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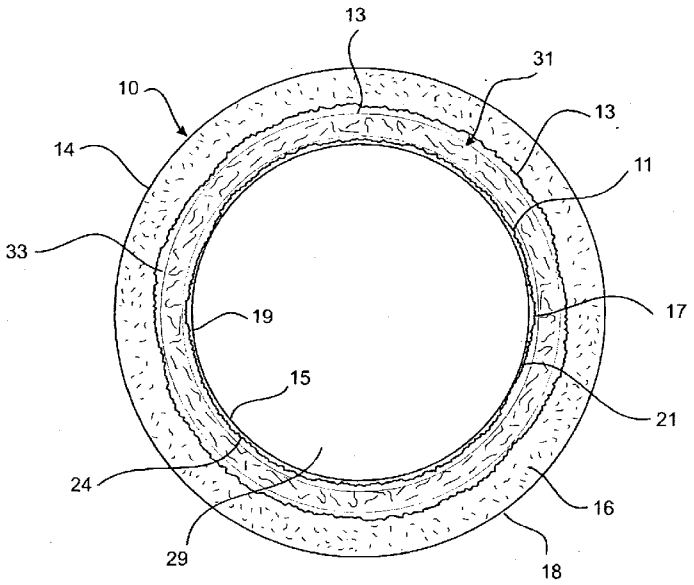


Fig. 2

(57) Abstract: An elongate hollow structure such as a pipe (10) and a method of constructing such an elongate hollow structure. The pipe (10) comprises a radially inner portion (11) and a radially outer portion (13), with the two portions (11, 13) merging together to provide an integrated tubular wall structure. The method comprising: providing the radially inner portion (11) in the form of an inner tube (21) and assembling the radially outer portion (13) about the inner tube (21). The outer portion (13) comprises an outer tube (30) of fibre reinforced composite construction surrounded by a flexible outer casing (31). The inner tube (21) is expanded to give form and shape to the outer portion (13).

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CONSTRUCTION OF PIPES

Field of the Invention

This invention relates to elongate hollow structures of composite construction, including in particular tubular structures.

While the inventions has been devised particularly in relation to the construction of tubular structures in the form of pipes, it may also be applicable to the construction of other elongate hollow elements including tubular elements such as ducts and tubes, tubular structural elements such as shafts, beams and columns, and other tubular elements of composite construction.

Background Art

The following discussion of the background art is intended to facilitate an understanding of the present invention only. The discussion is not an acknowledgement or admission that any of the material referred to is or was part of the common general knowledge as at the priority date of the application.

It is known to construct pipes using fibre-reinforced plastic composites. Typically, such pipes are constructed by a process in which rovings of filaments of fibre material, (such as glass fibres) are impregnated with a thermosettable resin or thermoplastic composition and wound back and forth on a mandrel to form a pipe wall structure of composite construction.

Further, there have been attempts to produce a continuous pipe by pultrusion involving a wet body of reinforcement fibres being drawn through a heated mould to cure the pipe and the pipe then wound onto a spool. Pipes constructed in this way are typically limited to lengths of about 1 km and diameters of about 100mm

Typically, such pipes are required to bear both hoop and axial stresses, and the construction can be a compromise between the hoop and axial stress bearing properties required for the pipe. Hoop strength can be optimised by winding the reinforcing filaments at an angle approaching 90° to the pipe axis. Axial strength

can be optimised by winding the reinforcing filaments at an angle approaching the pipe axis.

The length of pipe that can be constructed in such a way is dictated by the length of the mandrel or the roll of pipe that can be transported.. Consequently, the construction process is not conducive to construction of long pipes to form a transportation network for liquids and gasses; that is, pipes which are much longer than available mandrels and also pipes which are of a length to constitute a pipeline extending continuously between two distant locations, perhaps hundreds to thousands of kilometres apart.

It would be advantageous for there to be a way in which a pipeline could be constructed using a pipe constructed on a continuous basis; that is, without having to be composed of a series of pipe sections joined one to another at junctions which are likely constituted areas of weakness in structural integrity of the pipeline

It is against this background, and the problems and difficulties associated therewith, that the present invention has been developed.

Disclosure of the Invention

According to a first aspect of the invention there is provided a method of constructing an elongate hollow structure comprising a radially inner portion and a radially outer portion, with the two portions merging together to provide an integrated tubular wall structure, the method comprising: providing the radially inner portion: assembling the radially outer portion about the radially inner portion; and expanding the inner portion; wherein the outer portion comprises an outer tube of fibre reinforced composite construction surrounded by a flexible outer casing.

Preferably, the outer tube of fibre reinforced composite construction comprises reinforcement and a binder.

The reinforcement may comprise one or more layers of reinforcing fabric. Preferably, each layer is configured as a tubular layer disposed about the radially

inner portion. Typically, there is a plurality of tubular layers disposed one about another and hence also disposed about the inner tube.

The reinforcing fabric may comprise reinforcing fabric which incorporates reinforcement fibres featuring quadraxial fibre orientations. The reinforcement fibres may comprise glass fibres. The quadraxial fibre orientations offer the necessary hoop and axial stress bearing properties to the tubular structure.

Preferably, the binder comprises a settable plastic such as a resinous binder, which is commonly referred to as a resin. The binder sets to a resin matrix for binding the layers of reinforcing fabric together and to bind the reinforcement to the inner portion to provide the integrated tubular wall structure. The resin matrix may also bind the reinforcement to the outer casing.

Preferably, the inner portion comprises an inner tube comprising an inner liner with a fibrous layer bonded onto one face thereof, wherein the resinous binder impregnating the reinforcing fabric also impregnates the fibrous layer to integrate the outer portion with the inner portion

Preferably, the outer casing comprises an outer layer and a fibrous layer bonded onto one face thereof, the arrangement being that the fibrous layer confronts the reinforcement. With this arrangement the fibrous layer of the outer casing may provide a breather layer through which air can move.

Preferably, the flexible outer casing serves to resist radial expansion of the reinforcement, thereby causing it to be subjected to radial compression. With this arrangement, the reinforcement is confined in the space between the expanding inner portion and the flexible outer casing. The radially expanding inner portion operates in conjunction with the flexible outer casing to confine the reinforcement and also causes the volume of the space in which the reinforcement is confined to progressively decrease. This forces the binder within the reinforcement to fully impregnate the reinforcement; that is, the layers of reinforcing fabric become fully "wetted-out". In particular, it provides a compaction force to the reinforcement and effectively pumps the binder through the layers of reinforcing fabric to distribute the binder within the space in a controlled and constrained manner.

Further, the progressive decrease in volume of the space in which the reinforcement is confined may act to positively expel air from within the space which has the effect of enhancing impregnation of the binder within the reinforcement.

The outer casing and the various reinforcing fabric tubes may be adapted to facilitate the expulsion of the air. The outer casing and the various reinforcing fabric tubular layers may be configured to facilitate expulsion of air, for example, the outer casing and the various reinforcing fabric tubular layers may incorporate vents at intervals along their respective lengths to facilitate expulsion of the air. Additionally, or alternatively, the fibrous layer of the outer casing which provides the breather layer may facilitate displacement of air, typically upwardly and along the assembly to a release or venting point.

The flexible outer casing may have some resilience in order to yielding resist radial expansion of the reinforcing fabric tubes at least to some extent. However, the flexible outer casing typically has less resilience than the inner tube. In this way, the flexible outer casing can cushion the initial stage of the radial expansion of the reinforcing fabric tubular layers. In particular, it is desirable that the flexible outer casing have some elasticity. The flexible outer casing may have some elasticity for the purpose of enhancing control of the rate at which the binder progressively wets the reinforcement.

According to a second aspect of the invention there is provided a method of constructing an elongate hollow structure comprising a radially inner portion and a radially outer portion, with the two portions merging together to provide an integrated tubular wall structure, the method comprising: providing the radially inner portion comprising inner tube comprising an inner liner with a fibrous layer bonded onto one face thereof; assembling the radially outer portion about the radially inner portion; and expanding the inner portion; wherein the outer portion comprises an outer tube of fibre reinforced composite construction surrounded by a flexible outer casing and wherein the inner portion comprises an inner tube comprising an inner liner with a fibrous layer bonded onto one face thereof, whereby resinous binder impregnating the outer tube also impregnates the fibrous layer to integrate the outer portion with the inner portion

According to a third aspect of the invention there is provided a method of constructing an elongate hollow structure comprising forming a flexible tubular wall structure about a central portion, expanding the central portion to cause the tubular wall structure to assume a prescribed cross-sectional profile, and hardening, curing or otherwise setting the tubular wall structure.

The central portion may comprise part of the wall structure.

The flexible wall structure may comprise a fibre-reinforced plastic composite.

The flexible wall structure may further comprise settable plastic such as a resinous binder. Typically, the settable plastic comprises a curable resin.

The fibre reinforced plastic composite may comprise reinforcement configured as a fabric incorporating reinforcement fibres.

Preferably, the reinforcing fabric has quadraxial fibre orientations. The quadraxial fibre orientations offer hoop and axial stress bearing properties.

The flexible tubular wall structure may further comprise a flexible outer casing surrounding the fibre-reinforced plastic composite.

The expandable central portion may comprise an inner tube which provides an inflatable bladder to expand the flexible tubular wall structure prior to hardening, curing or other setting thereof.

Preferably, the inner tube is integrated with and forms part of the tubular wall structure.

The continuous movement and then expansion of the flexible tubular wall structure serves to pre-stress and align fibres within the reinforcing fabric to enhance hoop stress bearing properties over the entire length of the elongate hollow structure under construction.

Preferably, the reinforcing fabric is also pre-stressed axially (linearly) to enhance tensile load bearing properties.

The central portion may be configured as a bladder.

The bladder may be inflated using a fluid medium such as air or water.

Preferably, the bladder is expandable elastically.

In one arrangement, the tubular structure may be of a specific length. The tubular structure may, for example, comprise a tubular element such as a pipe made to a specific length.

In another arrangement, the tubular structure may be formed progressively to any desired length. The tubular structure may, for example, comprise a tubular element such as a pipe formed continuously until the desired length is attained. In this regard, the pipe may be of a length to constitute a continuous pipe providing a pipeline extending between two distant locations.

In contrast to the prior art arrangement where a pipeline extending between two distant locations would typically comprise a plurality of pipe sections joined one to another, the pipe according to the first aspect of the invention can permit the pipeline to be formed as one continuous pipe.

According to a fourth aspect of the invention there is provided a method of constructing an elongate hollow structure comprising forming a flexible tubular wall structure having an interior, inflating the interior of the flexible tubular wall structure to provide form and shape thereto; and hardening, curing, or otherwise setting the flexible wall structure to provide the tubular element.

The flexible wall structure may comprise a fibre-reinforced plastic composite which can cure to provide the tubular element.

The flexible wall structure may further comprise a flexible outer casing surrounding the fibre-reinforced plastic composite.

In certain applications the fibre-reinforced plastic composite cures to a rigid condition. In certain other applications the fibre-reinforced plastic composite cures to a more flexible condition.

The tubular wall structure may comprise a liner having a fluid impervious inner surface. The inner surface may be defined by a high gloss material such as a polyurethane liner.

According to a fifth aspect of the invention there is provided a method of constructing a pipe comprising forming a flexible tubular wall structure comprising a fibre-reinforced plastic composite, inflating the interior of the flexible tubular wall structure to provide form and shape thereto; and hardening, curing or otherwise setting the flexible wall structure to provide the pipe.

The pipe may be constructed on a continuous basis and progressively installed in position prior to curing of the flexible wall structure, whereby the flexible wall structure cures once in the installed position of the pipe

According to a sixth aspect of the invention there is provided a method of constructing a pipe on a continuous basis, comprising forming a flexible tubular wall structure comprising a fibre-reinforced plastic composite, inflating the interior of the flexible tubular wall structure to provide form and shape thereto; and curing the flexible wall structure to provide the pipe.

In the method according to the sixth embodiment, the flexible wall structure may comprise inner and outer portions, wherein the method further comprises forming the inner portion to define an inner tube and forming an outer tube of fibre reinforced composite construction about the inner tube to define the outer portion.

The outer tube may be formed using one or more layers of reinforcing fabric, wherein the method further comprises configuring each layer as a tubular layer disposed about the inner tube, impregnating the tubular layers with a resinous binder, inflating the inner tube to provide form and shape to the tubular wall structure, and curing the resinous binder to harden the tubular wall structure.

The flexible outer casing is installed around the tubular layers of reinforcing fabric to contain the resinous binder.

The flexible outer casing may be formed of any appropriate material, including for example polyethylene.

More particularly, the outer casing comprises an outer layer of polyethylene and a fibrous layer bonded onto one face thereof, the arrangement being that the fibrous layer confronts the reinforcement, as described above.

The outer casing may remain in place and ultimately form an integral part of the tubular structure, or it may be subsequently removed after having served its purpose.

The exterior of the outer layer of the outer casing may be configured to adherence to a surrounding protective sheath, such as a concrete casing. This may comprise a surface roughness or formations such as tufts on the exterior of the outer layer of the outer casing.

The inner tube may comprise an inner liner with a fibrous layer bonded onto one face thereof, and the resinous binder impregnating the reinforcing fabric may also impregnate the fibrous layer to integrate the outer portion with the inner portion.

The pipe may be constructed in a mobile installation plant configured as a vehicle which can move in relation to an installation site such that the continuously formed pipe can be progressively delivered to the installation site.

According to a seventh aspect of the invention there is provided a method of constructing a pipe in a flexible condition, laying the pipe at an installation site, and allowing the flexible pipe to transform into a rigid condition at the installation site.

The installation site may comprise a trench into which the pipe is progressively laid in the flexible condition. The pipe may be laid directly into the trench or placed alongside the trench and subsequently installed in the trench. The trench may have a foundation of sand or other material shaped to provide a curved depression upon which the pipe is laid for support.

The pipe may be assembled in a mobile installation plant which can move with respect to the installation site, laying the pipe in the flexible condition.

According to an eighth aspect of the invention there is provided an elongate hollow structure constructed in accordance with the method according to the first, second, third or fourth aspect of the invention.

According to a ninth aspect of the invention there is provided a pipe constructed in accordance with the method according to third, sixth or seventh aspect of the invention.

According to a tenth aspect of the invention there is provided an elongate hollow structure of composite construction, comprising a radially inner portion and a radially outer portion, wherein the two portions merge together to provide an integrated tubular wall structure.

The outer portion may be configured as an outer tube of fibre reinforced composite construction. More particularly, the outer portion may comprise reinforcement impregnated in a resinous binder.

The outer portion may further comprise a flexible outer casing surrounding the outer tube.

The reinforcement may comprise one or more layers of reinforcing fabric, each configured as a tube disposed about the inner portion. The reinforcement may comprise a plurality of layers, each configured as a respective tube disposed one about another.

The reinforcing fabric may comprise reinforcing fabric which incorporates reinforcement fibres featuring quadraxial fibre orientations. The reinforcement fibres may comprise glass fibres. The quadraxial fibre orientations offer the necessary hoop and axial stress bearing properties to the tubular structure.

The inner portion may comprise an inner liner with a fibrous layer bonded onto one face thereof. The other face of the liner may define the interior surface of the tubular structure.

The resinous binder impregnating the reinforcing fabric may also impregnate the fibrous layer bonded on the inner liner to integrate the outer portion with the inner portion.

Brief Description of the Drawings

The invention will be better understood by reference to the following description of several specific embodiments thereof as shown in the accompanying drawings in which:

Figure 1 is a schematic view of a pipe according to a first embodiment under construction;

Figure 2 is a schematic cross-sectional schematic view of the pipe shown in Figure 1;

Figure 3 is a schematic fragmentary side view of a section of the pipe;

Figure 4 is a schematic cross sectional view of the inner portion of the pipe;

Figure 5 is a schematic view of reinforcing fabric incorporating reinforcement fibres featuring quadraxial fibre orientations used in the construction of the outer portion of the pipe;

Figure 6 is a schematic cross sectional view of a reinforcing fabric tubular layer formed from the reinforcing fabric shown in Figure 5 and used in the construction of the outer portion of the pipe, the tubular layer being shown in a partly assembled condition

Figure 7 is a view similar to Figure 6, except that the tubular layer is shown in an assembled condition;

Figure 8 is a schematic cross-sectional view of an assembled tubular structure from which the pipe according to the first embodiment is constructed, the tubular structure being shown in a radially expanded (inflated) condition;

Figure 9 is a view similar to Figure 8, with the exception that there is shown provision for venting air from a space within the assembled tubular structure;

Figure 10 is also a view similar to Figure 8, with the exception that the tubular structure is shown in a collapsed (uninflated) condition;

Figure 11 is a schematic cross-sectional view of an inner tube forming part of the assembled tubular structure, the inner tube being shown collapsed into a flattened condition;

Figure 12 is a schematic cross-sectional view of the assembled tubular structure from which the pipe according to the first embodiment is constructed, the tubular structure being shown with the inner tube being folded using a different folding pattern;

Figure 13 is a schematic cross-sectional view of the inner tube forming part of the assembled tubular structure shown in Figure 12, with the inner tube being shown in a folded condition;

Figure 14 is a view similar to Figure 13, excepted that the inner tube being is shown in a partly flattened condition;

Figure 15 is a view similar to Figure 13, excepted that the inner tube being is shown in a fully flattened condition;

Figure 16 is a schematic perspective view of an assembly system for assembling the tubular layers depicted in Figure 7;

Figure 17 a schematic perspective view of a guide system for progressively moving a strip of reinforcing fabric as shown in Figure 5 through a transition from the first (flat) condition to the second (tubular) condition;

Figure 18 a schematic perspective view of a bonding system for securing overlapping edges of the strip of reinforcing fabric together to establish a joint to retain the strip in the second (tubular) condition;

Figure 19 is a schematic view of an assembly line for the pipe and is in two parts, being Figures 19A and 19B;

Figure 20 is a schematic sectional view of one end section of the pipe during fabrication thereof, with an end fitting installed on that end section; Figure 21 is a schematic side view of the other end section of the pipe during fabrication thereof, with an end fitting installed on that end section;

Figure 22 is a schematic sectional view of the end section of the pipe shown in Figure 21, together with an associated profile forming system;

Figure 23 is a schematic view of an assembly line for a pipe according to a second embodiment and is in two parts, being Figures 23A and 23B;

Figure 24 is a fragmentary view of part of the assembly line of Figure 23;

Figure 25 is a cross-section on line 25-25 of Figure 23B;

Figure 26 is a cross-section on line 26-26 of Figure 23B;

Figure 27 is a cross-section on line 27-27 of Figure 23B;

Figure 28 is a cross-section on line 28-28 of Figure 23B;

Figure 29 is a cross-section on line 29-29 of Figure 23B;

Figure 30 is a cross-section on line 30-30 of Figure 23B;

Figure 31 is a cross-section on line 31-31 of Figure 23B;

Figure 32 is a schematic view of an assembly line for a pipe according to a third embodiment;

Figure 33 is a schematic view of part of the assembly line of Figure 32, illustrating sets of elements for pinching the assembled tube structure and an outer casing therearound;

Figure 34 is a fragmentary view of part of the assembly line of Figure 32;

Figure 35 is a cross-section on line 35-35 of Figure 34;

Figure 36 is a cross-section on line 36-36 of Figure 34;

Figure 37 is a cross-section on line 37-37 of Figure 34;

Figure 38 is a cross-section on line 38-38 of Figure 34;

Figure 39 is a cross-section on line 39-39 of Figure 34;

Figure 40 is a cross-section on line 40-40 of Figure 34;

Figure 41 is a schematic cross-sectional view of the assembled tube structure and an outer casing therearound, illustrating a condition approaching full immersion in resinous binder;

Figure 42 is a view similar to Figure 41 but illustrating full immersion in resinous binder;

Figure 43 is a fragmentary cross-sectional view of the arrangement depicted in Figure 39;

Figure 44 is a schematic view of part of an assembly line for a pipe according to a fourth embodiment;

Figure 45 is a schematic view of part of an assembly line for a pipe according to a fifth embodiment;

Figure 46 is a schematic perspective view of apparatus used in the assembly line shown in Figure 45, the apparatus being provided to facilitate a relatively rapid wet-out of the reinforcement used in fabrication of the pipe;

Figure 47 is an elevational view of a roller array used in the apparatus shown in Figure 46;

Figure 48 is a fragmentary schematic view depicting a tubular structure assembled during fabrication of the pipe being subjected to manipulation akin to a peristaltic pressing action by the apparatus shown in Figure 46;

Figure 49 is a fragmentary side view depicting a section of a pipe according to a sixth embodiment, the section being configured as a straight section;

Figure 50 is a fragmentary side view depicting a further section of the pipe according to a sixth embodiment, the section being configured as a bend section;

Figure 51 is a fragmentary side view depicting a further section of the pipe according to a sixth embodiment, the section being configured as a further bend section

Figure 52 is a fragmentary side view depicting the further section of the pipe shown in Figure 51 prior to bending thereof to form the further bend section; and

Figure 53 is a schematic view of part of an assembly line for a pipe according to a seventh embodiment.

Best Mode(s) for Carrying Out the Invention

Referring to Figures 1 to 22 of the drawings, the first embodiment of the invention is directed to an elongate hollow structure in the form of a tubular element configured as a pipe 10, and to a method of construction of the pipe on a continuous basis.

The pipe 10 is of composite construction, comprising a radially inner portion 11 and a radially outer portion 13, with the two portions 11, 13 merging together to provide an integrated tubular wall structure. In the arrangement illustrated, the outer portion 13 is encased within a protective sheath 14 comprising a hardenable composition 16 such as cement or concrete contained by an outermost skin 18 of any suitable material; such as geotextile cloth. The protective sheath 14 is

intended to afford protection to the pipe 10 against compression loading to which it might be exposed once in the installed condition.

The inner portion 11 comprises an inner liner 15 with a layer 17 of resin absorbent material bonded onto one face thereof. The other face of the liner 15 defines the interior surface 19 of the pipe 10. Typically, the liner 15 presents a high gloss surface at the inner face 19. The inner liner 15 may, for example, comprise polyurethane, polyethylene or any other resiliently flexible material which is preferably also impervious to air and also compatible to fluid to be conveyed within the pipe 10. The resin absorbent layer 17 may, for example, comprise felt or flock.

As best seen in Figure 4, the inner portion 11 is configured as an inner tube 21 formed from a longitudinal strip 23 having longitudinal side edges 25. The strip 23 is rolled longitudinally into a tubular configuration to provide the inner tube 21, with the longitudinal edges 25 in abutting relationship to provide a butt joint 26. An inner jointing strip 27 is applied to the inner side of the inner tube 21 and an outer jointing strip 28 is applied to the outer side of the inner tube 21, with the two jointing strips 27, 28 bridging the butt joint 26 and providing a continuous, fluid tight connection between the abutting longitudinal side edges 25. In Figure 4, the jointing strips 27, 28 are shown spaced from the butt joint 26 for the purposes of clarity, but in practice are actually in contact with the butt joint.

The inner tube 21 defines an inflatable bladder 24 having an inflation cavity 29, the purpose of which will be explained later.

The outer portion 13 is configured as an outer tube 30 of fibre reinforced composite construction surrounded by a flexible outer casing 31. More particularly, the outer tube 30 comprises reinforcement 32 impregnated in a resinous binder. The flexible outer casing 31 is installed around the tube 30 to contain the resinous binder, as will be described in more detail shortly. The flexible outer casing 31 may be formed of any appropriate material, including for example polyethylene. The outer casing 31 may remain in place and ultimately form an integral part of the pipe 10, or it may be subsequently removed after having served its purpose.

