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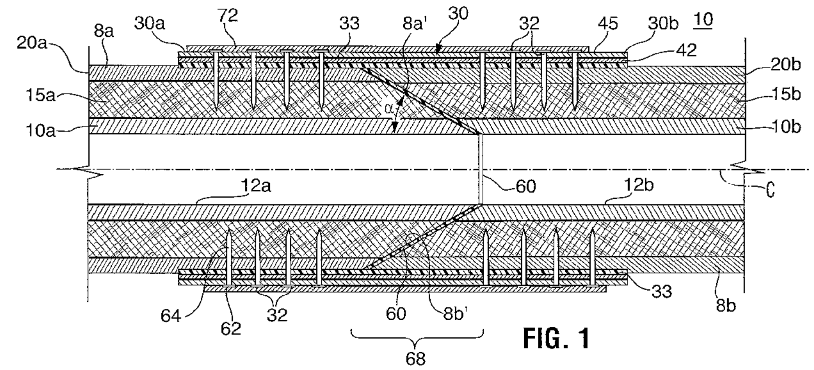


FIG. 1

(57) Abstract: A pipe joint includes: a coupling including a tubular wall with an outer surface and an inner surface defining an inner diameter; an end of a first pipe in the inner diameter of the coupling with an outer facing surface of the first pipe adjacent the inner surface; an end of a second pipe in the inner diameter of the coupling with an outer facing surface of the second pipe adjacent the inner surface, the end of the first pipe and the end of the second pipe arranged in an end-to-end scarf joint configuration and a seal between the end of the first pipe and the end of the second pipe; a thermoplastic weld between the coupling inner surface and the outer facing surface of the first pipe and the coupling inner surface and the outer facing surface of the second pipe; and a first plurality of fasteners installed substantially radially inwardly from the outer surface of the coupling and engaging the coupling and a fiber reinforced layer of the first pipe and a second plurality of fasteners installed to extend substantially radially inwardly from the outer surface of the coupling and in engagement with the coupling and a fiber reinforced layer of the second pipe.

WO 2017/049412 A1

JOINT FOR THERMOPLASTIC PIPE, ASSEMBLY AND METHOD

FIELD

The present invention relates to a connection for a pipe and, in particular, to a joint for thermoplastic pipe and pipe systems and methods for making the joint.

BACKGROUND

Pipe joints connect adjacent ends of pipe together to create longer lengths or to connect the pipe to an end fitting. Pipe joints should be reliable and relatively straight forward to construct.

SUMMARY

A pipe joint has been invented. A method for making the pipe joint has also been invented.

In accordance with one aspect of the present invention, there is provided a pipe joint comprising:

- a coupling including a tubular wall with an outer surface and an inner surface defining an inner diameter;

- an end of a first pipe in the inner diameter of the coupling, an outer facing surface of the end of the first pipe being positioned facing the inner surface of the coupling;
- an end of a second pipe in the inner diameter of the coupling with an outer facing surface of the second pipe being positioned facing the inner surface of the coupling, the end of the first pipe and the end of the second pipe arranged in an end to end scarf joint configuration and a seal between the end of the first pipe and the end of the second pipe;
- a thermoplastic weld between the coupling inner surface and the outer facing surfaces of the first pipe and the second pipe; and
- a plurality of fasteners installed substantially radially inwardly from the outer surface of the coupling and engaging the coupling and a fiber reinforced layer of the first pipe and a plurality of fasteners installed substantially radially inwardly from the outer surface of the coupling and engaging the coupling and a fiber reinforced layer of the second pipe.

In accordance with another broad aspect of the present invention, there is provided a pipe connection apparatus comprising:

- a coupling including a tubular wall with:
    - an outer surface;
    - an inner surface defining an inner diameter, the inner surface including a thermoplastic layer;
    - a first end opening to the inner diameter;
    - a second end opening to the inner diameter;
    - a first plurality of fastener holes spaced apart adjacent the first end and a second plurality of fastener holes spaced apart adjacent the

second end, each the first and the second plurality of fastener holes spaced around a circumference of the coupling and each of the fastener holes extending substantially radially through the tubular wall opening on the outer surface and the inner surface;

- the coupling configured to accept an end of a first pipe and an end of a second pipe arranged end to end in the inner diameter and the coupling configured to have the thermoplastic layer connected to the end of the first and second pipes by a thermoplastic weld between the coupling inner surface and outer facing surfaces of the ends of the first and second pipes; and
- a plurality of fasteners for installation substantially radially inwardly through the fastener holes and engaging the coupling and a fiber reinforced layer of each of the first and second pipes.

In accordance with another broad aspect of the present invention, there is provided a method for connecting a first pipe to a second pipe, the first pipe and the second pipe each having a wall including an inner surface defining an inner diameter, an open end through which the inner diameter is accessed, a thermoplastic-containing outer surface adjacent the open end and a fiber-reinforced layer between the inner surface and the thermoplastic-containing outer surface, the method comprising:

- inserting the open end of the first pipe into a coupling, the open end of the first pipe bevelled to define a protruding frustoconical surface and the coupling including a tubular wall with an outer surface and an inner thermoplastic-containing surface defining an inner diameter;
- inserting the open end of the second pipe into a coupling, the open end of the first pipe bevelled to define a recessed frustoconical surface;

- fitting the protruding frustoconical surface into the recessed frustoconical surface to form a scarf joint in the coupling;
- making a seal between the protruding frustoconical surface and the recessed frustoconical surface;
- thermoplastically welding the inner thermoplastic-containing surface of the coupling to the thermoplastic-containing outer surfaces of the first pipe and the second pipe;
- installing a plurality of fasteners to extend substantially radially inwardly from the outer surface of the coupling to engage the coupling and the fiber reinforced layer of the first pipe; and
- installing a plurality of fasteners to extend substantially radially inwardly from the outer surface of the coupling to engage the coupling and the fiber reinforced layer of the second pipe.

It is to be understood that other aspects of the present invention will become readily apparent to those skilled in the art from the following detailed description, wherein various embodiments of the invention are shown and described by way of illustration. As will be realized, the invention is capable for other and different embodiments and its several details are capable of modification in various other respects, all without departing from the spirit and scope of the present invention. Accordingly the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

A further, detailed, description of the invention, briefly described above, will follow by reference to the following drawings of specific embodiments of the invention. These drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. In the drawings:

Figure 1 a schematic axial sectional view through a pipe joint;

Figure 2 is a partially exploded, side elevation of a pipe joint;

Figure 3 is a perspective view, partly cut away, of an embodiment of an outer coupling for the pipe joint;

Figure 4 is a perspective view, partly cut away, of an embodiment of a pipe;

Figures 5A to 5C are axial sectional views of a series of steps in a method of constructing a pipe joint; and

Figure 6 is a side elevation of another method.

DETAILED DESCRIPTION OF THE INVENTION

The description that follows and the embodiments described therein are provided by way of illustration of an example, or examples, of particular embodiments of the principles of various aspects of the present invention. These examples are provided for the purposes of explanation, and not of limitation, of those principles and of the invention in its various aspects. In the description, similar parts are marked throughout the specification and the drawings with the same respective reference numerals. The drawings are not necessarily to scale and in some instances proportions may have been exaggerated in order more clearly to depict certain features.

Pipe joints connect pipes in an end to end configuration and/or connect a pipe to an end fitting. The present joint is reasonably durable, reliable and relatively easy to use.

Pipe joints according to the present invention are shown in the Figures. While the illustrated pipe joints are joining the ends of two adjacent lengths of pipe, it is to be appreciated that by replacing one illustrated side of the connection with a fitting, the coupling can be employed to connect a pipe to a fitting such as an end fitting, an elbow, etc.

With reference to Figures 1 to 3, the joint 10 is between the adjacent ends of two pipes 8a, 8b and the joint includes an outer coupling 30 into which the ends of the pipes are inserted.

Each pipe to be connected to the coupling in the joint includes an inner liner 10a, 10b having an inner surface 12a, 12b defining the inner diameter of the pipe, a reinforcing layer 15a, 15b containing fiber reinforcements and an outer jacket 20a, 20b. All of inner liners 10a, 10b, layers 15a, 15b of fiber reinforcements and outer jackets 20a, 20b include a thermoplastic.

Outer coupling 30 is formed as a sleeve including ends 30a and 30b that are open to its inner diameter ID. Coupling 30 includes an inner liner 42 having an inner surface defining inner diameter ID and a layer of fiber reinforcements 45. In the coupling, both inner liner 42 and layer of fiber reinforcements 45 include thermoplastic.

In the joint, the pipe ends are located within the coupling's inner diameter ID. Outer coupling 30 encircles the ends of pipes 8a, 8b. Coupling 30 is a separate component positioned over the ends of pipes 8a, 8b to be connected, in particular, with some overlap between the end of pipe 8a and outer coupling 30 and with some overlap between the end of pipe 8b and outer coupling 30.

While it will be described in further detail herein below, the joint further includes anchoring fasteners 32. Each anchoring fastener extends substantially radially inwardly passing through the coupling and engaging the pipe 8a, 8b within the coupling.

The joint also employs thermoplastic welding to form thermoplastic welded interfaces 33 connecting thermoplastic components of each pipe to thermoplastic components of the coupling. Thus, thermoplastically welded interfaces 33 connect each pipe to the coupling. An adhesively connected interface has not been found suitable.

The joint also includes a scarfed pipe-end to pipe-end arrangement within the coupling. The scarfed (i.e. tapered) ends 8a', 8b' of the pipes are connected together by a seal 60 of adhesive or thermoplastic weld.

As such, the joint is made durable and resistant to leakage by orienting the pipe ends in the scarf configuration and by sealing between the ends and then securing the outer coupling 30 to the pipe ends by thermoplastic welds 33 and fasteners 32.

