be understood that injection nozzle 54 corresponds to injection nozzle 36 shown in the block diagram of FIG. 1.

A valve 56 (which may be manually operable and which corresponds to valve 34 shown in the schematic diagram of FIG. 1) is provided to control the flow of grout from pressure line 58 to nozzle 54, and hence into annular void 46. When valve 56 is in an open position, the grout is supplied under pressure from the grout-generating apparatus through supply line 58 in the direction shown by arrow 60, and is injected into annular cavity 46 through injection nozzle 54. As the grout 62 is injected into the cavity, it flows around liner pipe 44 and longitudinally through sewer pipe 42 so as to fill annular cavity 46. Thus, it will be seen that the leading edge 64 of the grout proceeds longitudinally through the annular cavity, away from the first access point towards a second

access point (typically provided by a second access manhole). A second dam 66 may be installed at the second access point, and may have an ejection port 68 therethrough. As the leading edge of the grout proceeds longitudinally within the sewer line, air will be forced out of annular cavity 46. This air escapes through ejection port 68 in the direction shown by arrow 70. When the leading edge 64 of grout 62 reaches second dam 66, grout 62 will begin escaping from ejection port 68, indicating to an observer that grouting of the section of sewer line 40 between the first and second access points has been completed. It will be understood, of course, that it may be desirable under some circumstances to delete the second dam and simply permit the air and grout to escape from the annular gap between the two pipes at the second access point, particularly in those cases where it is likely that considerable soil or other debris will be forced out of annular cavity 46 by the advance of the grout.

Because of the low injection pressures made possible by the present invention, the steps described above are carried out with the interior of the liner pipe maintained at substantially atmospheric pressure, without fear of collapsing the liner. In other words, with the present invention it is unnecessary to pressurize the interior of the liner pipe to reduce the possibility of collapse. It will be understood that in some cases the flow (of water, sewage, etc.) which may be backed up within the liner to prevent it from floating may also develop a slight (e.g., 1–2 psi) head pressure due to the partial filling of manholes or other access points, or simply due to the gradient of the conduit; for purposes of this description and the appended claims, however, it will be understood that the term “substantially atmospheric pressure” includes such relatively incidental increases in the interior pressure of the liner which may occur due to damming, backing up, diversion, and so forth of the flow.

With further reference to FIG. 2, the pumpable cement grout 62 of the present invention will now be described in greater detail. Pumpable grout 62 is provided with suitable characteristics (e.g., fluidity) which permit it to be injected into a relatively confined annular space under minimal pressures, so as to avoid generating pressures which would collapse the liner pipe. Of course, the grout needs to retain these characteristics while it proceeds through the entire length of the sewer line between the first and second access points, or else excessive injection pressures may develop. For example, as the leading edge 64 of the grout advances along sewer line 40 as shown in FIG. 2, that portion of the grout which is proximate the leading edge will be hydrating (i.e., setting up), which hydration may be accelerated if the interior surface of sewer pipe 42 and/or the exterior surface of liner pipe 44 are dry, or if the sewer pipe is warm because of warm sewer water flowing through it; nevertheless, despite this hydration, grout 62 needs to remain sufficiently fluid until leading edge 64 reaches the second access point, so as to avoid developing excessive injection pressures. On the other hand, however, grout 62 must also be capable of setting up (i.e., solidifying) so as to form the solid cellular concrete matrix before the bubble structure of the foamed cement grout collapses or dissipates. In short, the pumpable cement grout must be fluid enough to be pumped into the annular cavity under low pressure, yet still be able to set up without excessive delay.

The pumpable cement grout of the present invention achieves these desired characteristics. First, the grout has an initial consistency which is very thin and “runny”, so that it may be injected under very low pressures; the initial consistency of the grout of the present invention is somewhat similar to that of cream. This consistency is achieved in part

by mixing water with the cement in the slurry mixer in an amount sufficient so that the water-to-cement ratio of the grout is a relatively high 0.60–1.00 by weight; in other words, the weight of the water in a given amount of the grout is from about 0.60 to about 1.00 times the weight of the cement in that amount of the grout. This is a significantly higher water-to-cement ratio than that utilized in other foamed cement mixes, such as conventional roof deck-type cellular concrete mixes, and consequently provides the grout of the present invention with a much thinner and more easily pumpable consistency.

The pregenerated aqueous foam is mixed with this water-to-cement mixture in an amount sufficient to adjust the wet density of the grout to a value of from about 48 to 72 pounds per cubic foot. In some applications, it may be desirable to adjust the wet density of the grout upwardly to a value of about 75 pounds per cubic foot. For use in grouting liners in sewer lines, it has usually been found preferable to use sufficient foam to adjust the wet density of the grout to a value of from about 55 to about 62.4 pounds per cubic foot; within this particular range, the density of the grout is generally less than that of the sewer water being carried through the sewer liner (this typically having a density of about 62.4 PCF), thus preventing the sewer liner from floating on the grout during the grouting operation. This is important in order to preserve the annular gap along the top of the liner pipe, so that this can be filled by the grout which will subsequently protect the top of the liner. Such relatively low densities are also important in achieving low injection pressures, particularly if it is necessary to inject against a head pressure, which occurs when the pipe is inclined upwardly and injection is being conducted at a relatively low point along the pipe.

As described, the pumpable cement grout of the present invention has a wet density of from about 48 PCF to about 72 PCF. Lightweight roof deck-type cellular concrete mixes have even lower densities, which may typically range from 20 to 45 pounds per cubic foot; however, as previously noted, the water-to-cement ratio of such typical roof deck type mixes is typically about 0.50 (as opposed to 0.68 to 1.00 in the grout of the present invention), rendering such roof deck-type mixes much thicker and more difficult to pump. However, a thin or runny consistency is not desired for roof deck applications, because the roof deck is typically constructed to have a certain pitch, and it is undesirable for the mix to run down the pitched roof. Roof deck-type cellular concrete mixes consequently have a consistency similar to that of whipped cream or meringue, and if an attempt were made to pump such a mix through the annular cavity between a sewer pipe and a plastic liner, excessive friction would result from the thick, viscous consistency of the mixture, resulting in higher injection pressures and probable collapse of the liner pipe. Furthermore, some such typical mixes contain sand or other mineral aggregate material, which would create still more friction and pressure.

While the grout of the present invention will therefore generally be free of mineral aggregate material for most applications, it may be desirable in some applications to replace a portion of the cement in the grout with fly ash in order to achieve cost savings, while still maintaining the desired density and fluidity of the grout. Fly ash, as is well known to those skilled in the art, is a finely divided residue that results from the combustion of pulverized coal, during which mineral impurities (e.g., clay, feldspar, quartz, and shale) fuse and form spherical particles; fly ash is inexpensive, and generally no processing is needed for using it in blended cement. Sand may also be included in relatively

small amounts, for example, on the order of 1,000 lbs./yd.³ in some applications, provided that the density of the grout remains within acceptable ranges and the abrasiveness of the sand does not cause the development of excessive back pressure for the particular job.

Furthermore, it may be desirable in some applications to add superplasticizers to the grout, so as to be able to reduce the amount of water used in the grout while maintaining its fluid consistency. As is known to those skilled in the art, superplasticizers are high range water reducers which are added to concrete (often to concrete having a low-to-normal slump and water-to-cement ratio) in order to make high-slump, flowing concrete. Examples of such superplasticizer chemicals which are compatible with the preformed aqueous foam in the grout of the present invention include those available under the trademark "Mighty 150" from Boremeo, Specialties Chemical Division, P.O. Box 02573, Fall River, Me. 02722, and under the trademark "WRDA 19" from W. R. Grace and Company, Derex Division, 62 Wittemore Avenue, Cambridge, Mass. 02140. Such superplasticizer chemicals may be lignum-based products, and, as is known to those skilled in the art, act as a cement dispersant which releases particles of cement which surround water particles in ordinary cement or concrete mixes. Superplasticizer chemicals may be desirable because they permit the use of a lower water-to-cement ratio, thus creating higher strength in the hardened cement, without a corresponding reduction in fluidity. For example, beginning with an exemplary pumpable cement grout mix in accordance with the present invention, which calls for 1093.85 lbs./yd.³ cement, 743.14 lbs./yd.³ water, and 22.76 lbs./yd.³ foam, a reduction of about 100 pounds of water per cubic yard of mix may be achieved by adding about 10 ounces of typical superplasticizer chemical per 100 pounds of cement in the mix. A range of from about 6 ounces of superplasticizer per 100 pounds cement (which achieves a 60 lbs./yd.³ water reduction) to about 20 ounces of superplasticizer chemical per 100 pounds of cement (which achieves about a 100 lbs./yd.³ water reduction) may be used in the grout of the present invention; using superplasticizer chemical in amounts in excess of 20 ounces per 100 pounds of cement may result in undesirable reduction in stability of the bubble structure of the grout.

Another additive which may be highly desirable for many applications of the present invention is bentonite, which serves to inhibit extraneous water in the annular space from contaminating the grout by absorption. This may be particularly critical matter if the old sewer pipe is badly deteriorated and significant amounts of water are flowing from the surrounding earth into the sewer pipe through fissures or holes in its wall. Incorporating bentonite in the pumpable cement grout of the present invention may also help control bleeding of water from the grout, particularly when the grout is being injected against relatively high head pressures. Bentonite itself is a soft, porous, moisture absorbing pulverized rock material, comprising generally a colloidal native hydrated aluminum silicate (clay), and has the property of forming gels or viscous suspensions in combination with water. When desired, it has been found useful to add bentonite to the grout of the present invention in amounts of about 5–10 pounds per cubic yard.

Having described the grout of the present invention and a method for its use, the results of two field tests will now be described.

In the first field test, a 14 inch outside diameter HDPE pipe was jacked into an existing 15 inch inside diameter concrete pipe over distances greater than 300 feet. The small clearances involved in this case (only a 1-inch difference in

diameters) made it impossible to block the new liner in position. Thus, in order to insure that the new liner was encased in the protective grout, it was necessary to prevent it from floating on the grout to the top of the sewer line; the HDPE liner was consequently filled with sewage having a density of about 62.5 pounds per cubic foot, and the grout was mixed to have a wet density of about 62 pounds per cubic foot.

A total of 5000 linear feet of the jacked-in HDPE liner pipe were backfilled with the grout. The grout was pumped downstream so as to minimize pressure on the pipe. In order to provide the required protection for the HDPE pipe liner, the compressive strength of the set grout needed to exceed 200 psi; once set, the grout installed in this field test developed compressive strengths exceeding 300 psi. Video cameras used to inspect the rehabilitated sewer after completion of the grouting operation detected no distortion in the HDPE liner pipe.

A second field test was conducted to grout an 18 inch outside diameter HDPE liner pipe which had been jacked into a 20 inch inside diameter concrete pipe over distances greater than 500 feet. A total of 4900 linear feet of HDPE liner pipe were backfilled, using grout mixed to have a wet density of 50 pounds per cubic foot. A major problem in this particular project was that it was impractical to stop the flow of the sewer while the liner was being grouted. Accordingly, in order to prevent the liner from floating on the grout, a plug containing holes for regulating the flow of sewage was installed in the downstream end of the liner. Using this system, the flow of sewage was maintained, but enough sewage was backed up to keep the section of liner full while it was being grouted. Careful monitoring of a backup bypass system prevented the sewer from overflowing through upstream manholes.

The grout was then injected in the manner previously described, with the pump output being carefully controlled so that the grout injection pressure did not exceed 2 psi. The vent at the downstream end was plugged when the undiluted grout appeared at the downstream bulkhead. The rapid set time of the grout allowed full sewer flow to be restored in less than six hours. Video inspection after completion of the grouting detected no deformation of the new liner.

In both of these projects, all grouting took place between manholes, so no excavation or drilling along the sewer line was required. Grout injection was monitored visually to insure that annular voids were completely filled and all water was displaced from the annular space between the old pipe and the new liner.

The proportions of the components of the grout may be adjusted to provide either higher or lower densities, as may be desired for a particular project. For example, during the first field test described above, batches of grout mixes were tested having unit weights ranging from 59.96 to 69.86 pounds per cubic foot. The compressive strength of the grout typically varies with its density, and so this can be adjusted (while still maintaining an acceptable level of fluidity) by varying the amount of foam injected into the grout within an acceptable range. For example, a grout backfill in accordance with the present invention, having a density of approximately 51 pounds per cubic foot, had an average 28 day compressive strength of 580 psi; for a ten percent increase in density to approximately 56 pounds per cubic foot, the average 28 day compressive strength increased 50 percent to 885 psi. One skilled in the art can adjust the proportions of cement, water, and pregenerated foam, within the ranges prescribed herein, to produce an acceptable grout

having a density between about 48 and about 75 pounds per cubic foot. Two exemplary mixtures in accordance with the present invention, each having a different density, are provided by the following tables:

TABLE 1

MATERIALS	WT., LBS.	VOLUME, CF.	UNIT WT., PCF
Cement	1093	3.23	
Water	634	10.16	
	1727	13.39	128.98
Foam	33	13.71	
	1760	27.10	64.94

TABLE 2

MATERIALS	WT., LBS.	VOLUME, CF.	UNIT WT., PCF
Cement	950	4.83	
Water	645	10.34	
	1595	15.17	105.14
Foam	28	11.83	
	1623	27.00	60.11

The exemplary grout mixes set forth above have been found satisfactory for use in a number of applications. However, as was briefly noted above, there are a number of factors which may be present in a grouting job which tend to make it more difficult than usual to maintain the fluidity of the grout as it is pumped longitudinally through the annular cavity: not only may the warmth of the environment and the dryness of the pipe and liner hasten hydration of the grout, but resistance to the grout injection may be very significantly increased if the exterior of the liner pipe is ribbed or corrugated. An example of a liner pipe having such an exterior is "Spirolite™" HDPE pipe which is available from Chevron Plexco, 14381 Lear Blvd., Reno, Nev. 89506. The Spirolite™ piping is manufactured with a spiral external corrugation which gives it relatively greater rigidity for its weight, but this corrugation also naturally impedes the flow of grout longitudinally through the annular cavity between the liner and the pipe in which it is installed. To illustrate this, FIG. 3 shows a length of sewer pipe 80 in which a spirally corrugated liner pipe 82 has been installed, so as to form an annular cavity 84. The fluid grout 86 of the present invention is injected longitudinally through this cavity in the manner previously described (from the left in FIG. 3), and this flows longitudinally through the cavity generally in the direction indicated by arrows 88, 89, behind a leading edge 90. The multiplicity of spiral corrugations 92 extend into the annular cavity 84 more-or-less perpendicularly to the flow path of the grout indicated by arrows 88 and 89, and so these corrugations tend to impede the flow of the grout in a longitudinal direction through the cavity, particularly if the grout is relatively thick and viscous; the resulting resistance thus tends to increase the injection pressure.