The outer casing 31 comprises an outer layer of polyethylene and a fibrous layer bonded onto one face thereof, the arrangement being that the fibrous layer confronts the reinforcement 32. The fibrous layer provides a breather layer and also is ultimately impregnated with the resinous binder for integration of the assembly.

The resinous material which provides the resinous binder may be of any appropriate type; a particularly suitable resinous materials comprise thermosetting resin such as epoxy vinyl ester or other suitable resin and thermoplastic resin systems.

The reinforcement 32 comprises one or more layers 33 of reinforcing fabric 34 (as shown in Figure 5), each layer being configured as a tubular layer 35 (as shown in Figure 7) disposed about the inner tube 21. In this embodiment, there is a plurality of layers 33 configured as the respective tubular layers 35 disposed one about another (and hence also disposed about the inner tube 21 as previously mentioned). Adjacent fabric layers 33 may be bonded together in any suitable way such as by a hot welding chemical bonding, and/or mechanical fixing such as by stitching or stapling.

The reinforcing fabric 34 comprises reinforcing fabric which incorporates reinforcement fibres featuring quadraxial fibre orientations, as shown in Figure 5. The reinforcement fibres comprise axial fibres36a (at an angle approaching the pipe axis, which is depicted by line 37 in Figure 3), transverse fibres 36b (at an angle approaching 90 degrees to the pipe axis) and angular fibres 36c (at an angle approaching 45 degrees to the pipe axis). The reinforcement fibres may comprise glass fibres. The quadraxial fibre orientations offer the necessary hoop and axial stress bearing properties to the pipe

Each reinforcing fabric tubular layer 35 is assembled from a strip 41 of reinforcing fabric material having longitudinal edges 43 which are brought together in overlapping relationship at joint 44 to form the tubular layer 35. The overlapping edges 43 are secured together in any appropriate way to maintain the tubular formation. In this embodiment, the overlapping edges 43 are secured together by hot melt welding using a hot melt adhesive. In Figure 6, the overlapping edges 43 are shown spaced apart for the purposes of clarity, but in practice are actually in

contact with each other to provide the joint 44, as shown in Figure 7. The structural integrity of the joint 44 is subsequently established by the impregnation of resinous binder into the reinforcing fabric 34 from which the respective tubular layer 35 is formed. Specifically, the resinous binder impregnates the overlapping edges 43 and bonds them together to supplement and supplant the initial bond established by the hot melt adhesive.

The various tubular layers 35 are oriented such that the respective joints 44 are offset with respect to each other, as shown in Figure 8. In the arrangement shown in the drawings, the tubular layers 35 are oriented such that the respective joints 44 are disposed towards the underside 46 of the pipe 10 under construction. This may be advantageous as the underside 46 is the area in which resinous binder is likely to be plentiful to enhance the bond between the overlapping edges 43 at each joint 44.

The resinous binder impregnating the reinforcing fabric 34 also impregnates the layer of felt 17 on the inner liner 15 to integrate the outer portion 13 with the inner portion 11.

The reinforcing fabric tubular layers 35 are impregnated with the resinous binder after the tubular layers have been disposed one about another and hence also about the inner tube 21 as previously described. In an alternative arrangement, the reinforcing fabric tubular layers 35 may be impregnated with resinous binder after each tubular layer has been assembled. Each assembled reinforcing fabric tubular layer may be attached to the preceding inner reinforcing fabric tubular layer, such as by hot melt welding. However, it may be preferable to not so attach adjacent reinforcing fabric tubular layers so that each can move freely relative to the others for transfer of loads and stress whereby each layer can accept its share of the load.

Typically, air is removed from the reinforcing fabric tubular layers 35 prior to impregnation with the resinous binder.

After the reinforcing fabric tubular layers 35 have been impregnated with the resinous binder, but prior to curing thereof, the inflatable bladder 24 defined by the inner tube 21 is inflated by introduction of an inflation fluid such as air into the

inflation cavity 29. This causes the inflatable bladder 24 to expand radially towards the flexible outer casing 31, providing form and shape to the surrounding outer portion 13 In particular, the outer portion 13 assumes a circular profile in cross-section.

The continuous expansion of the inflatable bladder 24 as it moves through the compression device 125 stretches the reinforcing fabric tubular layers 35 in all directions, serving to enhance hoop stress and axial stress bearing properties of the pipe 10. In particular, the expansion serves to pre-stress fibres within the reinforcing fabric tubular layers 35 to enhance hoop stress bearing properties and also axially tensions the reinforcing fabric tubular layers to pre-stress fibres therein axially to enhance tensile load bearing properties of the pipe 10.

The flexible outer casing 31 serves to resist radial expansion of the reinforcing fabric tubular layers 35, thereby causing the reinforcement 32 to be subjected to radial compression. With this arrangement, the reinforcement 32 is confined in the space 45 between the expanding inner tube 21 and the flexible outer casing 31. The radially expanding inner tube 21 operates in conjunction with the flexible outer casing 31 to confine the reinforcement 32 and also causes the volume of the space 45 in which the reinforcement 32 is confined to progressively decrease. This forces the resinous binder within the reinforcement 32 to fully impregnate the reinforcement 32; that is, the layers 33 of reinforcing fabric 34 configured as the tubular layer 35 become fully “wetted-out”. In particular, it provides a compaction force to the reinforcement 32 and effectively pumps the resinous binder through the layers 33 of reinforcing fabric 34 to distribute the resinous binder within the space 45 in a controlled and constrained manner. It is a particular feature of the embodiment that the step of delivering resinous binder to the reinforcement and the step of fully wetting out the reinforcement 32 with the resinous binder are separate and distinct actions.

Further, the progressive decrease in volume of the space 45 in which the reinforcement 32 is confined acts to positively expel air from within the space 45 which has the effect of enhancing impregnation of the resinous binder within the reinforcement 32. The outer casing 31 and the various reinforcing fabric tubular layers 35 may be adapted to facilitate the expulsion of the air. The breather layer

defined by the fibrous inner layer of the outer casing 31 facilitates this expulsion of air. Further, the outer casing 31 and the various reinforcing fabric tubular layers 35 may, for example, incorporate vents at intervals along their respective lengths to facilitate expulsion of the air, as shown in Figure 9. In one arrangement, the vents 48 may comprise perforations, such as puncture holes, formed in the outer casing 31 and the various reinforcing fabric tubular layers 35. With such an arrangement, the perforations are ultimately sealed by the resinous binder to ensure the sealed integrity of the pipe 10. In another arrangement, the vents may comprise ports inserted in the outer casing 31 and the various reinforcing fabric tubular layers 35. The ports may, for example, comprise tubular inserts formed of a material which dissolves or otherwise degrades upon exposure to the resinous binder. With such an arrangement, the apertures in which the ports were accommodated are ultimately sealed by the resinous binder to ensure the sealed integrity of the pipe 10.

The flexible outer casing 31 may have some resilience in order to yielding resist radial expansion of the reinforcing fabric tubular layers 35 at least to some extent. In this way, the flexible outer casing 31 can cushion the initial stage of the radial expansion of the reinforcing fabric tubular layers 35. In particular, it is desirable that the flexible outer casing 31 have some elasticity. The flexible outer casing 31 may have some elasticity elastic for the purpose of enhancing control of the rate at which the progressively rising pool of resinous binder progressively wets the reinforcement 32. If, on the one hand, the resinous binder rises within the space 45 too rapidly, it may be that full wet-out of fibres in the reinforcement 32 is not achieved. If, on the other hand, the resinous binder rises within the space 45 too slowly, it may be that the resinous binder could commence to cure before full wet-out of fibres in the reinforcement 32 is achieved.

The elastic nature of the flexible outer casing 311 installed around the assembled around the reinforcement 32 functions somewhat as a girdle for controlling external pressure exerted on the rising pool of resinous binder. The elastic characteristic of the flexible outer casing 31 is selected to achieve the desired rate of wet-out. The elastic force exerted by the outer casing 31 provides some counterbalancing of the tension exerted by the inflating bladder 24 defined by the inner tube 21

The inflatable bladder 24 is maintained in the inflated condition until such time as the resinous binder has hardened sufficiently to maintain the form and shape of the pipe, after which the inflation fluid can be released from the inflation cavity 29. The pipe 10 thus is formed, with the inner liner 15 defining the central flow passage within the pipe.

The inner tube 21 may be preformed, or may be assembled on site as part of the construction process for the pipe 10.

In circumstances where the inner tube 21 is preformed, it may be delivered to site in a collapsed condition. The inner tube 21 may be collapsed in any appropriate way. Typically, the inner tube 21 can assume a collapsed condition by being folded in a folding pattern to provide a compact arrangement in cross-sectional profile. In the arrangement shown in Figures 10 and 11, the inner tube 21 is collapsed into a flattened condition in cross-sectional profile using a folding pattern which defines two longitudinal side portions 51 and fold portions 52 therebetween. With this arrangement, the longitudinal side portions 51 can be in abutting contact with each other to provide a compact formation. In the arrangement shown in Figures 12 to 15, the inner tube 21 is collapsed into a flattened condition in cross-sectional profile using a folding pattern which defines two longitudinal side portions 53 and re-entrant fold portions 54 therebetween. With this arrangement, the re-entrant fold portions 54 each extend inwardly from one longitudinal side of the collapsed inner tube 21. Figure 13 is a schematic cross-sectional view of the inner tube 21 shown in a folded condition. In Figure 14, the inner tube 21 is shown in a partly flattened condition. In Figure 15, the inner tube is shown in a fully flattened condition. The inner tube 21 assumes the various conditions at various stages during fabrication of the pipe 10.

The reinforcement 32 is assembled about the inner tube 21. In particular, the reinforcing fabric tubular layers 35 are assembled sequentially about the inner tube 21. As described above, each reinforcing fabric tubular layers 35 is assembled from a respective strip 41 of reinforcing fabric material having longitudinal edges 43 which are brought together in overlapping relationship at joint 44 to form the tube structure.

The various tubular layers 35 are arranged in a series 36 comprising an innermost tubular layer 35a, an outermost tubular layer 35b, and one or more intervening tubular layers 35c disposed between the innermost tubular layer 35a and the outermost tubular layer 35b. The tubular layers 35 in the series are of progressively increasing diameters in order to provide a good fit and alignment one with respect to another and thereby afford some precision in the construction of the pipe 10. In order to accommodate the progressively increasing diameters between the tubular layers 35, the respective strips 41 of reinforcing fabric material need to be of different widths, with the widths progressively increasing from the innermost tubular layer 35a to the outermost tubular layer 35b. Each tubular layer 35 is designed to be inflated, unfolded or unfurled to its maximum diameter by the inflation force of the fluid pressing against the inner tube 21 to provide the full expansion of the assembly and the fibres within it to hold the loads of the pipe 10 in operation.

As described above, the various tubular layers 35 in the series 36 are oriented such that the respective joints 44 are offset with respect to each other, as best seen in Figure 8.

Each tubular layer 35 is assembled from its respective strip 41 by progressively moving the strip through a transition from a first condition in which the strip is flat to a second condition in which the strip is in a tubular configuration with the edges 43 in overlapping relation. In Figure 16 of the drawings, the strip 41 is depicted with a section 41a thereof in the first (flat) condition and a further section 41b thereof in the second (tubular) condition. In the first condition, the strip 41 can be stored in roll form 55 on a reel 56, as shown in Figure 16.

An assembly system 60 is provided for progressively moving the respective strip 41 through the transition from the first (flat) condition to the second (tubular) condition and for securing the overlapping edges 43 together to establish the joint 44 and thus form the tubular layer 35. As the strip 41 moves through the transition from the first (flat) condition to the second (tubular) condition it progressively envelopes the inner tube 21.

The assembly system 60 comprises a guide system 61 for progressively moving the respective strip 41 through the transition from the first (flat) condition to the

second (tubular) condition. The guide system 61, which is best seen in Figure 17, comprises a guide 62 comprising a body 63 defining an entry end 64, an exit end 65 and a guide path 66 extending between the entry end and the exit end. The body 63 is configured as a tubular structure 67 having longitudinal marginal edge portions 68 which are disposed in overlapping relation and spaced apart to define a longitudinal gap 69 therebetween. The tubular structure 67 is configured such that the guide path 66 tapers inwardly from the entry end 64 to the exit end 65. With this arrangement, the tubular structure 67 provides a tapering guide surface 67a which is presented to the respective strip 41 as it advances along the guide path 66 from the entry end 64 to the exit end 65 and which progressively moves the strip 41 through the transition from the first (flat) condition at the entry end 64 to the second (tubular) condition at the exit end. As the strip 41 advances along the guide surface 67a, the longitudinal marginal edges 43 of the strip are progressively turned inwardly by the tapering profile, with one of the longitudinal marginal edges 43 of the strip 41 partially entering the longitudinal gap 69 in the tubular structure 67 and the other of the longitudinal marginal edges 43 overhanging the inner marginal edge 68a. With this arrangement, the longitudinal edges 43 are progressively brought together in overlapping relationship in readiness to be secured together to establish the joint 44 and complete formation of the tubular layer 35.

As the strip 41 is being assembled into the tubular configuration to form the tubular layer 35, the inner tube 21 is also moving along the guide path 66 from the entry end 64 and the exit end 65. In this way, the tubular layer 35 can be assembled about the inner tube 21 and thereby envelopes it.

Similarly, the innermost intervening tubular layer 35c can be assembled about tubular layer 35a and the inner tube 21 about which the latter is formed, and then any other intervening tubular layers 35c and ultimately the outermost tubular layer 35b can be assembled about the preceding tubular layers 35.

The tubular structure 67 may incorporate means for attracting and holding the strip 41 against the guide surface 67a. Such means may comprise a suction system incorporating a plurality of holes in the guide surface 67a to which suction

is applied to draw the strip 41 into contact with the guide surface as the strip moves along the guide path 66.

The assembly system 60 further comprises a guide roller 71 about which the respective strip 41 turns in its path from the reel 56 to the entry end 64 of the tubular structure 67 in order to align the strip 41 correctly for entry into the tubular structure 67.

The assembly system 60 further comprises a bonding system 71 for securing the overlapping edges 43 together to establish the joint 44 and thus complete formation of the tubular layer 35. The bonding system 71, which is shown in Figure 18, comprises means 72 for applying hot melt adhesive between the overlapping edges 43 and then bringing the edges together to establish the joint 44. In the arrangement shown, such means 72 comprises a delivery head 73 for delivering one or more bands 74 of hot melt adhesive between the overlapping edges 43. The delivery head 73 is adapted to receive a supply of hot melt adhesive from a source 75 by way of a delivery line.

The bonding system 71 further comprises means 76 for bringing the overlapping edges 43 together with the hot melt adhesive therebetween to establish the joint 44. In the arrangement shown, such means 76 comprises a press 77 for pressing the overlapping edges 43 together. The press 77 comprises two cooperating press rollers 78 between which the overlapping edges 43 pass to be pressed together to establish the joint 44 by way of the hot melt adhesive. While not shown in the drawings, the assembly system 60 may further comprise means for facilitating rapid setting of the holt melt adhesives Such means may comprise an arrangement to deliver a cooling agent, such as cold air, to the area at and around the joint 44.

The construction process of the pipe 10 according to the embodiment will now be described in more detail. In this embodiment, the pipe 10 is constructed on a continuous basis and progressively laid into a trench 79 which has been dug to receive the pipe. The pipe 10 is laid in the trench79 prior to curing of the resinous binder which impregnates the reinforcing fabric 34 and also the layer of felt 17 on the inner liner 15. The curing occurs after laying of the pipe 10 within the trench

79. In this way, the pipe 10 is in a flexible condition to facilitate it being guided into the trench and laid into position, and hardens once in position.

Referring in particular to Figure 1, the pipe 10 is assembled in a mobile installation plant 80 configured as a vehicle which can travel alongside the trench 79 such that the continuously formed pipe 10 can "snake" from the mobile installation plant 80 into the trench 79. The pipe 10 may be cured within the trench 79 is any appropriate way. In the arrangement illustrated, a curing unit 71 is provided to progressively move along the trench 79 to expose the recently laid section of the pipe to a curing action. The curing unit 81 may, for example, apply heat or other radiation such as UV radiation or light (according to the nature of the resinous binder) to the pipe 10 to facilitate the curing process. In an alternative arrangement, the resinous binder may incorporate an appropriate catalyst to cure the pipe in ambient conditions.

The mobile installation plant 80 comprises a pipe assembly line 82, as shown in Figure 19 (which is presented in two parts, Figures 19A and 19B).

Referring to Figure 19A, the assembly line 82 comprises a supply of material 83 in strip form and stored on a roll 85. The material 83 provides the inner liner 15 with the layer of resin absorbent material 17 bonded thereto. The material 83 is progressively unwound from the roll 85 and conveyed as a strip 23 to a first assembly station 87 at which it is formed into the inner tube 21. As described previously, the strip 23 is rolled longitudinally into a tubular configuration to provide the inner tube 21, with the longitudinal edges 25 in abutting relationship to provide the butt joint 26, and the jointing strip 27 applied to the inner side of the inner tube 21 to bridge the butt joint 26 and provide a continuous, fluid tight connection.

The assembly line 82 further comprises one or more supplies of material 91, each in strip form and stored in roll form 55 on respective reels 56.In the arrangement shown in Figure 19A there are two reels 56, but other numbers are possible. The material 91 provides the reinforcing fabric 34 incorporating reinforcement fibres featuring quadraxial fibre orientations. The material 91 is progressively unwound from the respective reel 56 and conveyed as strip 41 to a second assembly station 95 at which it is formed into the respective reinforcing fabric tubular layer

35 about the inner tube 21. As described previously, each reinforcing fabric tubular layer 35 is assembled from the strip 41 of reinforcing fabric material having longitudinal edges 43 which are brought together in overlapping relationship to form the tubular layer. The overlapping edges 43 are secured together in to maintain the tubular formation. In this embodiment, the overlapping edges 43 are secured together by hot melt welding. The respective tubular layers 35 are disposed one about another and also disposed about the inner tube 21 as previously mentioned. Adjacent fabric layers 33 may be bonded together by a hot welding or chemical bonding process. The layers may comprise a bonding or forming material to more effectively hold the layers together. This may for example comprise chop strand mat, felt or veil to enhance the laminar shear between the layers of high strength quadraxial fabric and allow for easier release of air from the laminate.

The reinforcing fabric tubular layers 35 and the inner tube 21 provide a tube structure 100. The tube structure 100 is conveyed to a third station 103 at which it is compressed between compression rollers 105 to extract air therefrom and force the resinous binder into direct contact with the reinforcement 32 and the adjacent layer 17 of resin absorbent material.

The tube structure 100 is then conveyed to a fourth station 105 at which it is impregnated with the resinous binder. In the illustrated arrangement, the tube structure 100 is passed through a resin bath 107, circulating between rollers 109 to work the resinous binder into the felt 17 and the reinforcing baric 34. At least some of the rollers 109 are driven to assist movement of the tube structure 100.

The tube structure 100 is then conveyed to a fifth station 111 at which is engaged by doctor rollers 113 to remove excess resinous binder which can be collected in a catchment zone 115.

The tube structure 100, which is now impregnated with resinous binder, is then conveyed to a sixth station 117 at which the flexible outer casing 31 is installed to complete assembly of the tube structure 100. Referring now to Figure 19B, the assembled tube structure 100 is then conveyed to a seventh station 121 at which there is provided a compression device 125 comprising two endless drives 127 defining a passage 129 through which the tube structure 100 can pass. The

assembled tube structure 100 is compressed in the passage 129 to define a choked zone 123 blocking the passage of air along the interior of the assembled tube structure. The two endless drives 127 incorporate opposing elements 131 such as cleats which cooperate to pinch the tube structure 100 at intervals and close it against the passage of air while allowing the impregnated resinous binder within the tube structure to pass through the choke passage 129.

The compression device 125 also functions to apply traction to the assembled tube structure 100 to convey it along its path.

The section 100a of the assembled tube structure 100 beyond the device 125 is expanded by introduction of inflation fluid such as air into the interior thereof which defines the inflation cavity 29. This causes the assembled tube structure 100 to expand both radially and axially, providing form and shape thereto. The expansion of the assembled tube structure 100 stretches the reinforcing fabric tubes 35 in all directions, serving to enhance hoop stress and axial stress bearing properties of the pipe 10. In particular, the expansion serves to pre-stress fibres within the reinforcing fabric tubular layers 35 to enhance hoop stress bearing properties and also axially tensions the reinforcing fabric tubular layers to pre-stress fibres therein axially to enhance tensile load bearing properties of the pipe 10.

The inflation fluid cannot escape from the inflation cavity 29 because the end is closed by the chocked zone 123 of the assembled tube structure 100 as previously explained. In other words, the compression device 125 functions as a valve to close the interior of the tubular structure 100 to prevent the escape of inflation fluid from the inflation cavity 29. Further, the compression device 125 acts as a brake to hold the expansion loads imposed by the inflation of the inner tube 21 with an inflation fluid. Still further, the compression device 125 acts as a drive to start the process before the inflation begins.

As described previously, the flexible outer casing 31 serves to resist radial expansion of the reinforcing fabric tubular layers 35, thereby causing the reinforcement 32 to be subjected to radial compression. The reinforcement 32 is confined in the space 45 between the expanding inner tube 21 and the flexible outer casing 31. The radially expanding inner tube 21 operates in conjunction

with the flexible outer casing 31 to cause the volume of the space 45 in which the reinforcement 32 is confined to progressively decrease. This forces the resinous binder within the reinforcement 32 to progressively rise within the space 45 displacing the air and ultimately fully impregnate the reinforcement 32; that is, the layers 33 of reinforcing fabric 34 configured as the tubular layer 35 become fully "wetted-out". In this way, the resinous binder is forced through the layers 33 of reinforcing fabric 34 to distribute the resinous binder within the space 45 in a controlled and constrained manner.

It is a particular feature of the embodiment that the step of delivering resinous binder to the reinforcement 32, and the step of fully wetting out the reinforcement 32 with the resinous binder, are separate and distinct actions. Specifically, resinous binder is introduced into the tubular structure 100 before the latter passes through the compression device 125, and the resinous binder is caused to fully wet-out the reinforcement 32 following the introduction of inflation fluid into the inflation cavity 29 after the tubular structure 100 has passed through the compression device 125.

Further, the progressive decrease in volume of the space 45 in which the reinforcement 32 is confined acts to positively expel air from within the space 45 which has the effect of enhancing impregnation of the resinous binder within the reinforcement 32, as previously described.

At this stage the resinous binder has not cured and so the section 10a of the pipe 10 assembled in a mobile installation plant 80 is in a flexible condition. The uncured section 10a of the pipe 10 leaves the mobile installation plant 80 and is guided into the trench 79, as previously mentioned. The pipe 10 may be cured within the trench 79 is any appropriate way. In the arrangement illustrated, the curing unit 71 progressively moves along the trench 79 to expose the recently laid section of the pipe to a curing action.

The assembled tube structure 100 is maintained in the inflated condition until such time as the resinous binder has hardened sufficiently to maintain the form and shape of the pipe 10, after which the inflation fluid can be released from the inflation cavity 29. The pipe 10 thus is formed, with the inner liner 15 defining the central flow passage within the pipe.

Because the tubular structure 100 is assembled progressively as described, it can be considered to have a commencement end 133 and a terminal end 135. Typically, the inflation fluid such as air for the inner tube 21 is introduced through the commencement end 133 of the tubular structure 100.