The pipes in the joint are usually substantially similar in construction and diameter. For example, the pipes may have a composite construction such as a concentric laminate construction, for example, as described above, and may have similar inner and outer diameter dimensions.

In one embodiment, for example, a pipe 8 according to Figure 4 may be utilized with the connection. Pipe 8 includes inner tubular liner 10 forming inner surface 12 and with an outer surface 14, reinforcement layer 15 including a first ply 16 of reinforcing tape helically wrapped about the inner liner and a second ply 18 of reinforcing tape helically wrapped about the first ply of reinforcing tape and outer jacket 20 applied outwardly of the second ply. The first ply of reinforcing tape is wrapped either clockwise or counterclockwise and the second ply is wrapped in the other of the clockwise or counterclockwise directions, when compared to the first ply. Thus, stated another way, it may be said that one ply is wrapped at a positive helical angle and the other ply is wrapped in a negative helical angle.

While the pipe may include a reinforcement layer with only two plys of reinforcing tape, the embodiment illustrated in Figure 4 includes a reinforcement layer with a total of four plys including two further plys 22, 24 in addition to the first ply 16 and the second ply 18.

Pipe 8 may have various diameters such as of 50 to 600 mm (2 to 24 inches) or more outer diameter with a maximum operating pressure of 500 bar (7250 psi). The more common diameters are for example 125 to 300 mm (5 to 12 inches) outer diameter and typical operational pressures are 50 to 103 bar (725 to 1500 psi).

While being formable with large diameters, the pipe retains useful properties such as being self supporting and flexible with good pressure containment and impact resistance. Pipe 8 may be formed in discrete lengths and may be formable into longer lengths, as by connecting a plurality of shorter length pipes end to end using the above-described connections. The longer lengths may be spoolable for convenient handling.

While the full length of the pipe need not be fully bonded, the pipe ends may have a fully bonded construction. For example, in one fully bonded embodiment, the reinforcement layer is fully bonded to inner liner 10 and to outer jacket 20 and each ply of tape in the reinforcement layer is bonded to the plys radially inwardly and radially outwardly of it. The reinforcement layer, therefore, may have high inter-ply shear strength. Bonding may be achieved by thermoplastic melt fusion, which may include heating the materials to be contacted to a temperature above their melt temperature, bringing the materials into contact, and allowing the materials to cool at which time the contacted materials become fused together. In one embodiment, for example, a "thermoplastic tape placement" method may be employed at the ends or along the full length of the pipe.

Inner liner 10 is tubular having an inner diameter defined by inner surface 12 that is open for the passage of fluids therethrough. The reinforcement layer is applied over outer surface 14 of the liner.

The liner is the fluid containment layer and is selected to act as a leak and permeation barrier. The liner should be formed of the most molecularly impervious polymer that meets acceptable material costs, as determined by a cost benefit analysis. Generally, the liner should be selected to minimize diffusion of gaseous components of the fluid being conveyed. As will be appreciated, the liner is selected to be substantially resistant to degradation by the fluid to be passed therethrough.

The liner is as thin as possible. In particular, liner 10 can be as thin as it can be manufactured, thus reducing weight and material cost, and improving the flexibility of the pipe. For example, bearing in mind that the pipe diameter may be relatively large, for example offered in diameters of greater than about 6 inches, the liner may be less than less than 4 mm thick and may have an outside diameter to wall thickness ratio of 30:1 to 50:1. When the pipe is manufactured, the liner can be supported by an internal steel mandrel and, therefore, the liner is not required to support the loads induced by application of the outer layers such as during the winding process of reinforcing plys and the subsequent application of outer jacket 20.

As noted above, the liner includes a thermoplastic. In one embodiment, the liner includes a main tubular component formed of thermoplastic. Currently, polymers of greatest interest are polyamides, polypropylenes or polyethylene such as high density polyethylene (HDPE). For petroleum operations, HDPE is particularly useful as it provides good chemical compatibility with many oilfield chemicals at a reasonable cost.

In some embodiments, the liner or a ply thereof is filled, for example, with amorphous clays, chopped glass or carbon fibers. These materials can enhance liner stability, for example, against low temperature cracking, against polymer creep for long term integrity and may enhance the initial strength of the liner following extrusion. The fibers can be aligned or random.

In some embodiments, the liner may be a tubular laminate including a plurality of tubular layers. A multi-layered liner can include, for example, more than one layer of the same material or of different materials. Particular layers may be selected to confer various performance characteristics to the liner. For example, one layer in a multi-layered liner may confer resistance to degradation by the fluid being conveyed, and another layer may confer resistance to permeation of gaseous components of the fluid being conveyed. In one embodiment, for example, to enhance resistance to gas permeation, a barrier layer may be employed. For example, a polymeric barrier layer of material with high permeation resistance to gas may be employed. Examples of permeation resistant materials are polyamides and ethylene vinyl alcohol. Such a material may be positioned adjacent inner surface 12.

While the liner may be formed in various ways, extrusion offers a simple and rapid means of production. A multi-layered liner may be made, for example, by coextrusion of the various layers, as is known in the art.

The reinforcement layer, including the number of plys of reinforcement tape, the nature of the tape and the construction, determines, for the most part, many of the operational parameters of the pipe including, for example, burst strength, pressure holding capability, flexibility, etc. For example, the number of tape plys can be selected to determine the pressure class of the pipe, with fewer plys offering a lower pressure holding pipe.

Generally there are at least two plys of tape in the reinforcing layer of the pipe, the plys of reinforcing tape are configured with one ply wound in a positive or clock-wise helical direction and the other ply wound in a negative or counter-clockwise helical direction. One or more further plys of reinforcing tape may be applied between the inner liner and the outer jacket. Generally, as shown, further plys of reinforcing tape are added in pairs with one of the pair of plys wrapped in a positive helical direction and the other of the pair of plys wrapped in a negative helical direction. In a four ply pipe, as shown for example, plys 16, 18, 22, 24 of reinforcing tape are configured with two plys wound in a positive or clock-wise helical direction and the other two plys wound in a negative or counter-clockwise helical direction. The plys generally alternate in their winding direction from inside to outside. A ply is one or more substantially continuous lengths of tape wound at the same angle and direction onto the underlying liner or tape ply.

The tape employed to form the plys can be configured in various ways from pipe to pipe and from ply to ply. In an embodiment, a tape may be used.

The angle of winding of each ply 16, 18 is selected to maximize strength in the circumferential and axial directions. Winding angles of between about 8° and 86° can be used. In one embodiment, winding angles of between 40° and 70° are used, in one embodiment with winding angles of between 50° and 60°. In one embodiment, the plys of each pair are selected to have substantially equal load carrying capability. For example, the first and second plys can use similar tape, have substantially equal but opposite winding angles and be applied in substantially equal quantities.

Outer jacket 20 surrounds the reinforcement layer including plys 16 and 18, and in this embodiment plys 22 and 24, of tape. While the pipe will function to contain pressurized fluids without the outer jacket, outer jacket 20 operates with the couplings disclosed herein to provide pipe connections. Outer jacket 20 also acts to protect the reinforcement layer from damage, as by cut, abrasion, and impact.

The outer jacket is formed of thermoplastic, which is flexible, protects the reinforcing fibers to some degree and is capable of fusing to the underlying layer of the pipe.

As will be appreciated with consideration as to the intended use of the pipe, outer jacket 20 can be selected to be substantially resistant to degradation by environmental effects (i.e. ultraviolet light, weather, etc.) and by the chemicals that may come in contact with it. Currently, the thermoplastic of greatest interest is polyethylene, for example, HDPE.

As desired, the outer jacket can include or have attached thereto identifiers such as, for example, paint, coloration, bar-coding, chips, etc. or materials facilitating use or installation such as, for example, electrically conductive wire or survey locatable metal parts.

Outer jacket 20 may be coated with insulation, if desired, for thermal insulation of environmental temperature to conduit temperature. Insulation may include polymers, foaming agents, etc. If the insulation is not a thermoplastic and/or not bonded to the underlying layers, it should be removed from the pipe's end before being employed in a connection as described herein.

Jacket 20 may be applied to the pipe in various ways. For example, the jacket materials can be applied as by extrusion, spraying, dipping, tape winding, shrink wrapping, braiding, etc. In one embodiment, the jacket is extruded onto the pipe. In another embodiment, a tape can be employed such as a HDPE tape, for example a neat (i.e. non-reinforced) or a low fiber content reinforced HDPE tape. The tape can be wound and bonded about the reinforcement layer using a tape placement method.

Ends 8a', 8b' of the pipes are configured to form a scarf joint. A scarf joint is a type of joint that joins pipes end to end with the ends being correspondingly tapered to fit together while remaining substantially axially aligned. In this embodiment, both pipe ends are bevelled around their circumference with one bevelled on its outer circumference and one bevelled on its inner circumference. As such, one pipe has a frustoconically shaped, protruding end 8a' and the other pipe has a frustoconically recessed end 8b'. The pipes are joined with the frustoconically shaped, protruding end 8a' inserted into the frustoconically recessed end 8b' of the other pipe.

The degree of tapering at the frustoconical ends 8a', 8b' is substantially identical such that the two ends fit together snugly. In one embodiment, the taper angle α is between 10° and 40°, for example between 20° and 30°.