It has been discovered that the difficulties thus encountered when attempting to grout externally corrugated liner pipe such as Spirolite™ can be overcome using the grout of the present invention, specifically, by using a grout mix similar to those discussed above but having an increased water-to-cement ratio, so that the mix is significantly more fluid and thus more easily pumped through an annular cavity against the resistance offered by the corrugations or ribs.

Furthermore, the higher water-to-cement ratio offsets the absorption (i.e., water loss from the fluid grout) which is experienced due to the much greater external surface area of spirally corrugated pipe such as Spirolite™. Consequently, it has been found that foamed, pumpable cement grouts in accordance with the present invention having a water-to-cement ratio in the range of about 0.80 (or less) to about 1.00 are eminently suitable for these applications. The following tables illustrate two such grout mixes, both of these having a water-to-cement ratio of 1.00:

TABLE 3

MATERIALS	WT., LBS.	VOLUME, CF.	UNIT WT., PCF
Cement	932	4.74	
Water	932	14.94	
	1864	19.68	94.72
Foam	18	7.50	
	1882	27.18	69.24

TABLE 4

MATERIALS	WT., LBS.	VOLUME, CF.	UNIT WT., PCF
Cement	649	3.30	
Water	649	10.40	
	1298	13.70	94.74
Foam	32	13.33	
	1330	27.03	49.20

The range of suitable unit weights for grouts having water-to-cement ratios in this range (about 0.80-1.00) has been found to extend from about 48 PCF to about 70 PCF. As with the other grout mixes described above, a number of substitutions or additives can be made in the grout mixes having these higher water-to-cement ratios. In particular, fly ash can readily be substituted for cement in these mixes, being that it gives a very fluid grout mixture, but it must be kept in mind that a decrease in compressive strength may be encountered when using increased levels of fly ash in the composition. Also, superplasticizing agent may be optionally used in these mixes, preferably in the range of about 6-12 ounces per hundred weight of cement. Still further, these compositions can benefit greatly from the addition of bentonite in many applications, being that it minimizes the bleeding of water from the grout. It should also be recognized that, although the grout mixes having water-to-cement ratios in the range of 0.80-1.00 are most notably suitable for use with externally ribbed pipe liners, they may also be used with smooth-sided (i.e., non-corrugated) liners in some applications.

The mixes of the present invention also provide a light-weight cellular grout which is eminently suited to use for filling the annular cavities 108 of the "T-LOCK"-type liner system, as shown in FIG. 4. Because the material is both highly fluid and light in weight, the problem of excessive pressures developing against the lower sidewalls and bottom of the liner pipe is obviated. In this case, the grout flows through an elongate, curved path from the injection points, and circumferentially or annularly along the exterior of the liner pipe, rather than in a direction parallel to the long axis of the conduit/liner, i.e., the flow is generally in the direction of the curved axis of the cavity or chamber 108.

In using the grout mixes and techniques described above, a number of more general factors have also been found important in achieving successful grouting of HDPE sewer pipe liners:

- a) injection pressure should be closely monitored and carefully controlled by regulating the velocity and viscosity of the grout.
- b) densities should be checked on every batch both before and after foaming to insure that the grout was properly batched.
- c) variations and batched density should be corrected by adding water, foam, or both.
- d) no batch older than two hours should be used on a long run.
- e) pressure monitoring equipment should be carefully calibrated.

Properly trained personnel and quality control of the cellular foam concrete grout have also been found to be important factors in successful grouting of sewer pipe liners.

The foregoing description has focussed largely on the exemplary application of the present invention to the grouting of HDPE pipe liners; however, it should be understood that the grout mixes and grouting methods of the present invention may be used to grout a wide variety of void spaces in addition to those discussed. For example, these may be used to grout the annular space between the wire bundle and sheath pipe in bridge cable assemblies. It is thus to be recognized that these and various other modifications may be made to the illustrative embodiments described herein without departing from the spirit and scope of the present invention, and so the invention is not to be limited except as by the appended claims.

What is claimed and desired to be secured by Letters Patent of the United States is:

- 1. A method for lining a conduit, said method comprising the steps of:
 - placing a liner in said conduit so that at least one cavity is formed intermediate said conduit and said liner, an interior of said liner being maintained substantially unpressurized, and said liner having a tendency to collapse if subjected to an external pressure in excess of a predetermined maximum pressure;
 - forming a pumpable cement grout, said grout comprising:
 - hydraulic cement;
 - water in an amount sufficient so that the water-to-cement ratio of said grout is from about 0.60 to about 1.00 by weight; and
 - pre-generated aqueous foam in an amount sufficient to adjust the wet density of said grout to a value of from about 48 to about 72 pounds per cubic foot;
 - pumping said cement grout into said cavity under positive pressure, so that said grout fills said cavity by flowing in a direction generally along an axis of said cavity; and
 - maintaining said positive pressure under which said cement grout is pumped into said cavity intermediate said conduit and liner at about equal to or less than said predetermined maximum pressure.
- 2. The method of claim 1, wherein the step of forming said pumpable cement grout further comprises:
 - determining the density of said liner; and
 - mixing said pre-generated aqueous foam into said grout in an amount sufficient to adjust said density of said grout to a value substantially equal to or less than said density of said liner so as to avoid said liner floating on said grout to the top of the interior of said conduit.
- 3. The method of claim 2, further comprising the step of directing a flow of fluid through said liner, and wherein the step of determining the density of said liner comprises determining the density of said liner carrying said flow of said fluid.

4. The method of claim 3, wherein the step of directing said flow of fluid through said liner further comprises backing said flow of fluid up into said liner, so that said density of said liner is increased, so as to permit said density of said grout to be increased and still remain equal to or less than said density of said liner.

5. The method of claim 4, wherein the step of backing said flow of fluid up into said liner further comprises the step of backing said flow of fluid up so as to substantially fill said liner with said fluid.

6. The method of claim 1, wherein the step of placing a liner in said conduit comprises:

placing a tubular liner in said conduit so that a generally annular cavity is formed intermediate said conduit liner.

7. The method of claim 6, wherein the step of placing said tubular liner in said conduit comprises:

placing a tubular liner in said conduit which has an internal diameter equal to or less than about 60 inches, so that access to said interior of said liner is available at least one manhole located along a length of said liner.

8. The method of claim 6, wherein the step of placing said tubular liner in said conduit comprises:

placing a tubular liner in said conduit which has an internal diameter equal to or greater than about 60 inches, so that access to said interior of said liner is available through a bore of said liner.

9. The method of claim 6, wherein the step of placing said tubular liner in said conduit comprises:

placing a tubular liner in said conduit which has a generally continuous cylindrical outer surface, so that a substantially continuous annular cavity is formed along a length of said liner.

10. The method of claim 9, wherein the step of pumping said grout into said cavity comprises:

pumping said grout into said substantially continuous annular cavity so that said grout fills said cavity by flowing in a direction generally along a longitudinal axis of said liner.

11. The method of claim 6, wherein the step of placing said tubular liner in said conduit comprises:

placing a tubular liner in said conduit which has a plurality of longitudinally-spaced, radially extending support members formed on an exterior thereof, so that said support members engage an interior surface of said conduit and form a plurality of individual cavities which extend annularly about said liner.

12. The method of claim 11, wherein the step of pumping said grout into said cavity comprises:

pumping said grout into each of said annularly-extending cavities so that said grout flows therein in a direction generally along a curved axis of said cavity which extends circumferentially about said liner.

13. The method of claim 12, wherein the step of forming said grout further comprises:

forming said grout with said pre-generated aqueous foam in an amount which is sufficient to reduce said weight density of said grout to a density at which a weight of said grout filling said annular cavity is insufficient to cause a pressure exceeding said maximum pressure to be exerted against bottom portions of said liner.

14. The method of claim 1, wherein the step of forming said grout further comprises:

forming said pumpable cement grout with fly ash present in a predetermined amount.

15. A method of lining a pipe, said pipe having a longitudinal extent and a predetermined internal diameter, said

pipe further having access to the interior thereof from the surface at first and second longitudinally spaced-apart access manholes, said method comprising:

placing a tubular liner in said pipe, said liner having an external diameter such that an annular cavity is formed intermediate said pipe and said liner, an interior of said liner being maintained at substantially atmospheric pressure and said liner further having a tendency to collapse if subjected to an external pressure which is in excess of a maximum pressure which exceeds atmospheric pressure by a predetermined amount;

forming a pumpable cement grout, said grout comprising:

hydraulic cement;

water in an amount sufficient so that the water-to-cement ratio of said grout is from about 0.60 to about 1.00 by weight; and

pre-generated aqueous foam in an amount sufficient to adjust the wet density of said grout to a value of from about 48 to about 72 pounds per cubic foot;

pumping said cement grout under positive pressure into said annular cavity so that said grout fills said annular cavity by flowing in a generally longitudinal direction through said pipe from said first access manhole towards said second access manhole, said pressure under which said cement grout is pumped into said annular cavity being maintained about equal to or less than said maximum pressure; and

terminating said pumping of said cement grout into said annular cavity when said flow of said grout through said pipe reaches said second access manhole.

16. The method of claim 15, wherein the step of forming said pumpable cement grout comprises:

determining the density of said liner; and

mixing said pre-generated aqueous foam into said grout in an amount which is sufficient to adjust said wet density of said grout to a density which is substantially equal to or less than that of said liner, so as to avoid said liner floating on said grout to the top of the interior of said pipe.

17. The method of claim 16, further comprising the step of directing a flow of fluid through said liner, and wherein the step of determining the density of said liner comprises determining the density of said liner carrying said flow of said fluid.

18. The method of claim 17, wherein the step of directing said flow of fluid through said liner further comprises backing said flow of fluid up into said liner, so that said density of said liner is increased, so as to permit said density of said grout to be increased and still remain equal to or less than said density of said liner.

19. The method of claim 18 wherein the step of backing said flow of fluid up into said liner further comprises:

backing said flow of fluid up into said liner so that said liner is substantially filled by said fluid.

20. The method of claim 19 wherein the step of backing said flow of fluid up into said liner further comprises:

backing said flow of fluid up into said liner so that said access manholes are at least partially filled upwardly thereby, so as to ensure complete filling of said liner.

21. The method of claim 1, wherein the step of placing said tubular liner in said conduit comprises:

placing a tubular liner in said conduit which has an internal diameter equal to or less than about 60 inches, so that access to said interior of said liner is available at least one manhole located along a length of said liner, said liner being sized so that a radial clearance of about 3 inches or less is formed between said liner and said conduit.

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22. A method for lining a conduit, said method comprising the steps of:

placing a tubular liner in said conduit so that at least one cavity is formed intermediate said conduit and said liner, an interior of said liner being maintained substantially unpressurized and said liner having a tendency to collapse if subjected to an external pressure in excess of a predetermined maximum pressure, said conduit having an internal diameter equal to or less than about 60 inches so that access to said interior of said liner is available at least one manhole located along a length of said liner, and said liner being sized so that a radial clearance of about 3 inches or less is formed between said liner and said conduit;

forming a pumpable cement grout, said grout comprising: hydraulic cement;

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water in an amount sufficient so that the water-to-cement ratio of said grout is from about 0.60 to about 1.00 by weight; and

pre-generated aqueous foam in an amount sufficient to adjust the wet density of said grout to a value of from about 48 to about 72 pounds per cubic foot;

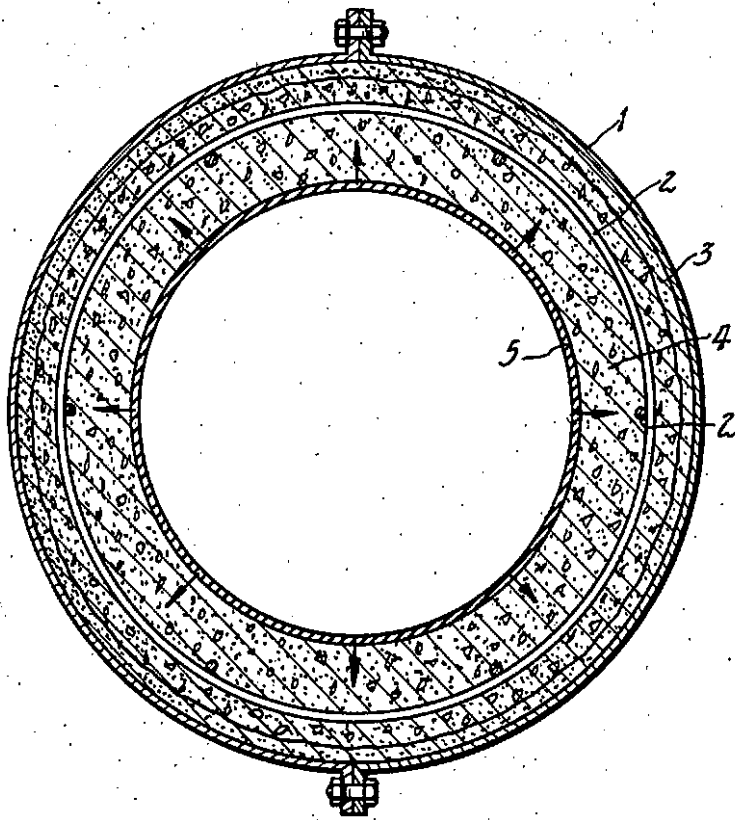
pumping said cement grout into said cavity under positive pressure, so that said grout fills said cavity by flowing in a direction generally along an axis of said cavity; and maintaining said positive pressure under which said cement grout is pumped into said cavity intermediate said conduit and liner at about equal to or less than said predetermined pressure.

* * * * *

June 28, 1949.

F. L. FITZPATRICK
MANUFACTURE OF PRESTRESSED CONCRETE
PIPE AND THE LIKE
Filed July 19, 1947

2,474,660



INVENTOR

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Attys

UNITED STATES PATENT OFFICE

2,474,660

MANUFACTURE OF PRESTRESSED
CONCRETE PIPE AND THE LIKE

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Application July 19, 1947, Serial No. 762,216
In Australia August 19, 1946

4 Claims. (Cl. 25-154)

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In the manufacture of reinforced concrete pipes by the rotary process I have previously subjected the pipe when it is newly formed and while it remains in the mould, to internal pressure in order to expel surplus water, prestress the metal reinforcement and obtain other advantageous results.

According to my previous procedure, as used or proposed, the required internal pressure has been imparted to the pipe by means of an expandible core of rubber, metal or other suitable material, and sand or other granular or powdered material (hereinafter included in the term "sandy material") has been interposed between the core and the inner surface of the pipe to serve as a pressure transmitting medium.

In order that the metal reinforcement may be pretensioned during this operation, it has heretofore been my normal practice to relax the outer mould slightly before or during the expanding operation, and thereby permit of a slight distension of the pipe and reinforcement therein. However, such relaxing of the outer mould may require a more elaborate and expensive mould construction than would otherwise be necessary, while the resultant movement is not uniform around the circumference of the pipe, and the operation is time absorbing.

The general object of the present invention is to provide improvements in the manufacture of prestressed concrete pipes and like prestressed concrete articles each having a cylindrical or substantially cylindrical inner cavity, while a specific object is to obviate the aforesaid disadvantages of the existing art.