The commencement end 133 is shown in Figures 20. In the arrangement shown, the commencement end 133 is fitted with an end fitting 136 which comprises an end flange portion 137 and a spigot portion 138. The end fitting 136 is installed onto the commencement end 133 immediately after it has emerged from the compression device 125. The installation procedure involves insertion of the spigot portion 138 into the end of the tubular structure 100 and then clamping the commencement end 133 of to the spigot portion, typically by clamping means 139 such as straps or clamping rings. A collar (not shown) may be installed onto the commencement end 133 to give it form and shape to receive the spigot portion 138 of the end fitting 136.

The flange portion 137 has provision 141 for communication with a fluid line 142 for delivery of inflation fluid into the inner tube 21. In the arrangement shown, the provision 152 includes a port 143 through which the delivery end section of the fluid line 142 extends.

The terminal end 135 is shown in Figures 21 and 22. In the arrangement shown, the terminal end 135 is fitted with an end fitting 144 which closes the end. The end fitting 144 comprises a clamp 145 adapted to clampingly engage the tubular structure to sealingly close the terminal end 135. The clamp 145 is adapted to be fitted onto the tubular structure 100 after the latter has been assembled but prior to it passing through the compression device 125. The clamp 145 is adapted to pass along the passage 129 between the two endless drives 127 without interfering with the operation of the opposing elements 131 which cooperate to pinch the tube structure 100 at intervals along the passage 129. The arrangement is such that the clamp 145 moves in timed relation with the two endless drives 127 so that the position of the clamp 145 along the passageway does not at any stage coincide with a point at which the tubular structure 100 is being pinched closed by cooperating opposing elements 131 of the two endless drives 127. In this way, the clamp 145 can pass along the passage 129 while

attached to the tubular structure 100 without interfering with the operation of the opposing elements 131.

In circumstances there may be a requirement for the end section of the tubular structure 100 adjacent to the terminal end 135 to be of a specific cross-sectional profile. In such circumstances, a profile forming system 146 may be utilised, as shown in Figure 22. The profile forming system 146 comprises an external die 147 corresponding to the desired profile, the arrangement being that the end section of the tubular structure 100 adjacent to the terminal end 135 passes through the die 147 after having exited the compression device 125. Internal pressure may be applied to the end section of the tubular structure 100 adjacent to the terminal end 135 in order to urge the end section outwardly into contact with the die 147 so that the desired profile can be applied to the end section. In the arrangement shown, the internal pressure is applied by way of an inflation assembly comprising inflatable bladder 148 and an associated flexible fluid delivery line 149 along which an inflation fluid can be delivered to inflate the bladder 148. The inflatable bladder 148 is adapted to be inserted into the end section of the tubular structure 100 adjacent to the terminal end 135 prior to attachment of the clamp 145 to the terminal end 135. The fluid delivery line 149 extends to the exterior of the tubular structure 100, passing through a hole formed for the purpose in the tubular structure 100. The inflatable bladder 148 is inserted into the end section of the tubular structure 100 in a deflated condition and passed through the compression device 125 in the deflated condition along with the flexible fluid delivery line 149. The bladder 148 is inflated once the terminal end 135 has exited the compression device 125 but prior to the end section of the tubular structure 100 adjacent to the terminal end 135 being engaged by the die 147. Inflation of the bladder 148 applies internal pressure to the end section of the tubular structure 100 adjacent to the terminal end 135, thereby urging the end section outwardly into contact with the die 147 so that the desired profile can be applied to the end section.

It is a particular feature of the embodiment that the step of delivering resinous binder to the reinforcement 32 and the step of fully wetting out the reinforcement 32 with the resinous binder are separate and distinct actions. Specifically, the resinous binder is delivered to the reinforcement prior to passage of the tubular

structure 100 through the compression device 125. The inner tube 21 is inflated after the tubular structure 100 has passed through the compression device 125. The inflation of the inner tube

Referring now to Figure 23 (which is presented in two parts, Figures 23A and 23B), there is shown a pipe assembly line 150 for a pipe according to a second embodiment. The pipe assembly line 150 is similar in some respects to the pipe assembly line 81 used for the first embodiment and corresponding reference numerals are used to identify corresponding parts.

The second embodiment does not use a resin bath (as was the case in the first embodiment) for impregnating the tube structure 100 with the resinous binder. Rather, resinous binder is delivered to the assembled tube structure 100.

Referring to Figure 23A, a flexible outer casing 31 is installed around the assembled portion of the outer tube structure 100 to contain the resin binder, as will be described in more detail shortly. The outer casing 31 may be formed of any appropriate material, including for example polyethylene. The outer casing 151 may remain in place and ultimately form an integral part of the pipe, or it may be subsequently removed after having served its purpose. The material 153 from which the outer casing 31 is assembled is in strip form and stored on roll 155. The material 153 is progressively unwound from the roll 155 and conveyed as a strip 156 to station 157 at which it is assembled into a tube 159 which provides the outer casing 31. The tube 159 is assembled from the strip 156 by bring the longitudinal edges of the strip together in overlapping relationship to form the tube. The overlapping edges are secured together to maintain the tubular formation by any appropriate means such as stitching, welding or stapling.

Resinous binder is delivered into the flexible outer casing 31 through open end 161 thereof. The resinous binder is delivered along delivery line 163 which extends into the flexible outer casing 31 through the open end 161 and has an outlet end 162 disposed inwardly of the open end 161. The delivery line 163 receives the resin from a reservoir 165 such as a supply tank. A pump 167 is provided for pumping the resin along the delivery line 163 from the reservoirs 165 to the outlet end 162. Resinous binder is delivered into the flexible outer casing

31 tends to a pool 171 at the bottom of the tube 159 which provides the outer casing 31.

The assembled tube structure 100 is compressed to define the choked zone 123 by the compression device 125 comprising the two endless drives 127. The opposing elements 131 (such as cleats) on the two endless drives 127 cooperate to pinch the tube structure 100 and close it against the passage of air while allowing the impregnated resinous binder confined within the flexible outer casing 31 to pass through the choke passage 129. The action of the cooperating elements 131 serves to pinch the assembled tube structure 100, together with the outer casing 31, at intervals. This causes the resinous binder, which is contained in the outer casing 31 and which is pooling at the bottom thereof, to collect in "puddles" in the sections of the outer casing 31 between each set of cooperating elements 131, as shown in Figure 24.

As the assembled tube structure 100 progressively moves beyond the compression passage 129 defined by the device 125, the pool 171 of resinous binder progressively rises in the annular space 45 between the inner liner 21 and the surrounding flexible outer casing 31. This occurs because the expanding inner tube 21 progressively reduces the cross-sectional size of the annular space 45, thereby causing the level of the pool 171 of resinous binder to progressively rise. This is depicted schematically in Figure 8B and Figures 10 to 16 in which the surface of the pool 171 is identified by reference numeral 177. The rising pool 171 of resinous binder within the annular space 45 progressively displaces air within the annular space. The outer casing 31 is constructed to facilitate the displacement of the air. This may involve provision of slow release air valves within the outer casing 31 at intervals along its length and non woven breather materials as part of the outer casing to facilitate air release from the pipe and along the length of the pipe. Additionally, or alternatively, vacuum points may be provided along the length of the tubular structure 100.

The surface 177 of the progressively rising pool 171 forms a wave profile as depicted by line 179 in Figure 23B.

The progressively rising pool 171 of resinous binder progressively wets the reinforcement 32 and the adjacent resin absorbent layer 17 of the inner liner 21.

Ultimately, the assembled tube structure 100 is fully impregnated with resinous binder.

Referring now to Figures 32 to 43 there is shown part of a pipe assembly line 200 for a pipe according to a third embodiment. The pipe assembly line 200 is similar in some respects to the pipe assembly line 150 used for the second embodiment and corresponding reference numerals are used to identify corresponding parts.

The pipe assembly line 150 used for the second embodiment employed a flexible outer casing 31 installed around the assembled outer tube structure 100 to contain the resin binder and establish the progressively rising pool 171 of resinous binder for progressively wetting the assembled tube structure 100 .

The pipe assembly line 200 used for the third embodiment also employs an flexible outer casing 31 to contain the resin binder within the assembled outer tube structure 100 and establish the progressively rising pool 171 of resinous binder.

In this third embodiment, the flexible outer casing 31 is elastic for the purpose of enhancing control of the rate at which the progressively rising pool 171 of resinous binder progressively wets the assembled tube structure 100. If, on the one hand, the pool 171 of resinous binder rises within the annular space 45 too rapidly, it may be that full wet-out of fibres in the assembled tube structure 100 is not achieved. If, on the other hand, the pool 171 of resinous binder rises within the annular space 45 too slowly, it may be that the resinous binder could commence to cure before full wet-out of fibres in the assembled tube structure 100 is achieved.

The elastic nature of the flexible outer casing 31 functions somewhat as a girdle for controlling external pressure exerted on the rising pool 171 of resinous binder. The elastic characteristic of the flexible outer casing 31 is selected to achieve the desired rate of wet-out. The elastic force exerted by the outer casing 31 provides some counterbalancing of the tension exerted by the inflating inner tube 21.

In this embodiment, the tube structure 100 is compressed prior to installation of the elastically flexible outer casing 31 to complete assembly of the tube structure.

In the arrangement shown, the compression of the tube structure 100 is achieved by passing it through a constriction 180 which is configured as a funnel.

Referring now to Figure 44, there is shown part of a pipe assembly line 300 for a pipe according to a fourth embodiment. The pipe assembly line 300 is similar in some respects to the pipe assembly line 81 used for the first embodiment and corresponding reference numerals are used to identify corresponding parts.

In this fourth embodiment, resinous binder is delivered to the various tubular layers 35 forming the reinforcement 32 during assembly of the tube structure 100, rather than using a resin bath as was the case in the first embodiment. The tube structure 100 is progressively assembled by forming the reinforcing fabric tubular layers 35 about the inner tube 21, with each tubular layer 35 being formed from respective strip 41 within the respective assembly system 60, as shown in Figure 44. As each reinforcing fabric tubular layers 35 is assembled, a quantity of resinous binder is deposited into the interior of the tubular layer. Further, resinous binder may be sprayed, rolled or otherwise deposited onto the exterior of each tubular layer 35 after assembly thereof. In the arrangement shown in Figure 44, there is provided a delivery system 301 for depositing a slug of resinous binder into the interior of each tubular layer 35 as the respective strip 41 from which the tubular layers is formed moves through the transition from the first (flat) condition to the second (tubular) condition . In the arrangement shown in Figure 44, there is further provided a spray roller or other system 303 for spraying resinous binder onto the exterior of each tubular layer 35 after assembly thereof and prior to installation of the next tubular layer 35 therearound. With this arrangement, resinous binder is applied to the reinforcement 32 to fill most of the available volume while still allowing for movement of the resinous binder through the various tubular layers 35 to displace air from the lower region of the space 45 between the expanding inner tube 21 and the flexible outer casing 31 to the upper region of the space for subsequent venting.

In certain applications, there may be a need to facilitate a relatively rapid wet-out of the reinforcement 32 and the adjacent resin absorbent layer 17 of the inner liner 21, rather than relying solely on progressively rising pool of resinous binder as described in previous embodiments. Such an application may, for example,

relate to a pipeline installation in which the tubular structure 100 has an inclined section in which the resinous binder would migrate downwardly under the influence of gravity and not achieve a satisfactory wet-out the reinforcement 32 and the adjacent resin absorbent layer 17 of the inner liner 21.

Referring now to Figures 45, 46 and 47, there is shown part of a pipe assembly line 400 for a pipe according to a fifth embodiment. The pipe assembly line 400 is similar in some respects to the pipe assembly line 81 used for the first embodiment and corresponding reference numerals are used to identify corresponding parts.

In the arrangement shown the tubular structure 100 has a section 401 thereof which is steeply inclined to an extent that the resinous binder would migrate downwardly under the influence of gravity and not achieve a satisfactory wet-out of the reinforcement 32 and the adjacent resin absorbent layer 17 of the inner liner 21.

The pipe assembly line 400 incorporates apparatus 403 to facilitate a relatively rapid wet-out of the reinforcement 32 and the adjacent resin absorbent layer 17 of the inner liner 21.

The apparatus 403 comprises a plurality of roller arrays 405 disposed in spaced apart relation. Each roller array 405 comprises a plurality of rollers 407 arranged in an annular formation 409 defining a central circular space 411 through which the assembled tubular structure 100 can pass in a constricted condition.

Each roller array 405 comprises a central axle 413 configured as a ring upon which the respective rollers 407 are rotatably mounted. The rollers 407 are disposed angularly one with respect to another because of the ring configuration of the central axle 413. The rollers 407 are also located close together. Because of the angular disposition and close positioning of the rollers 407, the cylindrical rolling surfaces 415 of the rollers 407 cooperate at the inner side 416 of the annular array 405 to present a rolling contact surface 417. Additionally, gaps 419 are formed between adjacent rollers 407 at the outer side 420 of the annular array 405.

The roller arrays 405 are spaced axially one with respect to another, with spaces 421 defined between each two adjacent roller arrays.

The rings 415 are connected one to another to maintain the roller arrays 405 in position. In the arrangement shown, the axles 413 are connected together by connecting rods 423. The presence of the gaps 419 between adjacent rollers 407 at the outer side 420 of the annular array 405 provides access for attachment of the connecting rods 423 to the axles 413.

The apparatus 403 is adapted to be progressively moved along the assembled tubular structure 100 once the inner tube 21 has been inflated. In the arrangement shown in Figure 45, the apparatus 403 is positioned closely behind the device 125.

Typically, the apparatus 403 is pulled along the assembling tubular structure 100 closely behind the compression device 125.

The apparatus 403 may also be adapted to impart vibration to the tubular structure 100 to excite the resinous binder and enhance the wetting process.

With this arrangement, the tubular structure 100 is subjected to manipulation akin to a peristaltic pressing action when passing through the apparatus 403, as depicted schematically in Figure 48. Specifically, the tubular structure 100 is constricted when passing through each central circular space 411 and then expands into the intervening spaces 419 under the influence of the inflation pressure within the inner tube 21. This successive constriction and expansion manipulates the assembled tubular structure 100 to distribute the resinous binder and facilitate relatively rapid wet-out of the reinforcement 32 and the adjacent resin absorbent layer 17 of the inner liner 21.

The preceding embodiments have been described with reference to construction of the pipe 10 which is progressively laid into a trench dug to receive the pipe.

The invention, including the pipe according to various embodiments which have been described and illustrated, is not limited a pipe which is and progressively laid into a trench dug to receive the pipe.

The pipe may be adapted to be laid on the ground, either directly or indirectly in a support arrangement such as suspension cradles disposed along its length. The pipe may also be supported in an elevated condition, such as for example in an installation in an industrial or chemical plant.

It is a particular feature of the pipe constructed in accordance with the invention that it can be constructed and then installed in position prior to curing of the resinous binder. In this way, the pipe may be in a flexible condition to facilitate it being guided into an installation position, with the pipe subsequently becoming rigid once in position upon curing of the resinous binder. With this arrangement, the pipe while in the flexible condition can be carried or otherwise conveyed into intended position and then installed prior to curing of the resinous binder.

Such an arrangement may be particularly advantageous in circumstances where a pipe in required to follow a path weaving around one or more obstructions or to otherwise follow a tortuous path. This can be a common occurrence for pipelines in industrial or chemical plant.

Referring now to Figures 49 to 52, there are shown sections of a pipe 10 according to a sixth embodiment. The pipe 10 according to the sixth embodiment incorporates one or more straight sections, one of which is depicted in Figure 49 and identified by reference numeral 501. The pipe 10 also incorporates one or more bend sections, one possible form of which is depicted in Figure 50 and identified by reference numeral 503, and another possible form of which is depicted in Figure 51 and identified by reference numeral 505.

The bend section 503 is configured as a gentle curve having an outer side 507 and an inner side 509. The flexible outer casing 31 stretches on the outer side 507, and contracts on the inner side 509, to accommodate the curvature. The fibres within the reinforcement 32 are able to slip to also accommodate the curvature and spread the load.

The bend section 505 is configured as a tight curve having an outer side 511 and an inner side 513. The bend section 505 is formed by removing sections of the assembled tubular structure 100 adjacent the inner side 513, as shown in Figure 52, to create recessed formations 515 along the inner side to facilitate folding of

the tubular structure to form the assembled tube structure 100. In the arrangement shown, the removed sections are of a v-configuration such that each recessed formation 515 has two opposed inclined side edges 517 which abut in overlapping relation upon formation of the bend section 505, as shown in Figure 51. The abutting edges 517 are sealing bonded together.

In certain applications there may be a need for the pipe 10, or at least a section of the length thereof, to be flexible after construction of the pipe and curing of the resinous binder. Such an application may involve a pipe 10 which provides a flexible pipeline extending between an underwater location and a facility at the water surface.

A pipe 10 according to a seventh embodiment, which is shown in Figure 53, is constructed for use in such an application. The pipe 10 may, for example, provide a flexible riser between a subsea location and an offshore production rig. In this embodiment, the pipe 10 is assembled at an installation plant 600 aboard a marine vessel such as a ship or a barge and is laid into a body of water 601, the surface of which is identified by reference numeral 603.

The installation plant 600 assembles the tubular structure 100 is a manner similar to the previous embodiments. In this embodiment, the installation plant 600 employs apparatus 403 to facilitate a relatively rapid wet-out of the reinforcement 32 and the adjacent resin absorbent layer 17 of the inner liner 21, as described previously in relation to the fifth embodiment. Additionally, the installation plant 600 has a support structure 605 to support the assembled tubular structure 100 as it is laid into the water 601.

In this embodiment, the resinous binder used in the construction of the pipe 10 hardens but to a more flexible state (as opposed to hardening to a rigid state as was typically the case with previous embodiments). Specifically, the resinous binder remains flexible after curing in order to provide the pipe 10 with the required flexibility. Resinous binders and other binding agents suitable for such purpose are well known in composite construction techniques and examples of which include rubber modified polyester, rubber modified vinyl ester, rubber modified epoxy and polyurethane. In this embodiment, rubber modified vinyl ester is preferred as the resinous binder, as it has high shear strength and good inter-

laminar bonding but also affords the structure some ability to yield to accommodate movement.

Because of the need for the assembled tubular structure to descend in the water as the pipe 10 is laid, it may not be appropriate to use air as the inflation fluid for the inner liner 21 as air may provide undesirable buoyancy to the assembled tubular structure. In this embodiment, water is used as the inflation fluid. The water acting as the inflation fluid is sourced from the surrounding body of water 601. In the arrangement shown, the bottom of the descending tubular structure (being its commencement end 133) has a fitting 607 through which water can be pumped into the tubular structure 100 to inflate the inner liner 21. The inflation fluid is introduced to establish and maintain a level above the water surface 603 in order to establish a pressure head for pressurising the water sufficiently to inflate the liner 21 as necessary. The level of the water within the tubular structure 100 above the water surface 603 is identified by reference numeral 611.

In this embodiment, the compression apparatus 125 functions as a brake system to control the descent of the assembled tube structure 100 rather than applying traction for movement relative to the tubular structure as was the case with preceding embodiments..

The preceding embodiments have related to construction of pipes of a length to constitute a pipeline extending continuously between two distant locations. The invention need not, however, be limited to construction of such long pipes. Indeed the invention may have application in the production of other pipes, such as for example production of pipes which are adapted to be connected one to another to form a pipeline and as such are typically of shorter length for handling and installation as individual units. The production of such pipes may be accommodated within a production facility such as a factory.

The next embodiment, which is not shown in the drawings, is directed to such a pipe. The embodiment is similar in some respects to previous embodiments and corresponding terminology is thus adopted in the description of the embodiment.

In this embodiment, the inner portion is placed on a core (such as a mandrel) adapted for axial and radial expansion, and the outer portion is positioned about

the inner portion to provide an assembled tube structure. The outer portion may be positioned about the inner portion before, during, or after placement of the inner portion on the core. The resinous binder impregnating the reinforcing fabric of the outer portion also impregnates the layer of felt on the inner liner to integrate the outer portion with the inner portion, as was the case with earlier embodiments. Prior to curing of the resinous binder, the core is expanded, thereby causing the assembled tube structure to expand both radially and axially, providing form and shape thereto. The expansion of the assembled tube structure stretches the reinforcement in the outer portion in all directions, serving to enhance hoop stress and axial stress bearing properties of the pipe 10, as was the case with previous embodiments. The assembled tube structure 100 can then be removed from the core once the resinous binder has cured sufficiently, thereby providing the pipe.

In this embodiment, the core is used to expand the assembled tube structure both radially and axially, rather than an inflation fluid as was the case with the earlier embodiments.

In another arrangement, a relatively short pipe can be produced by producing a pipe in accordance with any one of the first, second or third embodiments and then cutting the pipe into sections each constituting a short pipe.

A pipe in accordance with any of the preceding embodiments may require a coupling at one or both of its ends. The coupling may be required to couple the pipe to other pipe in a pipeline, or to connect the pipe to another component (such as a filters, pump and valve). Further, it may be necessary to fit a coupling to a pipe at the start and end of a construction run in which the pipe is produced.

The couplings may be fitted to the pipe ends in any appropriate way. One way may involve a coupling device having an anchoring portion and a coupling portion, the anchoring portion being configured for attachment to the pipe and the coupling portion presenting a coupling part (such as a coupling flange) for attachment to a corresponding coupling part on another other pipe or component to which the pipe is to be coupled.

The anchoring portion may be adapted to be embedded in the adjacent end of the pipe 10. The anchoring portion may be configured to key with the pipe. The

keying may be achieved in any suitable way, such as by provision of formation which keys with the outer portion 13 of the pipe 10. The formation may comprise lateral protrusions such as pins which key with the reinforcement 32 and the resinous binder impregnated therein. Alternatively, or additionally, the formation may comprise holes into which the reinforcement 32 and the resinous binder impregnated therein can locate to effect the keying action. Further, fibres in the reinforcement 32 can be wound about, inserted through, or otherwise attached to the formation to assist in securing the anchoring portion in position.

The preceding embodiments have related to construction of composite tubular structures configured as pipes.

The invention may have application to construction of any appropriate tubular structure, including for example, various tubular objects, elements, parts or other formations. The tubular structures may include structural elements such as shafts, beams and columns. The tubular structures may also include hollow structural sections of composite construction and also tubing.

Such tubular structures may be constructed in any appropriate way. A particularly convenient way of constructing such tubular structures may be similar to the process described in relation to an earlier embodiment involving a core (such as a mandrel) adapted for axial and radial expansion, and the outer portion is positioned about the inner portion to provide an assembled tube structure which constitutes the tubular structure.

The feature of applying vibration to the assembled tubular structure 100 to excite the resinous binder and enhance the wetting process may be used in relation to the construction of any of the elongate hollow structures according to the invention.

From the foregoing it is apparent that it is a particular feature of the embodiments described that the step of delivering resinous binder to the reinforcement 32, and the step of fully wetting out the reinforcement 32 with the resinous binder, are separate and distinct actions. Specifically, resinous binder is introduced into the tubular structure 100 before the latter passes through the compression device 125, and the resinous binder is caused to fully wet-out the reinforcement 32

following the introduction of inflation fluid into the inflation cavity 29 after the tubular structure 100 has passed through the compression device 125.

Further, the progressive decrease in volume of the space 45 in which the reinforcement 32 is confined acts to positively expel air from within the space 45 which has the effect of enhancing impregnation of the resinous binder within the reinforcement 32, as previously described.

It should be appreciated that the scope of the invention is not limited to the scope of the embodiments described.