To ensure that the scarfed surfaces are joined and substantially sealed against lifting and fluid infiltration, the joint includes a seal 60 at the interface of the ends. Seal 60 may be of an adhesive suitable for the plastics used in the pipe, such as for example an acrylic-based adhesive. In another embodiment, seal 60 may be of thermoplastic weld wherein adjacent thermoplastic components of the two scarfed surfaces are connected across the interface. The ends 8a', 8b' of the pipes have all layers of the concentric laminate exposed and the scarf configuration ensures that liners 10a, 10b are positioned very close if not touching each other and the same is true of reinforcing layers 15a, 15b and jackets 20a, 20b. A thermoplastic weld that forms seal 60 may fuse liner 10a to liner 10b and may possibly fuse: the thermoplastic matrix of reinforcing layer 15a to the thermoplastic matrix of reinforcing layer 15b; and jacket 20a to jacket 20b.

The coupling 30 is installed about the pipes 8a, 8b. The coupling is connected onto the outer surfaces of pipes by a thermoplastic weld 33.

The outer coupling in this embodiment, has a composite construction such as a tubular laminate construction including for example, a liner 42, a reinforcement layer 45 including one or more plys of reinforcing fibers and an outer jacket 50 encircling the reinforcement layer.

In one embodiment, the liner, the reinforcement layer and the outer jacket each contain a thermoplastic. For example, the plys of reinforcements making up layer 45 may include reinforcing fibers in a matrix containing thermoplastic and the inner liner and the outer jacket may each include at least one layer of a thermoplastic. The thermoplastic may have one or more of the following characteristics: (i) a softening temperature greater than 100°C, (ii) a brittleness temperature less than -60°C, (iii) a melt temperature of 120 to 300°C, (iv) a tensile strength of 16 to 100 MPa, (v) an elongation to break of at least 50%, for example, of 100 to 1000%, (vi) resistance to fatigue cracking when subjected to 1 million cycles at 1% strain, and (vii) a notched IZOD impact strength greater than 30 J/m. In one embodiment, the inner liner, the reinforcement layer and the outer jacket each contain the same type or compatible types of thermoplastic and those thermoplastics have all of the above noted attributes (i) to (vii) and are capable of becoming fused together.

The thermoplastic's low melt temperature offers a mold-ability that allows coupling components to be readily fused to other components, such as during construction of the coupling or formation of the joint connecting the pipes. For example, by forming parts of the same type of thermoplastic, they can be fused together when heated above the melt temperature of that thermoplastic.

The thermoplastic's low brittleness temperature and high elongation provide the outer coupling with a flexibility suitable for installation by ploughing into the ground and for spooling.

The thermoplastic resistance to fatigue cracking enables the outer coupling to achieve fatigue performance of greater than 730,000 pressure cycles from atmospheric to maximum allowable pressure without leaking. Greater than 2,000,000 cycles has been demonstrated in testing.

The thermoplastic impact strength allows the outer coupling to withstand a 125 J impact at -25 °C, and retain sufficient strength to satisfy a 20 year life at maximum operating pressure for the outer coupling.

The thermoplastic has excellent chemical resistance, which makes the outer coupling suitable for conditions where it may come in contact with water, CO_2, and gaseous and liquid hydrocarbons.

Examples of suitable thermoplastic types include polyamides (PA), polyethylene and polypropylene.

Outer coupling may have various diameters such as of 50 to 600 mm (2 to 24 inches) inner diameter with a maximum operating pressure of 500 bar (7250 psi). The more common diameters are for example 125 to 300 mm (5 to 12 inches) inner diameter and typical operational pressures are 50 to 103 bar (725 to 1500 psi). Even while being formable as a large diameter, composite outer coupling, it retains useful properties such as being self supporting and having good impact resistance. Outer coupling may be formed in specified final lengths or may be obtained from cutting a longer pipe into the desired final lengths.

The outer coupling may have a fully bonded construction. For example, in one embodiment, the reinforcement layer is fully bonded to inner liner 42 and to outer jacket 50 and each ply of reinforcements is bonded to any plys radially inwardly and radially outwardly of it. The reinforcement layer, therefore, may have a high inter-ply shear strength. Bonding may be achieved by thermoplastic melt fusion, which may include heating the materials to be contacted to a temperature above their melt temperature, bringing the materials into contact, and allowing the materials to cool at which time the contacted materials become fused together. In one embodiment, for example, a “thermoplastic tape placement” method may be employed whereby the thermoplastic tape and the substrate over which the tape is being applied are heated above their melting points. At the zone of contact, the tape is forced onto the substrate, for example, with a compaction roller. As a result of heat and pressure, the tape and the substrate onto which the tape is applied are fused together.

Inner liner 42 is tubular having an inner surface defining inner diameter ID. The reinforcement layer is applied over the outer surface of the inner liner.

If electrofusion is employed, the liner is selected to support conductor 34 and to provide material with which the pipe outer jacket may fuse. When formed of a thermoplastic material, liner 42 supplies an amount of molten thermoplastic to fuse with the thermoplastic of the pipe outer jacket 20.

As noted above, the liner may include a thermoplastic. In one embodiment, the liner includes a main tubular component formed of thermoplastic. Currently, polymers of greatest interest are polyamides, polypropylenes or polyethylene such as high density polyethylene (HDPE). For petroleum operations, HDPE is particularly useful as it provides good chemical compatibility with many oilfield chemicals at a reasonable cost.

Thermoplastic weld 33 between the inner surface of coupling 30 and the outer surface of pipes 8a, 8b may be generated in various ways using a plastic welding apparatus. In one embodiment, as shown in Figure 3, a plastic welding apparatus is based on electrofusion. For example, the coupling may carry an electrically resistive conductor wire 34 to permit electrofusion to form weld 33.

For example, heat may be generated by electrically resistive conductor 34 to melt an amount of the coupling and an amount of the jackets 20a, 20b of the pipes and cause the jackets to bond to the coupling. The coupling liner about the resistive conductor may be melted by the electrically resistive conductor, allowing the melted jacket material and the melted material of the coupling, which was adjacent to conductor 34, to combine and create a fused material that, when allowed to set, causes the pipe and the coupling to become integrally connected.

Liner 42 supports resistive conductor 34. The resistive conductor may be exposed on the inner surface or embedded in the liner material. The resistive conductor may be a metal strip, wire, etc. that encircles the coupling's inner diameter. In one embodiment, the resistive conductor 34 is a wire wrapped at least once around the coupling inner diameter and connected at each end to a terminal 38a, 38b. Terminals 38a, 38b are exposed for electrical communication to the wire. As shown, the wire may be coiled a number of times to create an axial length of the coupling over which the electrical conductor acts. While, a single conductor could be supported over a length to act on both pipe ends to be inserted into the coupling, the present coupling includes two conductors each with a set of terminals 38a, 38b, 38a', 38b', respectively. The conductors are installed to extend a sufficient length along the coupling such that there are one or more conductors positioned to act on both pipes 8a, 8b.

If there are two conductors, as shown, each pipe can be connected independently to the coupling. Allowing the pipes to be connected into the coupling one at a time provides for greater flexibility in operations. For example, the coupling can be attached to one pipe and the coupling and that pipe can be transported to the field together before being connected to another pipe in the field.

Conductor 34 can include various metals such as copper, steel, aluminium, etc. that generate heat when an electrical current is established therein. In the illustrated embodiment, copper wire is employed with a pitch dependent on the melting temperature of the material of liner 42 and jacket 20, the wire diameter, the desired length of the fusion zone and the internal coupling diameter. As shown, the copper wire may be wrapped a large number of times about the coupling's inner diameter to form conductor 34.

While an embedded copper wire conductor is shown in Figure 3, for generating weld 33, it is noted that other technologies could be used to form the weld. For example, a heating sheet 36 (Figure 5A), such as one available from LaminaHeat LLC, Greenville, South Carolina, may be employed between the parts. A heating sheet is formed of a network of conductive fibers such as of carbon, for example, graphite. The network may be very thin and permits the sheet to be thin and flexible. The heating sheet may be placed between the parts to be welded or may be embedded in one part before assembly of the parts to be welded. The heating sheet can be heated by various means. In one embodiment, an electromagnetic source may be used to weld the thermoplastic, such as according to an Emabond™ system available from Emabond Solutions, Norwood, New Jersey. A heating sheet useful for heating with electromagnetic source is sometimes termed a "susceptor". A susceptor is a material such as a paste, film or screen used for its ability to absorb electromagnetic energy and to convert it to heat. The susceptor is a conductive metal or non-metal material that is used to transfer heat to a target by conduction or radiation, called induction heating. The susceptor is often made from graphite, because it is highly conductive and very machinable. However, other materials can be employed such as stainless steel, molybdenum, silicon carbide, aluminium, etc.

A heating sheet, such as a susceptor, may be installed at the interface of the parts to be welded. For example, the heating sheet 36 may be secured on the outer surfaces of pipe ends 8a, 8b (as shown) or within the inner diameter of the coupling.

Forming the jackets 20a, 20b and liner 42 of at least compatible, if not the same material, such as HDPE or PA, facilitates fusion and ensure that the two materials melt under similar conditions.

The reinforcement layer 45, including the number of plys of reinforcements, the nature of the reinforcements and their construction, determines, for the most part, many of the operational parameters of the outer coupling including, for example, burst strength, axial pull strength, pressure holding capability, and flexibility. For example, the number of reinforcement plys can be selected to determine the axial strength and pressure class of the outer coupling, with fewer plys offering a coupling with lower pressure holding and/or lower axial strength characteristics.

There are one or more plys of reinforcements in layer 45. The plys may be arranged axially, that is extending substantially directly from end 30a to end 30b, and/or may be wound circumferentially around the diameter of the coupling. In one embodiment, layer 45 includes at least one ply applied with the fiber reinforcements extending substantially axially along the length of the coupling, at least one ply wound in a positive or clock-wise helical direction and at least one ply wound circumferentially such as substantially circumferentially or in a negative or counter-clockwise helical direction. One or more further plys of fiber reinforcements may be applied between the inner liner and the outer jacket. In one embodiment, layer 45 includes (i) at least one ply 45a applied over liner 42 with the fiber reinforcements extending substantially axially along the length of the coupling and (ii) at least one ply 45b wound substantially circumferentially and positioned radially outwardly of ply 45a.