The present invention broadly comprises inserting the reinforcement in a mould, lining the inner surface of the mould with a layer of compressible material which ultimately becomes incorporated in and forms the outer layer of the pipe, forming therein the main body of a reinforced concrete pipe or like reinforced concrete article having a cylindrical or substantially cylindrical inner cavity and subsequently, while said pipe or like article is in the newly formed condition and has not finally set by chemical hardening to any appreciable extent, subjecting it to outwardly directed pressure, so that the said compressible material yields sufficiently to permit of the distension of the main body of the pipe or like article necessary to produce the required pretensioning of the reinforcement.

As the application of the invention to a reinforced pipe does not differ from its application to like reinforced concrete articles having cylindrical or substantially cylindrical inner cavities,

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a pipe only is referred to in the following description.

The term "compressible material" is used herein to mean a material which will contract sufficiently in volume under the pressure in the process to permit the desired pretensioning of the reinforcement of the pipe.

A subsidiary feature of the invention resides in applying said layer of compressible material to the inner surface of the mould by pouring a fluid cementitious mixture into the mould while the latter is being rotated; that is to say, the said layer is formed by the same procedure as that by which the main body of the pipe is subsequently formed.

The compressible layer may be formed of a cement mixture incorporating a foaming agent and/or fibrous material and/or any other constituents, which will result in the formation on the inner surface of the mould of a layer of material which contains a substantially greater percentage of voids and/or of expressible liquid than the concrete of which the main body of the pipe is to be formed. On account of this higher percentage of voids and/or of expressible liquid this layer on the inner surface of the mould is substantially more compressible than the concrete of which the main body of the pipe is formed. It is necessary for the latter concrete to be compact and to contain a relatively low percentage of voids because otherwise upon the subsequent application of pressure according to this process there would be excessive yielding and change of the inner diameter of the pipe and also this concrete would pass through the reinforcement instead of stretching the latter.

The term "concrete" as used herein comprehends mixtures of Portland or other hydraulic cement with water and any other suitable material such as sand and/or crushed stone.

Other features of the invention are hereinafter described.

One practical specific example of the invention will now be described with reference to the accompanying drawing showing a cross-section through a mould containing a pipe formed with an outer compressible layer and containing an inner core of rubber or other expandible material. The mould 1 may be any suitable construction of rotary or centrifugal pipe mould. This mould, in which the necessary metal reinforcement 2 has been inserted, is rotated in the usual way, and a relatively fluid cement mixture 3 which will ultimately set to form on the inner surface of the mould a relatively thin compressible layer,

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is poured thereinto and passes through the reinforcement, and is centrifugally distributed over the inner surface of the mould outside the reinforcement. The layer of material so formed may conveniently be of the order of about one eighth to one quarter of an inch in thickness.

Preferably the said mixture comprises cement, water, a suitable fibrous material (e. g. short fibred asbestos) and a small amount of a foam-generating agent, such as sodium resinate. However, many different materials which will form a layer possessing a suitable measure of compressibility may alternatively be used.

Preferably, after the said mixture has been introduced and distributed the mould should be rotated at a sufficiently high speed to compact the mixture to some extent.

The main body of the pipe is then formed in the usual way by pouring into the rotating mould the required amount of a suitable concrete mixture 4 which is centrifugally distributed on and united to the inner surface of the previously formed outer compressible layer.

After the pipe so formed has set by rotation sufficiently to be self-sustaining, but before chemical hardening due to hydration has proceeded to any appreciable extent, a hollow expandible core 5 is inserted therein, the pipe at this stage being still contained within the outer mould.

Preferably the core is substantially smaller in cross section than the interior of the pipe, in which case the intervening space is filled with sandy material.

The core is then expanded by supplying thereto a fluid under pressure so that pressure is transmitted outwardly approximately in the direction of the arrows through the granular material to the surrounding pipe. The pressure so imparted to the concrete cylinder is sufficiently high to expand it slightly, and this expansion is permitted by the yielding of the outer layer of compressible material which is simultaneously compressed.

The pressure applied to the core may be of the order of 300 pounds per square inch but this depends in every case upon such factors as the diameter of the pipe in question, the amount of circumferential reinforcement and the degree of prestressing required.

In the course of the compression air and/or liquid are expelled and will escape through mould openings, or perforations can be provided in the mould for that purpose. Where the outer layer includes expressible water this may pass through the main body of concrete into the layer of sandy material.

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Consequently, by this invention the desired prestressing of the reinforcement of the concrete is effected in a simple and expeditious manner without the necessity for relaxing the outer mould or of using moulds of special construction, and substantial economies are obtained while the desired even degree of expansion around the full circumference is achieved.

I claim:

1. The manufacture of a prestressed reinforced concrete pipe, or like prestressed reinforced concrete article having a cylindrical or substantially cylindrical inner cavity, comprising inserting the reinforcement in a mould, lining the inner surface of the mould with a layer of compressible material (which ultimately becomes incorporated in and forms the outer layer of the pipe or like article), forming therein by the rotary process the main body of a reinforced concrete pipe, or like reinforced concrete article having a cylindrical or substantially cylindrical inner cavity, and subsequently subjecting the said pipe or like article to outwardly directed pressure, so that the said compressible material yields sufficiently to permit of the distension of the main body of the said pipe or like article.

2. The manufacture of a prestressed reinforced concrete pipe, or like prestressed reinforced concrete article, having a cylindrical or substantially cylindrical inner cavity, as claimed in claim 1, in which the inner surface of the mould is lined with the layer of compressible material by pouring a fluid cementitious mixture into the mould while the latter is being rotated.

3. The manufacture of a prestressed reinforced concrete pipe, or like prestressed reinforced concrete article having a cylindrical or substantially cylindrical inner cavity, as claimed in claim 1, in which the compressible material is a cement mixture incorporating a foaming agent.

4. The manufacture of a prestressed reinforced concrete pipe, or like prestressed reinforced concrete article having a cylindrical or substantially cylindrical inner cavity, as claimed in claim 1, in which the compressible material is a cement mixture incorporating fibrous material.

FRANK LIONEL FITZPATRICK.

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(12) **United States Patent**
Blömer et al.

(10) **Patent No.:** **US 6,174,569 B1**
(45) **Date of Patent:** ***Jan. 16, 2001**

(54) **THREE-LAYER METAL PIPE COATING COMPOSITIONS AND PROCESS FOR THE EXTERIOR COATING OR METAL PIPES BY A THREE-LAYER METHOD**

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(73) **Assignee:** **BASF Coatings AG, Muenster-Hiltrup (DE)**

(*) **Notice:** This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

(21) **Appl. No.:** **08/892,081**

(22) **Filed:** **Jul. 14, 1997**

Related U.S. Application Data

(63) Continuation of application No. 08/522,379, filed as application No. PCT/EP94/00888 on Mar. 22, 1994, now abandoned.

(30) **Foreign Application Priority Data**

Mar. 31, 1993 (DE) 43 10 525

(51) **Int. Cl.⁷** **B05D 1/36; B29D 23/00; B32B 15/08; F16L 9/147**

(52) **U.S. Cl.** **427/410; 138/146; 427/386; 428/35.9; 428/416; 523/466; 525/481**

(58) **Field of Search** **428/36, 35.9, 416; 525/481; 523/466; 427/410, 386; 138/146**

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Primary Examiner—Robert E. L. Sellers

(57) **ABSTRACT**

The invention relates to three-layer metal pipe coating compositions based on a powder primer, on a thermoplastic hard adhesive and on a polyolefin cladding. The powder primer contains epoxidized novolak resins, phenolic crosslinking agents and fillers based on crystalline silicic acid modifications. The invention likewise relates to a process for the exterior coating of metal pipes by a three-layer method, in which the powder primer described is applied to the metal pipe, a thermoplastic hard adhesive is applied to the powder primer, and subsequently a polyolefin cladding is applied.

13 Claims, No Drawings

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THREE-LAYER METAL PIPE COATING COMPOSITIONS AND PROCESS FOR THE EXTERIOR COATING OF METAL PIPES BY A THREE-LAYER METHOD

This is a continuation of U.S. pat. application Ser. No. 08/522,379, filed Oct. 30, 1995, abandoned which is a 371 of PCT/EP94/00888 filed Mar. 24, 1994.

FIELD OF THE INVENTION

The present invention relates to three-layer metal pipe coating compositions based on a powder primer containing epoxy resins and phenolic crosslinking agents, on a thermoplastic hard adhesive and on a polyolefin cladding. Furthermore, the invention relates to a process for the exterior coating of metal pipes by a three-layer method.

BACKGROUND OF THE INVENTION

Metal pipes are used worldwide for the transportation of, for example, petroleum, petroleum products, gas, water and solids from the place where they are found or produced to the consumer. Metal pipes must be protected on the one hand against corrosion and on the other hand against mechanical defects, in order to ensure the operational reliability of the lines over a long period. Exterior coatings of metal pipes must possess a high impact strength, compressive strength and abrasion resistance, and it is necessary to prevent damage to the exterior coatings during the transportation, storage, laying and operation of the metal pipes. In addition, exterior coating compositions for metal pipes should have a good aging resistance, good weathering resistance during the interim storage of the pipes, an outstanding resistance to external influences, good dielectric properties and a low permeability to water vapor and to gases.

One-coat systems based on epoxy resin are known for the exterior coating of metal pipes, but because of the low mechanical strength of the epoxy resin coatings these systems are disadvantageous when subjected to impact stress.

It is also known to coat the exterior of metal pipes using a three-layer method which involves first applying a powder primer based on epoxy resin to the metal substrate, applying a hot melt adhesive to the powder primer, and subsequently applying a polyolefin cladding. Three-layer coatings of this kind for metal pipes are described in, for example, EP-A-57 823, GB 1 542 333, DE-A-22 22 911, DE-A-22 57 135, DE-A-19 65 802, DE-A-29 44 809 and DE-A-32 30 955. These three-coat systems comprising epoxy resin primer, thermoplastic hard adhesive and polyolefin cladding material go a long way to fulfilling many of the requirements. They are markedly superior to the one-coat systems. The three-coat systems combine the positive properties of the thermosetting primer layer (good adhesion to steel) with the thermoplastic polyolefin cladding (toughness, long-term resistance, good dielectric properties, low gas permeability).

The use of powder coatings based on epoxy resins, dicyandiamide curing agents and crystalline or amorphous silicic acids as powder primer in the three-layer exterior coating compositions for metal pipes is known. Also known are powder primers comprising epoxy resins, phenolic curing agents and amorphous silicic acid fillers.

However, the disadvantages of the three-layer systems known up to now consist in an inadequate peel strength after storage in hot water, in which partial detachment of the powder coating from the substrate occurs during peeling after storage in hot water. Furthermore, the properties with regard to submigration during cathodic delamination are a continual target for improvement.

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The object of the present invention was therefore to provide multi-layer coatings for the coating of metal pipes, which coatings do not have the disadvantages described above. The intention was thus to increase, in particular, the peel resistance of the coatings after storage in hot water, and also to obtain excellent results in respect of cathodic delamination. The coatings were to be firmly adhering and resistant and were to provide a high degree of protection against corrosion.

SUMMARY OF THE INVENTION

The object of the present invention is achieved by three-layer metal pipe coating compositions based on a powder primer containing epoxy resins and phenolic crosslinking agents, on a thermoplastic hard adhesive and on a polyolefin cladding. The metal pipe coating compositions are characterized in that the powder primer contains epoxidized novolak resins, phenolic crosslinking agents and fillers based on crystalline silicic acid modifications.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The epoxy resin primer, which is in powder form, contains epoxy novolak resins. In these novolak resins, the phenolic hydroxyl groups are etherified with alkyl or aryl groups or the like. Epoxide groups are incorporated into the molecule by reacting the phenolic hydroxyl groups with epichlorohydrin. The so-called epoxy novolak is formed on the basis of novolaks. The epoxidized novolaks are related in structure to bisphenol A resins. The basic model for the epoxidized novolaks is the diglycidyl ether of bisphenol F. Epoxidized novolaks can be prepared by epoxidization of novolaks which are composed, for example, of from 3 to 4 phenolic rings interconnected via methylene bridges. Other novolak resins which can be used are alkyl-substituted phenols which are reacted with formaldehyde. Epoxidized novolak resins have a higher functionality than bisphenol A resins. It is preferred to use epoxidized novolak resins having an average functionality in the range from 2.4 to 2.8 and an epoxide equivalent weight in the range from 600 to 850.

Suitable epoxidized novolak resins are commercially available, for example, under the designation DER 672U (Manufacturer: Dow Chemicals), Epikote 2014 (Manufacturer: Shell) and GT 7220 and GT 7255 (Manufacturer: Ciba Geigy).

In order to cure the epoxidized novolak resins, the powder primer contains phenolic crosslinking agents. These may, for example, be any phenolic resin, provided it has the methylol functionality which is necessary for reactivity. Preferred phenolic resins are reaction products of phenol, substituted phenols and bisphenol A with formaldehyde, which products are prepared under alkaline conditions. Under such conditions the methylol group links to the aromatic ring in either the ortho or para position. The present invention gives particular preference to employing, as phenolic crosslinking agents, hydroxyl group-containing bisphenol A or bisphenol F resins having a hydroxy equivalent weight in the range from 180 to 600, particularly preferably in the range from 180 to 300. Such phenolic curing agents are prepared by reacting bisphenol A or bisphenol F with components which contain glycidyl groups, for example the diglycidyl ether of bisphenol A. Phenolic crosslinking agents of this kind are available, for example, under the trade name DEH 81, DEH 82 and DEH 87 from Dow, DX 171 from Shell and XB 3082 from Ciba Geigy.

The epoxy resin primer contains one or more catalysts which are suitable for the epoxy resin/phenolic resin curing. Suitable catalysts are phosphonium salts of organic or inorganic acids, imidazoles and imidazole derivatives, quaternary ammonium compounds and amines. The catalysts are generally employed in proportions of from 0.001% by weight to about 10% by weight, based on the overall weight of the epoxy resin and the phenolic crosslinking agent.

Examples of suitable phosphonium salt catalysts are ethyltriphenylphosphonium iodide, ethyltriphenylphosphonium chloride, ethyltriphenylphosphonium thiocyanate, ethyltriphenylphosphonium acetate/acetic acid complex, tetrabutylphosphonium iodide, tetrabutylphosphonium bromide and tetrabutylphosphonium acetate/acetic acid complex. These and other suitable phosphonium catalysts are described in, for example, U.S. Pat. Nos. 3,477,990 and 3,341,580.

Examples of suitable imidazole catalysts are 2-styrylimidazole, 1-benzyl-2-methylimidazole, 2-methylimidazole, 2-butylimidazole. These and other imidazole catalysts are described in, for example, Belgian Patent No. 756,693.

Some commercially available phenolic curing agents already contain catalysts for the epoxy resin/phenolic resin crosslinking.