Throughout the specification and claims, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

The Claim Defining the Invention is as Follows:

1. A method of constructing an elongate hollow structure comprising a radially inner portion and a radially outer portion, with the two portions merging together to provide an integrated tubular wall structure, the method comprising: providing the radially inner portion: assembling the radially outer portion about the radially inner portion; and expanding the inner portion; wherein the outer portion comprises an outer tube of fibre reinforced composite construction surrounded by a flexible outer casing.

2. The method according to claim 1 wherein the outer tube of fibre reinforced composite construction comprises reinforcement and a binder,

3. The method according to claim 2 wherein the reinforcement comprises one or more layers of reinforcing fabric.

4. The method according to claim 3 wherein the or each layer is configured as a tubular layer disposed about the radially inner portion.

5. The method according to claim 4 wherein there is a plurality of tubular layers disposed one about another and about the inner tube.

6. The method according to any one of claims 3 to 5 wherein the inner portion comprises an inner tube comprising an inner liner with a fibrous layer bonded onto one face thereof, wherein the binder impregnating the reinforcing fabric also impregnates the fibrous layer to integrate the outer portion with the inner portion .

7. The method according to any one of claims 2 to 6 wherein the flexible outer casing serves to resist radial expansion of the reinforcement, thereby causing it to be subjected to radial compression.

8. The method according to claim 7 wherein the reinforcement is confined in the space between the expanding inner portion and the flexible outer casing, whereby the radially expanding inner portion operates in conjunction with the flexible outer casing to cause the volume of the space to progressively decrease thereby to cause the binder within the reinforcement to fully impregnate the reinforcement.

9. The method according to claim 7 wherein the reinforcement is confined in the space between the expanding inner portion and the flexible outer casing, whereby the radially expanding inner portion operates in conjunction with the flexible outer casing to causes the volume of the space to progressively decrease thereby to cause expulsion of air from within the space.

10. The method according to claim 7 wherein the reinforcement is confined in the space between the expanding inner portion and the flexible outer casing, whereby the radially expanding inner portion operates in conjunction with the flexible outer casing to cause the volume of the space to progressively decrease thereby to cause the binder within the reinforcement to fully impregnate the reinforcement and to also to cause expulsion of air from within the space.

11. The method according to claim 9 or 10 wherein the outer casing and the various reinforcing fabric tubular layers are configured to facilitate expulsion of the air.

12. The method according to any one of claims 7 to 11 wherein the flexible outer casing has some resilience in order to yieldingly resist radial expansion of the reinforcing fabric tubular layers.

13. The method according to claim 12 wherein the flexible outer casing has less resilience than the inner tube.

14. The method according to claim 12 or 13 wherein the flexible outer casing has elasticity for the purpose of enhancing control of the rate at which the binder progressively wets the reinforcement.

15. The method according to any one of claims 3 to 14 wherein the reinforcing fabric comprises reinforcing fabric incorporating reinforcement fibres featuring quadraxial fibre orientations.

16. A method of constructing an elongate hollow structure comprising a radially inner portion and a radially outer portion, with the two portions merging together to provide an integrated tubular wall structure, the method comprising: providing the radially inner portion comprising inner tube comprising an inner liner with a fibrous layer bonded onto one face thereof; assembling the radially outer portion about the radially

inner portion; and expanding the inner portion; wherein the outer portion comprises an outer tube of fibre reinforced composite construction surrounded by a flexible outer casing and wherein the inner portion comprises an inner tube comprising an inner liner with a fibrous layer bonded onto one face thereof, whereby resinous binder impregnating the outer tube also impregnates the fibrous layer to integrate the outer portion with the inner portion.

17. A method of constructing an elongate hollow structure comprising forming a flexible tubular wall structure about a central portion, expanding the central portion to cause the tubular wall structure to assume a prescribed cross-sectional profile, and hardening, curing or otherwise setting the tubular wall structure.

18. The method according to claim 17 wherein the central portion comprises part of the wall structure.

19. The method according to claim 17 or 18 wherein the flexible wall structure comprises a fibre-reinforced plastic composite.

20. The method according to claim 19 wherein the flexible wall structure further comprise settable plastic such as a resinous binder.

21. The method according to claim 19 or 20 wherein the fibre reinforced plastic composite comprise reinforcement configured as a fabric incorporating reinforcement fibres.

22. The method according to claim 21wherein thethe reinforcing fabric has quadraxial fibre orientations.

23. The method according to any one of claims 17 to 21 wherein the flexible tubular wall structure further comprises a flexible outer casing surrounding the fibre-reinforced plastic composite.

24. The method according to any one of claims 3 to 14 wherein the expandable central portion comprises an inner tube which provides an inflatable bladder to expand the flexible tubular wall structure prior to hardening, curing or other setting thereof.

25. The method according to claim 24 wherein the inner tube is integrated with and forms part of the tubular wall structure.

26. A method of constructing an elongate hollow structure comprising forming a flexible tubular wall structure having an interior, inflating the interior of the flexible tubular wall structure to provide form and shape thereto; and hardening, curing, or otherwise setting the flexible wall structure to provide the tubular element.

27. The method according to claim 24 wherein the flexible wall structure comprises a fibre-reinforced plastic composite which can cure to provide the tubular element.

28. The method according to claim 27 wherein the flexible wall structure further comprises a flexible outer casing surrounding the fibre-reinforced plastic composite.

29. The method according to claim 27 or 28 wherein the fibre-reinforced plastic composite cures to a rigid condition. I

30. The method according to claim 27 or 28 wherein the fibre-reinforced plastic composite cures to a flexible condition.

31. The method according to any one of claims 26 to 30 wherein the tubular wall structure comprises a liner having a fluid impervious inner surface.

32. A method of constructing a pipe comprising forming a flexible tubular wall structure comprising a fibre-reinforced plastic composite, inflating the interior of the flexible tubular wall structure to provide form and shape thereto; and hardening, curing or otherwise setting the flexible wall structure to provide the pipe.

33. The method according to claim 32 wherein the pipe is constructed on a continuous basis and progressively installed in position prior to curing of the flexible wall structure, whereby the flexible wall structure cures once in the installed position of the pipe.

34. A method of constructing a pipe on a continuous basis, comprising forming a flexible tubular wall structure comprising a fibre-reinforced plastic composite, inflating the

interior of the flexible tubular wall structure to provide form and shape thereto; and curing the flexible wall structure to provide the pipe.

35. A method of constructing a pipe in a flexible condition, laying the pipe at an installation site, and allowing the flexible pipe to transform into a rigid condition at the installation site.

36. The method according to claim 35 wherein the pipe is assembled in a mobile installation plant which can move with respect to the installation site, laying the pipe in the flexible condition.

37. A mobile installation plant for constructing a pipe in accordance with the method of claim 35.

38. An assembly line for constructing an elongate hollow structure according to any one of claims 1 to 31.

39. A pipe constructed according to the method of claim 35 or 36.

40. An elongate hollow structure constructed in accordance with the method according to according to any one of claims 1 to 31.

41. An elongate hollow structure of composite construction, comprising a radially inner portion and a radially outer portion, wherein the two portions merge together to provide an integrated tubular wall structure.

42. The elongate hollow structure according to claim 41 wherein the outer portion is configured as an outer tube of fibre reinforced composite construction

43. The elongate hollow structure according to claim 41 wherein the outer portion further comprises a flexible outer casing surrounding the outer tube.

44. The elongate hollow structure according to claim 42 or 43 wherein the reinforcement comprises one or more layers of reinforcing fabric, each configured as a tubular layer disposed about the inner portion.

45. The elongate hollow structure according to claim 44 wherein the reinforcing fabric comprises reinforcing fabric incorporating reinforcement fibres featuring quadraxial fibre orientations.

46. The elongate hollow structure according to any one of claims claim 41 to 45 wherein the inner portion comprises an inner liner with a fibrous layer bonded onto one face thereof.

47. The elongate hollow structure according to claim 46 wherein the other face of the liner defines the interior surface of the tubular structure.

48. The elongate hollow structure according to claim 46 or 47 wherein resinous binder impregnating the reinforcing fabric also impregnates the fibrous layer bonded on the inner liner to integrate the outer portion with the inner portion.

49. A method of constructing an elongate hollow structure substantially as herein described.

50. An assembly line for constructing an elongate hollow structure substantially as herein described with reference to the accompanying drawings.