While the reinforcements can be applied in various ways, one embodiment applies the reinforcements in the form of a tape. The tape employed to form the plys can be configured in various ways. In an embodiment, a tape includes a plurality of reinforcing fibers in a matrix.

The reinforcing tape has a length much greater than its width and the reinforcing fibers extend along the length of the tape to accommodate loads applied along the length of the tape, regardless of the applied orientation of the tape. The fibers should also be resistant to degradation by chemicals, such as hydrocarbons and water, intended to be handled, or environmentally present, during use of the outer coupling. Suitable fibers include, for example, glass, carbon, nylon, polyester or aramid. For petroleum operations, glass fibers are of greatest interest due to the low cost and ability to carry the required loads. Elongation to failure of fiber glass is generally less than 3.0% and glass fibers may exhibit a filament strength greater than 1,600 MPa. Particularly useful glass fibers may be very straight and have low boron content, typically less than 1% by weight.

The tape includes 30 to 80% reinforcement fiber by weight, with 50 to 70% by weight fiber content being quite useful for embodiments employing glass fiber reinforcements.

The reinforcing tape includes a thermoplastic matrix. As noted above, the thermoplastic is selected to exhibit characteristics that ensure the flexibility and durability of the outer coupling. For example, the thermoplastic in one embodiment is HDPE. The reinforcing tape may further have a strength optimized by selection of the thermoplastic matrix composition. The tape's impact resistance may also be optimized by selection of the thermoplastic matrix composition.

To enhance the bonding of the matrix to the reinforcing fibers, the matrix may include a coupling agent. The inclusion of a coupling agent has been shown to increase the shear strength and the tensile strength of the tape. The coupling agent also assists the fusion of the reinforcement layer to outer jacket 50 and liner 42. For example, the matrix of the reinforcing tape may include in excess of 5% by weight content coupling agent, with the most useful range determined to be between 10 and 20% by weight. An example of a suitable coupling agent for use with high density polyethylene is maleic anhydride grafted polyethylene. The inclusion of maleic anhydride grafted polyethylene to HDPE has shown to improve the shear strength and tensile strength of a thermoplastic reinforcement tape by 20% when the coupling agent content was increased from 5% to 18% by weight of the matrix.

The matrix composition tape may include additives to improve the impact resistance of the matrix and, therefore, the tape and the outer coupling. Specific to HDPE thermoplastic, impact modifier additives of particular interest include rubber, ethylene vinyl acetate (EVA), styrene butadiene styrene (SBS), styrene isoprene styrene (SIS), styrene ethylene butylene styrene (SEBS) and polyethylene such as medium density polyethylene. Such additives may be added in the range of 1 to 40% by weight of thermoplastic. SEBS, for example, may be added in the range of 3 to 13% by weight thermoplastic content. As another example, the medium density polyethylene may be added in the range 10 to 30% by weight thermoplastic. A useful combination has been determined to be 7 to 10% SEBS and 16 to 18% medium density polyethylene, each by weight in HDPE. When compared to HDPE alone, a matrix containing 8% SEBS and 17% medium density polyethylene in HDPE increased the impact resistance of the matrix composition from 31 to 400 J/m (notched IZOD).

An example of a suitable SEBS is Kraton G1657™, which is a clear, linear triblock copolymer based on styrene and ethylene/butylene with a polystyrene content of about 13%. An example of a suitable medium density polyethylene is Nova RMs539U™, with a density of about 0.9 g/cc and more specifically about 0.939 g/cc.

The thermoplastic matrix can contain both a coupling agent and an additive for improved impact resistance, each of which are as described above.

In one embodiment, the thermoplastic matrix has a high melt index of, for example, 9 to 60. The high melt index ensures adequate impregnation of the matrix into the reinforcing fibers. The tape void content should be no more than 5% and in one embodiment is no more than 3%.

The dimensions of the reinforcing tape may vary, but in one embodiment, they are selected for ease of manufacture. For example, the tape can be relatively thick and wide, for example, having a thickness between its upper surface and its lower surface in the range 0.6 to 1.5 mm for example, 0.7 to 1.1 mm. The tape can have a width of 25 to 40% or 30 to 35% of the coupling's outer diameter to facilitate tape placement, meaning that for most large diameter embodiments the tape has a width of greater than 45 mm. The large thickness and width of the tape allows the outer coupling to be efficiently manufactured, for example, using a tape placement method.

Reinforcement layer 45 provides axial and circumferential strength to the coupling. In order to minimize material use and coupling diameter, which is important for handling by ploughing, plys of reinforcing tape are orientated in the primary direction of the load to be borne by the coupling. In some embodiments, outer coupling may be substantially isolated from circumferential loads at the connection and the coupling in such an embodiment tends to bear primarily axial loads, those forces tending to pull the pipes apart. The reinforcement layer 45 may, therefore, include reinforcing tape plys to provide the coupling with significant strength in the axial direction. For example, in one embodiment, the reinforcement layer 45 includes one or more hoop wound (i.e. substantially circumferentially extending) plys 45b and one or more plys 45a where the reinforcement fibers extend substantially axially along the length of the coupling from end 30a to end 30b.

In one embodiment, one or more reinforcing plys 45a in layer 45 are applied at an angle of less than 20° off the center axis c providing strength predominantly in the pipe axial direction. If these plys are applied at an angle significantly off 0° (i.e. closer to 20°), these plys may be added in even numbers with alternating clockwise and counter clockwise directions to avoid a structural imbalance in the coupling. In one embodiment, plys 45a are applied at an angle of less than 10° off the center axis c. In addition, thereover, one or more reinforcing plys may be hoop wound at angles greater than 70° and possibly greater than 85° off the center axis c, to provide dimensional stability in manufacturing and handling, to absorb some minor circumferential stresses to minimize radial expansion under pressure, to minimize in-plane shear of reinforcing plys, to improve fatigue performance and to provide added impact resistance.

In one embodiment, the reinforcement layer includes two plys applied at less than 20° providing strength predominantly in the coupling's axial direction, along axis c, and then one ply applied at greater than 70°, such as between 85° and 90°, providing strength predominantly in the coupling's circumferential direction.

Outer jacket 50 surrounds reinforcement layer 45. While the outer coupling will function without the outer jacket, it acts to protect the reinforcement layer from damage, as by cut, abrasion, and impact.

The outer jacket can be formed of any flexible material that can protect the reinforcing fibers to some degree and in this embodiment, is capable of fusing to the underlying layer of the outer coupling. As will be appreciated with consideration as to the intended use of the outer coupling, outer jacket 50 can be selected to be substantially resistant to degradation by environmental effects (i.e. ultraviolet light, weather, etc.) and by the chemicals that may come in contact with it. In this embodiment, as noted above, the outer jacket includes a thermoplastic and can be filled with reinforcements, if desired. Currently, the thermoplastic of greatest interest is polyethylene, for example, HDPE.

As desired, the outer jacket can include or have attached thereto identifiers, paint, coloration, bar-coding, chips, etc. or materials facilitating use or installation such as, for example, survey locatable metal parts.

Jacket 50 may be applied to the outer coupling in various ways. For example, the jacket materials can be applied as by extrusion, spraying, dipping, tape winding, shrink wrapping, and braiding. In one embodiment, the jacket is extruded onto the outer coupling. In another embodiment, a tape can be employed such as a HDPE tape, for example a neat (i.e. non-reinforced) or a low fiber content reinforced HDPE tape. The tape can be wound about the reinforcement layer using a tape placement method.

In the coupling, as noted, all layers 42, 45 and 50 may be bonded together. Such bonding ensures that there is adequate load transfer from coupling liner 42 and jackets 20 into reinforcement layer 45 of the coupling.

To facilitate welding of the coupling to the pipes, the coupling inner diameter ID may be selected to be substantially similar to or slightly less than the outer diameter of the pipes, such that any gap between the liner 42 and jackets 20a, 20b will be closed readily during the welding process.

The joint also includes fasteners 32 engaging through coupling 30 into the underlapping pipes 8a, 8b. Fasteners 32 are formed of durable materials. In one embodiment, fasteners 32 may be constructed of metal such as steel or, if a non-metal construction is of interest, the fasteners may be of composite, such as high strength composites. The fasteners are positioned each with their long axis extending substantially radially relative to center axis c of the coupling, which will be substantially coaxial with the center axes of the pipes. A suitable fastener engages both the coupling and the pipe. A suitable fastener may, then, include a head 62 of enlarged diameter over the diameter of its shank 64. The head remains on or slightly embedded in the coupling and the shank penetrates the coupling, the weld 33 and the pipe below. Fastener 32 engages into reinforcement layer 15 of the pipe, but does not penetrate into the liner 10.

Fastener 32 may be a screw, a nail, a pin, a staple, etc. In one embodiment, shown in Figures 5A to 5C, fasteners 32 include barbs such as hooks or threads on their shank 64. Barbs include lateral extensions from the shanks rather than having a smooth shank. Barbs grip the material in which they reside and tend to prevent back migration of the fastener. Screws may be useful to pull the laminate layers of the coupling, weld 33, any remaining portion of jacket 20 and reinforcement layer 15 all into compression.

A plurality of fasteners is secured through coupling 30 and into each pipe. In one embodiment, at least 100 fasteners, and for example greater than 125 fasteners, are included between the coupling and each pipe. The fasteners at the outer end of the coupling tend to have the greatest holding effect.