The powder primer contains crystalline silicic acid modifications as filler. These modifications are conventionally employed in a proportion of from 10 to 50% by weight, based on the overall weight of the powder primer. In some cases, it is also possible to have proportions of more than 50% by weight of filler. Crystalline silicic acid modifications can be obtained, for example, under the names Sikron SH 500 and Sikron SF 600 (Manufacturer: Quarzwerke GmbH) and Quarzsand F 31, F 32, F 34, F 36, G 30, G 32, G 34, G 36, H 30, H 31, H 32, H 33 and H 34 (Manufacturer: Quarzwerke GmbH).

The crystalline silicic acid modifications include quartz, cristobalite, tridymite, keatite, stishovite, melanophlogite, coesite and fibrous silicic acid. The fillers preferably employed in the powder primers are surface-treated crystalline silicic acid modifications. These are, for example, silane-modified silicic acid modifications based on quartz, cristobalite and vitreous fused silica. Fillers of this kind are available under the registered trademark Silbond® (Manufacturer: Quarzwerke GmbH).

It is particularly advantageous if the silicic acid modifications used as fillers in the powder primers are glycidyl-functionalized. Such modifications are available, for example, under the name Silbond 600 EST and Silbond 6000 EST (Manufacturer: Quarzwerke GmbH) and are prepared by reacting crystalline silicic acid modifications with epoxy silanes.

The powder primer preferably contains from 10 to 40% by weight, based on the overall weight of the powder primer, of crystalline silicic acid modifications.

The powder primers may also contain other inorganic fillers, for example titanium dioxide, barium sulfate and fillers based on silicate, for example talc, kaolin, magnesium silicates, aluminum silicates, mica and the like. The powder primers may if desired also contain other auxiliaries and additives. Examples of these are leveling agents, flow aids and deaerating agents, for example benzoin.

The powder primers are prepared by known methods (cf. e.g. the product information leaflet from BASF Lacke +Farben AG, "Pulverlacke" [Powder Coatings], 1990) by homogenization and dispersion, for example using an

extruder, screw kneader and the like. After the powder coatings have been prepared, they are adjusted to the desired particle size distribution by milling and, if desired, by classifying and sieving.

The powder primers are applied electrostatically or triboelectrostatically to the preheated surface of the metal pipe. The applied thickness of the epoxy powder primer is usually in the range from 30 to 400 μm .

The second layer of the metal pipe coating, the thermoplastic hard adhesive, is applied either as a melt by an extrusion method or by a powder application method to the powder primer layer. Suitable adhesives (adhesion promoters) are copolymers, graft copolymers and ionomers which contain carboxyl groups, anhydride groups or groups which can be hydrolyzed to give carboxyl groups. Suitable copolymers can be prepared by copolymerizing ethylene or propylene with α,β -ethylenically unsaturated carboxylic acids such as, for example, acrylic acid, methacrylic acid, itaconic acid, crotonic acid, isocrotonic acid, maleic acid and fumaric acid, with the corresponding anhydrides or with the corresponding esters or half-esters having 1 to 8 carbon atoms in the alcohol residue. It is also possible to employ the corresponding salts of the carboxylic acids listed. Further suitable adhesives are polymers which can be prepared by grafting at least one polymer from the group comprising polyolefins with up to 10% by weight, based on the overall weight of the monomers, of at least one monomer from the group comprising α,β -ethylenically unsaturated carboxylic acids, their anhydrides, esters or salts in the presence or absence of peroxides. Thermoplastic hard adhesives which have proven suitable for coating metal pipes are copolymers of ethylene, (meth)acrylic esters and (meth)acrylic acid. Such adhesives are commercially available under the name Lucalen® (Manufacturer: BASF AG). Examples of appropriate Lucalen grades are Lucalen A 2910 M, Lucalen A 2910 M Q 47, Lucalen A 3110 M and Lucalen A 3110 M Q 244. The applied thickness of the thermoplastic hard adhesive is generally in the range from 100 to 500 μm , and the substrate temperature during the application of the thermoplastic hard adhesive is in the range from 150 to about 220° C. It should be ensured that the epoxy resin powder layer has not yet fully cured at the time of application of the adhesion promoter, in order to produce a firm bond.

To form the third layer, the metal pipe coating compositions according to the invention comprise polyolefin coating compositions which are applied to the melted adhesive at elevated temperature, usually by an extrusion method. Suitable polyolefins are low density, medium density and high density polyethylene, linear low density and linear very low density polyethylene, and also polypropylenes, their copolymers with ethylene and other monomers, and the copolymers of ethylene and of propylene with one or more comonomers from the group comprising vinyl esters, vinyl alkyl ethers, unsaturated mono- and dicarboxylic acids, and their salts, anhydrides and esters. The polyolefin coating material which is employed with particular preference is ethylene homopolymer. Suitable polyethylenes are obtainable, for example, under the tradename Lupolen® (Manufacturer: BASF AG). Examples of suitable Lupolens are Lupolen 2441 D, Lupolen 2452 D, Lupolen 3821 D and Lupolen 3652 D (BASF AG).

The present invention also relates to a process for the exterior coating of metal pipes by a three-layer method, which involves applying a powder primer based on epoxy resin to the metal pipe, applying a thermoplastic hard adhesive to the powder primer and subsequently applying a polyolefin coating material. The process is characterized in

that the powder primer contains epoxidized novolak resins, phenolic resin crosslinking agents and fillers based on crystalline silicic acid modifications. With regard to the description of the multi-layer metal pipe coating composition, reference is made to the statements made above. In the process according to the invention, the surface of the metal pipe is first conventionally cleaned to remove rust, grease, oil, dust etc. A chemical pretreatment may be carried out if desired (chromating and/or phosphatizing). The cleaned metal pipes are then heated, by inductive heating or in a gas oven, to a coating temperature of from approximately 170 to 220° C. The powder primer is applied electrostatically or by means of triboelectric charging to the hot surface of the metal pipe. Conventional application thicknesses of the powder primer are in the range from 30 to 400 μm , preferably in the range from 80 to 100 μm . In accordance with the present process, the second layer—the thermoplastic hard adhesive—is applied either as a melt by an extrusion method or by a powder application method to the powder primer layer. A particularly good bond between the powder primer layer and the adhesive layer is achieved if the degree of crosslinking of the powder primer, at the time of application of the thermoplastic hard adhesive, is from 40 to 60%. In any case, however, it should be ensured that the epoxy resin powder primer has not yet fully cured at the time of application of the thermoplastic hard adhesive, in order to achieve adequate adhesion. During the application of the thermoplastic adhesive, the substrate temperature is usually in the range from 150 to 220° C. The conventional application thickness of the thermoplastic adhesion promoter is in the range from 100 to 500 μm , preferably in the range from 180 to 350 μm . In a further step, the polyolefin cladding material is then applied by an extrusion method to the melted thermoplastic hard adhesive. Conventional applied thicknesses of the polyolefin cladding layer are in the range from 1.8 to 3.7 mm. The polyolefin cladding material is applied, in the case of small pipe diameters, by the annular die method using a crosshead, and, in the case of larger metal pipe diameters, by the extrusion cladding method using a slot die. In the annular die method, the thermoplastic adhesive can either be coextruded with the polyolefin cladding material or else the thermoplastic hard adhesive can be applied by a powder application method and the polyolefin cladding material by tube extrusion. After it has been coated in three layers, the metal pipe with sleeve is conventionally cooled in a water bath.

The three-layer metal pipe coatings which can be obtained by the process according to the invention have outstanding properties. For instance, there is no detachment of the powder primer from the substrate. Good properties are obtained in respect of the elongation at break of the polyolefin cladding layer and in respect of the specific cladding resistance. An increase is obtained in the peel resistance of the coating after storage in hot water, and the results in respect of cathodic delamination are very good.

In the following text the invention is illustrated in more detail using exemplary embodiments. Parts denote parts by weight unless stated otherwise.

COMPARATIVE EXAMPLE 1:

A powder coating is prepared having the following composition:

titanium dioxide, rutile	5% by weight
crystalline silicic acid	30% by weight
leveling agent	1% by weight
deairing agent	1% by weight
epoxy resin (Epikote 1055 from Shell) having an epoxide equivalent weight of 800)	59% by weight
diacydiamide	4% by weight

COMPARATIVE EXAMPLE 2:

A powder coating is prepared having the following composition:

titanium dioxide, rutile	5% by weight
amorphous silicic acid	30% by weight
leveling agent	1% by weight
deairing agent	1% by weight
epoxidized novolak resin (Shell Epikote 2014, EEW 700)	48% by weight
phenolic curing agent based on bisphenol A (commercial product XB 3082 from Ciba-Geigy, hydroxy equivalent weight 250)	15% by weight

EXAMPLE 1:

A powder coating is prepared from the following components:

titanium dioxide, rutile	5% by weight
crystalline silicic acid, functionalized with glycidyl groups (Silboad 6000 EST from Quarzwerke GmbH)	30% by weight
leveling agent	1% by weight
deairing agent	1% by weight
epoxidized novolak resin (Epikote 2014 from Shell, EEW 700)	48% by weight
phenolic curing agent based on bisphenol A (commercial product XB 3082 from Ciba-Geigy, hydroxy equivalent weight 250)	15% by weight

The three formulations described above (Comparative Example 1 and 2, Example 1) are processed to give powder coatings of commercially conventional particle size distribution. The three powder coatings prepared are employed as primer in a three-layer method for the exterior coating of metal pipes.

For this purpose, pipes having a diameter of 300 mm and a wall thickness of 12 mm are blasted in a blasting unit to degree of cleanliness SA 3. The peak-to-valley height should be approximately 50 μm . The pipes are then heated with an induction coil to 200 $\pm$ 5° C.

The powder coatings of Comparative Examples 1 and 2 and of Example 1 are applied electrostatically at a layer thickness of from 80 to 100 μm . After a degree of crosslinking of from 40 to 60% has been determined, a pulverulent thermoplastic hard adhesive (Lucalcn A 3110 M Q 244 from BASF AG) is in each case applied electrostatically to the powder primer in a layer thickness of 300 $\pm$ 50 μm . About 10 sec. after the extrusion of the adhesive, a 3 $\pm$ 0.2 mm thick layer of the polyolefin having the tradename Lupolen 3652 D (Manufacturer: BASF AG) is applied by an annular die

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method at $220\pm 10^{\circ}\text{C}$. About 30 sec. after completion of the three-layer coating, the pipes are cooled to room temperature in a water bath.

The three pipes obtained are divided into test rings of about 15 cm in width. CD tests in accordance with DIN 30671 are carried out on the three different three-layer structures under the conditions of 30 days at room temperature, 2 days at 65°C ., and 14 days at 65°C . in 0.5 molar sodium chloride solution.

Submigration [mm]

	2 days 65°C	14 days 65°C	30 days 23°C
Comparative Ex. 1	2	7	4
Comparative Ex. 2	2	5	4
Example 1	0	5	1

In addition, the peel resistance according to DIN 30 670 is determined for all three structures. The values found are in each case $>40\text{ N/cm}$ at 23°C .

A test segment of each layer structure is stored for 6 weeks in mains water at 80°C .

For the pipe section with the primer powder according to Comparative Example 1, peel values of about 15 N/cm are found. In this case there is detachment of the powder coating from the substrate in addition to cohesive fracture of the adhesive layer.

For the pipe section with the primer powder according to Comparative Example 2, peel values of about 20 N/cm are found. Here too, detachment of the powder coating from the substrate is observed at some points in addition to cohesive fracture of the adhesive layer.

For the pipe section with the powder primer according to Example 1, peel values of over 25 N/cm are found. Cohesive fracture occurs only in the adhesive layer.

What is claimed is:

1. A three-layer metal pipe coating composition comprising a first layer that is applied to the pipe and is a powder primer, a second layer that is a thermoplastic hard adhesive, and a third, outer layer that is a polyolefin cladding, wherein the powder primer contains epoxidized novolak resins, phenolic crosslinking agents, and crystalline silicic acid modifications.

2. A metal pipe coating composition according to claim 1, wherein the epoxidized novolak resins have an average functionality in the range from 2.4 to 2.8 and an epoxide equivalent weight in the range from 600 to 850.

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3. A metal pipe coating composition according to claim 1, wherein the phenolic crosslinking agents used are selected from the group consisting of hydroxyl group-containing bisphenol A resins and hydroxyl group-containing bisphenol F resins, wherein said resins have a hydroxyl equivalent weight in the range from 180 to 600.

4. A metal pipe coating composition according to claim 1, wherein the crystalline silicic acid modifications are glycidyl-functionalized.

5. A metal pipe coating composition according to claim 1, wherein the powder primer contains from 10 to 40% by weight of crystalline silicic acid modifications.

6. A process for the exterior coating of metal pipes by a three-layer method, comprising applying a powder primer to a metal pipe, applying a thermoplastic hard adhesive to the powder primer, and subsequently applying a polyolefin cladding, wherein the powder primer contains epoxidized novolak resins, phenolic crosslinking agents, and crystalline silicic acid modifications.

7. A process according to claim 6, wherein the epoxidized novolak resins have an average functionality in the range from 2.4 to 2.8 and an epoxide equivalent weight in the range from 600 to 850.

8. A process according to claim 6, wherein the crystalline silicic acid modifications are glycidyl-functionalized.

9. A process according to claim 6, wherein the powder primer contains from 10 to 40% by weight crystalline silicic acid modifications.

10. A process according to claim 6, wherein the phenolic crosslinking agents used are selected from the group consisting of hydroxyl group-containing bisphenol A resins and hydroxyl group-containing bisphenol F resins, wherein said resins have a hydroxyl equivalent weight in the range from 180 to 600.

11. A process according to claim 6, wherein the thermoplastic hard adhesive used comprises copolymers of ethylene and compounds selected from the group consisting of acrylic acid, methacrylic acid, esters of acrylic acid having 1 to 8 carbon atoms in the alcohol residue, esters of methacrylic acid having 1 to 8 carbon atoms in the alcohol residue, and mixtures thereof.

12. A process according to claim 6, wherein the polyolefin cladding used is a polyethylene sleeve.

13. A process according to claim 6, wherein the degree of crosslinking of the powder primer during the application of the thermoplastic hard adhesive is from 40 to 60 %.