51. An elongate hollow structure substantially as herein described with reference to the accompanying drawings.

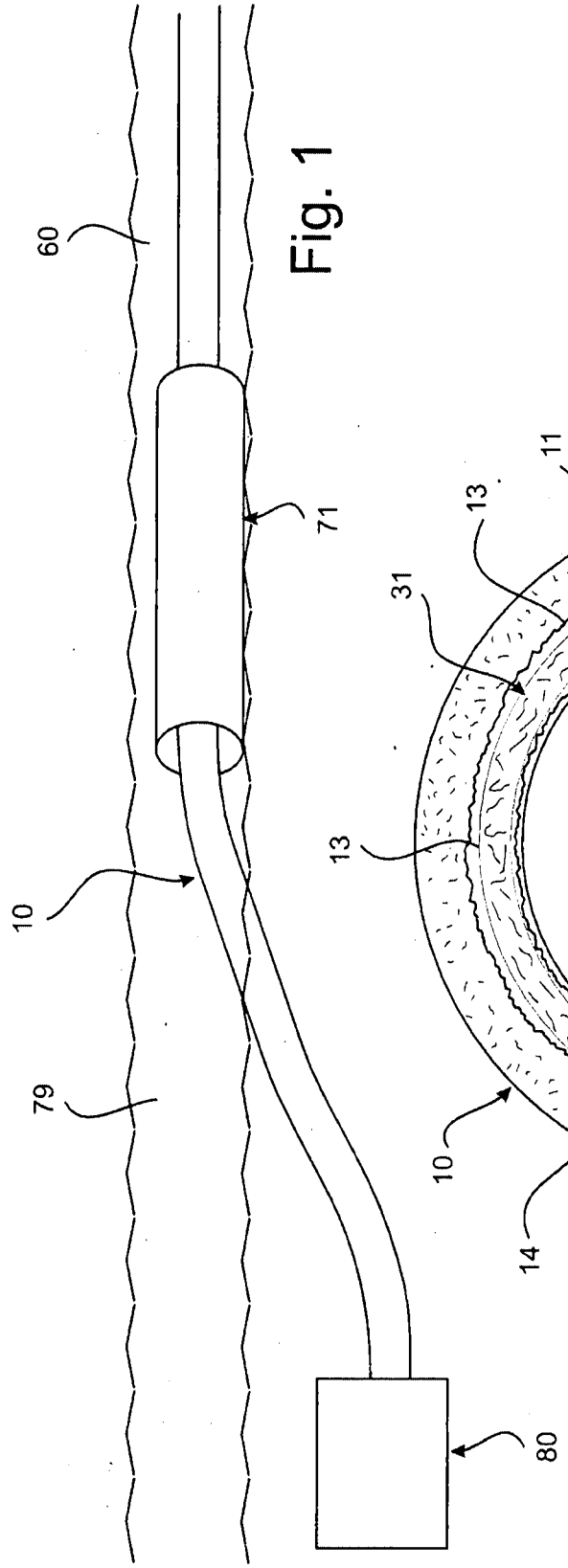


Fig. 1

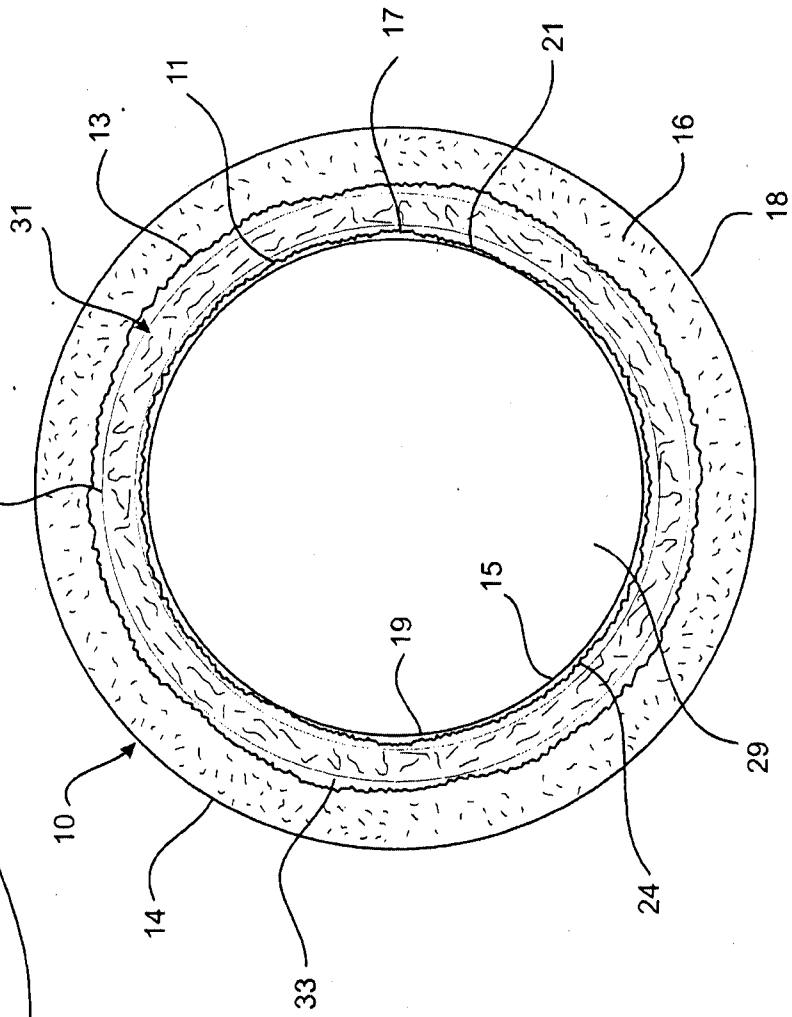


Fig. 2

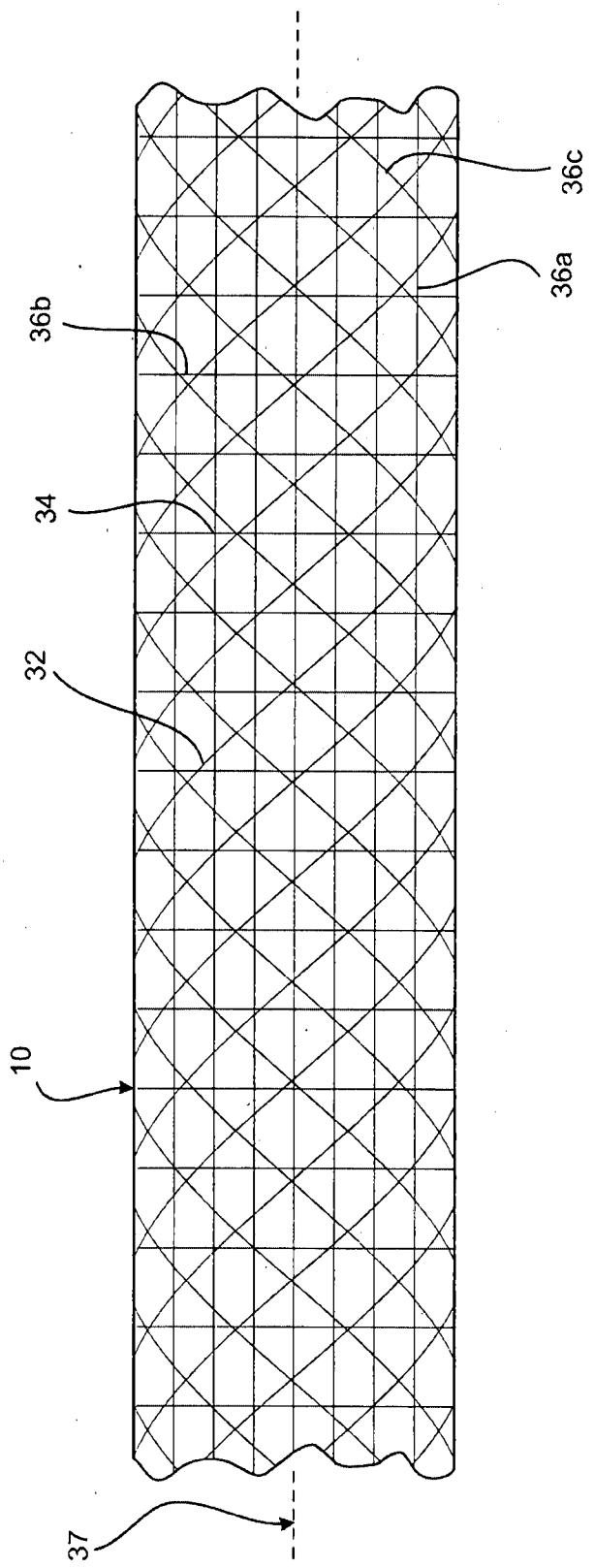


Fig. 3

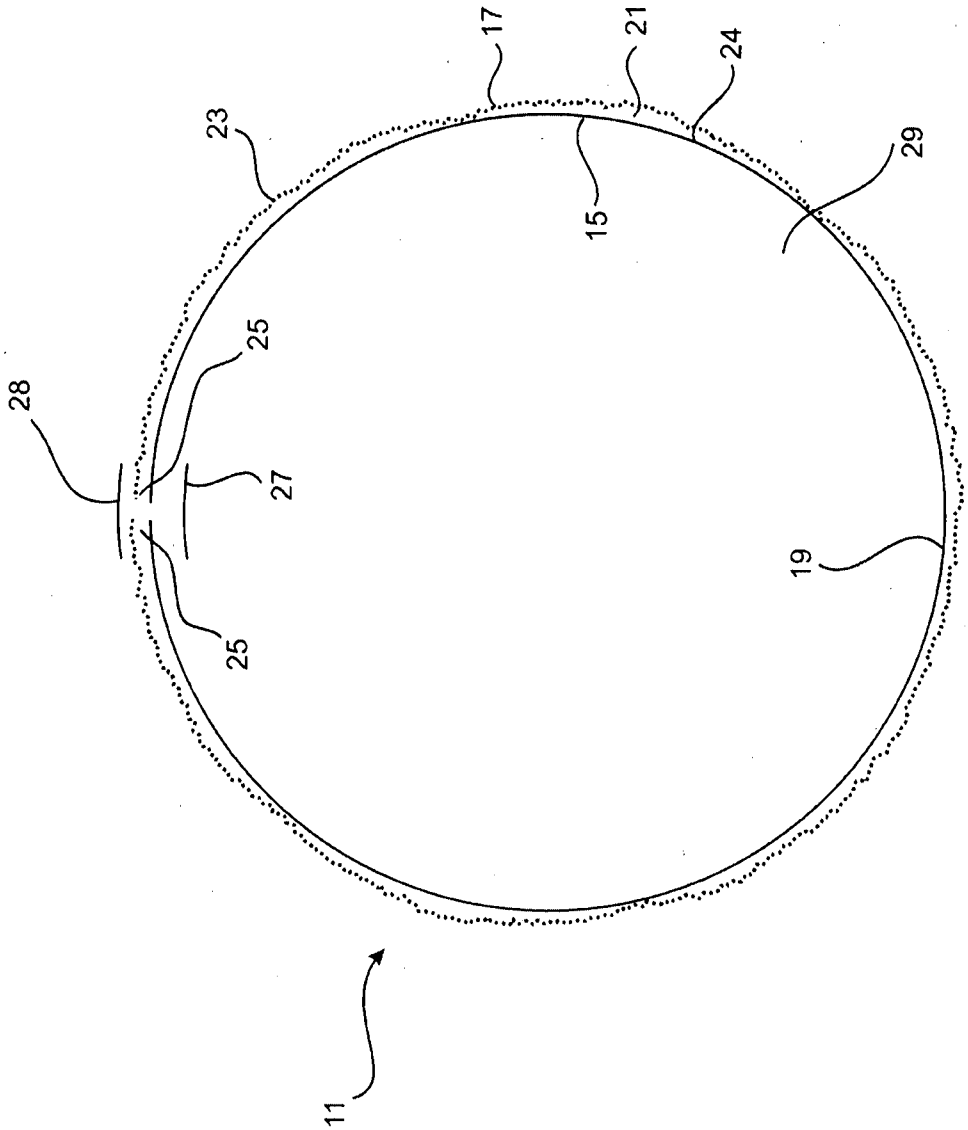


Fig. 4

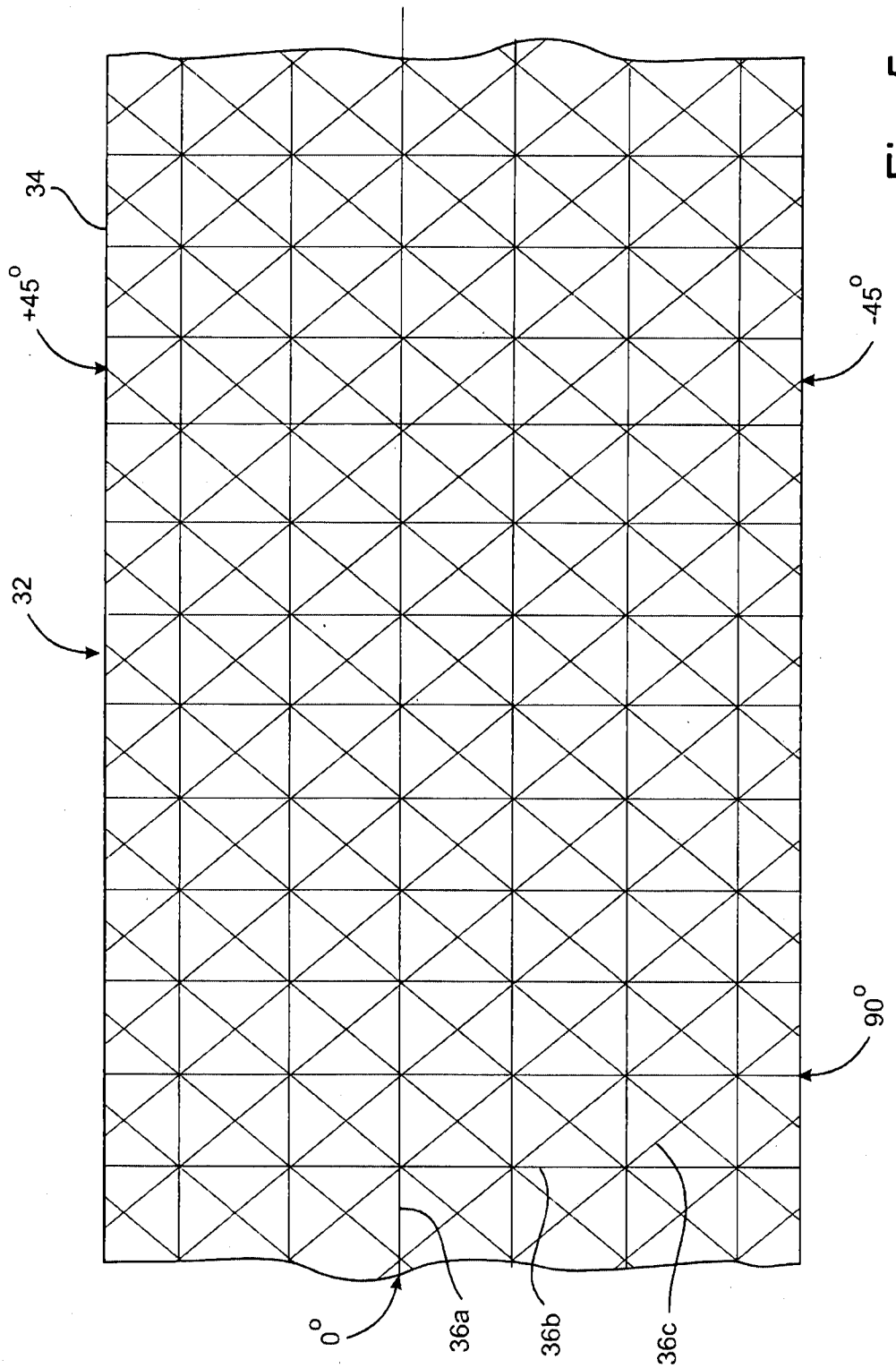


Fig. 5

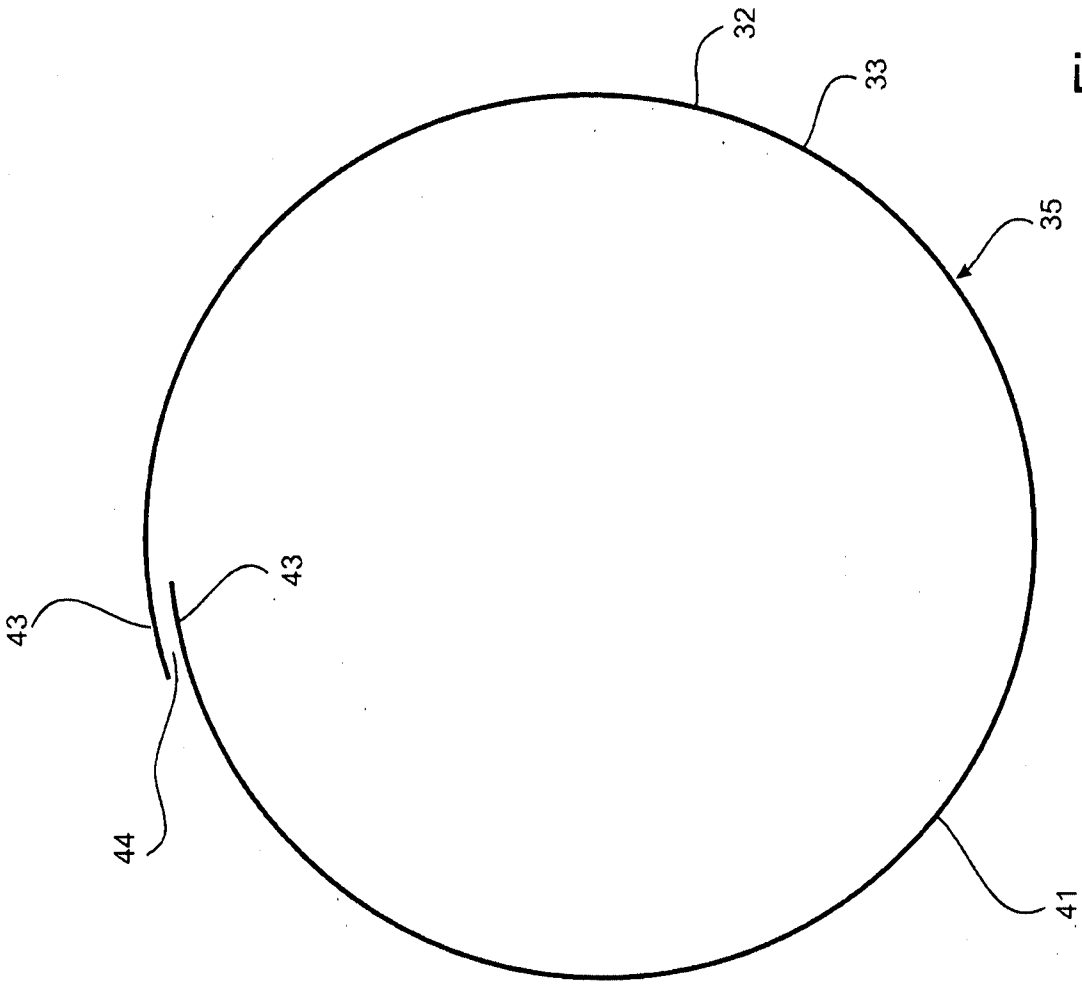


Fig. 6

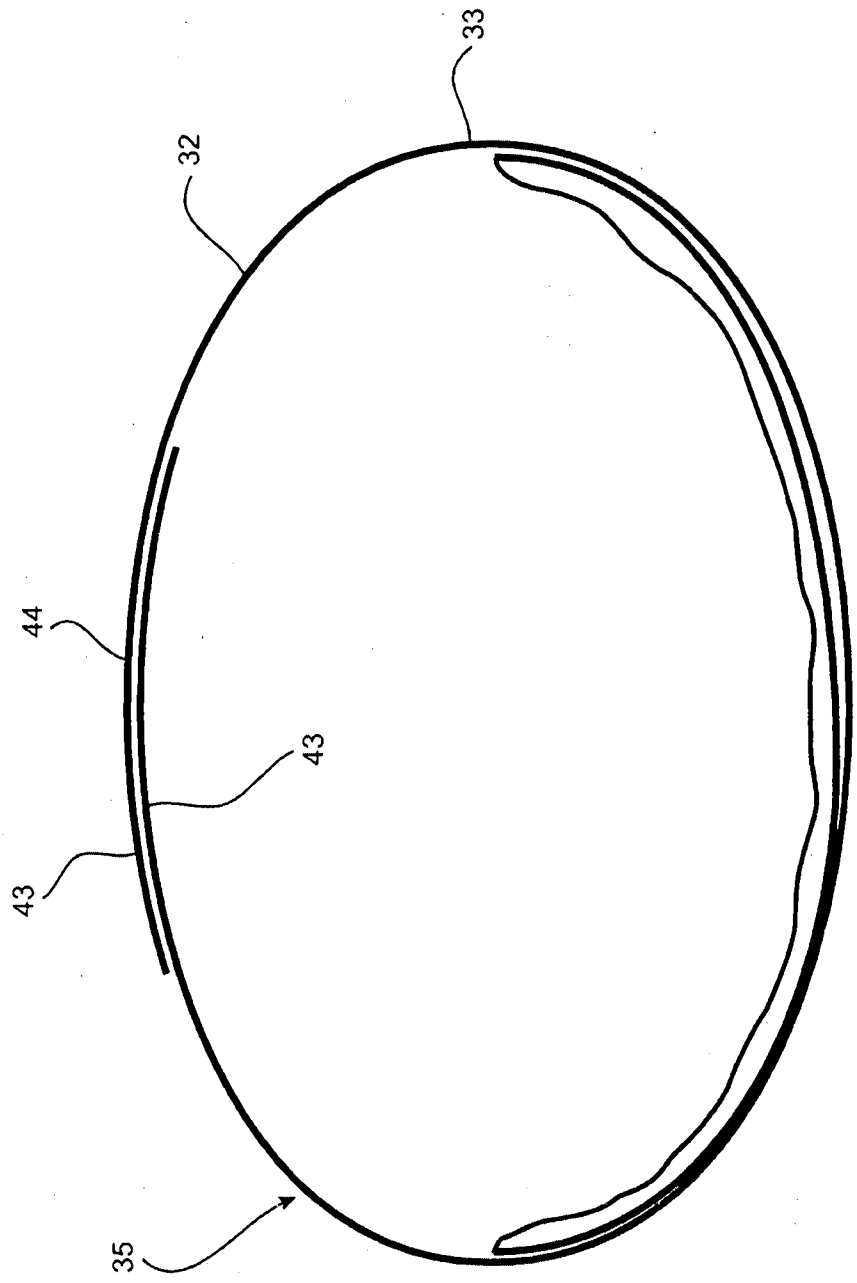


Fig. 7

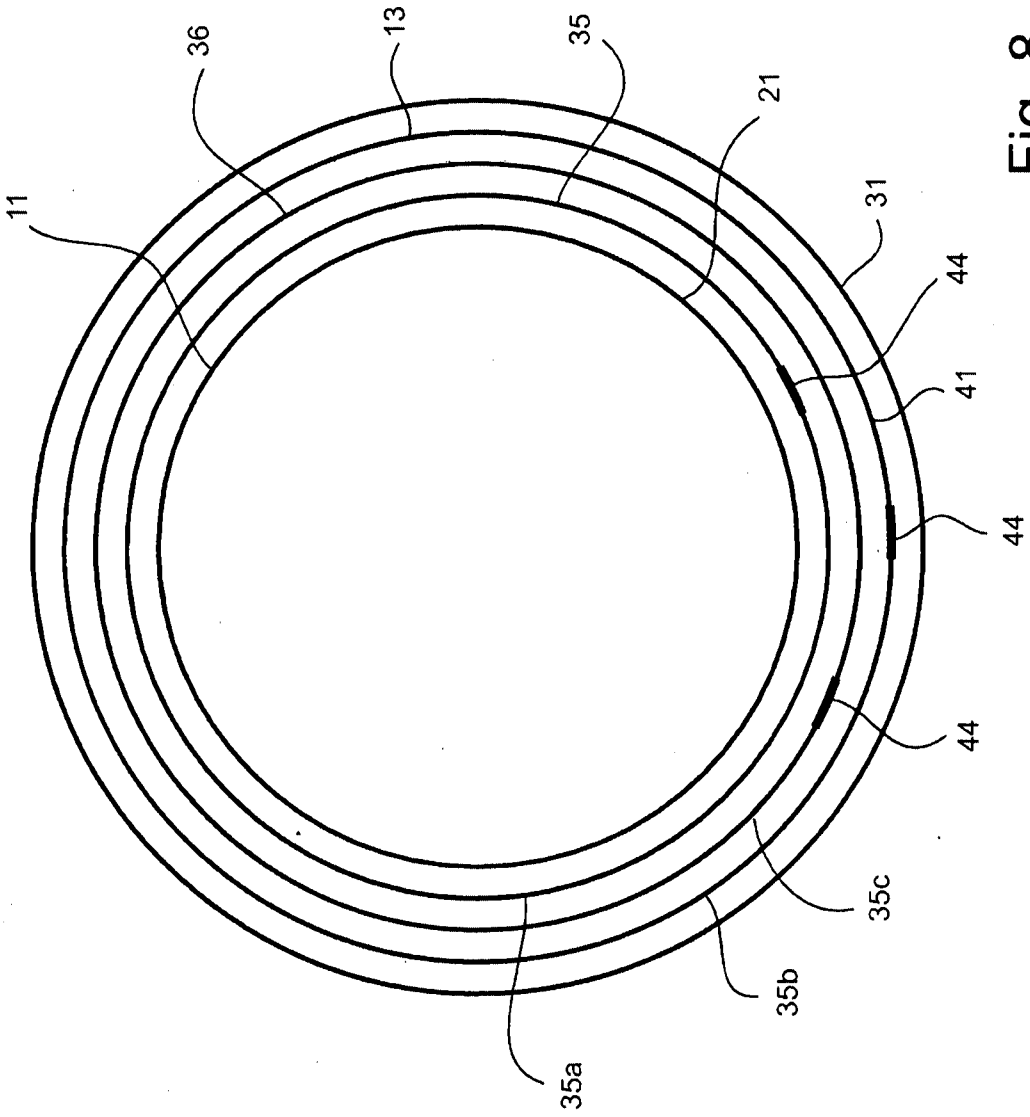


Fig. 8

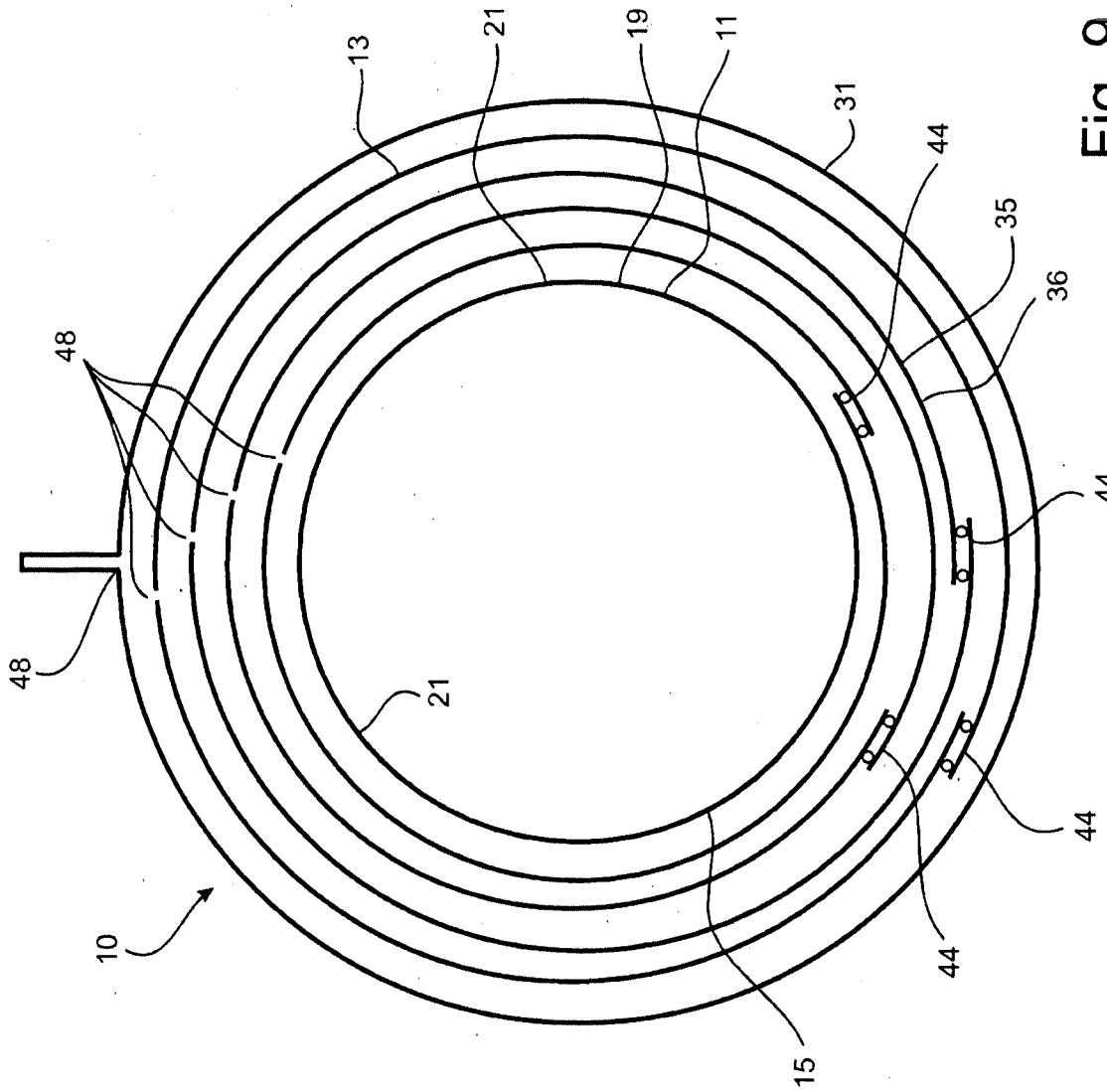


Fig. 9

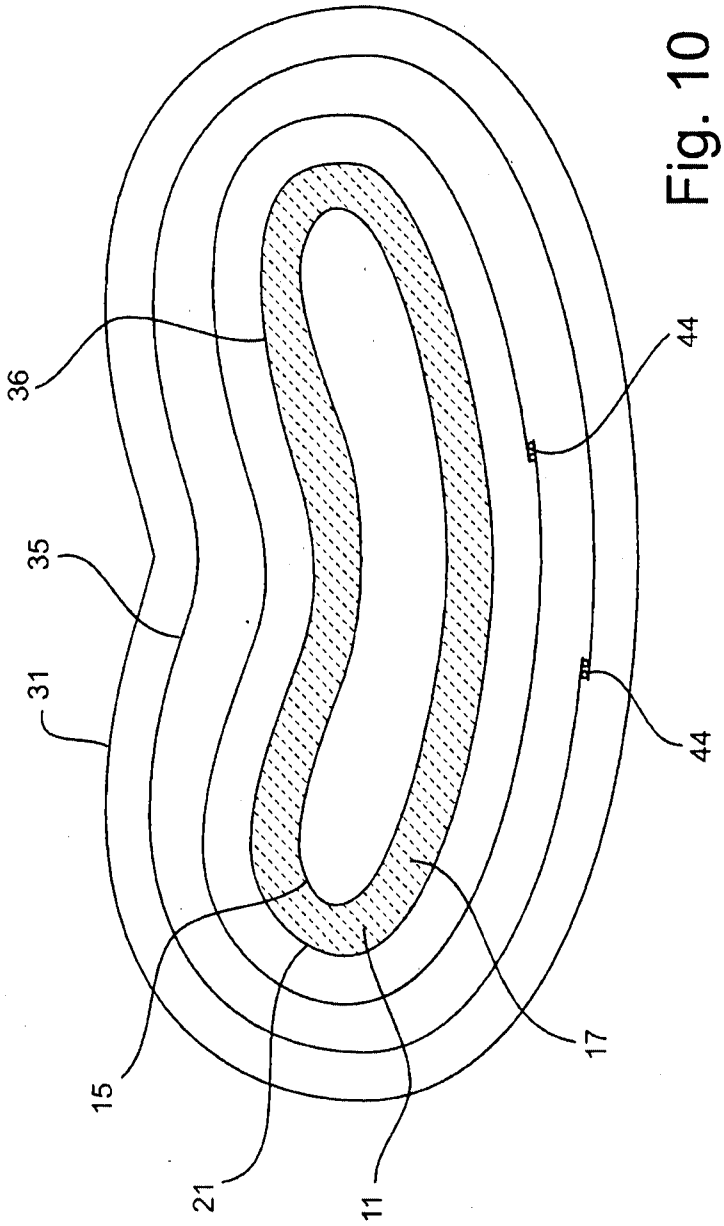


Fig. 10

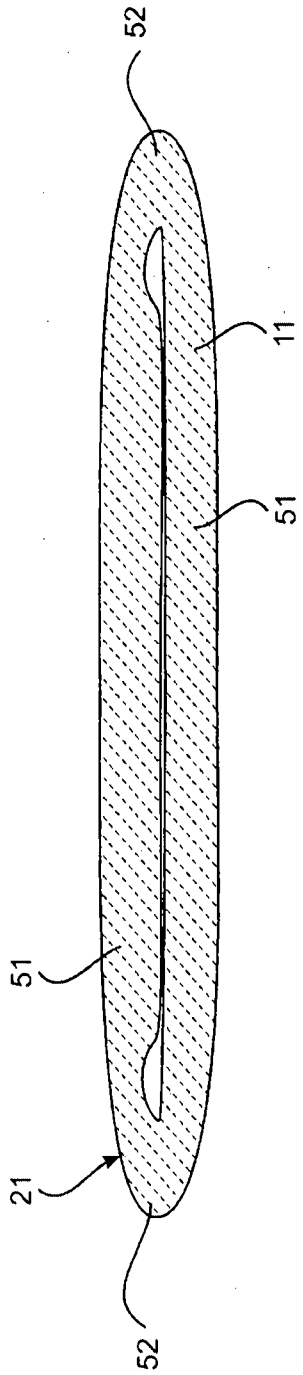


Fig. 11

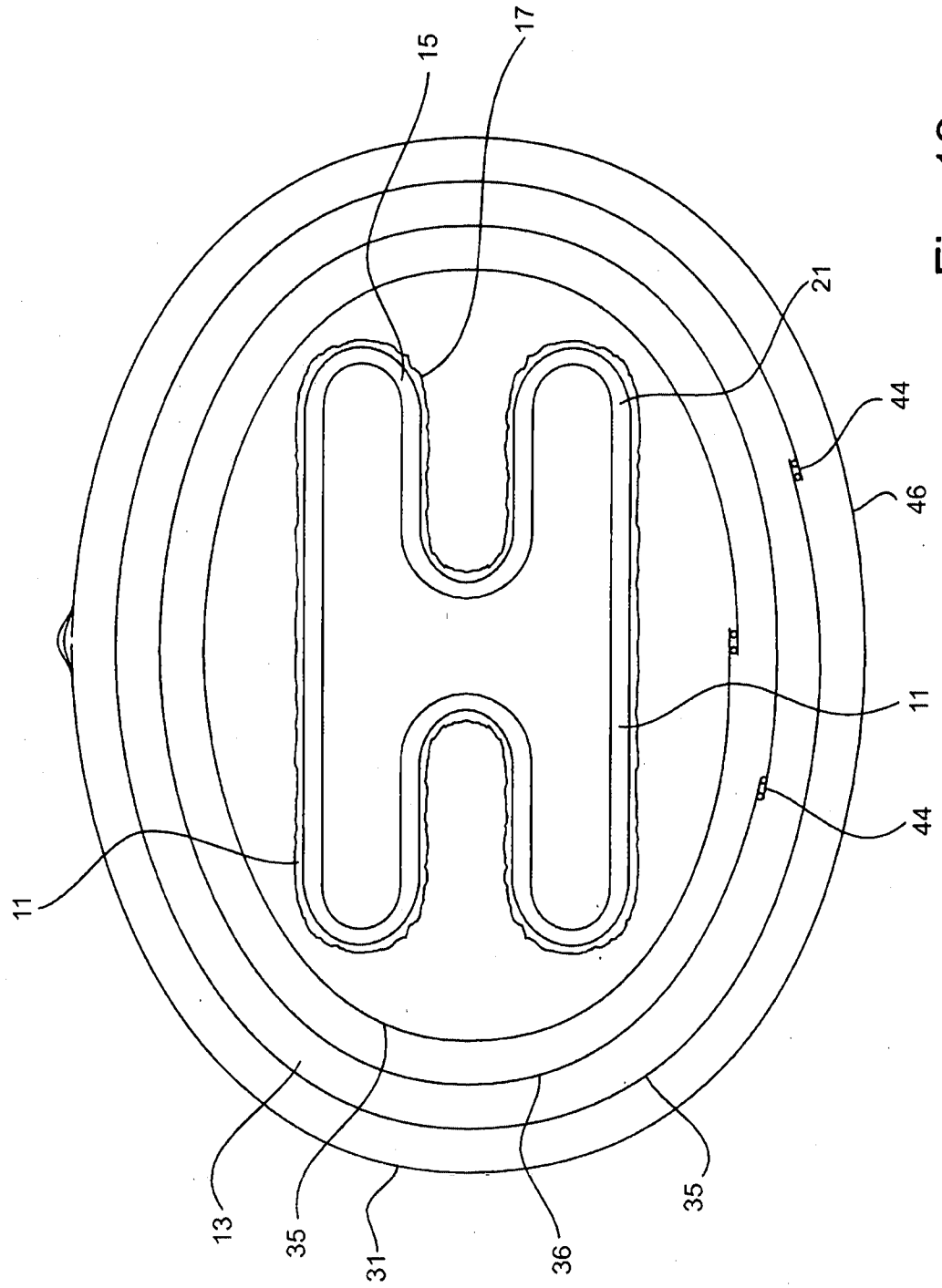


Fig. 12

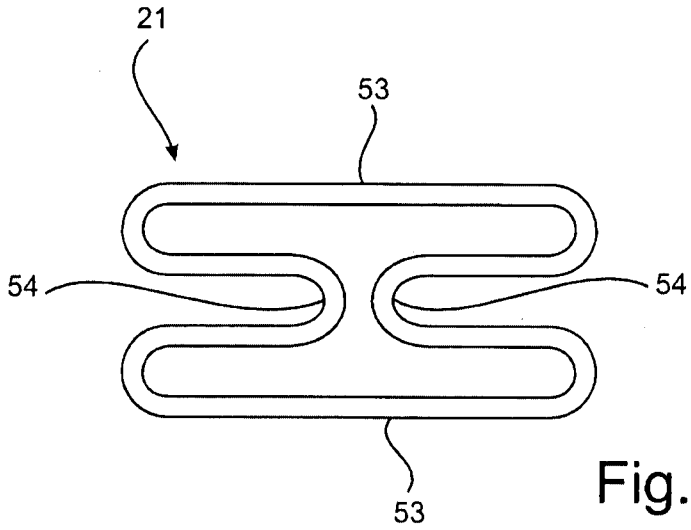


Fig. 13

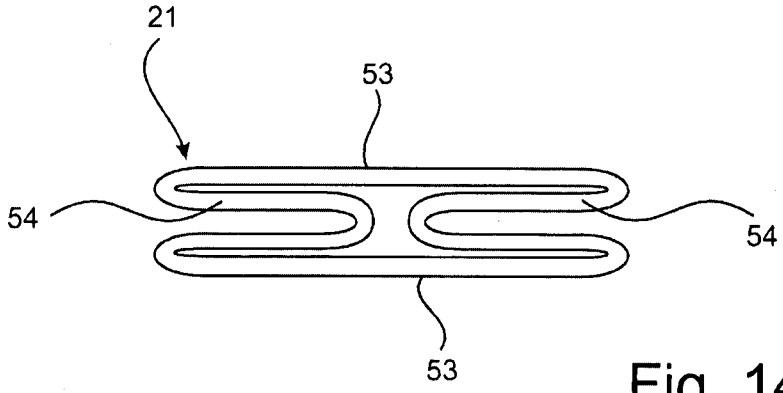


Fig. 14

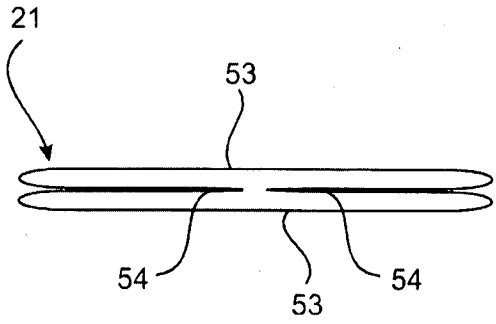


Fig. 15

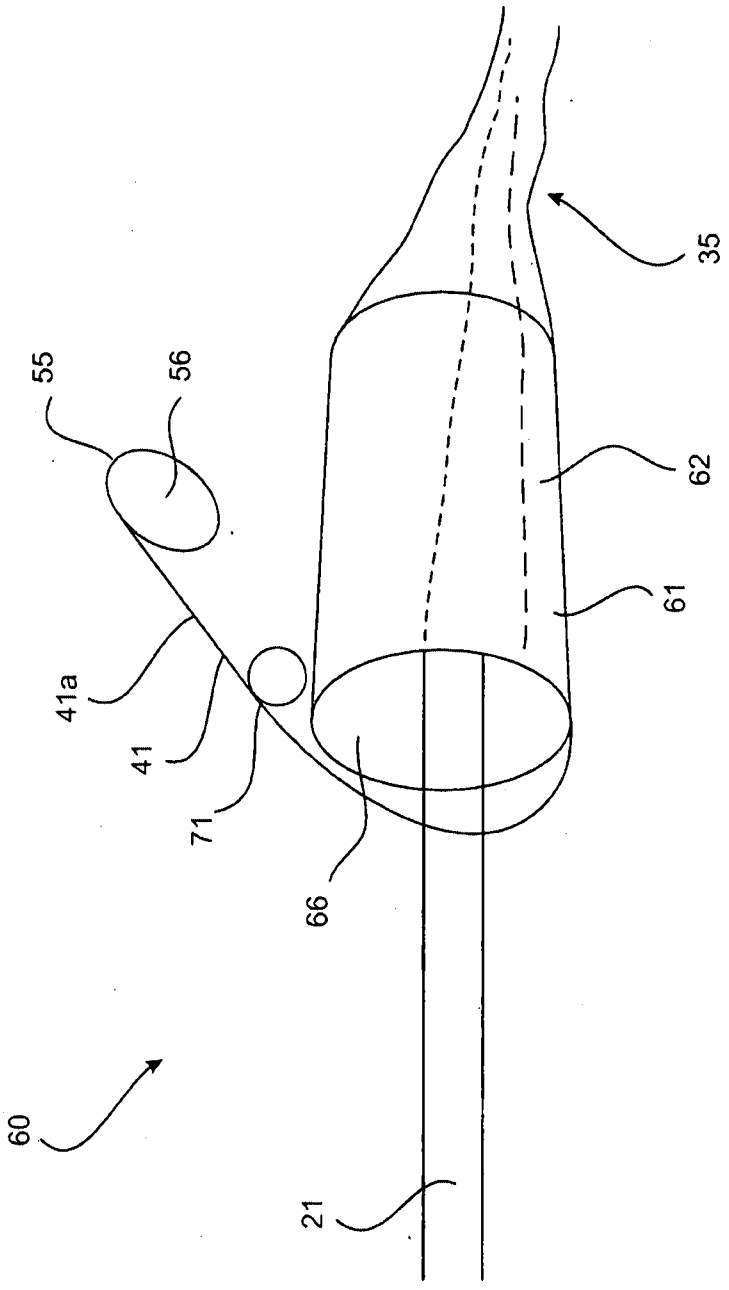


Fig. 16

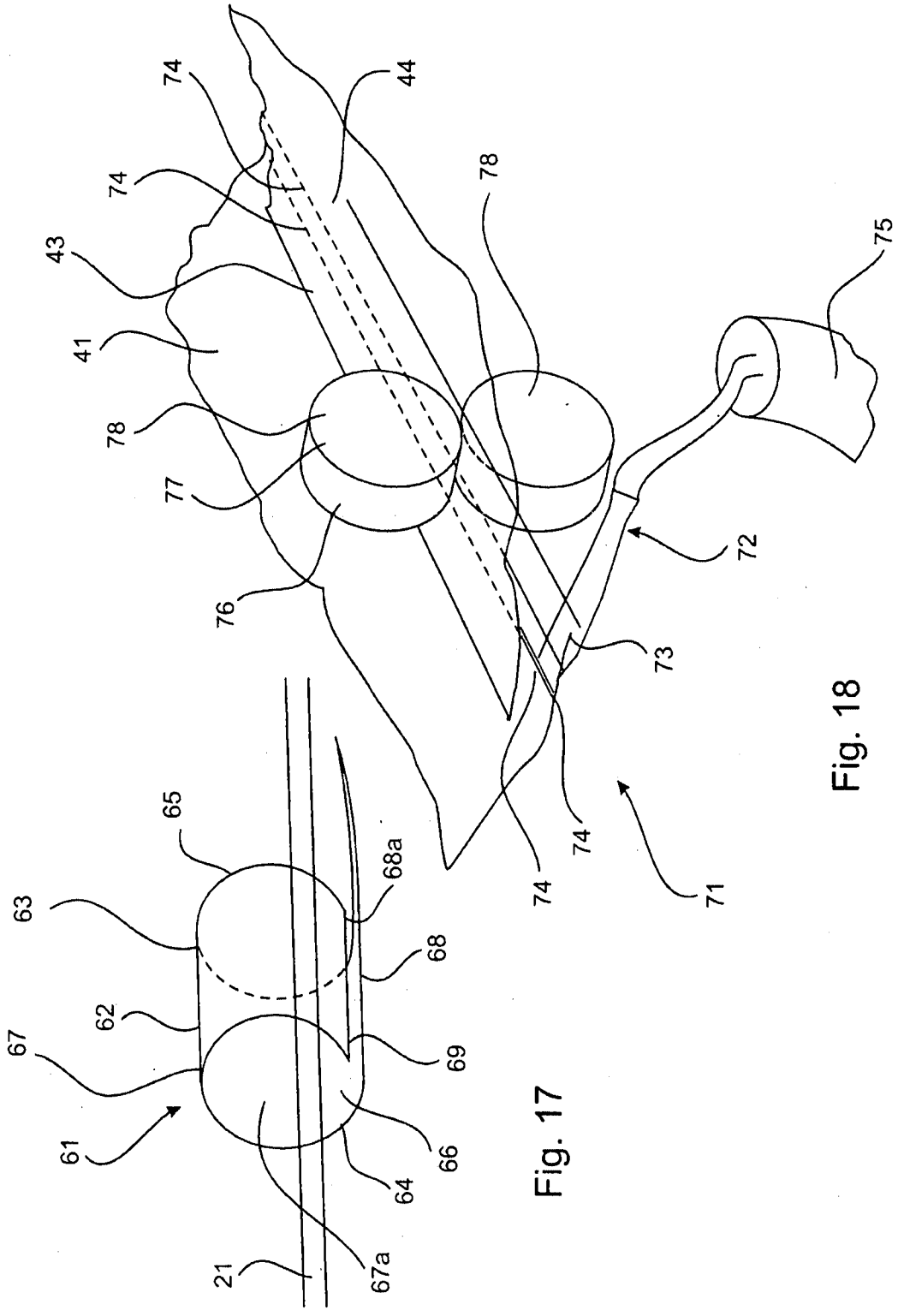

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Fig. 17

Fig. 18

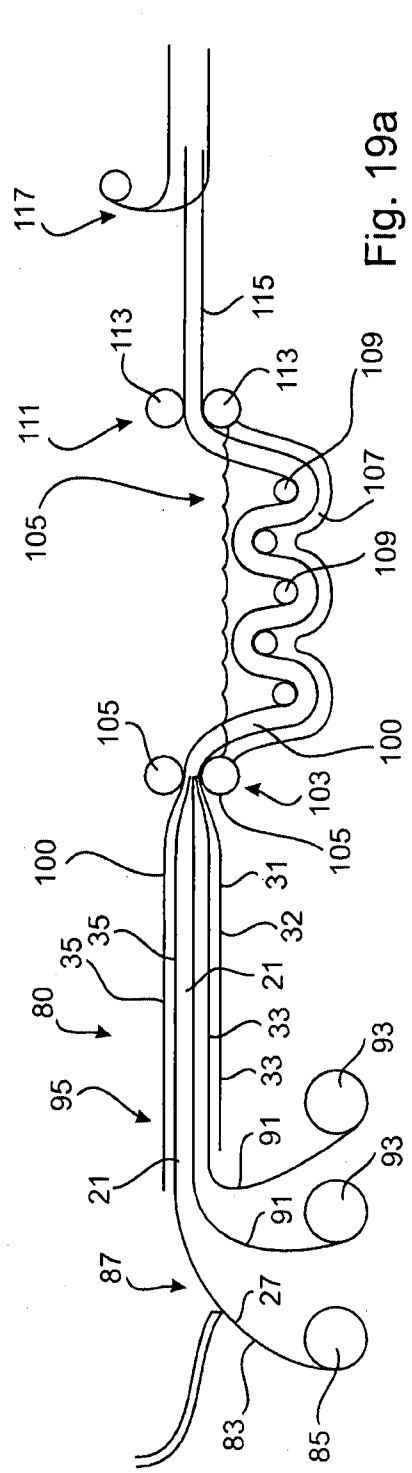


Fig. 19a

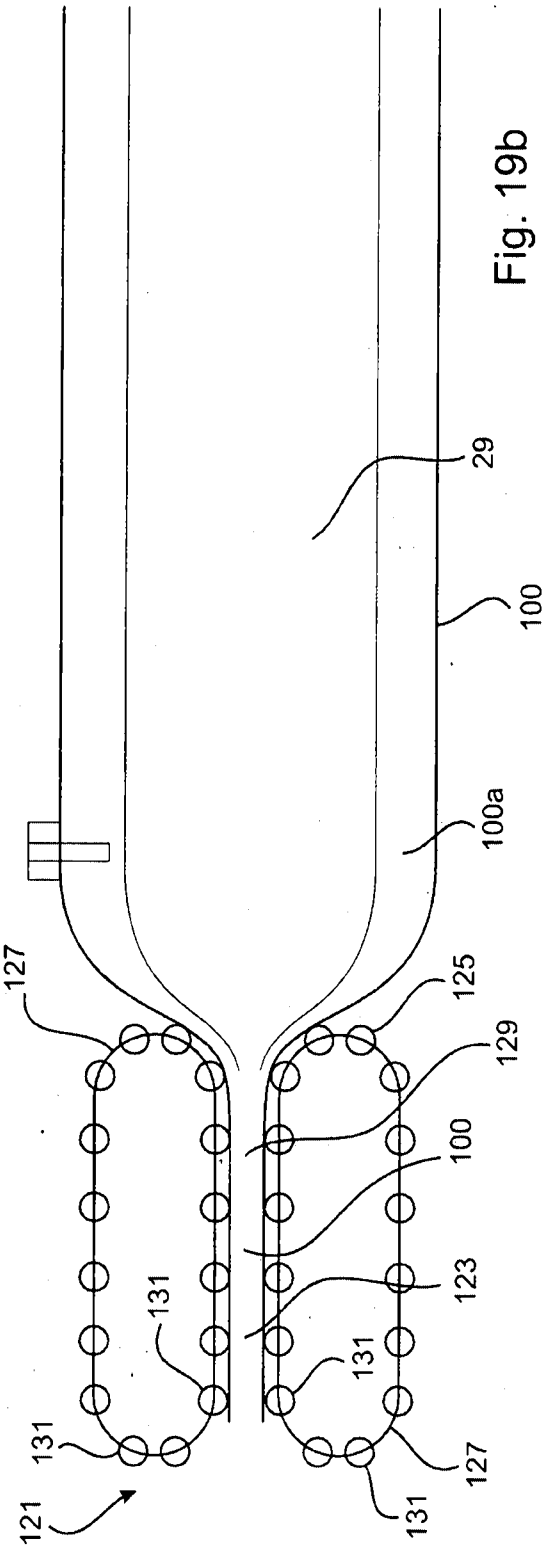


Fig. 19b

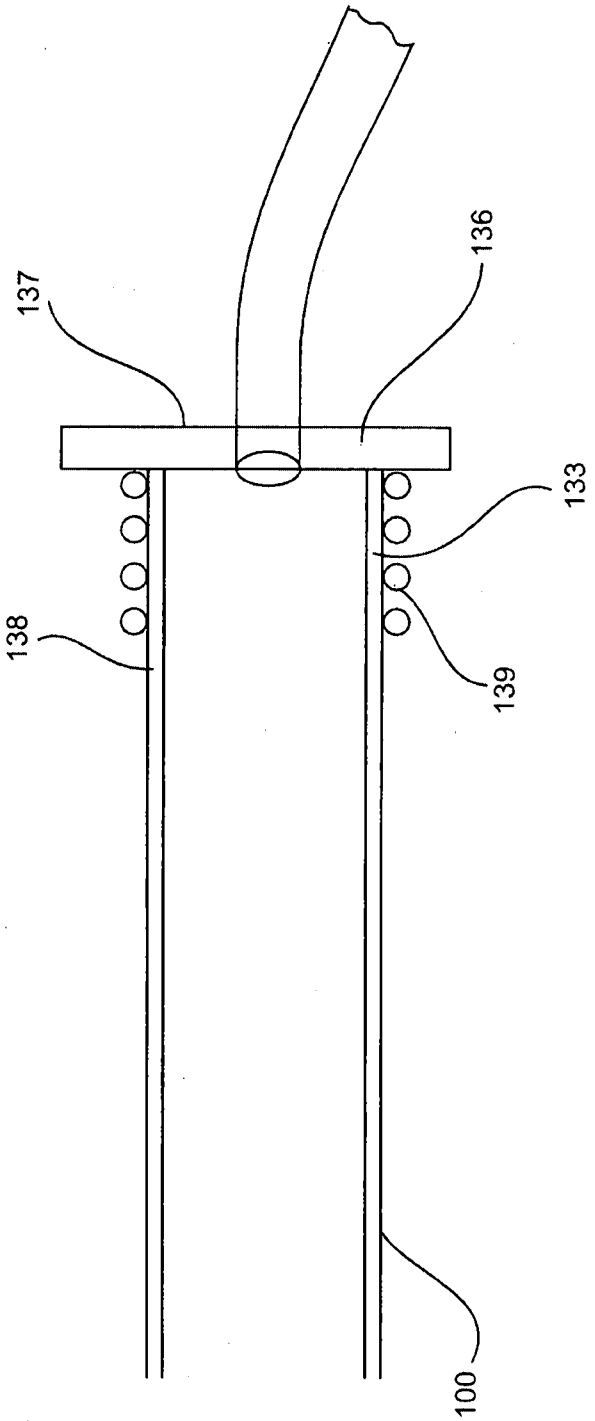


Fig. 20

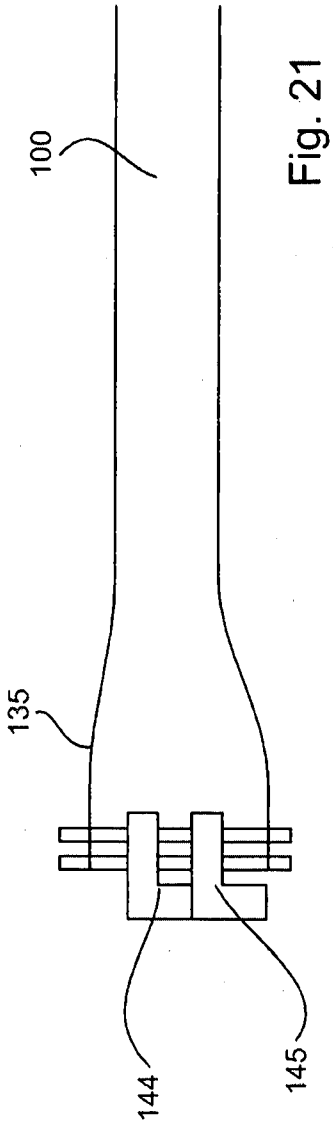


Fig. 21

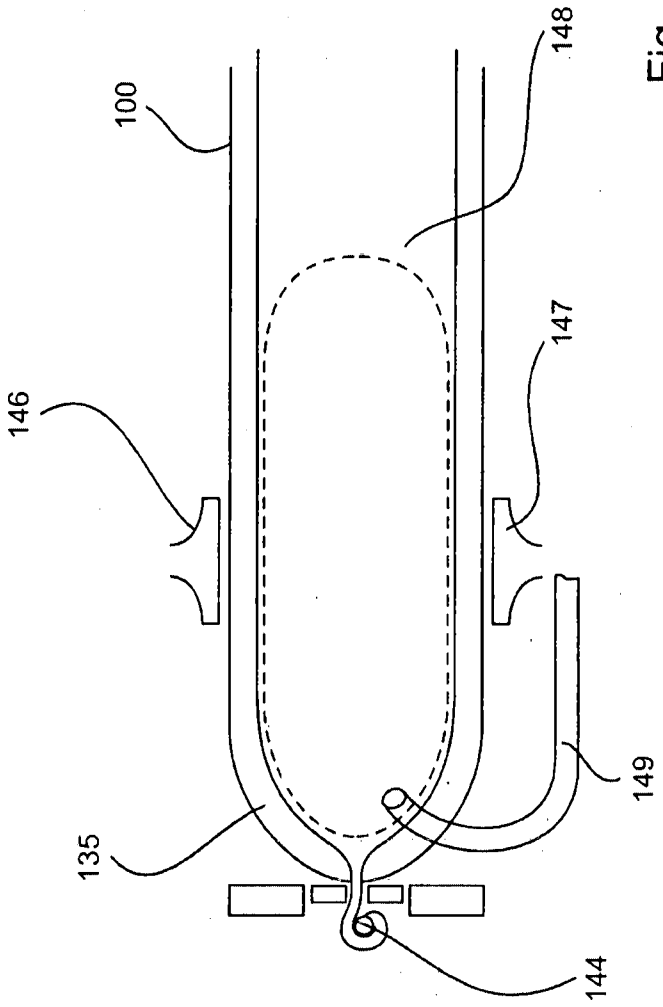


Fig. 22

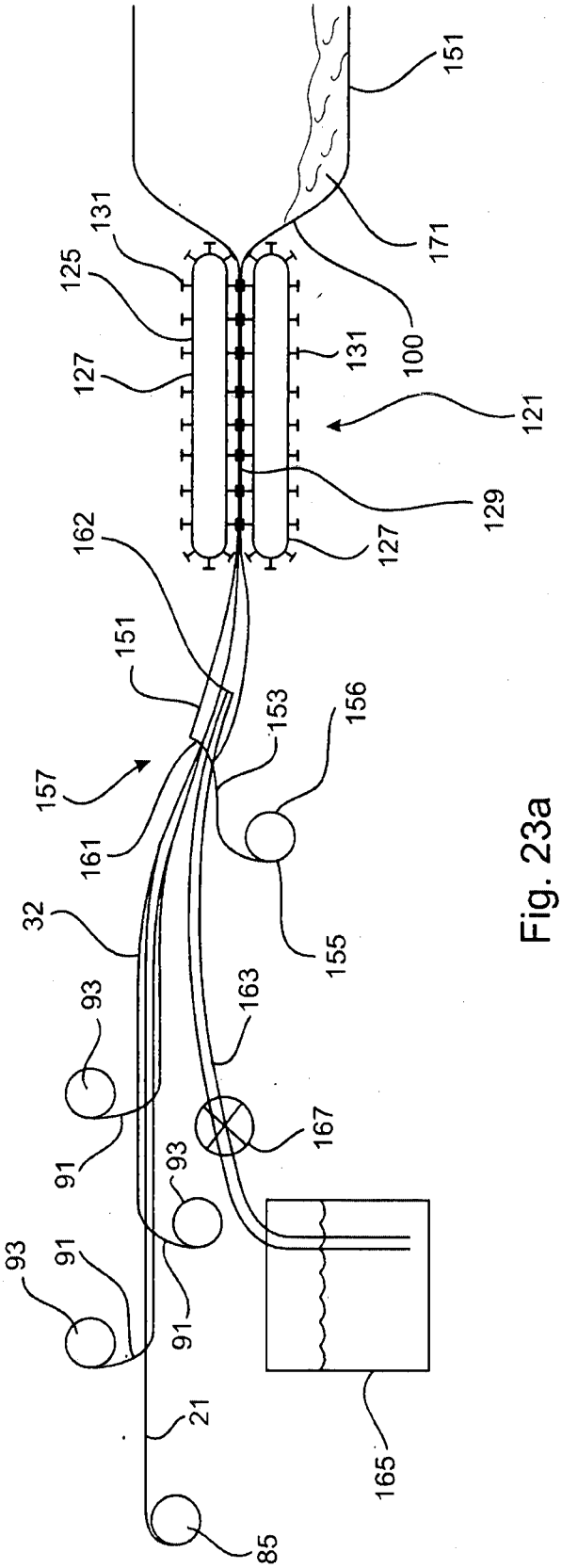


Fig. 23a

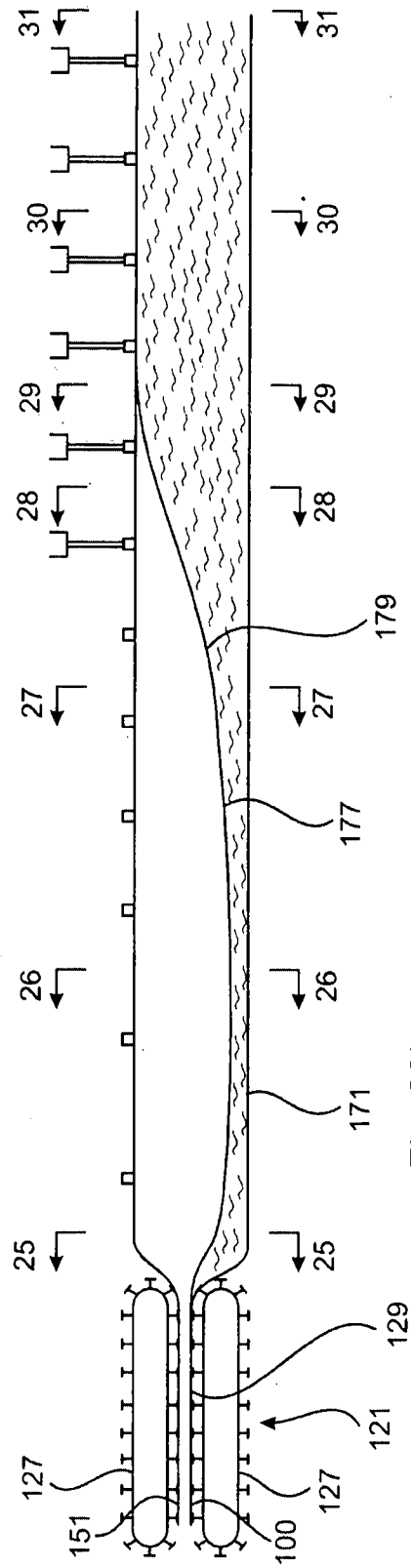


Fig. 23b

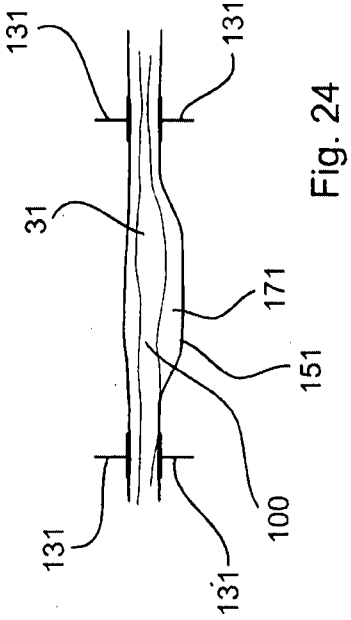


Fig. 24

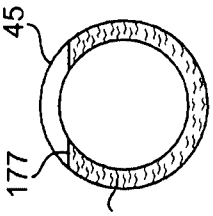


Fig. 28

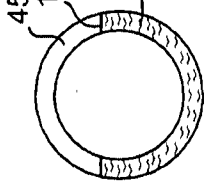


Fig. 27

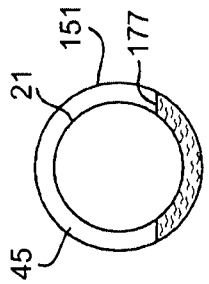


Fig. 26

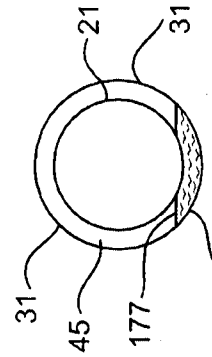


Fig. 25

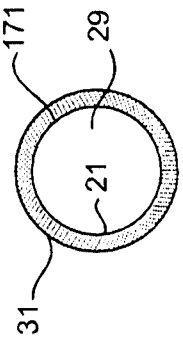


Fig. 31

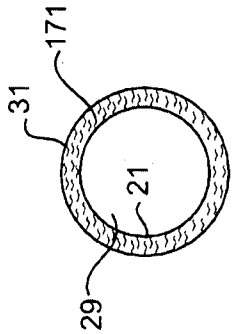


Fig. 30

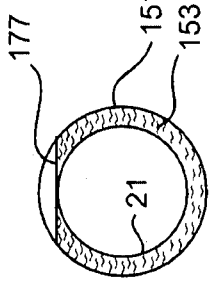


Fig. 29

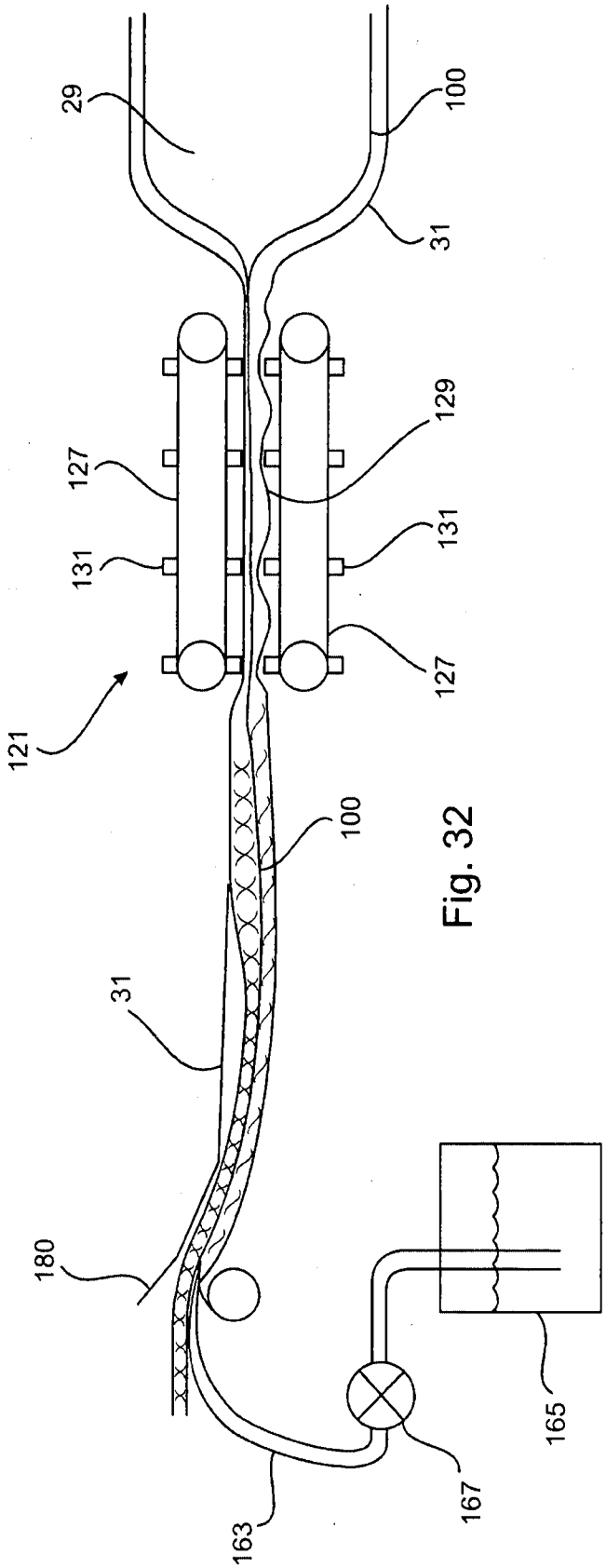

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Fig. 32

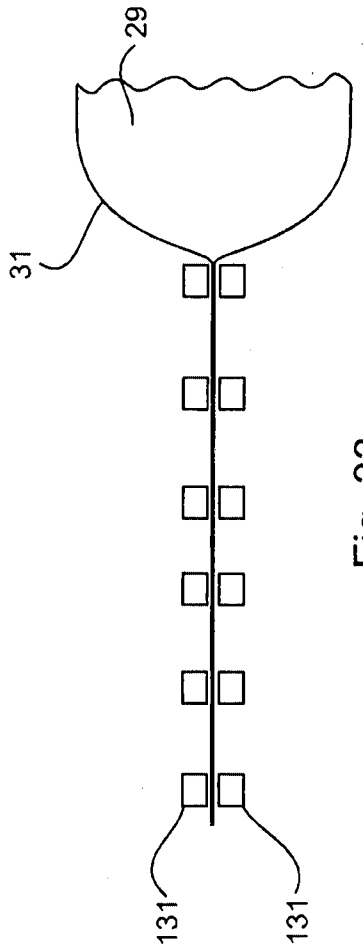

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Fig. 33