The fasteners may be spaced apart about the circumference of the coupling and spaced in a number of circumferential rows at increasing distances from ends 30a, 30b of coupling. The location of the fasteners in one row may be positioned axially offset (i.e. rotated about axis c) from the fasteners in adjacent rows. Installation of fasteners 32 through the scarfed surfaces 8a', 8b' should be avoided.

The number and placement (i.e. density and pattern) of fasteners may be optimized based on materials employed and intended response. Generally, a spacing of at least 20mm between fasteners offers good performance.

In one embodiment, coupling 30 includes preformed holes 66 for accepting fasteners 32. The preformed holes facilitate placement of the coupling and layers 20 and 15 into compression. The preformed holes 66 dictate the positioning and number of the fasteners to be installed. As such, in one embodiment, at least 100 holes are present at each end of the coupling.

In a coupling with a conductor 34 installed, care may be taken when forming holes 66 to ensure that the conductor is not damaged. For example, in one embodiment, holes 66 may extend down through jacket 50 and layer 45 but terminate before reaching conductor 34 in layer 42. If there is no electrofusion conductor or a heating sheet or susceptor is employed that is not affected by holes, the holes can pass fully through the coupling from its outer surface to its inner surface.

Holes 66 may be spaced apart about the circumference of the coupling and may be arranged in a plurality of circumferential rows at each end of the coupling. The rows are spaced at increasing distances from each end 30a, 30b of the coupling. The holes in one row, and therefore the fasteners eventually to be installed therein, may be axially offset from the holes in directly adjacent rows, so that the holes are not arranged to place the fasteners in all rows in axial alignment with fasteners in all other rows. In other words, the holes/fasteners in the holes are staggered with one ring of circumferentially arranged fasteners rotated out of axial alignment with the next adjacent ring of circumferentially spaced fasteners. One possible staggered arrangement is shown in Figure 2. Also, the coupling has mid section 68 free of fastener holes, so that the scarfed surfaces 8a', 8b' can be positioned in the midsection without risk of a fastener being driven therethrough. The midsection 68, which is free of the holes indicates the intended installation site of the pipe ends, where the scarfed joint is to be positioned within the coupling.

The holes, and therefore the fasteners, also have been found to react best to a particular minimum spacing. Testing has shown that if the fasteners are too tightly spaced, the chance of coupling failure increases due to the development of stresses in the coupling and pipes. As such a spacing between adjacent holes in the coupling, and likewise between fasteners in the assembled joint, should be no closer than 20mm. In particular, fasteners should be installed in the coupling at least 20mm spaced apart from all other adjacent fasteners.

The preformed holes also facilitate installation of the fasteners and prevent damage to the coupling during fastener installation. Also, the advancement of the pipes into the coupling can be observed by looking through the holes.

To make up the joint of Figures 1 and 2, the ends of the pipes 8a, 8b are bevelled: one about the inner diameter and one about the outer diameter. This forms frustoconical, scarfed protruding surface 8a' and recessed surface 8b'.

Coupling 30 is slid over the end of one pipe. This may require application of some force, as the tolerances can be quite close.

The second pipe may be driven, arrow P (Figure 5A), into coupling 30 to butt against and fit into the scarfed surface of the other end. The scarfed surfaces are positioned close together and likely in contact.

Advancement of the pipes into the coupling can be observed through holes 66 that extend all the way through, if any. Ends 8a', 8b' are positioned in midsection 68.

As noted previously, a seal 60 is made between ends 8a' and 8b'. Seal 60 may be made by application of adhesive to ends 8a' and 8b' before they are pushed together. For example, before pipe 8b is installed, adhesive may be applied to end 8a' and end 8b' and then pipe 8b is pushed in to bring the ends into contact. The adhesive then sets. Alternatively, ends 8a' and 8b' may be fused by thermoplastic welding such as by electrofusion, induction, use of heating sheets or electromagnetic bonding, all as described above. If welding is employed, the heat from conductor 34 or sheet 36 at the coupling inner surface may be sufficient to achieve the thermoplastic weld. Alternately, an electrofusion conductor may be positioned within the pipes or a heating sheet, or other form of a susceptor, may be used that becomes installed at the interface of conical ends 8a', 8b'.

Regardless of the method of forming seal 60, the seal should at least connect and possibly seal against fluid infiltration at the interface of liners 10a, 10b. Connections across the matrices of reinforcement layers 15a, 15b may also be made by seal 60.

The coupling is also, at the same time or thereafter, thermoplastically welded to the pipes (Figure 5B). Weld 33 fuses thermoplastic material of the coupling with thermoplastic material of the pipe. Here weld 33 fuses jackets 20a, 20b of the pipes with liner 42 of the coupling. Weld 33 is made by welding processes such as by electrofusion, induction such as use of heating sheets 36 such as by electromagnetic bonding, all as described above. The outer surface of the pipes may be cleaned or non-thermoplastic jackets if any, such as any insulation layers, may be peeled back to ensure that the thermoplastic pipe jackets 20a, 20b are exposed for bonding to the coupling.

To protect against collapse and delamination of the pipe during thermoplastic welding, the pipes may be internally supported with an internal support. A temporary internal support is of greatest interest. For example, a removable support, such as an expandable bladder, may be placed within the inner diameter of the pipes radially inwardly of the length to be welded. After welding is complete and the risk of collapse and delamination of the pipe during thermoplastic welding has passed, the support is removed to ensure the inner diameters of the pipes are open through the joint. In such an embodiment, for use, the pipe inner diameters are fully open, for example, the seal 60 between ends 8a' and 8b' is exposed in the inner diameters.

While a temporary internal support is of greatest interest, in some embodiments, such as where the inner diameter of the pipes cannot be readily accessed during welding such as at connections made between long pipe coils, a longer term or permanent internal support may be useful to support the pipes. The internal support has an inner bore such that pipe flows may pass therethrough. The internal support may be simply to support across the area being welded and need not contain welding structures or seals. In one embodiment, the internal support may be placed in a recess formed in liners 10a, 10b, such that the support sits flush or only slightly protrudes into the pipes being connected.

To protect against distortion and delamination of the coupling during electrofusion, sufficient reinforcements may be incorporated to the coupling to resist such damage or the coupling may be externally supported. For example, if coupling distortion is observed to occur as a result of welding, additional circumferential reinforcement may be added in the coupling reinforcement layer to increase hoop strength. This is possible, but not preferable, as the additional material adds cost, weight, and increases the coupling's outer diameter hindering ploughing. Another option to resist distortion of the coupling is to employ an external clamp. The external clamp may be applied to the exterior of the electrofusion coupling. The clamp should be in place when the coupling is being fused to the pipe ends, but the clamp is removed once the risk of coupling damage has passed.

The pipe joints, as described above, operate to connect one or more pipes with outer thermoplastic components to a coupling. While the foregoing describes a liner of the coupling fused to jackets on the pipes, the weld may be between the thermoplastic matrix of reinforcing layers, such as layers 15 and 45.

As shown in Figure 5C, fasteners 32 are installed to mechanically engage coupling 30 and pipe 8a at one end of the coupling and other fasteners are installed to engage coupling 30 to pipe 8b at the other end of the coupling. Fasteners 32 are installed to extend substantially radially inwardly toward the center axis c. When installed, fasteners 32 engage both the reinforcement layer of the coupling and the reinforcement layer of the pipe. The fasteners terminate in the reinforcement layer of the pipe without penetrating into the liner. The fasteners are installed in positions spaced about the circumference of the coupling and in a plurality of rows spaced from ends 30a, 30b.

In one embodiment, a driver 70 may be used to install the fasteners. The driver is appropriate for the fastener, such as a hammer, a press, a screw driver, etc. Some drivers act on one fastener at a time, other drivers can act on more than one fastener at a time.

If the coupling includes preformed holes 66, the fasteners may be driven into holes 66 to a depth to mechanically engage the reinforcements in reinforcing layers 15a, 15b of the pipes, but not to penetrate into liners 10a, 10b. Holes 66 facilitate installation of fasteners 32. The holes properly direct the fasteners substantially radially inwardly and dictate the placement and number of the fasteners according to the desired operational parameters.

In this embodiment, fasteners 32 are screws that are driven by rotating driver. The fasteners are threaded by the driver into the holes in coupling 30 and therethrough into engagement with pipes 8a, 8b. Heads 62 and threads on shanks 64 pull the coupling, weld 33 and pipe layers 15 and 20 into compression and prevent the fasteners from penetrating too deep into the pipe and from migrating back out of engagement with the pipe. The fasteners terminate in the fiber reinforcing layer. Holes 66 facilitate compression.

In another embodiment, the fasteners are barbed pins installed by a driver that presses the pins into the coupling and therethrough into the underlying pipe. In one embodiment, shown in Figure 6, the fasteners 132 are pins, a plurality of which are carried on and protrude from an inner surface 171a of a wrap 171. The wrap 171 can be wound around the coupling 130 and pressure may be applied, as by a press, to push the pins substantially radially inwardly into the coupling and into engagement with pipe 108a.

The guidance provided herein above with respect to Figures 1 to 5C, such as with respect to spacing and staggering of fasteners 132, is be applied equally in respect of the coupling of Figure 6.

Fasteners 32, 132 are only added after the pipes are inserted into the coupling ID and generally after welding.

In one embodiment, an outer sleeve 72 may be installed over fastener heads 62 exposed on the outer surface of the pipe joint to protect the outer surface of coupling and exposed ends of fasteners and/or to seal off against liquid infiltration through coupling 30 along fasteners 32. Sleeve 72 may be applied by various means such as by application as a liquid coating or a shrink sleeve or by wrapping around or sliding axially over the surface of the coupling and fasteners.

In one embodiment, outer sleeve 72 is rigid to prevent fasteners 32 from migrating outwardly. Outer sleeve 72 may be made of a rigid material such as metal or rigid plastic that resists movement of fasteners radially outwardly from the outer surface of the coupling.