* * * * *



US006076562A

United States Patent [19]

Kuo

[11] **Patent Number:** **6,076,562**

[45] **Date of Patent:** **Jun. 20, 2000**

[54] **PRE-STRESSED CONCRETE PIPE**

[76] **Inventor:** **Ming C. Kuo, 19350 Christina Ct., Cerritos, Calif. 90703**

[21] **Appl. No.:** **09/318,114**

[22] **Filed:** **May 25, 1999**

[51] **Int. Cl.⁷** **F16L 9/08**

[52] **U.S. Cl.** **138/175; 138/98; 138/141; 138/178; 138/DIG. 5**

[58] **Field of Search** **138/175, 98, 141, 138/178, DIG. 5**

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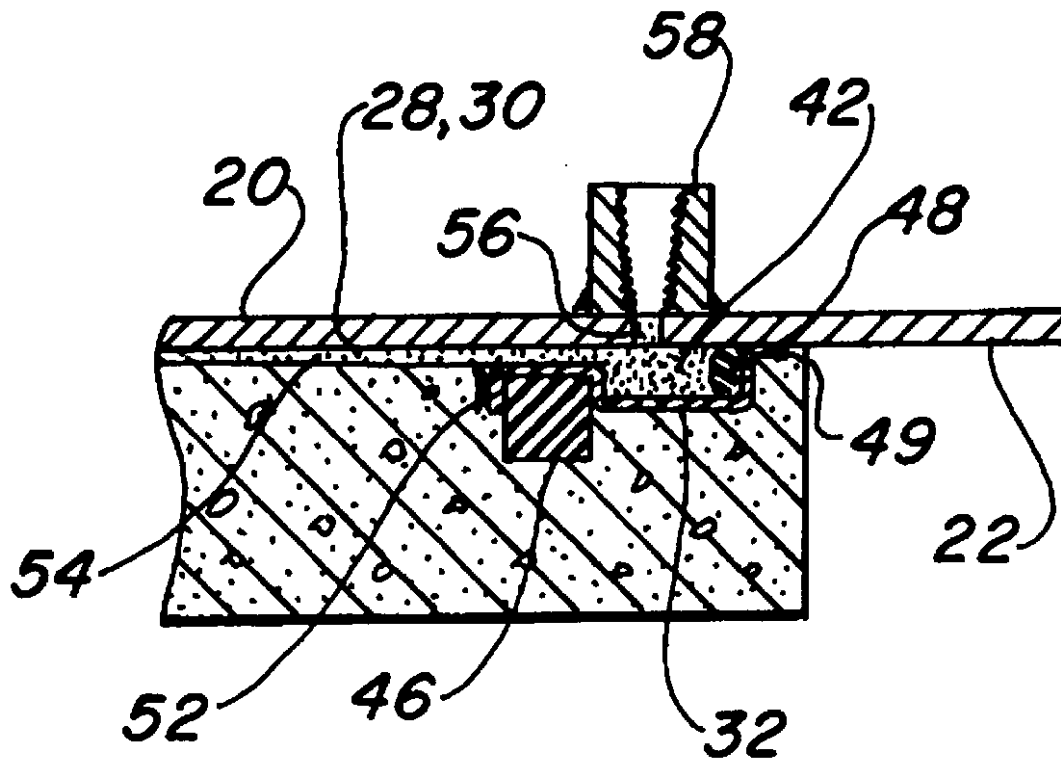
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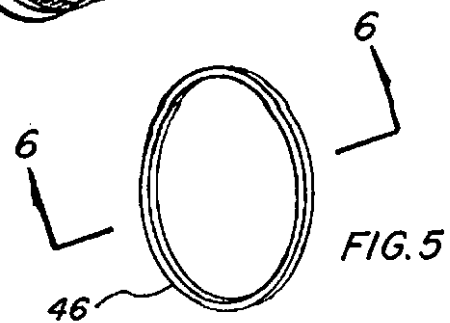
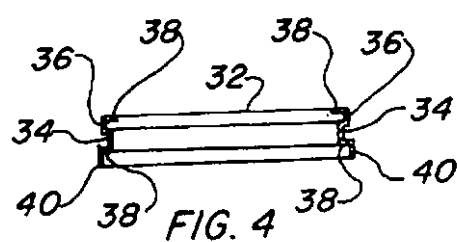
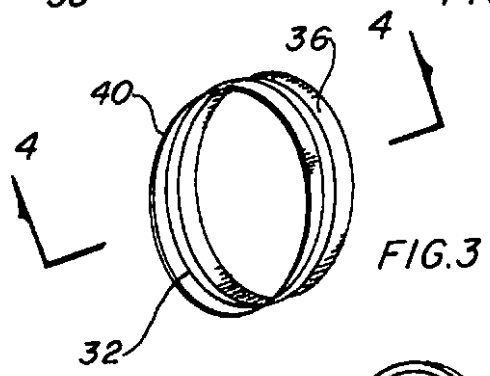
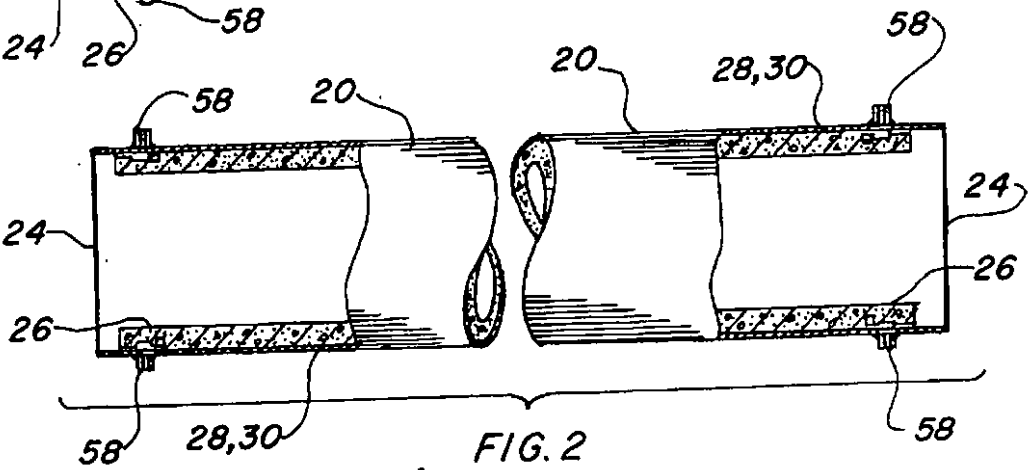
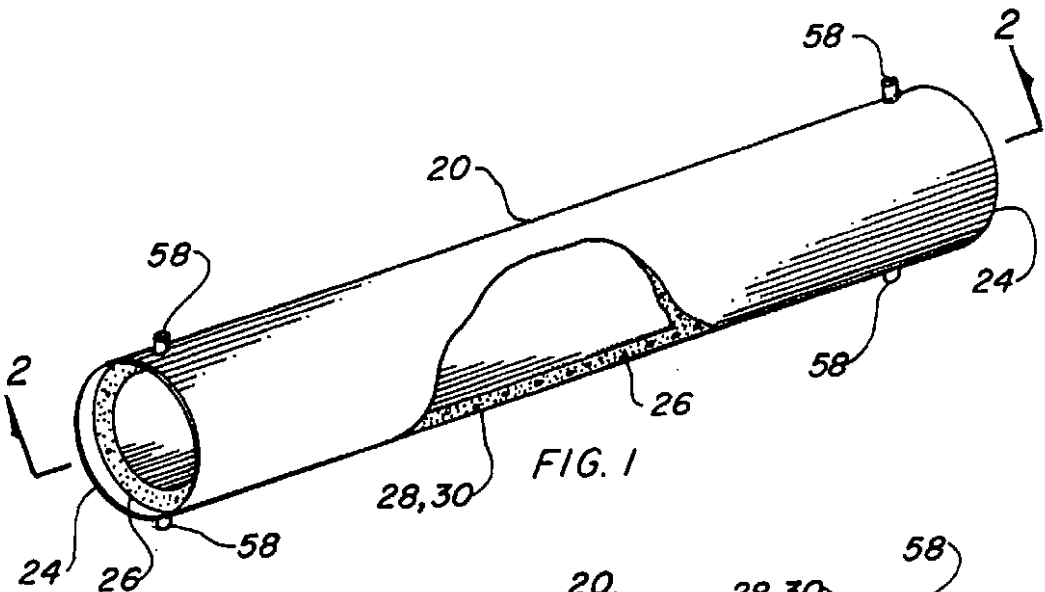
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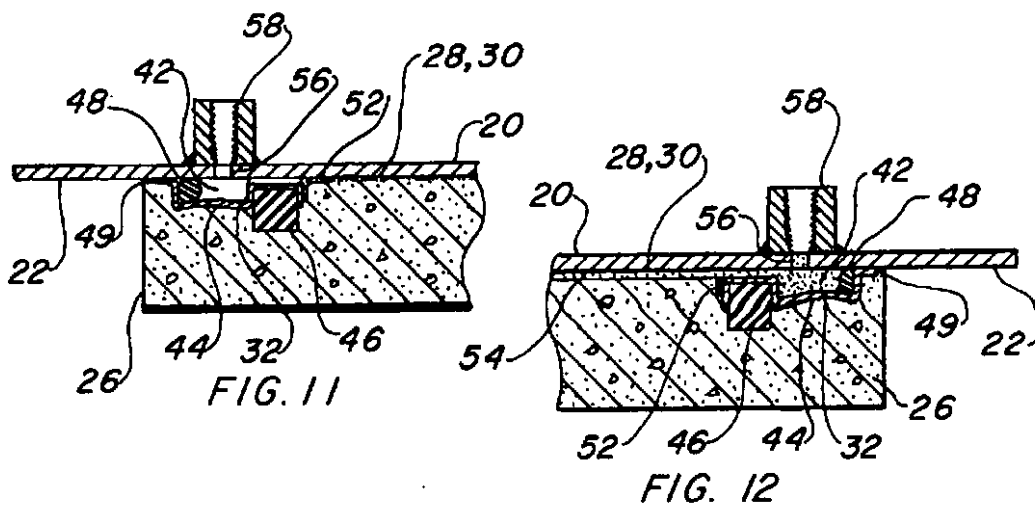
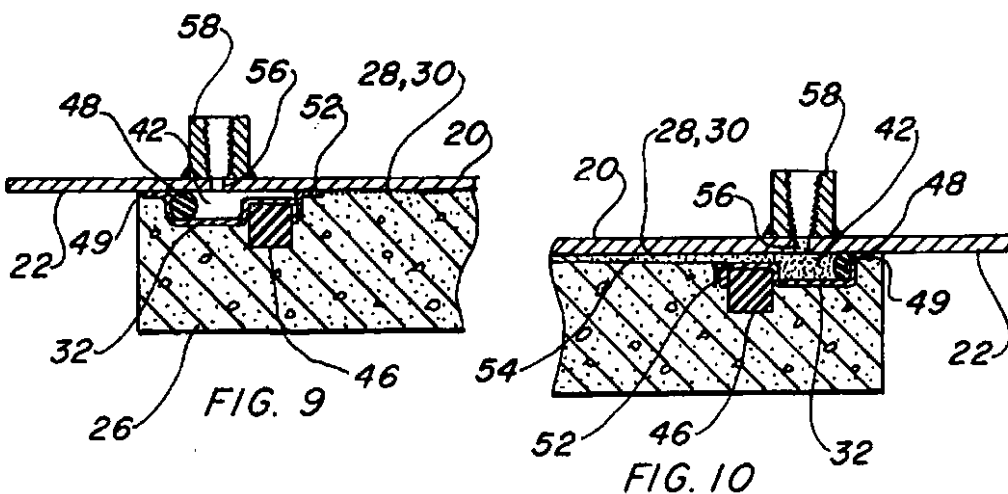
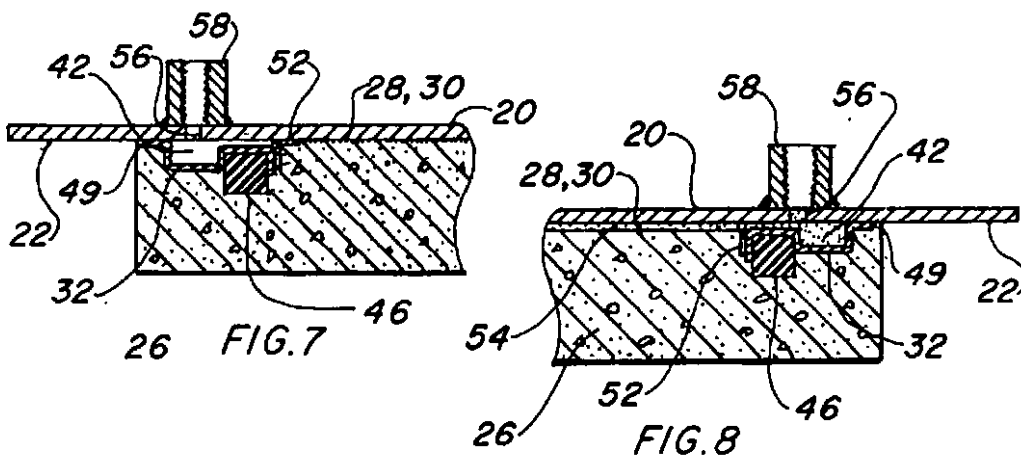
[57] **ABSTRACT**

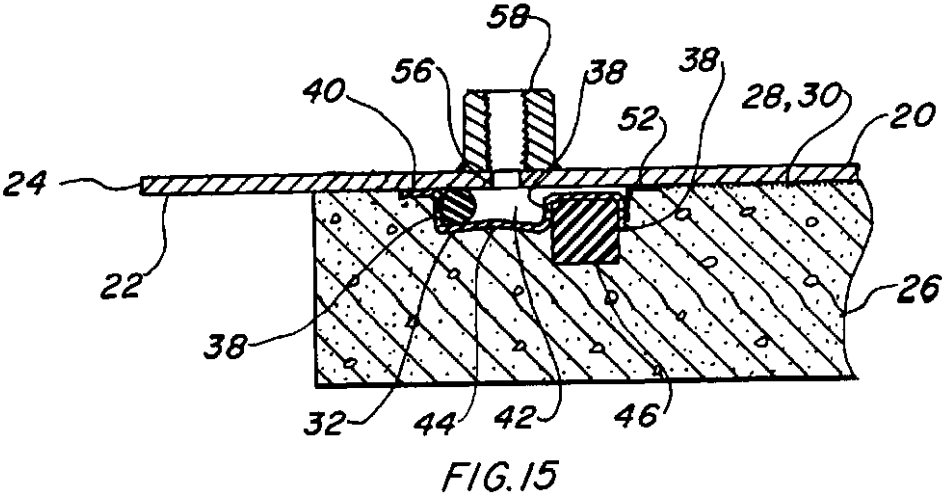
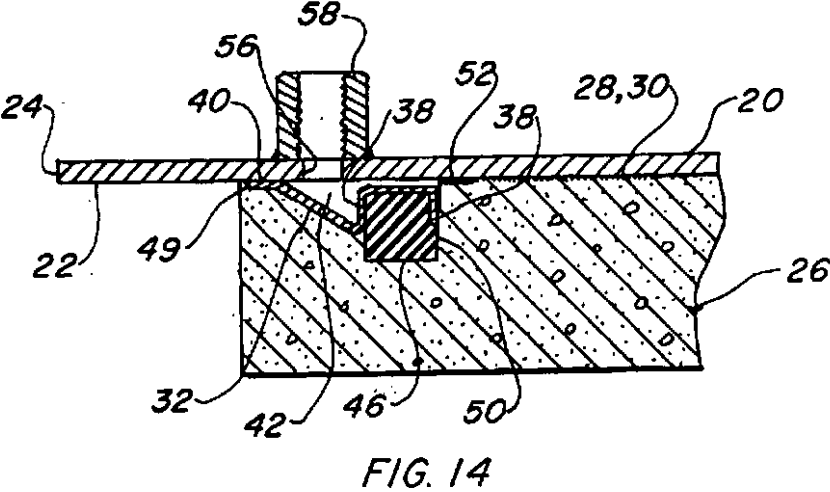
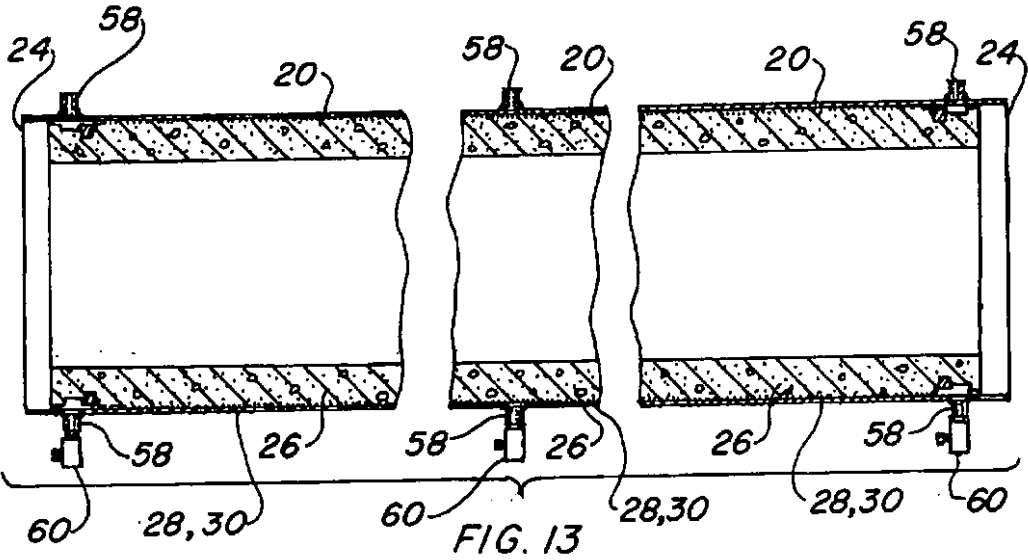
An outer pipe casing (20) and a concrete tube (26) cast inside, form a pre-stressed concrete pipe in its elementary form. Prior to casting, a layer of non-cohesive material (28) is sprayed on the inside of the pipe casing and an annular ring (32) is welded inside adjacent to each end. A resilient seal ring (46) is captivated into the inwardly facing legs (38) of the second channel (36) of each annular ring and a temporary seal (52) separates each annular ring from the material (28). After the concrete of the tube cures, a pressurized solidifying compound (54) is inserted under pressure to a pathway (42) formed into each annular ring and it is also extruded into a region (30) coated by the non-cohesive material. Pressurization of the compound is sufficient to cause the pipe casing to bulge outwardly and compression of the concrete in the tube is achieved. When the compound hardens, the compressive force remains and pre-loads the pipe. As the outer casing bulges externally when pressurized by the compound, the seal ring (46) is compressed tightly against the concrete of the tube assuring and maintaining an absolute closure between the tube and the annular ring.

19 Claims, 4 Drawing Sheets









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PRE-STRESSED CONCRETE PIPE
TECHNICAL FIELD

The present invention relates to concrete pipe in general, and more particularly to a pipe that includes a metallic outer casing with pressurized solidifying compound between the casing and the concrete pipe.

BACKGROUND ART

Previously, pre-stressed concrete pipe and members used for building columns, liquid storage tanks, bridges, fluid flow, etc., have utilized tensioning members made of steel, usually bars or wires commonly called tendons that have been tensioned by stretching with hydraulic jacks, or the like. The goal is to eliminate tension forces on load bearing members, as concrete has considerable compression potential, but little tensile strength. It has been found that many approaches have been attempted in order to solve this problem, including both pre-tensioning and post-tensioning, which are well known in the art, also some have encased concrete pipe in an enclosure and filled the gap with grout or some other solidifying substance under pressure.

A search of the prior art did not disclose any patents that read directly on the claims of the instant invention, however, the following U.S. patents are considered related:

Patent No.	Inventor	Issue Date
5,065,795	Creedon	Nov. 19, 1991
4,840,200	Creedon	Jun. 20, 1989
4,771,530	Creedon	Sep. 20, 1988

U.S. Pat. No. 5,065,795, issued to Creedon, discloses a pre-stressed concrete article that overlays the ends and utilizes gasket rings between the end walls. A hardenable medium is injected in between a jacket and the concrete article which generates sufficient pressure to outwardly bulge the jacket, drawing the end walls together, thereby compressing the gaskets.

Creedon's U.S. Pat. No. 4,840,200 teaches a pre-stressed tube and a method of manufacture. A non-adhering lamina layer receives a medium that is injected under pressure. The medium provides a force to the tube with one or both walls of the layer enlarging and when hardened, provides a permanent leak-proof pre-stress force to the tube. The tube is preferably wound with filaments around a thin walled inner shell and the non-adhering lamina is a film of Teflon or waxed paper. The utility is for lightweight tubes capable of withstanding large bursting forces, such as a rail gun barrel.

U.S. Pat. No. 4,771,530 of Creedon is for methods of pre-stressed concrete members using a pressure containing casing positioned around the outside surface leaving a cavity therebetween. A pressurized medium is injected into the cavity at a pressure sufficient to apply the required pre-stress force. The pressurized medium changes form by hardening after injection and includes grout, thermoset plastic, and epoxy resin. When the concrete member is cast, a cavity is formed by peeling the concrete member and casing away from each other as the medium is injected.

It will be noted that the teachings of pre-stressing a pipe using a hardenable medium under pressure is old and well known in the art, however, simple and reliable methods have been lacking. Further utilization of mechanical features that

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provide a substantial seal at the end of the tube along with convenient entry points have not been taught by the prior art disclosed.

DISCLOSURE OF THE INVENTION

Historically, because concrete structures, such as pipes, conduits, columns and storage tanks have little tensile strength, and yet, ample compression strength, significant development has been directed into pre-stressing these configurations to make their use practical. As previously mentioned, reinforcement, such as stretched reinforcing members and, in its simplest form, bars and wires embedded in the concrete itself have proven to be practical. However, when pre-stressing is required, the known methods have been cost and labor intensive. Winding wire around a structure and coating the outside has also been attempted with some success, however, again cost is a factor. It is, therefore, a primary object of the present invention to pre-stress a concrete pipe by forming a minute gap between an outer casing made of a thin metal and an inner concrete tube. The invention utilizes a liquidous substance that is injected, without voids, throughout the gap under high pressure while maintaining a positive seal on each end of the pipe. The substance is allowed to harden in place therefore maintaining its compressive forces.

An important object of the invention is a simple and easy method of construction accomplished by simply coating the inside of the casing with a non-cohesive material, preferably a petroleum based substance, such as oil. This process is extremely uncomplicated and easily accomplished with a minimum of labor, further, the coating creates a relatively even region throughout the casings inner wall in-between the concrete pipe.

Another object of the invention is the ease in which trapped air may be relieved from the spatial pathway at each end of the pipe. A vent is provided at both places by drilling a hole in the casing and welding on a boss or simply tapping the hole. A plug is twisted into the threaded opening permitting trapped air to be vented easily and then sealed with the plug.

Still another object of the invention is directed to the use of a standard sized steel outer pipe casing that is easily fabricated and available throughout the country. As the only modification necessary is to add the holes and couplings, these casings are relatively inexpensive and welding an annular ring adjacent to each end is easily accomplished with conventional automatic tools and moderately skilled personnel.

If the application requires a precision fit between pipes, the casing may be sized by expansion using conventional methods without affecting the balance of the modifications. Further, the concrete tube is cast over a conventional mandrel using construction methods that are both well known and within the skill of those knowledgeable in the art.

Yet another object of the invention is accomplished by the unique configuration and positioning of an annular ring having a resilient seal ring embedded therein welded adjacent to each end of the pipe's metallic casing. When pressure is applied within a region coated with non-cohesive material between the casing and the concrete tube, the casing expands and the seal ring is pressed into a tight relationship with the concrete tube. The actual presents of pressure around the resilient deal ring assures an effective seal.

A further object of the invention has to do with the attachment means between the ends of each pipe. As each extremity consists of a simple open ended round metallic

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pipe, conventional methods may be employed such as welding, couplings with O-rings, slip fit, etc., all within the capabilities of a skilled artisan.

These and other objects and advantages of the present invention will become apparent from the subsequent detailed description of the preferred embodiment and the appended claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial isometric view of the preferred embodiment.

FIG. 2 is a fragmentary cross-sectional view taken along lines 2—2 of FIG. 1.

FIG. 3 is a double channel annular ring completely removed from the invention for clarity.

FIG. 4 is a cross-sectional view taken along lines 4—4 of FIG. 3.

FIG. 5 is a resilient seal ring completely removed from the invention for clarity.

FIG. 6 is a partial cross-sectional view taken along lines 6—6 of FIG. 5 illustrating only half of the seal ring.

FIG. 7 is a partial end cross section view of the invention.

FIG. 8 is a partial end cross section view of the invention with solidifying compound in place.

FIG. 9 is a partial end cross section view of the invention including an O-ring.

FIG. 10 is a partial end cross section view of the invention including an O-ring with solidifying compound in place.

FIG. 11 is a partial end cross section view of the invention including an O-ring and a upset bend in the annular ring.

FIG. 12 is a partial end cross section view of the invention including an O-ring and a upset bend in the annular ring with solidifying compound in place.

FIG. 13 is a fragmentary cross-sectional view of the invention with check valves in place within the bosses.

FIG. 14 is a partial end sectional view of the invention with an alternate embodiment of the seal ring.

FIG. 15 is a partial end sectional view of the invention less the weld for the annular ring.

FIG. 16 is a partial end sectional view of the invention with a threaded hole and a swaged pipe casing.

FIG. 17 is a partial end sectional view of the invention with the annular ring having an O-ring, unequal length channel legs, a threaded hole and a swaged pipe casing.

BEST MODE FOR CARRYING OUT THE INVENTION

The best mode for carrying out the invention is presented in terms of a preferred embodiment with other secondary configurations. The preferred embodiment, as shown in FIGS. 1 through 17, is comprised of a hollow tubular outer pipe casing 20 of metal, preferably steel. The casing 20 may be seamed or seamless of a construction that is conventional and easily obtained. Obviously, the casing has an inner wall 22 and opposed ends 24, and the thickness of the material may vary relative to the diameter of the pipe and the amount of pre-stress required for the application. The thickness, however, must be sufficient to permit controlled expansion and deformation when subjected to internal pressure.

A concrete tube 26 is formed within the interior of the casing 20 by casting with liquidous concrete poured over a mandrel in an ordinary manner well known in the industry.

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Prior to casting, a film layer of a non-cohesive material 28 is applied by spraying, or the like, to the inner wall 22 of the pipe casing 20, thus forming a superficial fissure region 30 therebetween when the concrete tube 26 is cured. This non-cohesive material 28 may be of any type suitable for the application as long as it prevents adherence of the concrete to the metal wall of the casing 20, however, a petroleum based substance, such as oil, has been found to be ideal and is inexpensive and easy to obtain, leaving a uniform gap of a thickness dependent upon the viscosity of the oil.

A metallic double channel shaped annular ring 32 is positioned within each end of the pipe casing 20 prior to casting the tube 26. Each annular ring 32 is located adjacent to the casing ends 24 contiguous with its inner wall 22. The annular ring 32 is of a roll-formed construction with its ends welded together forming a continuous annulus. The ring 32 is illustrated by itself in FIGS. 3 and 4 and in cross-section in the remainder of the figures. The configuration of the ring 32 is important as it is formed with a first channel 34 and an opposed second channel 36 with the legs 38 of the first channel facing the pipe casing 20 inner wall 22. The second channel 36 has its legs 38 facing inwardly in the opposite direction. A longitudinal flange 40 integrally extends from an outermost leg 38 of the first channel 34, as depicted in FIG. 4 and is of a diameter only slightly smaller than the inside diameter of the casing 20 permitting a slip-fit therebetween. The flange 40 intimately embraces the casing 20 while the first and second channels 34 and 36 are away from the inner wall in the open and inverted direction, thereby forming a peripheral spatial pathway 42 within the void. This pathway 42 is larger within the first channel 34 and considerably smaller over the second channel 36, as it is inverted, therefore, only the spacing of the back of its web creates a secondary portion of the pathway 42, however, it will be seen that both channels contribute to the pathway. FIG. 14 illustrates an embodiment of the ring 32 wherein one flange of the first channel 34 is omitted. The thickness of the metal forming the annular ring 32 is of utmost importance, as it needs to be thin enough to bend or yield at the proper time, and yet, thick enough to have the necessary rigidity to hold the weight of the tube 26 if the tube is vertically cast.

In a secondary embodiment of the annular ring 32, illustrated in FIGS. 11, 12 and 15, the first channel 34 incorporates an upset bend 44 facing the inner wall 22 of the pipe casing 20. The purpose of this bend 44 is to permit the ring 32 to bow at the bend when linear contraction of the pipe casing 20 is encountered, due to the Poisson ratio effect on steel, without deforming the balance of the annular ring 32.

The annular ring second channel 36 provides a seat for a resilient seal ring 46 captivating this ring on three sides with a snug fit, as shown in FIGS. 1, 2 and 7 through 17. There are two potential leakage paths around this annular ring 32 the first may be designated the inner leakage path which runs between the rings longitudinal flange 40 and the pipe casing 20. The second leakage path may be called the outer leakage path which exists between the inside portions of the annular ring 32, the periphery of the seal ring 46 and the interface with the concrete tube 26 as the concrete may develop minute shrinkage when it hardens leaving a slight cleavage therebetween. The seal ring 46 is contiguous with the concrete tube 26 and forms an impervious restricting band assuring a hermetic closure within the outer leakage path when the pipe is pressurized. The seal ring 46 is preferably square in cross-section, as shown in FIG. 6 and others, however, it may be rectangular, chamfered at the lower inner

corner to avoid air bubbles during casting, or even square with an inverted step 50, as depicted in FIG. 14 and still be within the scope of the invention. Any resilient material may be employed for the ring 46, such as neoprene, polyurethane, silicone, Teflon, Viton BUNA-N, etc., in either a hollow or solid configuration.

An optional O-ring 48 may be disposed within each first channel 34 of the annular ring 32 positioned toward the pipe casing end 24 to ensure a hermetic seal within the inner leakage path when pressure is introduced into the spatial pathway 42 formed by the presence of the annular ring 32. This O-ring 48 is depicted in its preferred location in FIGS. 9 through 12, 15 and 17, and is constructed of a conventional resilient material compatible with the elements involved. This element is described as being round, however, other configurations are acceptable, such as square, irregular, including one commonly known as a quad-ring.

FIG. 17 illustrates yet another embodiment of the annular ring 32 wherein the legs 38 of the first channel 34 are uneven, making the web even easier to bend upwardly.

Joining means hermetically seal the inner leakage path between the annular ring 32 and the pipe casing 20, preferably by welding a circumferential weld head 49. This weld is simply a coalescence of metal produced by heating to the melting point and as both the casing 20 and annular ring 32 are of the same material, arc welding is the preferred method, as it creates a homogeneous joint, a hermetic seal and also a strong connection. Another alternate embodiment of this joining means is illustrated in FIG. 15 and consists of casting a portion of concrete material in front of the annular ring 32 holding it in place by adherence of the concrete to both the annular ring 32 and the pipe casing 20 at its inner wall 22 as no non-cohesive material 28 is present. With this embodiment it is imperative that the O-ring 48 is used within the first channel 34 of the annular ring 32 to assure a definite hermetic seal when pressure is applied and no non-cohesive material is employed on the inner wall 22 adjacent to the pipe ends.

A temporary seal 52 is disposed between the annular ring 32 and the inner wall 22 of the pipe casing 20. This seal 52 is used to separate the ring from the concrete tube 26 and block the spatial pathway 42 from being filled with concrete when the tube 26 is being poured. The seal 52 is only temporary, as it is ruptured when pressure is applied to the pathway 42, therefore, the preferred material is a waterproof pressure sensitive tape, however, other forms of material may also be used with equal ease.

To pre-stress the concrete pipe, a pressurized solidifying compound 54 is disposed between the inner wall 22 of the pipe casing 20 and the concrete tube 26 within the spatial pathway 42 and the region coated with non-cohesive 30. The solidifying compound 54 is pressurized from 50 to 1,500 pounds per square inch (345 kPa to 10,343 kPa), according to the diameter of the pipe and the desired pre-stress. This pressurization compresses the concrete tube 26 inwardly toward the center of the tube creating a stressed condition or internal distribution of force on the concrete deforming its basic structure producing supplementary tensile strength to the composite pipe. The pressurization may be sufficient to bulge the pipe casing 20 outwardly or force it to grow in diameter, and because of the Poisson's ratio effect, when the casing 20 swells in diameter, it shortens slightly in length, this shrinkage of the casing 20 may cause the annular ring 32 to buckle, therefore, in the alternate embodiment, the upset bend 44 in the first channel 34 permits controlled deformation in an area that does not compromise the integ-

rity of the seal ring 46, as previously discussed. When the solidifying compound 54 hardens, the compression upon the concrete tube 26 is retained and the pressurization source may be detached. It should be noted that the compression of the compound 54 may be by any convenient means, such as a mechanical pump.

Any non-compressible fluid may be used in its liquidous state as the solidifying compound 54, such as a grout of cementitious material, thermoset plastic, hydraulic cements, etc. It has been found, however, that an epoxy substance having a resin and a hardener in two parts is ideal for the application, as it has little shrinkage and substantial compressive strength when it hardens.

Means to introduce the solidifying compound 54 into the annular ring spatial pathway 42 and region coated with non-cohesive material 30 are provided by drilling a series of holes 56 in the casing 20 in linear alignment with the spatial pathway 42 and covering them with hollow threaded bosses 58 in the form a pipe couplings or hex nuts welded in place. When the pipe casing 20 has sufficient thickness, the holes 56 may be tapped in place eliminating the necessity of the addition of the bosses 58. In either event an unrestricted route is provided directly into the appropriate space. These bosses 58 are illustrated in FIGS. 1, 2 and 7 through 15 and the threaded holes 56 in FIGS. 16 and 17. On particularly long runs either element 56 or 58 may be additionally located in the middle of the pipe casing or if the occasion demands, with FIG. 13 illustrating such a position. At least two of these bosses 58 or threaded holes 56 are appositely positioned over each pathway 42 with one used for entry and the other for venting atmospheric pressure when the compound 54 is introduced. A plug or valve may be either removed or opened for venting.

The other two or more bosses 58 opposite the vents are used for introduction of the compound 54 and may incorporate a check valve 60 permitting the requisite pressurizing equipment to be detached for cleaning while the compound 54 is still in the liquid state.

The fabrication technique is basically simple and not difficult for those familiar with the industry methodology. The pipe casing 20 is first cut to length and holes 56 are drilled near each end 24 with the hollow bosses 58 welded over the holes. An annular ring 32 is positioned into the casing 20 at each end and welded in place on the trailing edge of the longitudinal flange 40. The temporary seal 52 in the form of tape is placed on the leg 38 of the second channel 36 of each ring 32 and jointly to the adjacent inner wall 22 of the casing 20 as illustrated in FIGS. 14-17. The resilient seal ring 46 is embedded into each second channel 36 of the ring 32 and a layer of non-cohesive material 28, such as oil, is sprayed upon the inner wall 22 of the casing. The casing 20 is placed over a standard mandrel (not shown) and concrete is poured in the remaining space.

After the concrete has cured and the mandrel is removed, the solidifying compound 54 is injected through the check valves 60 into the pathway under pressure. When this void is filled the vent bosses 58 are plugged and the required pressure is allowed to build up, forcing the compound into both passageways 42 and expanding into the region coated with non-cohesive material 30. The presence of the non-cohesive material 28 permits the compound to penetrate the region 30 entirely with minimal effort. This pressure on the non-compressible compound 54 not only fills the region 30, but expands the casing 20 slightly, and shrinks the concrete tube 26, providing the desired compressive stress on the tube. The presents of pressure on the resilient seal ring 46

assures a proper and continuous seal of the outer leakage path between the concrete tube 26 and the inner surface of the annular ring second channel 36 and also the resilient seal ring 46. The shape of the annular rings permits radial pressure to be applied to each seal ring 46 compressing the seal against the tube 26. The pressurized compound supply may be removed, whereby the check valve 60 retains the internal pressure until the compound 54 solidifies, thereafter continuing the stressing by compression against the solid material.

In the event O-rings 48 are employed, they function as a secondary seal for the inner leakage path between each annular ring 32 and the casing 20 in the event that the circumferential weld beads 49 are not integrally sound having cracks or voids present in the weld, not achieving a flawless seal.

Connection of the pre-stressed concrete pipe, one end to the other is accomplished by conventional joints, such as butt welding with a back-up ring over the weld! lapped one end inside the other and then welded, or a rolled seal groove section welded to the casing 20 with an O-ring gasket completing the seal. Grout with steel reinforcement is normally poured in the gap between the ends of the concrete tube 26 creating a smooth inner surface of material having the same inside diameter as the tube 26.

While the invention has been described in complete detail and pictorially shown in the accompanying drawings, it is not to be limited to such details, since many changes and modifications may be made in the invention without departing from the spirit and scope thereof. Hence, it is described to cover any and all modifications and forms, which may come within the language and scope of the appended claims.

What is claimed is:

1. A pre-stressed concrete pipe comprising;

a hollow tubular outer pipe casing having an inner wall and opposed ends,

a concrete tube within said pipe casing,

a film layer of a non-cohesive material positioned between the inner wall of the pipe casing and the concrete tube, forming a superficial fissure region therebetween,

a metallic double channel annular ring positioned within each end of the outer pipe casing contiguous with both the concrete tube and the casing defining a peripheral spatial pathway,

joining means hermetically sealing the annular rings to the pipe casing on the casing inner wall adjacent to each end,

a resilient seal ring held captive by each annular ring and contiguous with the concrete tube forming impervious restricting bands,

a temporary seal disposed between each annular ring and the inner wall of the pipe casing for transitorily separating the rings from the concrete tube, and

a pressurized solidifying compound disposed between the pipe casing and the concrete tube within the spatial pathways and the region coated with non-cohesive material such that the concrete of the tube is constantly compressed in an inward direction creating a stressed condition on the concrete producing supplementary tensile strength to the composite pipe.

2. The pre-stressed concrete pipe as recited in claim 1 wherein said hollow tubular outer pipe is metallic and of a thickness permitting controlled expansion when pressurized by said solidifying compound.

3. The pre-stressed concrete pipe as recited in claim 1 wherein said concrete tube is cast over a mandrel.

4. The pre-stressed concrete pipe as recited in claim 1 wherein said non-cohesive material is a petroleum based substance.

5. The pre-stressed concrete pipe as recited in claim 1 wherein said metallic double channel annular rings are of a roll-formed construction, each having a first channel and a second channel opposed to each other with the first channel legs facing the pipe casing inner wall and the second channel legs facing inwardly in an opposite direction.

6. The pre-stressed concrete pipe as recited in claim 5 wherein said annular ring first channel incorporates an upset bend facing the inner wall of the pipe casing such that when pressure is applied to the solidifying compound the annular rings may bow at the bend, due to linear contraction of the pipe casing, without deforming the balance of the annular ring.

7. The pre-stressed concrete pipe as recited in claim 5 wherein said annular ring second channel encloses said resilient seal ring on three sides with a snug fit providing a hermetic seal when pressure is applied to the solidifying compound assuring closure as the concrete tube is pressurized.

8. The pre-stressed concrete pipe as recited in claim 5 further comprising an O-ring disposed within each first channel of the annular ring toward each pipe casing end to insure a hermetic seal when solidifying compound is introduced into the spatial pathway of each annular ring.

9. The pre-stressed concrete pipe as recited in claim 1 wherein said joining means is a coalescence of metal produced by heating to the melting point such as welding.

10. The pre-stressed concrete pipe as recited in claim 1 wherein said joining means are a portion of concrete material cast in front of each annular ring holding them in place by adherence of the concrete to both the annular ring and the pipe casing inner wall.

11. The pre-stressed concrete pipe as recited in claim 1 wherein said temporary seal is waterproof pressure sensitive tape.

12. The pre-stressed concrete pipe as recited in claim 1 wherein said pressurized solidifying compound is an epoxy substance having a resin and a hardener in two parts in its liquidous state.

13. The pre-stressed concrete pipe as recited in claim 1 wherein said solidifying compound is pressurized at a pressure of from 50 pounds per square inch (345 kPa) to 1,500 pounds per square inch (10,343 kPa).

14. The pre-stressed concrete pipe as recited in claim 1 further comprising means to introduce said solidifying compound into said annular ring spatial pathway and the region coated with non-cohesive material.

15. The pre-stressed concrete pipe as recited in claim 14 wherein said means to introduce said solidifying compound into said annular ring spatial pathway and the region coated with non-cohesive material further comprising, said pipe casing having a plurality of threaded apertures within the casing in linear alignment with each annular ring spatial pathway such that an unrestricted route is provided directly into appropriate spaces.

16. The pre-stressed concrete pipe as recited in claim 15 wherein at least two threaded apertures are oppositely positioned over each spatial pathway for venting atmosphere therefrom when the solidifying compound is introduced.

17. The pre-stressed concrete pipe as recited in claim 15 wherein at least two threaded apertures temporarily contain a check valve for maintaining pressure on the solidifying

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compound after introduction permitting detachment of pressurizing equipment for cleaning following use.

18. A method of making a pre-stressed concrete pipe comprising the steps of,

providing a hollow tubular outer pipe casing having an inner wall and opposed ends,

attaching a metallic double channel annular ring within each end of the outer pipe casing with hermetically sealed joining means leaving a peripheral spatial pathway between each ring and the pipe casing,

positioning a resilient seal ring within each double channel annular ring forming restricting bands,

installing a temporary seal between each annular ring and the inner wall of the pipe casing creating a transitorily securement therebetween,

applying a film layer of non-cohesive material upon the inner wall of the pipe casing,

casting a concrete tube within said pipe casing over a mandrel leaving a superficial fissure region between the casing and the concrete as permitted by the presence of the film layer of non-cohesive material, and, after the concrete tube has cured,

injecting under pressure, a solidifying compound jointly into the ring spatial pathways and into the region coated

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with the non-cohesive material, between the pipe casing and the concrete tube by rupturing the temporary seal, such that when the solidifying compound has hardened the concrete is constantly compressed in an inward direction creating a stressed condition on the concrete producing supplementary tensile strength to the composite pipe.

19. A pre-stressed concrete pipe comprising,

a hollow outer pipe casing covering a concrete tube,

a pair of metallic annular rings joined one within each end of the pipe casing, each having a peripheral spatial pathway and said rings contiguous with the concrete tube,

a pair of resilient seal rings held captive by each annular ring forming impervious restricting bands, and

a pressurized solidifying compound disposed within the spatial pathways and between the outer pipe casing and the concrete tube such that the concrete of the tube is constantly compressed in an inward direction creating a stressed condition on the concrete producing supplementary tensile strength to the composite pipe.

* * * * *

- [54] METHOD OF MAKING PRESTRESSED
CONCRETE POLES, TUBES, AND SUPPORT
COLUMNS
- [75] Inventor: Burton D. Morgan, Hudson, Ohio
- [73] Assignee: Top Roc Precast Corporation,
Hudson, Ohio
- [21] Appl. No.: 126,906
- [22] Filed: Mar. 3, 1980
- [51] Int. Cl.³ B28B 21/34; B28B 1/20;
B28B 1/30
- [52] U.S. Cl. 264/503; 264/228;
425/111; 425/435
- [58] Field of Search 264/228, 503; 425/111,
425/435

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Weber

[57] ABSTRACT

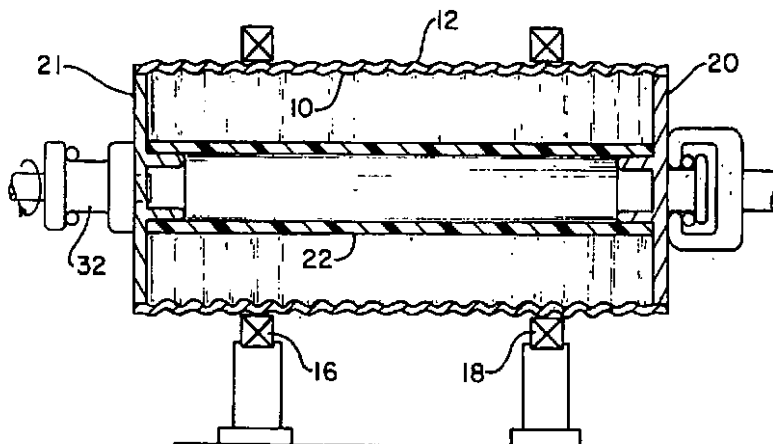
A method of making a prestressed concrete pole, including placing a heat softenable plastic pipe in a metal tube or pipe and filling the space between the pipes with concrete, rotating the metal pipe-concrete assembly rapidly to center the plastic pipe therein, applying hot fluid pressure to the interior of the plastic pipe, longitudinally prestressing the concrete pipe assembly for several hours while the concrete sets, and gradually releasing the fluid pressure and prestressing pressure to obtain a prestressed concrete pole.

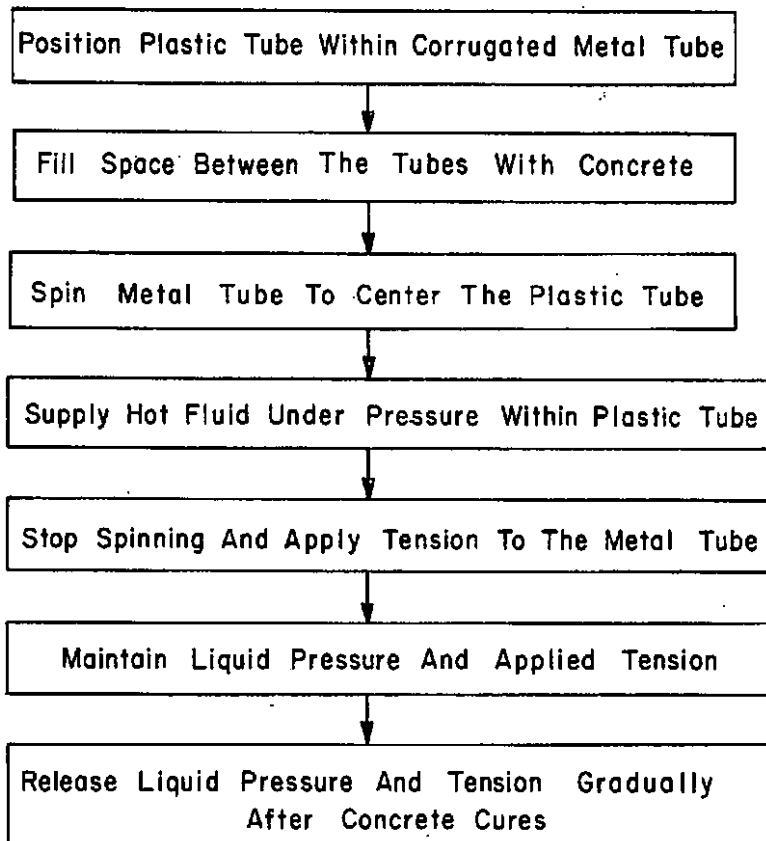
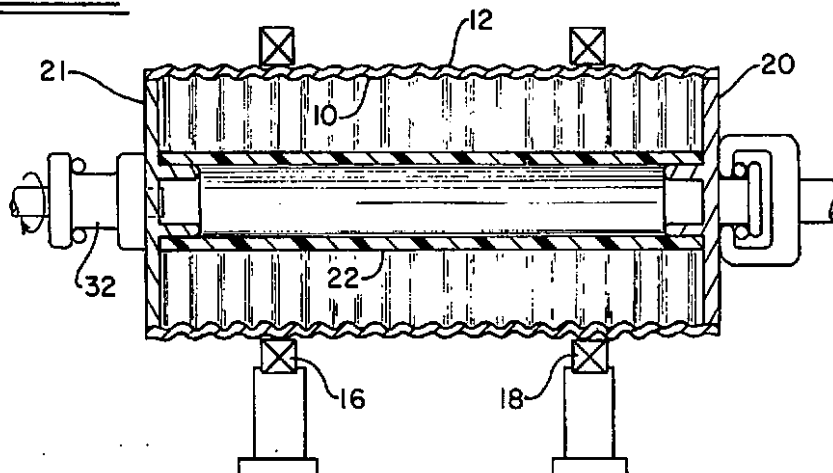
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7 Claims, 4 Drawing Figures



FIG. -1FIG. -2

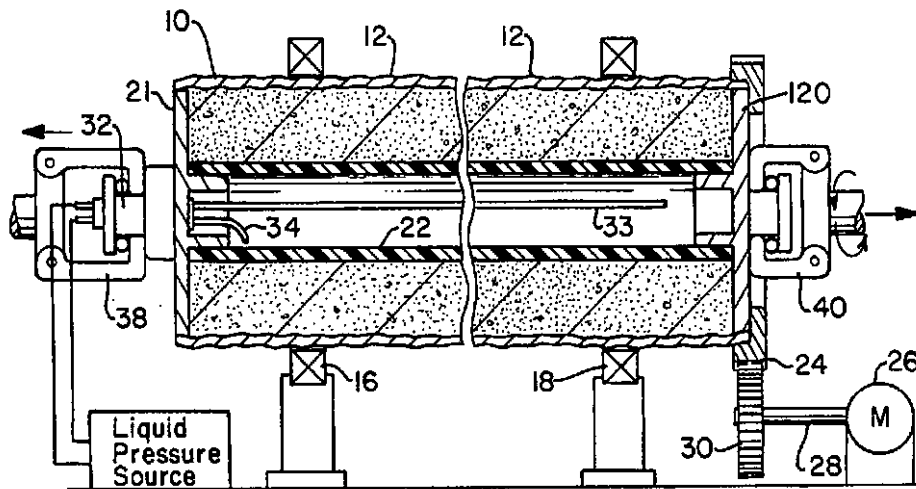


FIG.-3

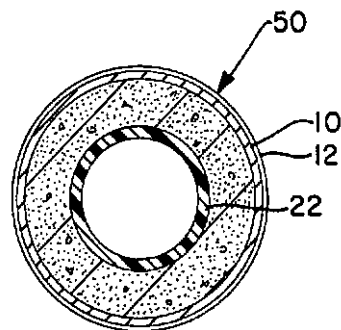


FIG.-4

METHOD OF MAKING PRESTRESSED CONCRETE POLES, TUBES, AND SUPPORT COLUMNS

BACKGROUND OF THE INVENTION

Heretofore, there have been many commercial articles made from prestressed concrete materials. These articles may include tubular pipes, beams, support columns, etc., and the concrete may include reinforcing rods, bars, and/or tubes therein. A large number of such prestressed concrete-metal reinforced articles have been made heretofore. Naturally, it is always desirable to make improved concrete products at reduced costs, or to obtain better physical properties in such products by novel production steps.

It is the general object of the present invention to provide an improved process for forming hollow prestressed concrete articles, such as poles, which have a metal outer shell.

Another object of the invention is to provide prestressed concrete columns, tubes, or poles positioned in metal enclosure tubes and which have desirable physical properties.

Another object of the invention is to provide an improved method for obtaining prestressed concrete poles which are made by substantially conventional apparatus and including using a corrugated thin wall metal enclosure tube in forming the concrete poles.

The foregoing and other objects and advantages of the invention will be made more apparent as the specification proceeds.

Reference now is particularly directed to the accompanying drawings, wherein:

FIG. 1 is a diagrammatic flow diagram chart of the method of the invention of making a prestressed concrete pole.

FIG. 2 is a diagrammatic view of apparatus involved in the first step of forming a prestressed concrete pole in accordance with the principles of the invention;

FIG. 3 is a diagrammatic view of other apparatus and means used in the further processing, rotating, and tensioning the article of the invention during its manufacture; and

FIG. 4 is a cross-sectional view of the article in FIG. 3.

When referring to corresponding members and steps shown in the drawing, and referred to in the specification, corresponding numerals are used to facilitate comparison therebetween.

SUBJECT MATTER OF THE INVENTION

The present invention, as one embodiment thereof, relates to a method of making a prestressed concrete pole having a hollow interior and a metal tube outer wall having transversely extending corrugations therein comprising steps of coating the inner wall of the metal pipe or tube with a liquid epoxy plastic, placing a heat softenable plastic pipe in the metal tube on the longitudinal axis thereof and filling the space between the pipes with concrete, rotating the metal pipe rapidly to center the plastic pipe in the concrete in the metal pipe, applying hot fluid pressure to the plastic pipe interior to expand it and apply expanding pressure on the metal pipe through the concrete, longitudinally prestressing the concrete pipe assembly and establishing tension in the outer metal shell which remains for the life of the structure. By having the tension at the outside diameter it is

in its most effective position, and maintaining the stress for several hours while the concrete is setting, and releasing the fluid pressure.

Attention now is particularly directed to the details of the structure shown in the drawings, and FIG. 2 shows a metal pipe or tube 10 which preferably has transversely directed corrugations 12 formed therein, which tube is made from a suitable metal, usually steel, and which tube or pipe has a thin metal wall of, for example, about 1/16 inches thick. Furthermore, the tube has the corrugations 12 therein which are relatively flat. The tube can expand lengthwise and have its corrugations flattened slightly during the manufacturing operations, as outlined hereinafter in more detail.

As an initial step, the interior of the metal tube 10 is coated with a two-part epoxy liquid solution. This epoxy is a special adhesive provided by Adhesive Engineering Company of San Carlos, Calif., and is particularly adapted for aiding in the bonding of concrete to metal such as the wall of the tube 10. The epoxy can be mixed and placed in the tube while the tube 10 is supported, for example, on a pair of suitable bearing units 16 and 18. These bearings 16 and 18 can be supported in any desired manner and usually it is preferred to have end caps 20 and 21 on the metal tube 10 after the epoxy material has been poured thereinto. Then the metal tube can be suitably rotated on its longitudinal axis, as by means indicated in FIG. 2, so as to spread the epoxy material into a uniform coat on the interior wall surface of the tube 10, and any excess plastic can be poured from an end of the tube.

Next, a plastic pipe 22 is placed on the center axis of the tube 10. This plastic pipe is made from a heat softenable material, usually polyethylene, and it can be supported on the end caps. Then concrete is poured into the metal pipe-plastic pipe assembly by removing one of the end caps and introducing liquid concrete after which the end caps 20, 21, or similar members, are engaged with the metal pipe assembly. Any desired removable cap or opening can be provided in one or both of the end caps to enable liquid concrete to be introduced into the assembly of the metal tube and plastic tube until the space between these tubes is filled. This filling of the tube 10 with concrete should occur before the epoxy plastic on the metal pipe wall has set.

FIG. 3 of the drawings shows that a pipe cap 120 may have suitable ring gear 24 formed thereon, and a motor 26 by its output drive shaft 28, with a drive gear 30 thereon, engages this ring gear 24 so that the assembly of the concrete, metal tube and plastic tube can be rapidly rotated in the annular bearings 16 and 18 at a relative speed, such as about 2,000 rpm's. Such high-speed rotation and the centrifugal action provided thereby centers the plastic pipe 22 in the metal tube or pipe 10. Obviously the concrete pipe assembly of FIG. 3 can be supported and rotated on its longitudinal axis in any conventional manner. After about 2 or 3 minutes of rotation of the assembly shown in FIG. 2, the plastic pipe should be positively located or centered on the longitudinal axis of the metal tube 10 and then a hot fluid such as hot water is supplied under pressure to this plastic pipe 22, as through a rotary coupling 32. This rotary coupling 32 has inlet and outlet tubes 33 and 34 connected thereto and extending therefrom, whereby a hot fluid, usually water, can be circulated around under pressure in this plastic pipe to soften it, and the pressure will, naturally, expand this polyethylene pipe and exert

radially outwardly directed pressures on the concrete and on the wall of the metal tube 10. After spinning this tube 10 and the assembled materials therein, under the pressurized conditions described, for about 10 minutes, then a longitudinally prestressing tensioning force is applied to the metal tube-concrete assembly. Hence, I have shown diagrammatically jaws 38 for engaging one end of the assembly, and a second set of jaws 40 for engaging the opposite end of the metal tube-concrete assembly. These gripper jaws 38 and 40 of any suitable construction to be moved into engagement with the tube 10 and its contents. The jaws are connected to a conventional tensioning machine not shown for exerting tension on this unit of the invention. Rotation of the tube and concrete assembly can be terminated prior to tensioning the assembly longitudinally. Preferably the hot liquid pressure applied to the concrete-metal tube assembly is maintained in effect for about two to three hours and, at the same time, the prestressing tensioning forces are applied to the assembly for about three hours or longer. Then the prestress tensioning forces, which may amount to about a 20-ton pull, as used in forming prestressed concrete poles on conventional size, is gradually released over a period of five to ten minutes. Such article formed, for example, may be about 60 feet long, and be of a suitable outer diameter, and center bore size.

After these tensioning forces are released, the end caps on the pole are removed, the bearings 16 and 18 are released, and a finished concrete tubular pole 50 can be removed from the apparatus and is ready for use.

The pressure applied by the hot water may be, for example, about 3000 lbs. per square inch and any conventional rotary coupling can connect the pressure supply lines to the concrete article being produced. It is expected that the pole will grow 12 to 18 inches in length due to the fluid pressure and longitudinal tension force.

By the apparatus and method of the invention, a good bond is obtained between the concrete and the tube 10, and some flattening of the corrugations in the metal tube is effected, as indicated in FIG. 3. This aids in obtaining the desired density and stresses in the concrete material as it sets up and cures in making the finished tube 50 of the invention. The metal tube is made at reasonable cost and has very desirable support properties, in addition to being the actual tensioning member and provides a durable, smooth outer surface pole. Due to the fortunate location (at the outer surface of the pole) it is calculated that only $\frac{1}{3}$ the weight of steel normally used as tensioning wire in prestressed poles will produce the same strength pole. Thus, it is believed that the objects of the invention have been achieved.

While one complete embodiment of the invention has been disclosed herein, it will be appreciated that modification of this particular embodiment of the invention

may be resorted to without departing from the scope of the invention.

What is claimed is:

1. A method of making a prestressed concrete pole comprising the steps of coating the inner wall of metal tube with a liquid epoxy plastic material, placing a heat softenable plastic pipe in a concentric position in the metal pipe and filling the space between the pipes with concrete, rotating the metal pipe rapidly to center the plastic pipe therein and compact the concrete, applying hot fluid pressure to the plastic pipe interior to soften and expand such plastic pipe and to place expanding pressure on the metal pipe, and to further compact the concrete, longitudinally prestressing the concrete-pipe assembly for several hours while the concrete sets, and releasing the fluid pressure and prestressing pressure to obtain a prestressed concrete pole.
2. A method of making a prestressed concrete pole as in claim 1 where radial corrugations are present in said metal tube, and they are partly flattened during formation of the concrete pole.
3. A method of making a prestressed concrete pole as in claim 1 or 2 and including filling the metal tube with concrete before the epoxy plastic has set up.
4. A method of making a prestressed concrete pole as in claim 1 or 2 and including maintaining the hot fluid pressure and longitudinal stress on the concrete pipe assembly for at least about three hours and releasing such pressure and stress.
5. A method of making a prestressed concrete pole comprising the steps of uniformly coating the inner wall of a metal tube with a liquid adhesive, a heat softening plastic pipe being positioned in the metal pipe on its longitudinal axis, filling the metal pipe with fluid concrete which encompasses the plastic pipe, rotating the metal pipe rapidly to center the plastic pipe in said metal pipe and the concrete therein, applying hot liquid pressure to the plastic pipe interior causing the metal outer pipe to prestress itself, longitudinally stressing the concrete-pipe assembly before the concrete sets, and adding to the prestressing done by the previous fluid pressure, and releasing the two prestressing pressures to obtain a prestressed concrete pole.
6. A method of making a prestressed concrete article, such as a pole, as in claim 5 and including continuing the rotation of the metal pipe and its contents for a few minutes while applying the liquid pressure, and stopping the rotation before applying the longitudinal stress thereto.
7. A method as in claim 6 and including using a metal tube with transversely extending corrugations therein, and stretching the metal tube to tension it and maintaining such tension by the concrete as it sets.