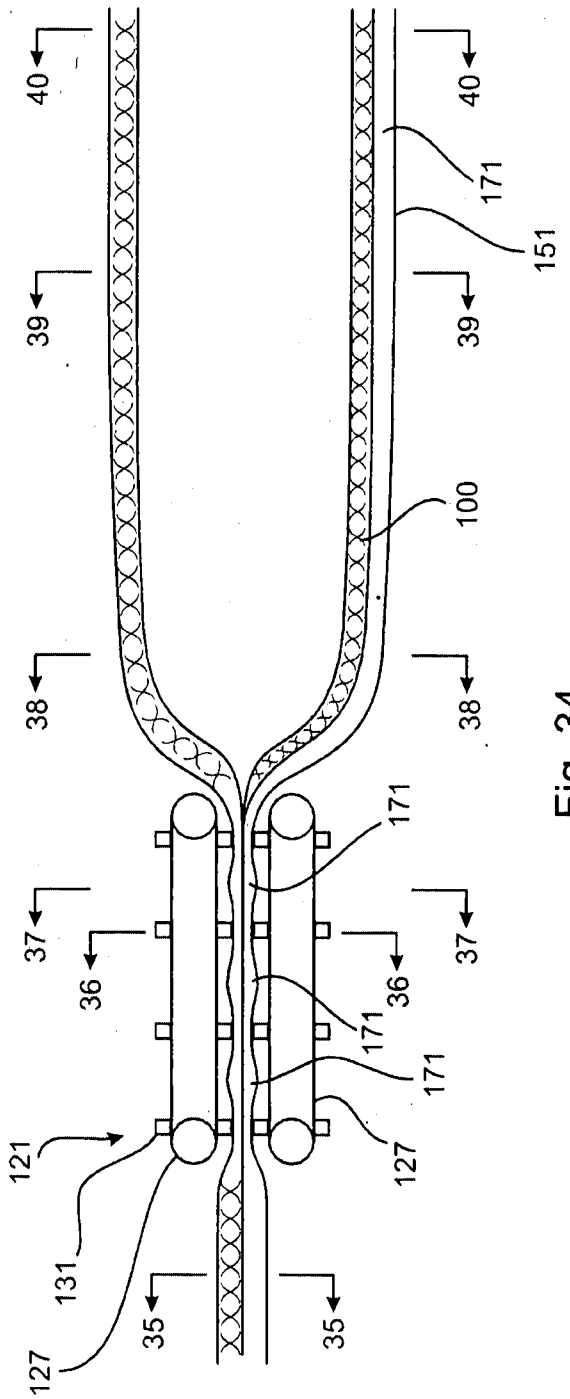


Fig. 34

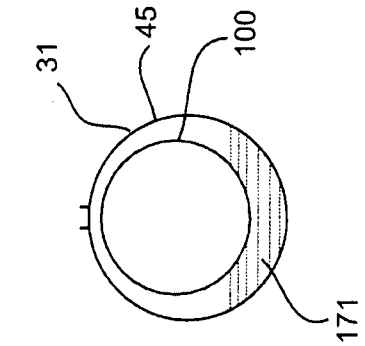


Fig. 38

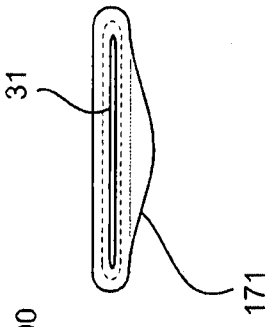


Fig. 37

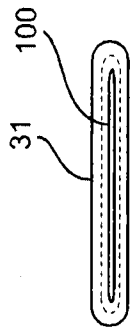


Fig. 36

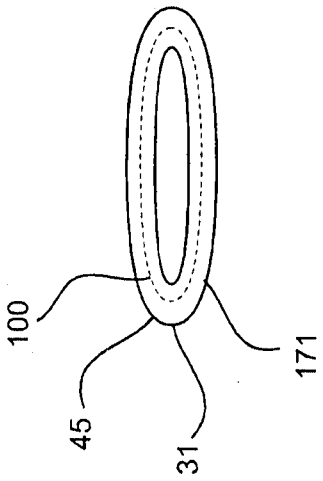


Fig. 35

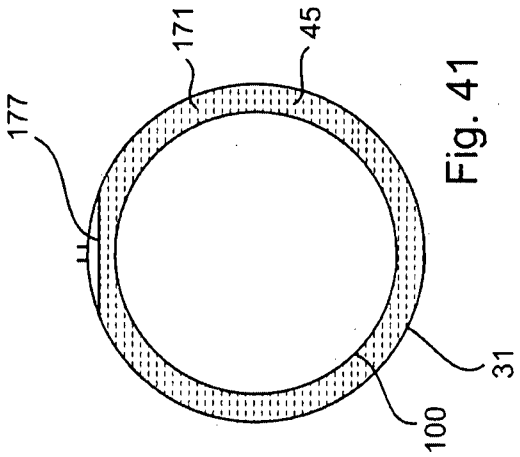


Fig. 41

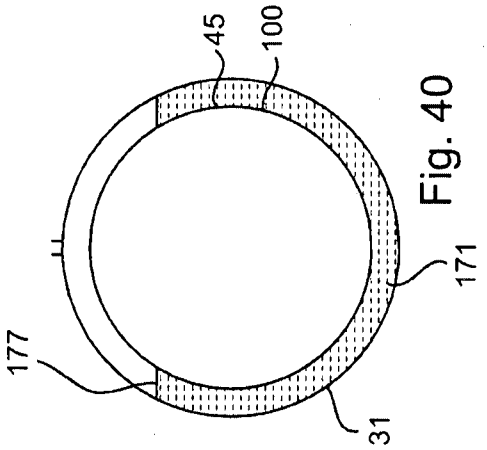


Fig. 40

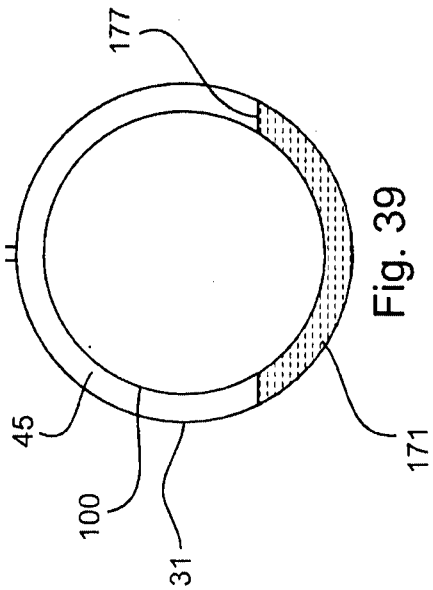


Fig. 39

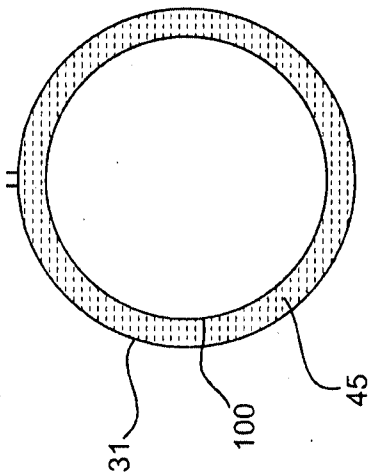


Fig. 42

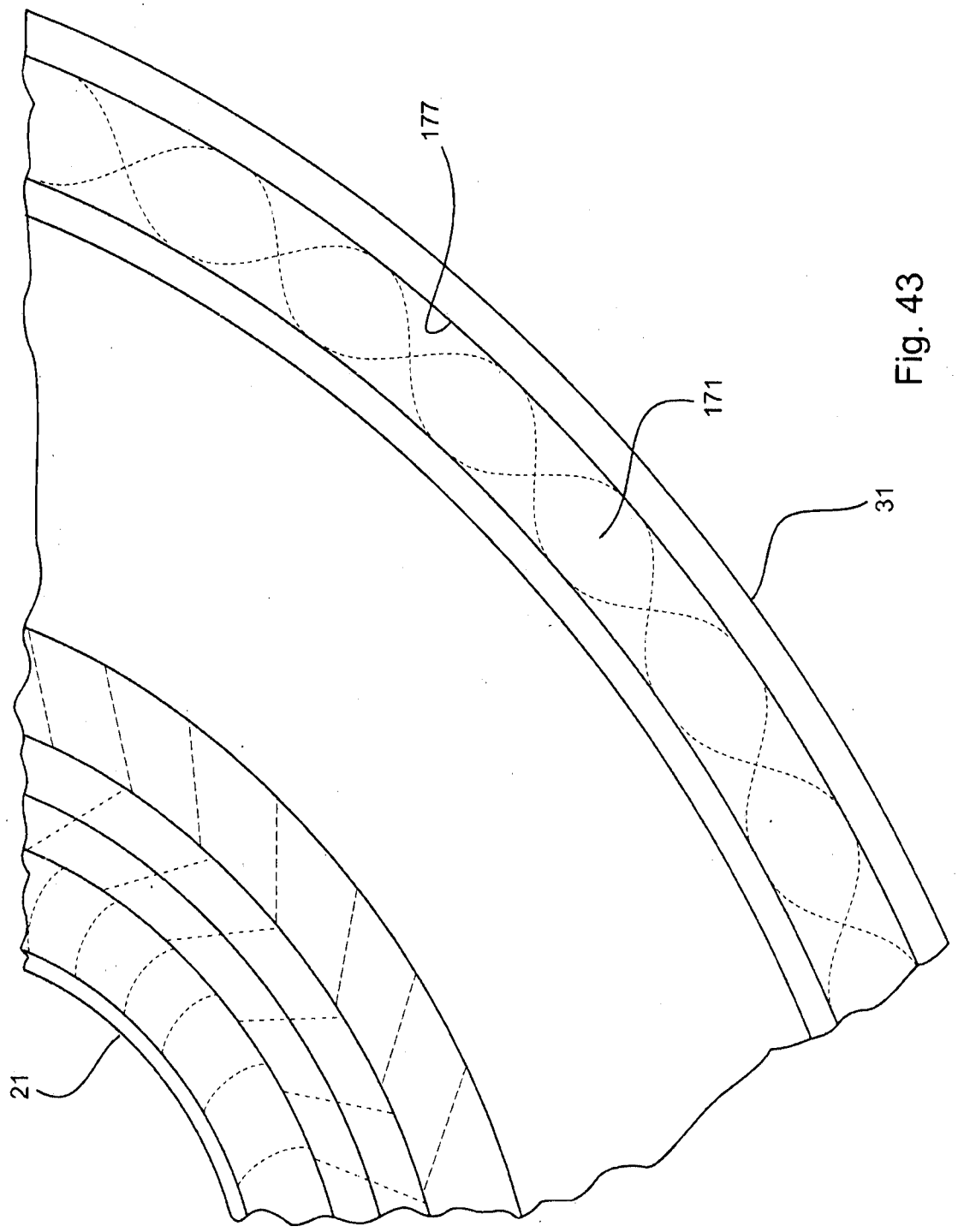


Fig. 43

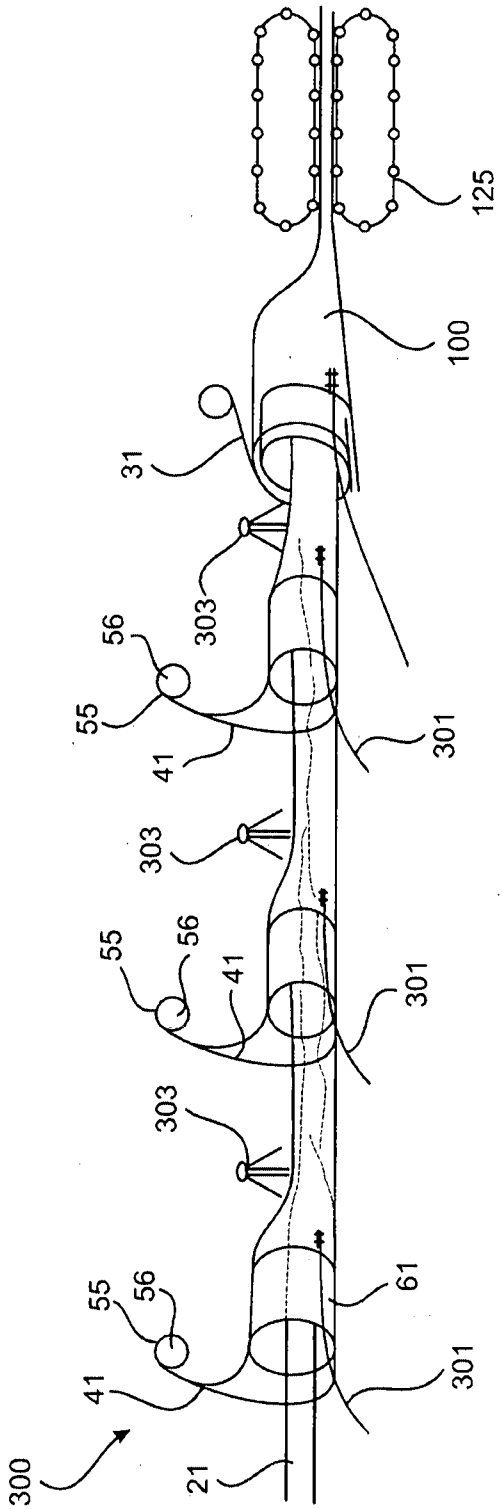

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Fig. 44

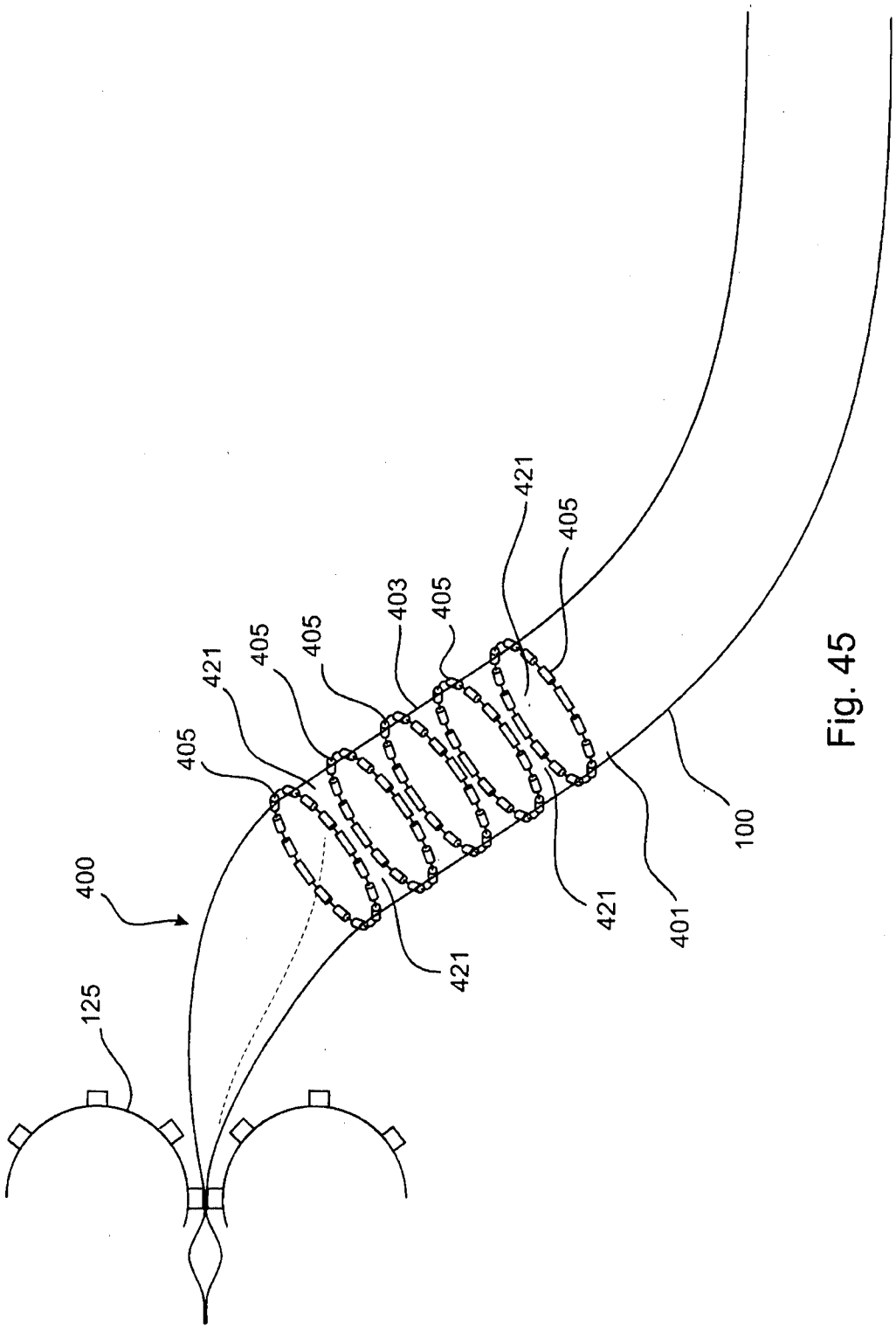


Fig. 45

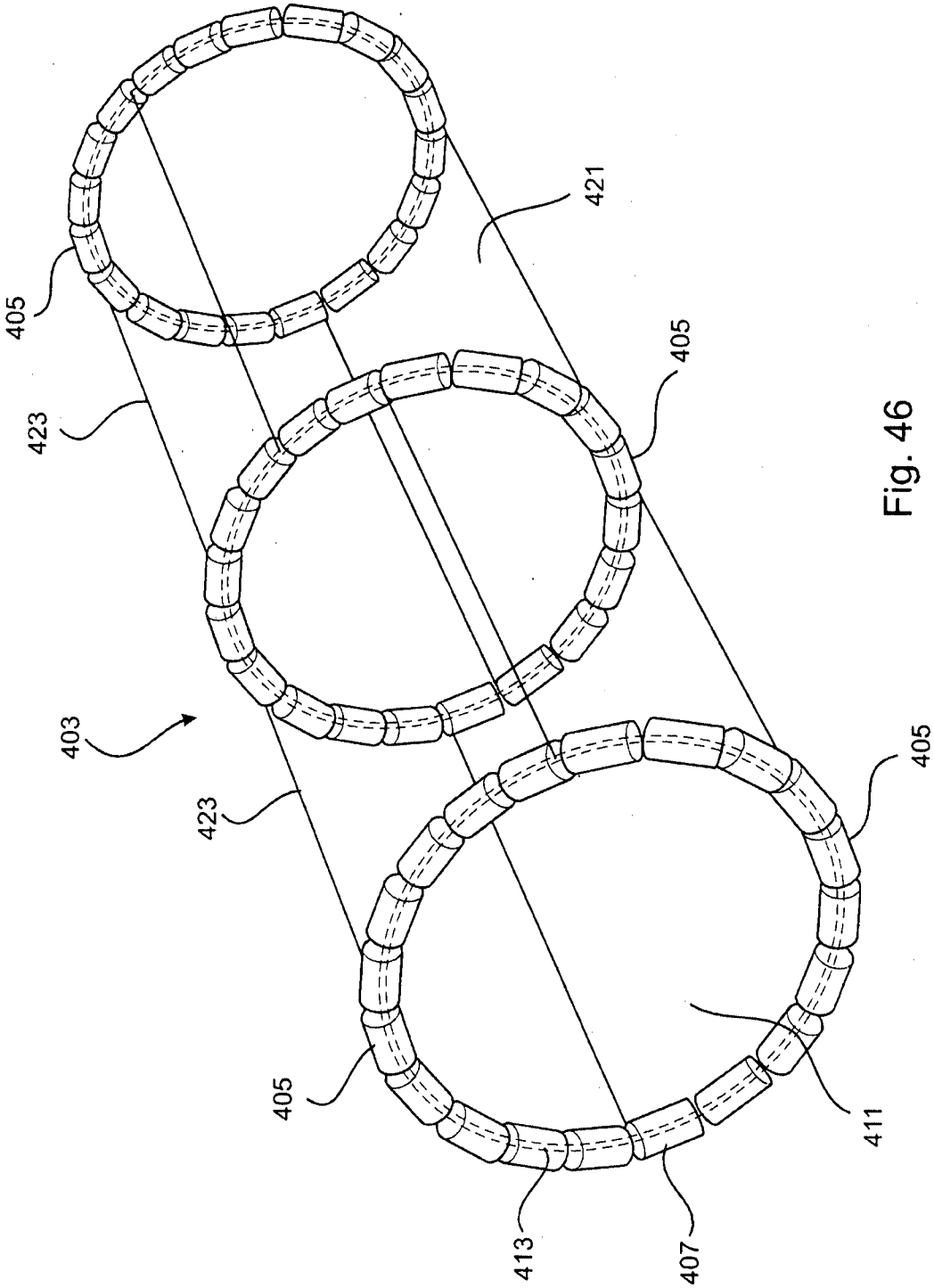


Fig. 46

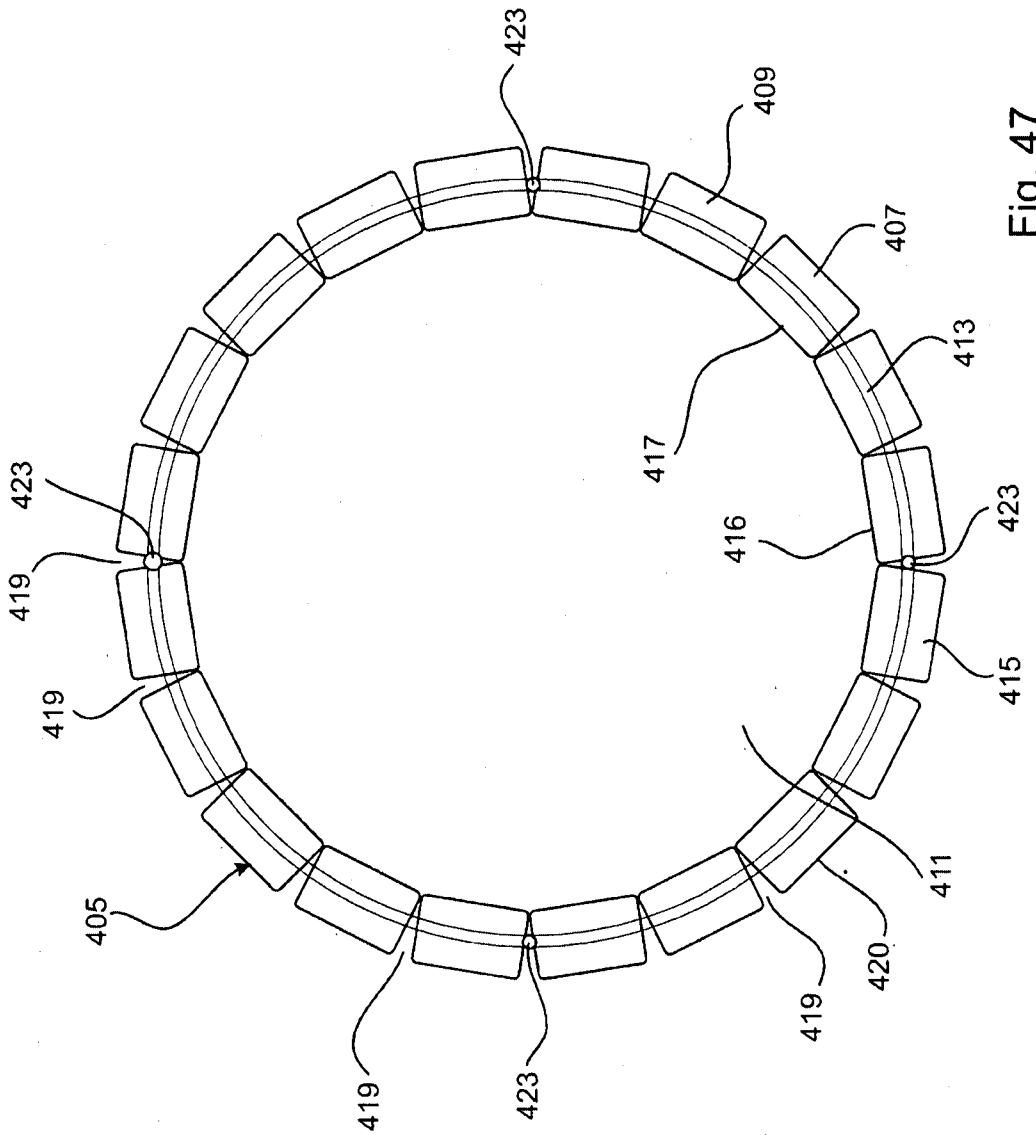


Fig. 47

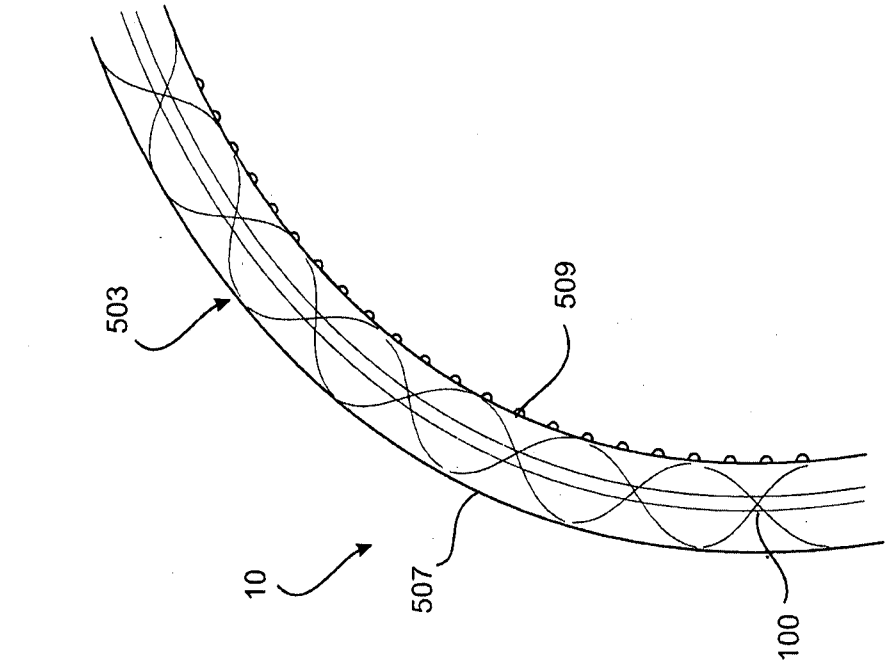


Fig. 50

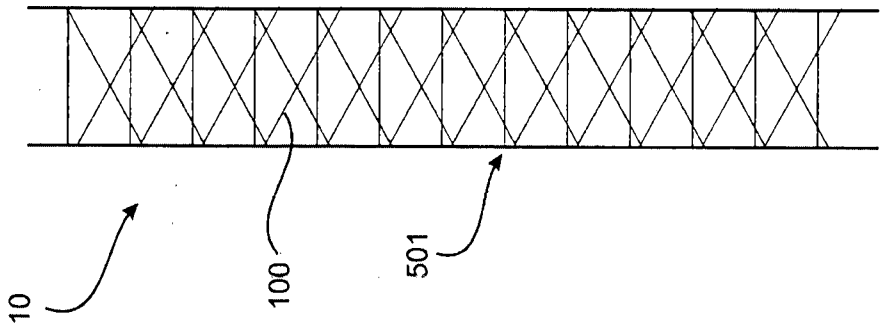


Fig. 49

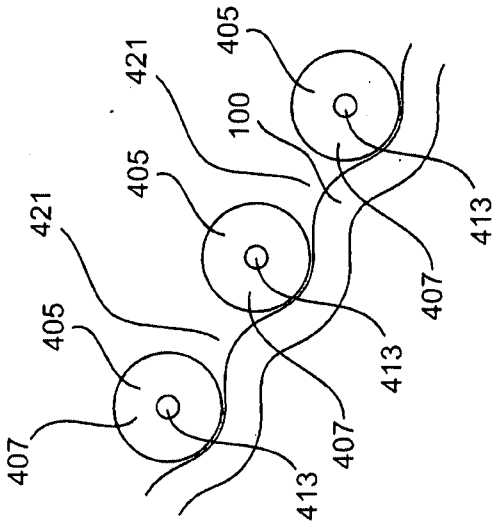


Fig. 48

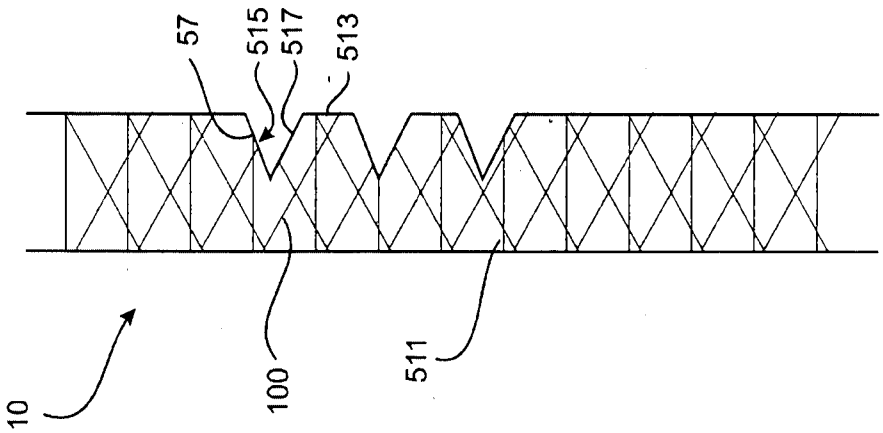


Fig. 52

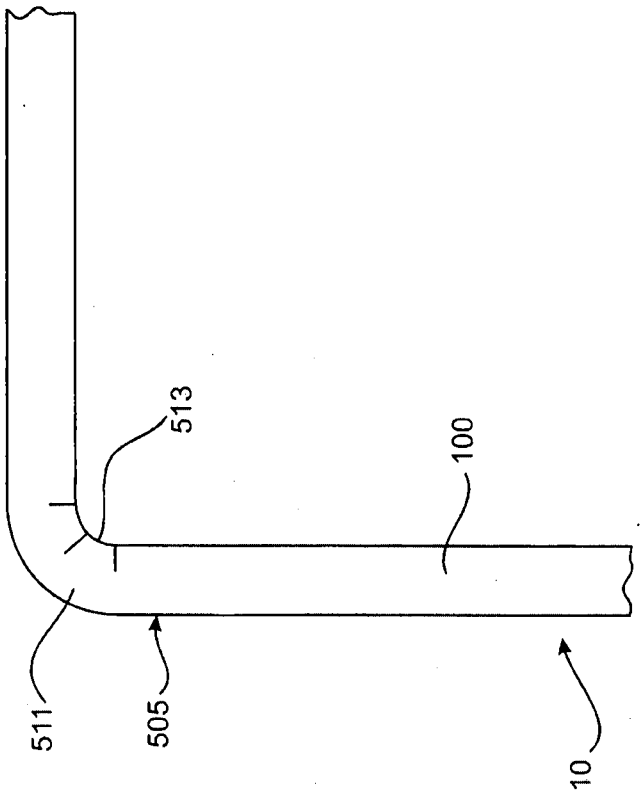


Fig. 51

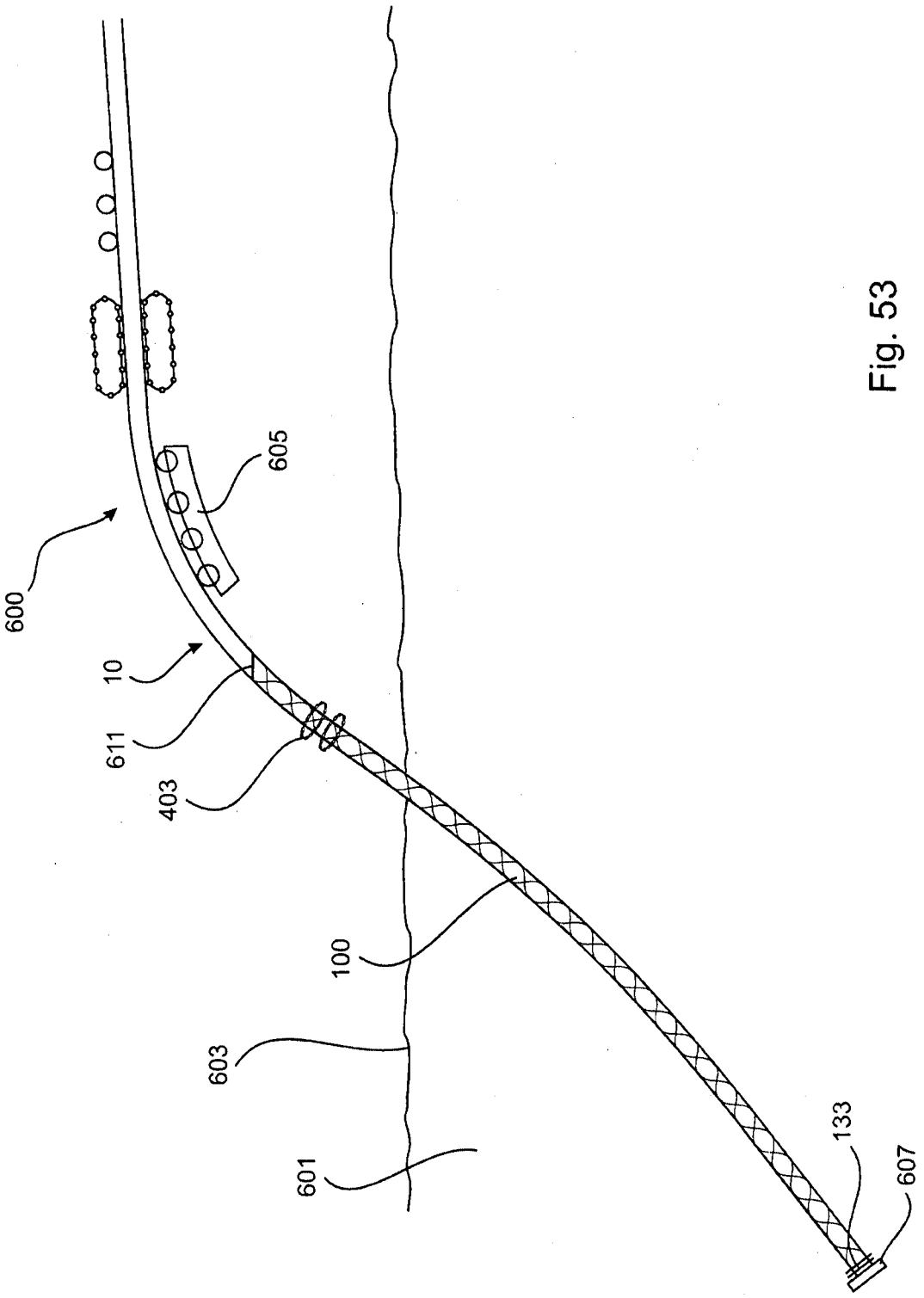


Fig. 53

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2011/001401

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

F16L 1/038 (2006.01) ***F16L 9/14*** (2006.01) ***F16L 11/04*** (2006.01) ***B29C 63/02*** (2006.01) ***F16L 9/16*** (2006.01) ***F16L 11/24*** (2006.01) ***B29C 63/26*** (2006.01) ***F16L 9/18*** (2006.01) ***F16L 11/26*** (2006.01) ***F16L 7/00*** (2006.01) ***F16L 9/21*** (2006.01) ***F16L 9/12*** (2006.01) ***F16L 11/00*** (2006.01) ***B29C 70/50*** (2006.01) ***B29D 23/00*** (2006.01) ***B32B 3/00*** (2006.01) ***B29C 47/06*** (2006.01) ***B29D 23/18*** (2006.01) ***B32B 17/00*** (2006.01) ***B29C 70/68*** (2006.01) ***B32B 1/08*** (2006.01) ***B32B 27/02*** (2006.01) ***B32B 37/10*** (2006.01) ***B32B 37/00*** (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)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI; EPODOC: F16L 1/038, 9/14, 9/16, 11/04, 11/24, 9/18, 11/26, 7/00, 9/21, 9/12, 11/00; B29C 