With reference to Figure 6, the wrap 171 can also function as the outer sleeve 72.

EXAMPLES

A metal coupling was installed to join two 6" diameter pipe ends. 144 metal screws (#6 – 5/8") were installed through the coupling and into each pipe end. No other means of connection was used between the coupling and the pipes (i.e. no adhesive was applied). At 4,285 psi internal pressure, the joint failed with screws being sheared off. Relying on polymeric welding (i.e. HDPE shear strength is 3380 psi at ambient temperature) alone is not sufficient to engage coupling at anticipated pressures. However, combining polymeric welding, of even 500 psi (much less than HDPE) with fasteners, will provide a pipe joint able to withstand significant internal pressures.

It will be apparent that many other changes may be made to the illustrative embodiments, while falling within the scope of the invention and it is intended that all such changes be covered by the claims appended hereto.

We claim:

1. A pipe joint comprising:

- a coupling including a tubular wall with an outer surface and an inner surface defining an inner diameter;

- an end of a first pipe in the inner diameter of the coupling with an outer facing surface of the first pipe adjacent the inner surface;

- an end of a second pipe in the inner diameter of the coupling with an outer facing surface of the second pipe adjacent the inner surface, the end of the first pipe and the end of the second pipe arranged in an end-to-end scarf joint configuration and a seal between the end of the first pipe and the end of the second pipe;

- a thermoplastic weld between the coupling inner surface and the outer facing surface of the first pipe and the coupling inner surface and the outer facing surface of the second pipe; and

- a first plurality of fasteners installed substantially radially inwardly from the outer surface of the coupling and engaging the coupling and a fiber reinforced layer of the first pipe and a second plurality of fasteners installed to extend substantially radially inwardly from the outer surface of the coupling and in engagement with the coupling and a fiber reinforced layer of the second pipe.

2. The pipe joint of claim 1 wherein the first and the second pluralities of fasteners include barbed shanks.

3. The pipe joint of claim 2 wherein the first and the second pluralities of fasteners are screws.

4. The pipe joint of claim 1 wherein the end-to-end scarf joint configuration is open to an inner diameter of the first pipe and the second pipe.

5. The pipe joint of claim 1 wherein there is a gap between the first plurality of fasteners and the second plurality of fasteners at a midpoint of the coupling and the end-to-end scarf joint configuration is positioned in the gap, such that the end-to-end scarf joint configuration is not penetrated by fasteners.

6. The pipe joint of claim 1 wherein the first plurality of fasteners and the second plurality of fasteners terminate in the fiber reinforcing layer.

7. A method for connecting a first pipe to a second pipe, the first pipe and the second pipe each having a wall including an inner surface defining an inner diameter, an open end through which the inner diameter is accessed, a thermoplastic-containing outer surface adjacent the open end and a fiber-reinforced layer between the inner surface and the thermoplastic-containing outer surface, the method comprising:

- inserting the open end of the first pipe into a coupling, the open end of the first pipe bevelled to define a protruding frustoconical surface and the coupling including a tubular wall with an outer surface and an inner thermoplastic-containing surface defining an inner diameter;
- inserting the open end of the second pipe into a coupling, the open end of the first pipe bevelled to define a recessed frustoconical surface;
- fitting the protruding frustoconical surface into the recessed frustoconical surface to form a scarf joint in the coupling;
- making a seal between the protruding frustoconical surface and the recessed frustoconical surface;
- thermoplastically welding the inner thermoplastic-containing surface of the coupling to the thermoplastic-containing outer surfaces of the first pipe and the second pipe;

- installing a plurality of fasteners to extend substantially radially inwardly from the outer surface of the coupling to engage the coupling and the fiber reinforced layer of the first pipe; and
- installing a second plurality of fasteners to extend substantially radially inwardly from the outer surface of the coupling to engage the coupling and the fiber reinforced layer of the second pipe.

8. The method of claim 7 further comprising supporting the inner diameter of the first pipe with a support during thermoplastically welding.

9. The method of claim 7 wherein installing avoids positioning a fastener through the scarf joint.

10. The method of claim 7 wherein making a seal includes applying adhesive.

11. The method of claim 7 wherein making a seal includes thermoplastically welding.

12. The method of claim 7 wherein installing includes screwing the plurality of fasteners to place the fiber reinforcing layer, the thermoplastic-containing outer surface and the coupling in compression.

13. The method of claim 7 wherein installing engages barbs on the plurality of fasteners into the fiber reinforcing layer.

14. The method of claim 7 wherein installing includes driving the plurality of fasteners into preformed holes in the coupling.

15. A pipe connection system comprising:

- a coupling including a tubular wall with:
  - an outer surface;

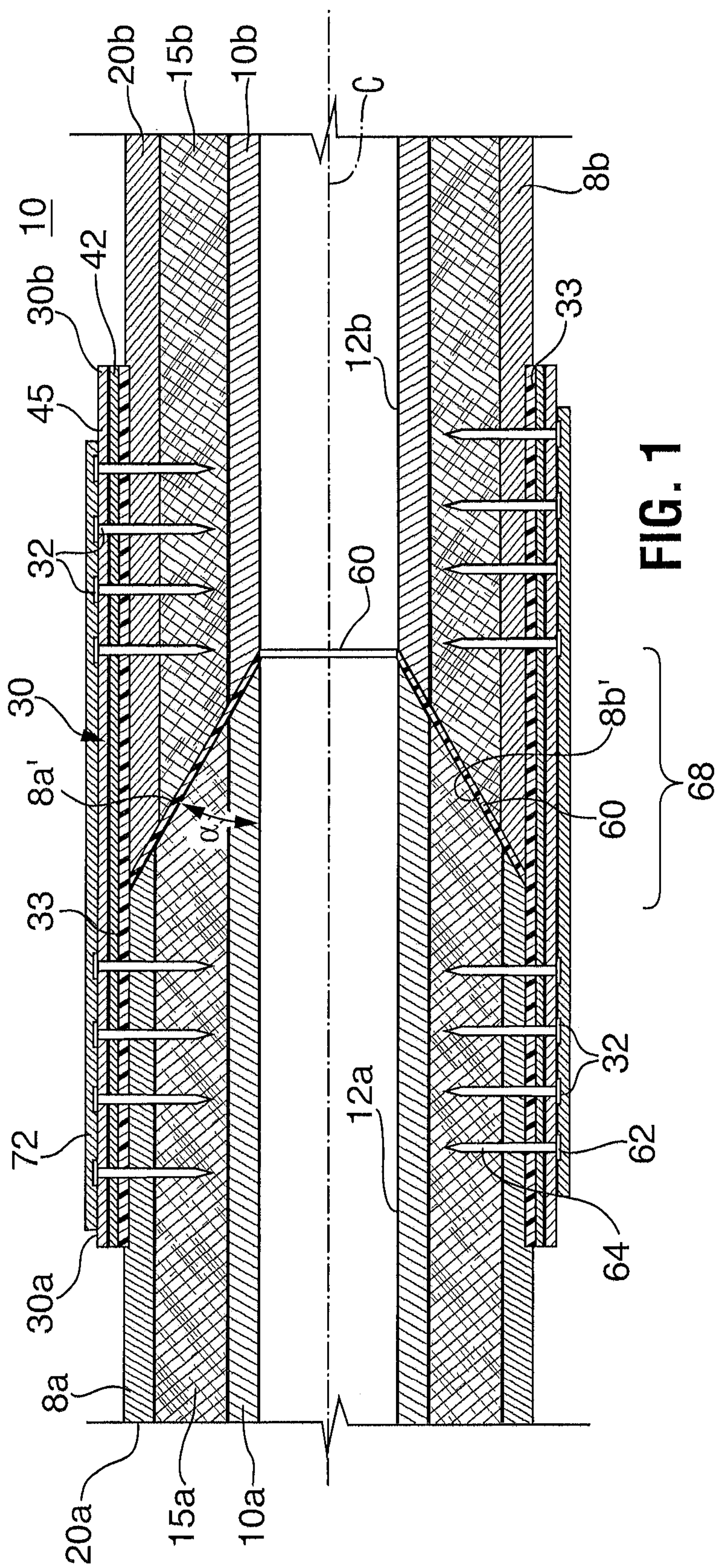
  - an inner surface defining an inner diameter, the inner surface including a thermoplastic layer;
  - a first end opening to the inner diameter;
  - a second end opening to the inner diameter;
  - a first plurality of fastener holes spaced apart adjacent the first end and a second plurality of fastener holes spaced apart adjacent the second end, each the first and the second plurality of fastener holes spaced around a circumference of the coupling and each of the fastener holes extending substantially radially through the tubular wall opening on the outer surface and the inner surface;

- the coupling configured to accept an end of a first pipe and an end of a second pipe arranged end to end in the inner diameter and the coupling configured to have the thermoplastic layer connected to the end of the first and second pipes by a thermoplastic weld between the coupling inner surface and outer surfaces of the ends of the first and second pipes; and
- a plurality of fasteners for installation substantially radially inwardly through the fastener holes and engaging the coupling and a fiber reinforced layer of each of the first and second pipes.