63/02, 70/50, 47/06, 70/68; B29D 23/00, 23/18; B32B 3/00, 17/00, 1/08, 27/02, 37/10, 31/00, 37/00 and fiber+, fibro+, fabric+, cloth+, film+. expan+ inflate+ inner, outer, interior, inside, outside, line+, flexib+, bend+, supple, plastic+, resin+, polymer+, binder, impregnate+, merg+, fuse+, weld+, join+, seal+, harden+, cur+, set+, bind+, tub+, hose+, duct+, conduit+, cylind+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6899842 B1 (CORRE ET AL) 31 May 2005 Whole document	17-23, 26, 28-40
X	CA 843231 A (AMERICAN CYANAMID CO) 2 June 1970 Abstract; claims; figures; page 2 line 6 – page 6 line 3; examples	1-34, 41-48

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 February 201227 February 201227 February 2012	29 February 2012
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **G DIVEN** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2992

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2011/001401

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3329173 A (SKOGGARD ET AL) 4 July 1967 Abstract; figures; claims; examples	1-34, 41-48
X	JP 06-031820 A (TOYOTA MOTOR CORP) 8 February 1994 JAPIO abstract	17-23, 26, 28-34
X	EP 114361 A2 (HOECHST AG) 1 August 1984 Whole document	1-34, 41-48

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2011/001401

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: **49-51**

because they relate to subject matter not required to be searched by this Authority, namely:

The claims do not comply with Rule 6.2(a) because they rely on references to the description and/or drawings.

2. [ ] Claims Nos.:

because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:

because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

[See Supplemental Box]

1. [X] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. [ ] As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

Supplemental Box
(To be used when the space in any of Boxes I to IV is not sufficient)

Continuation of Box No: III