16. The pipe connection system of claim 15 wherein the plurality of fasteners include barbed shanks.

17. The pipe connection system of claim 16 wherein the plurality of fasteners are screws.

18. The pipe connection system of claim 15 wherein there is a gap between the first plurality of fastener holes and the second plurality of fastener holes at a midpoint of the coupling.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8b
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10
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45
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12b
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60
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62
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20a
15a
10a

FIG. 1

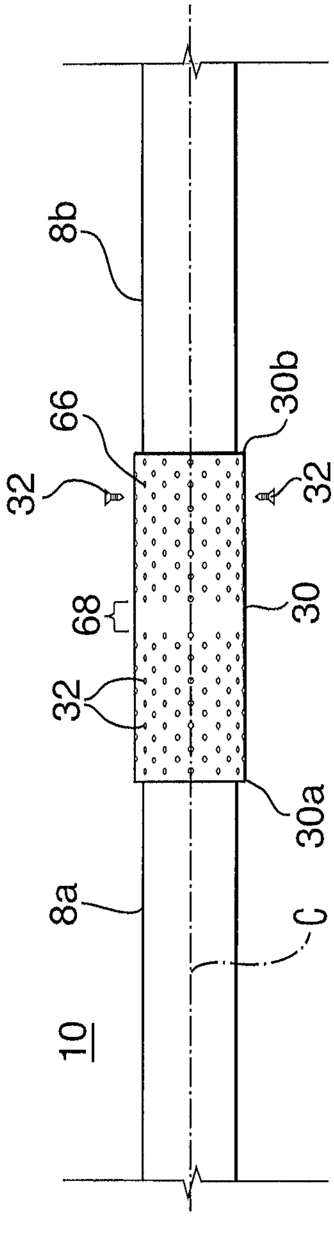
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FIG. 2

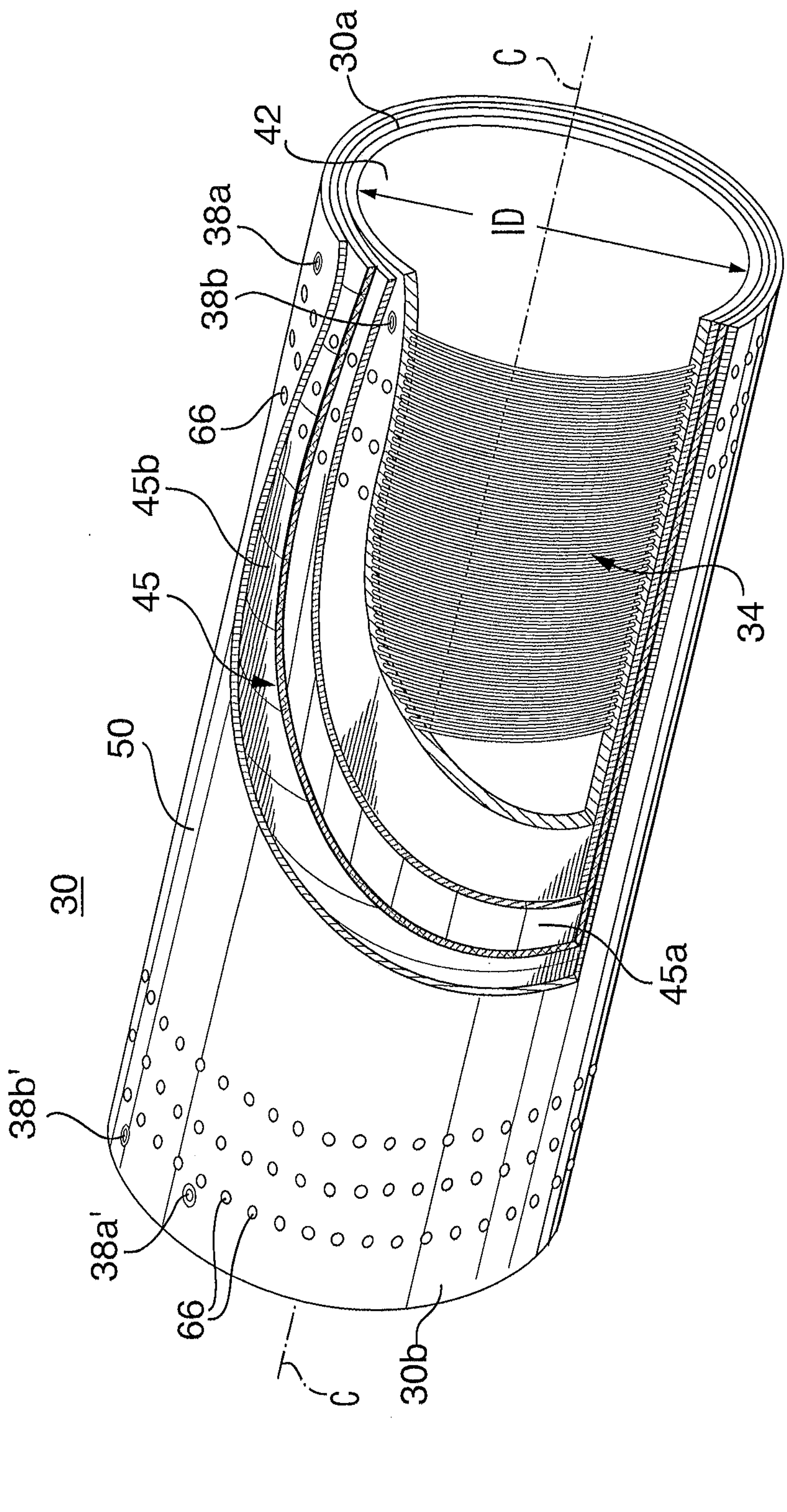
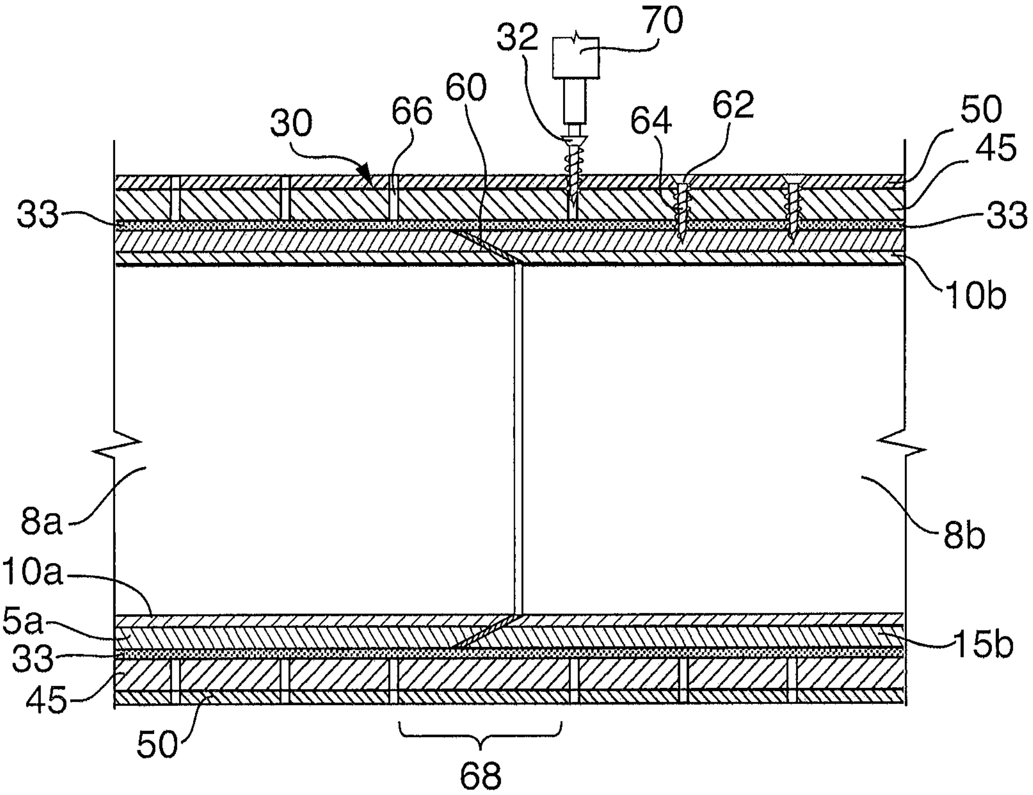


FIG. 3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66
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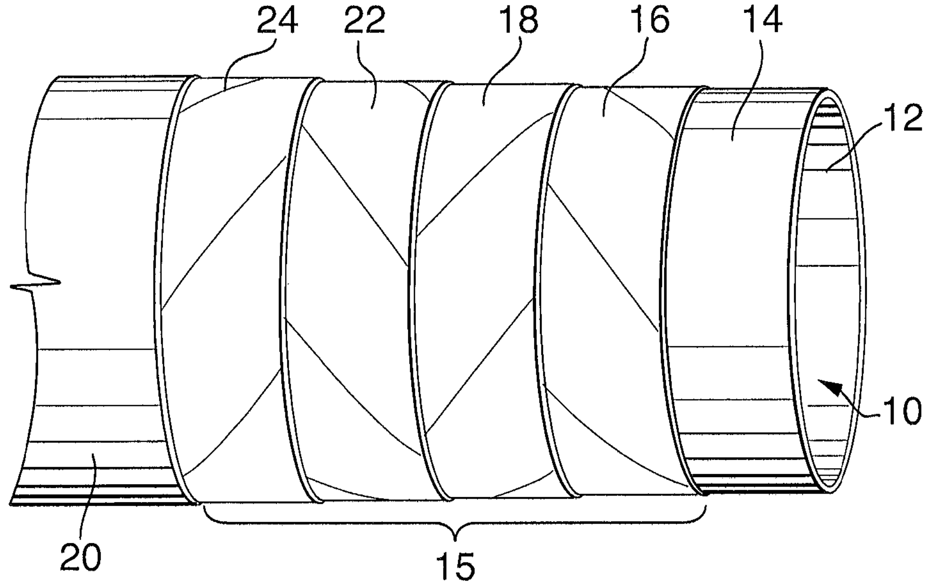
50
68

FIG. 5C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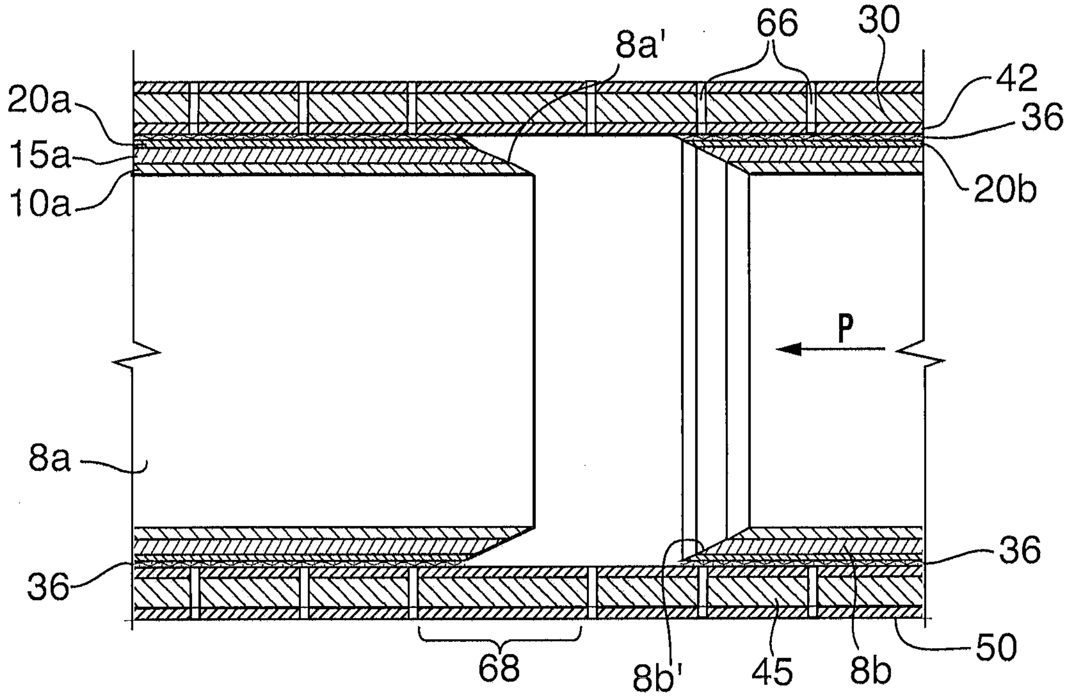
20
15

FIG. 4


8a'
66
30
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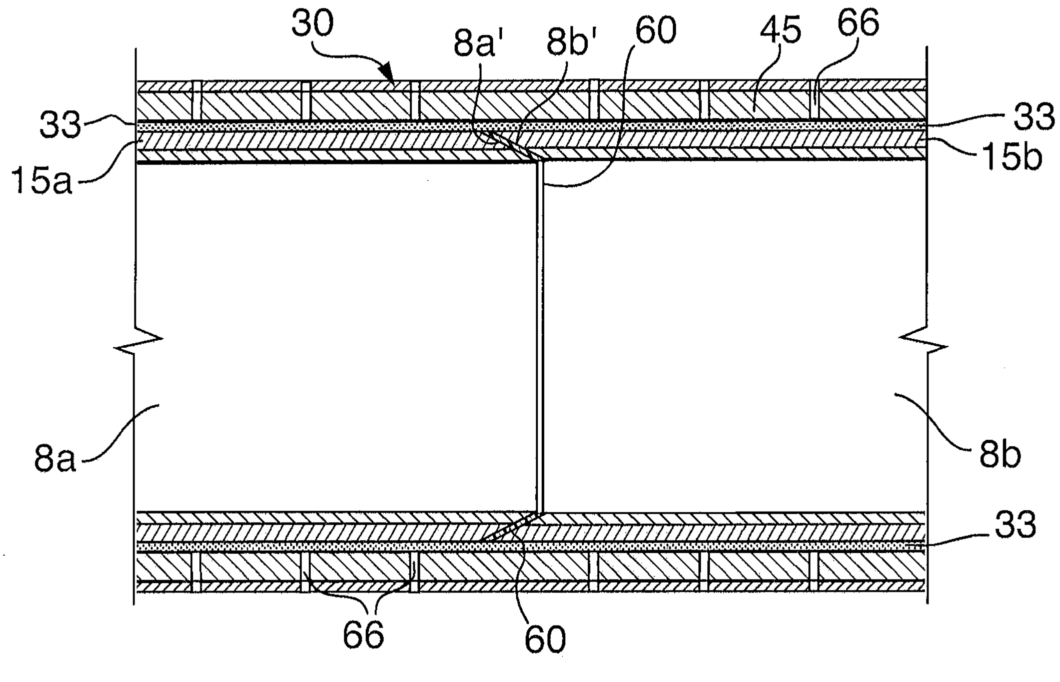
36
20a
15a
10a
20b
P
8a
36
36
68
8b'
45
8b
50

FIG. 5A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8a'
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45
66
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33
15a
15b
8a
8b
33
66
60

FIG. 5B

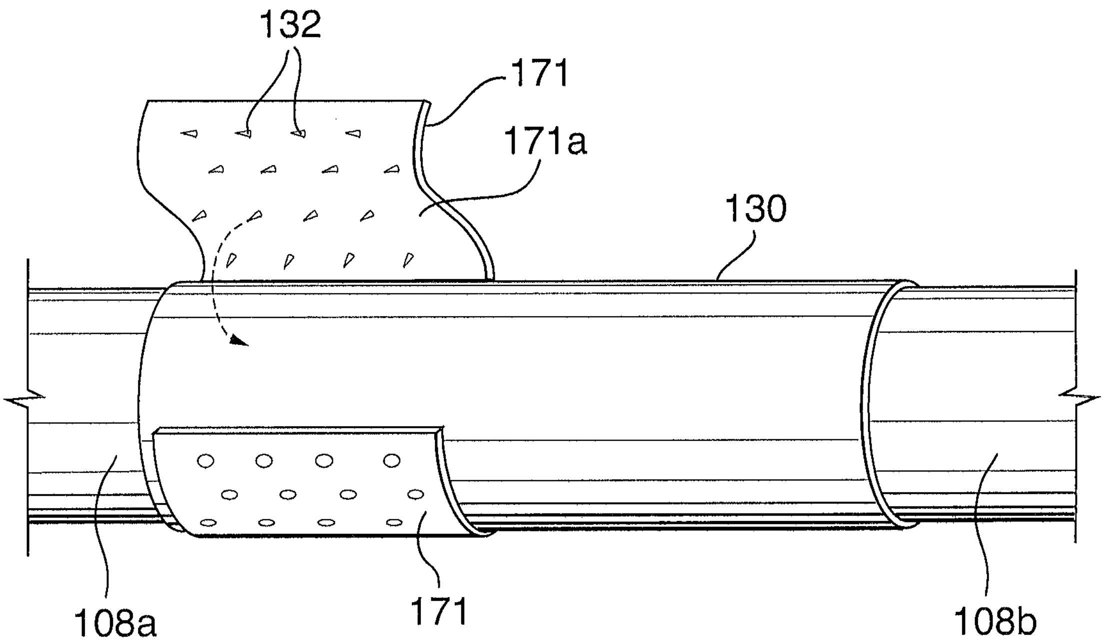

FIG. 6

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***F16L 47/02*** (2006.01) , ***B29C 65/70*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: F16L 47/02 (2006.01) , B29C 65/70 (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
N/A

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Questel Orbit (fampat); Keywords (Joint, pipe, nail+ or screw+ or fastener+, weld+, thermoplas+, frusto+, taper+, scarf+, coupler, coupling)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US2005251986, (KATAYAMA et al.) 17 November 2005 (17-11-2005) *Fig.4a, Fig.11*	1-18
A	US4363505, (SMITH) 14 December 1982 (14-12-1982) *Fig.1*	1-18
A	WO200947507, (DAVIDSON) 16 April 2009 (2009-04-16) *Fig.1*	1-18
A	WO200933608, (SPAETH et al.) 19 March 2009 (2009-03-19) *Fig.1*	1-18
A	US2008187697, (AMANO) 07 August 2008 (07-08-2008) * Fig.3*	1-18

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP2005324392, (TASAKA et al.) 24 November 2005 (24-11-2005) *Fig.1*	1-18
A	US2004161563, (WELLMAN et al.) 19 August 2004 (19-08-2004) *Fig.1*	1-18
A	US6918618B2, (ALLOUCH) 19 July 2005 (19-07-2005) *Figs.7-8*	1-18
A	JP2002317894A, (SASAKI) 31 October 2002 (31-10-2002) *Fig.1*	1-18

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US4363505A	14 December 1982 (14-12-1982)	None	
WO2009047507	16 April 2009 (2009-04-16)	None	
WO2009033608	19 March 2009 (2009-03-19)	DE102007042807 EP2185343	12 March 2009 (2009-03-12) 19 May 2010 (2010-05-19)
US2008187697A1	07 August 2008 (07-08-2008)	US2008187697A1 JP2006247892A WO2006095546A1	07 August 2008 (07-08-2008) 21 September 2006 (21-09-2006) 14 September 2006 (14-09-2006)
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US2004161563A1	19 August 2004 (19-08-2004)	US2004161563A1 CN1764532A CN100339210C MY143976A TWI327519B US2004209027A1 WO2004074725A2 WO2004074725A3	19 August 2004 (19-08-2004) 26 April 2006 (26-04-2006) 26 September 2007 (26-09-2007) 29 July 2011 (29-07-2011) 21 July 2010 (21-07-2010) 21 October 2004 (21-10-2004) 02 September 2004 (02-09-2004) 11 November 2004 (11-11-2004)
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JP2002317894A	31 October 2002 (31-10-2002)	None	