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-16 and 41-48 are directed to methods of constructing elongate hollow structures, and to the structure itself, comprising a radially inner portion, a radially outer portion, with the two portions merging together to provide an integrated tubular wall structure the method comprising providing the inner portion, assembling the outer portion around the inner portion and expanding the inner portion, the outer portion comprises an outer tube of fibre reinforced composite surrounded by a flexible outer casing. The feature of a radially inner portion, a radially outer portion, with the two portions merging together to provide an integrated tubular wall structure is specific to this group of claims.

- Claims 17-34 are directed to methods of constructing elongate hollow structure comprising forming a flexible tubular wall structure about a central portion, expanding the central portion to give prescribed shape and form to the tube and hardening, curing or otherwise the wall structure. The feature of forming a flexible tubular wall structure about a central portion, expanding the central portion to give prescribed shape and form to the tube and hardening, curing or otherwise the wall structure is specific to this group of claims.

- Claims 35-40 are directed to a method of constructing a pipe in a flexible condition, laying the pipe at a site and transforming the pipe into a rigid structure. The feature of constructing a pipe in a flexible condition, laying the pipe at a site and transforming the pipe into a rigid structure is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori*.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2011/001401

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	6899842	AU	31699/00	CA	2365665	EP	1159556
		FR	2790534	WO	0053963		
CA	843231	NONE					
US	3329173	BE	655707	DE	1504870	GB	1037959
		NL	6413262	US	3399094	US	3407107
JP	6031820	JP	61189497				
EP	0114361	AR	230964	BR	8307084	DE	3247617
		JP	59120421	ZA	8309520		

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX