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HYDRAULIC GROUTING PACKER

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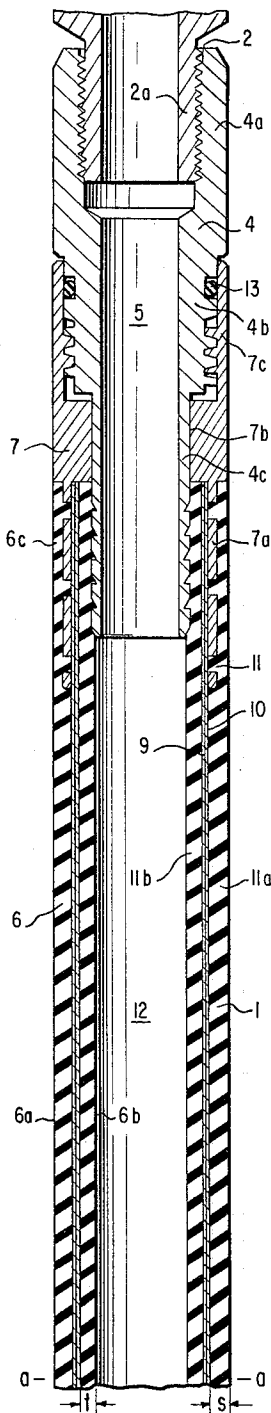


FIG. 1A

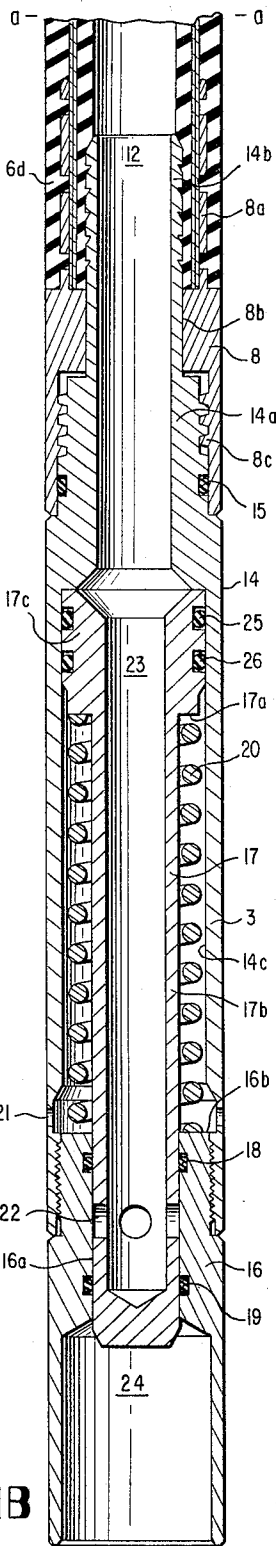


FIG. 1B

FIG. 2

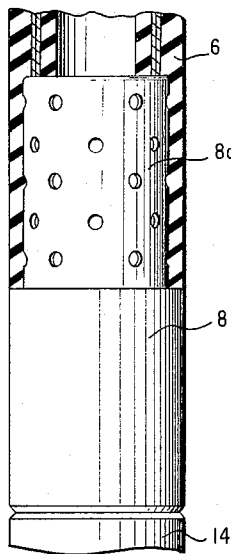
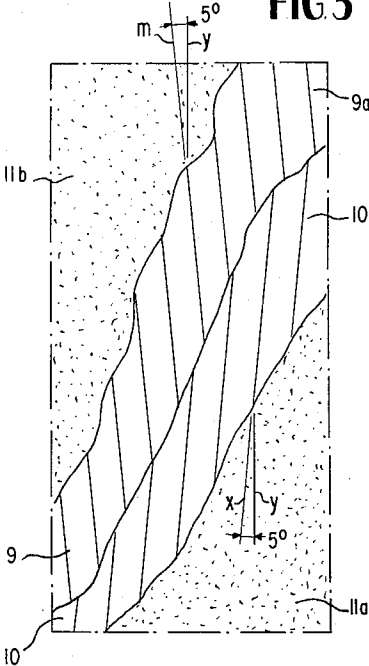


FIG. 3



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1

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HYDRAULIC GROUTING PACKER

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This invention pertains to methods and apparatus for discharging fluid into isolated cavity portions. In particular, the invention relates to a method and apparatus which may be utilized to position a fluid, such as grout, at a predetermined location within an open hole or passage.

In grouting operations it frequently is necessary to inject grouting fluid into cavities which are filled with fluid such as water. Where such conditions are encountered, it often becomes necessary to isolate the portion of the cavity into which the grouting fluid is to be discharged.

A variety of devices have been developed for both isolating a portion of a cavity and allowing the discharge of grouting fluid into this isolated portion. However, the structural characteristics of such devices have been such as to make their removal or relocation difficult, or at times altogether impossible.

A particularly effective grouting tool, recently developed, has been characterized by an inflatable, sleeve-type packer carried by a central mandrel. However, because of the presence of the mandrel, precautions are sometimes required while operating this tool so as to facilitate proper packer contraction and subsequent tool removal or re-setting.

Recognizing the problems inherent in previously developed grouting tools, which have impeded their relocation or removal from a cavity being grouted, it is an object of the present invention to provide a material-discharging method and apparatus which substantially obviates the difficulties in tool removal or relocation described above.

It is a particular object of the invention to provide an improved grouting technique and tool which utilizes an inflatable and elastic, tubular body to isolate a cavity portion. By means of this improved technique and tool, impedance with the contraction of the previously distended tubular body is minimized or altogether obviated.

A further object of the invention is to provide a grouting tool employing an inflatable, tubular body type of packer which is devoid of an internal mandrel connecting and supporting the packer ends.

Yet another object of the invention is to provide a unique grouting method and apparatus which particularly facilitates multiple repositioning and setting of a grouting tool within a particular cavity.

It is also an object of the invention to provide such an improved method and apparatus wherein a packer defines an elastic, flexible connection between a conduit string and pressure regulating means which serves to keep the packer expanded while grouting fluid is being discharged.

A still further object of the invention is to provide a method and apparatus, of the type heretofore noted, wherein oppositely disposed, distensible wall portions of the tubular packer are in free and unobstructed fluid communication when the packer is filled with fluid.

An additional object of the invention is to provide a grouting tool including an elastic, tubular body packer, the ends of which are axially contractible, even though appreciable contraction of these ends may not always occur.

A final object of the invention is to provide a new and improved grouting tool which simplifies grouting operations and enables the performance of grouting jobs in a more rapid and reliable manner.

In accomplishing the foregoing objects, a method of discharging fluid within an isolated portion of a cavity is

2

employed wherein pressure-regulating means are supported upon an outermost end of elastic, laterally distensible and contractible, packer means within a cavity. The term outermost end, as here used in relation to the packer means, is considered as being the end of the packer means most remote from conduit means supplying pressurized fluid to its interior. Pressurized fluid is supplied to the interior of the packer means through an inner most end thereof, i.e., the end in closest proximity to the fluid-supplying conduit means.

In response to the supplying of pressurized fluid, the packer means distends laterally into engagement with the cavity periphery so as to isolate a portion thereof. Thereafter, fluid is flowed out of the outermost end of the packer means into the isolated cavity portion. After the desired amount of fluid has been so discharged into the isolated cavity portion, lateral contraction of the packer means is accomplished by reducing the pressure of fluid within its interior.

The laterally distended portion of the packer means, in contracting laterally, tends to displace fluid generally radially toward a central axis of the packer means, with opposing inner wall portions of the packer means being in unobstructed fluid communication.

The apparatus employed in practicing this invention includes conduit means adapted to be inserted into a cavity and to transmit pressurized fluid. Flexible walled, elastically and laterally distensible and contractible packer means are carried by and define an interiorly unobstructed continuation of this conduit means. Pressure-regulating means are connected with and supported by the packer means. The packer means defines a flexible connection disposed between the conduit means and the pressure-regulating means.

In describing the invention, reference will be made to a preferred apparatus embodiment illustrated in the accompanying drawings.

In the drawings:

FIGURES 1-A and 1-B, when joined together along the dividing line *a-a*, provide a sectioned, elevational view of a fragmentary portion of a conduit string supporting a tubular-body, grouting packer, which in turn supports a pressure-regulating check-valve assembly;

FIGURE 2 is a fragmentary, partially sectioned, elevational view of a portion of the FIGURES 1-A and 1-B apparatus showing the manner in which the packer is connected by an adaptor to an adjacent apparatus component; and

FIGURE 3 is a fragmentary, schematic, partially and multiple sectioned view showing the relationship of the various layers of the packer tube of the apparatus shown in FIGURES 1-A and 1-B.

The principal components of the grouting tool, as shown in the drawings, comprise an inflatable packer assembly 1 which defines a flexible connection between a packer-supporting, conduit string 2 and a check-valve assembly 3. It will be understood, of course, that the conduit string 2 a fragmentary, lower portion of which is shown in FIGURE 1-A, may comprise a conventional assembly of series and threadably interconnected, tubular conduit sections.

As shown in FIGURE 1-A, conduit string 2 includes a terminal coupling portion 4 adapted to connect the conduit string 2 to the packer assembly 1. Coupling portion 4 includes a threaded female coupling portion 4a connected with a threaded male portion 2a, an intermediate and externally threaded coupling portion 4b, and a thermal cylindrical portion 4c which may be exteriorly indented or roughened as shown.

An axial, i.e. central, passage 5 extends through the conduit string 2 and terminates at the open extremity of cylindrical portion 4c.

Packer assembly 1, in the preferred, illustrated form, comprises a generally tubular and cylindrical body 6 having coupling adaptors 7 and 8 bonded to its opposite ends.

Tubular body 6 is fabricated, in part, of elastomeric material such as rubber. In the preferred embodiment, two concentric, substantially contiguous layers 9 and 10 of nylon reinforcing elements are embedded within the elastic material 11 of the tubular body 6.

As shown in FIGURES 1-A and 3, each reinforcing layer 9 and 10 comprises a cylindrical layer coaxially embedded within the tubular body 6. As shown in FIGURE 3, the outermost layer 10 includes nylon reinforcing strands 10a which extend throughout the longitudinal length of the tubular body 6 between its opposite ends. These nylon reinforcing strands, which may comprise individual strands or the longitudinal strands of commercially available nylon ribbon or tape, are inclined at an acute angle with respect to the direction of the longitudinal axis of the tubular body 6. In a preferred embodiment, which has been found under field conditions to perform in a particularly efficacious fashion, longitudinal direction "x" of the strands 10a is inclined with respect to the axial direction "y" of the tubular body 6 at an angle of approximately 5 degrees. In this same embodiment, the individual strands 9a of the inner reinforcing element layer, which extend between opposite ends of the tubular body 6 throughout its length, are also inclined at an acute angle with respect to the axial direction of the tubular body. However, the longitudinal direction "m" of the strands 9a is inclined at an angle of approximately 5 degrees to the axial, tubular body direction "y" at an inclination direction opposite to that of the inclination of the strands 10a, as shown in FIGURE 3.

It is considered that the two-layer, biased-angle, nylon-strand, reinforcing arrangement illustrated in FIGURE 3 is particularly advantageous. Its oppositely inclined, generally helically extending, nylon reinforcing strands 9a and 10a enable the tubular body 6 to function in a particularly effective fashion. With this arrangement of reinforcing elements, the body 6 is effectively prevented from undergoing undesirable elongation in response to the application of internal fluid pressure. This particular arrangement of reinforcing elements has been found to allow the packer body 6 to freely inflate while enabling it to consistently contract to its original cylindrical configuration when inner fluid pressure is relieved.

Relative dimensions of the reinforcing layers 9 and 10 and the inner and outer, annular rubber layers 11a and 11b may vary to some extent, depending upon the overall dimensions of the tool as they are adapted to particular job requirements. However, in a field-demonstrated embodiment, where the outer diameter of the tubular body 6 was approximately 1.75 inches and the inner diameter approximately .90 inch, each reinforcing layer 9 and 10 was fabricated from nylon ribbon having a ply thickness of approximately .035 inch.

In order to provide optimum elasticity, lateral distensibility, and contractability in combination with a passage-wall-engaging surface of maximum-wear-resistant properties, the packer body 6 may be fabricated with a unique disposition of its reinforcing elements. Thus, the thickness of the rubber layer 11a which extends between the nylon reinforcing layer 10 and the passage-wall-engaging, tubular body exterior 6a may be of a thickness "s" which exceeds the thickness "r" of the annular rubber layer 11b extending between the inner nylon reinforcing layer 9 and the tubular body inner wall 6b.

As shown, inner tubular body wall 6b defines an axial passage 12 which constitutes an axial, i.e. central or non-annular extension of the conduit string passage 5 and communicates directly and axially with this latter passage.

The interior of the tubular body 6 is unobstructed such that diametrically and laterally opposite inner wall portions thereof are in unobstructed fluid communication.

With the tubular body in its relaxed, or cylindrical, configuration, i.e., the configuration prior to fluid-pressure-induced distention, the wall portions of the tubular body 6 are laterally and freely movable into the axial passage 12.

Each coupling 7 and 8 is securely bonded to the end of the tubular body 6 to which it is adjacent so as to comprise an integral portion of the packer assembly 1.

Adaptor 7, for example, includes a perforate cylindrical portion 7a which extends coaxially into the upper end 6c of the tubular body 6 as shown in FIGURE 1-A so as to lie outside but adjacent the reinforcing layer 10. The rubber material 11 of the tubular body 6 is bonded to the cylindrical portion 7a, including its perforate areas, by conventional rubber-to-metal bonding techniques. A cylindrical, perforate coupling portion 8a of adaptor 8 is similarly bonded in coaxial relationship within the lower end 6d of the tubular body 6 as shown in FIGURE 1-B and FIGURE 2.

Adaptor 7 includes a central opening 7b and an internally threaded female coupling portion 7c. As shown in FIGURE 1-A, cylindrical portion 4c of conduit string 2 extends through the opening 7b to tightly and sealingly engage the inner wall 6b of the tubular body 6. Coupling portion 7c of packer assembly adaptor 7 is threadably secured to coupling portion 4b of conduit string 2. In order to assure the existence of a fluid tight seal between the coupling portions 4b and 7c, a conventional O-ring seal 13 may be employed, as shown.

Check valve assembly 3 includes an upper connecting portion, as shown in FIGURE 1-B, comprising an externally threaded portion 14a of a generally cylindrical, casing member 14 and a terminal, exteriorly roughened or indented, cylindrical portion 14b. Cylindrical portion 14b of check valve assembly 3 extends coaxially through a central aperture 8b of adaptor 8 into tight fitting and sealing engagement with the inner wall 6b of the tubular body 6.

An internally threaded, terminal portion 8c of adaptor 8 is threadably secured to coupling portion 14a so as to firmly join the packer assembly 1 to the check valve assembly 3. A conventional, O-ring gasket 15 may be employed between the coupling portions 14a and 8c as shown in FIGURE 1-B.

Tubular body 6, in being connected to conduit string 2 by adaptor 7, which may be considered as comprising first coupling means, and in being connected to pressure regulating means 3 by adaptor 8, which may be considered as comprising second coupling means, defines a flexible connection between the conduit string 2 and the check valve assembly 3. Owing to the elastic and flexible character of the tubular body 6, the check valve assembly 3 is capable of undergoing lateral deflection in relation to the conduit string 2. In addition, the distensible and reinforced character of the tubular body 6 is such that its opposite ends 6c and 6d may, at times, undergo axial contraction or convergence when the body 6 is expanded under the influence of internal fluid pressure. Such axial contraction may not always be appreciable or readily discernible. For example, where the passage into which the packer body 6 has been inserted is of a diameter closely approaching its outer diameter, little or no axial contraction may take place. However, the ability of the body ends 6c and 6d to undergo such contraction may be a significant factor in relieving internal stress so as to prolong the operating life of the body. In addition, the axially contractible and elastic character of the body 6 provides a resilient, and potentially shock absorbing, connection between the check valve assembly 3 and the conduit string 2. This connection may serve to absorb, to some extent, mechanical shocks imposed upon the check valve assembly 3 when the tool is being inserted into a cavity such as a formation hole or a hole in a mass of unconsolidated earthen material so as to minimize damage to this portion of the apparatus.

5

Check valve assembly 3 includes an outer body or casing defined by threadably interconnected and generally cylindrical body sections 14 and 16. A hollow piston 17 is telescopically mounted within a central, apertured portion 16a of body section 16 as shown in FIGURE 1-B, so as to extend upwardly into the interior of body section 14. Conventional sealing means such as O-rings 18 and 19 may be employed to effect a seal between the relatively movable piston 17 and the body section 16, as shown.

Piston 17 is biased toward tubular body 6, as shown in FIGURE 1-B, by a coil spring 20. Spring 20 engages an annular abutment 17a formed on the outer periphery of the upper end of the piston 17 and also engages an annular shoulder 16b disposed generally at the lower end of the valve assembly 3, adjacent the apertured portion 16a and within the interior of the valve body.

The valve body and piston 17 are appropriately ported to allow for freedom of movement of the piston 17 and the expelling of fluid from the passage 12. Venting port means, such as the lateral port 21, intersect the cylinder 14 so as to allow for suitable freedom of axial movement of the piston 17 within the valve body. Lateral port means, including at least one and preferably a plurality of ports 22, intersect the cylindrical side wall 17b of the piston 17. Ports 22 provide fluid communication between the hollow interior 23 of the valve assembly 3 and the valve assembly exterior when the piston 17 is displaced downwardly, as shown in FIGURE 1-B. In this displaced position, the ports 22 are exposed within fluid discharge opening 24. As illustrated, discharge opening 24 comprises an axial passage in the lower end of the valve body section 16 having a diameter exceeding the diameter of the piston embracing passage 16a.

The upper end of piston 17 is enlarged to define a cylindrical piston head 17c in telescoping engagement with inner wall 14c of body section 14. Sealing engagement between piston head 17c and casing wall 14c may be assured through the conventional utilization of piston-head-carried O-ring gaskets 25 and 26.

Coil spring 20 exerts a biasing force against the annular shoulder 17a of the piston head portion 17c of a predetermined magnitude. Where grouting operations are being performed with a packer dimensioned as described above, it has been found that a satisfactory spring strength should be sufficient to overcome a fluid pressure differential, between the zones 23 and 24, of about one hundred pounds per square inch. When pressurized fluid, supplied through the axial passage defined by passage portions 5, 12, and 23, causes this pressure differential to be exceeded, the piston 17 will move outwardly of the valve body so as to expose the ports 22 and allow the discharge of fluid into the discharge zone 24.

The predetermined, substantial biasing force of the spring 20 will insure that the pressure within the packer passage 12 exceeds the fluid pressure at the tool exterior 24. This differential, governed by the spring biasing force, is such as to insure the distension of the packer body 6 into cavity-periphery engagement prior to the opening of the valve 3 which allows the discharge of fluid through ports 22. Even with the valve 3 opened, the spring 20 will insure the maintenance of a pressure differential sufficient to hold the packer body in its set, or cavity wall engaging, distended condition.

The tool heretofore described is particularly adapted for use in discharging grouting fluid into cavities such as bored holes, fissures in subterranean formations, openings in ground surfaces, passages in other masses, etc. The tool may be employed to inject a variety of grouting fluids. However, ordinarily it would be employed to inject grouting fluid, the viscosity of which would increase with the passage of time. A representative grouting fluid which may be successfully discharged from the illustrated tool comprises a catalyzed aqueous mixture of acrylamide and N,N'-methylenebisacrylamide which gels rapidly at ordinary concentrations and temperatures.

6

In utilizing the apparatus of this invention, the packer assembly 1 and check valve assembly 3, are moved on conduit string 2, to a desired position within a cavity or passage to be grouted. After the grouting fluid outlet 24 has been disposed at the generally desired location, pressurized grouting fluid may then be pumped down through the passage 5 to enter the packer passage 12. The elasticity of the packer body 6 allows the lateral distension of at least a portion of the packer wall 6a into engagement with the wall of the cavity to be grouted, prior to the opening of the check valve 3. After the packer has distended laterally and engaged a cavity periphery so as to isolate the cavity portion into which the valve 3 projects, the continued pressurization of grouting fluid within the passage 5 and 12 will cause the piston 17 to move outwardly of the passage 16a so as to expose the ports 22 and allow the discharge of grouting fluid into the isolated passage portion. The coil spring biased character of the valving piston 17 will insure the maintenance of packer distending pressure within the passage 12 while grouting fluid is being discharged from the ports 22.

When a desired amount of grouting fluid has been discharged, pressure may be relieved within the packer body 6 by reducing the pressure of fluid supplied to the conduit string 2. This reduction in pressure will allow the packer body 6 to contract laterally so as to free the packer from the passage wall while also allowing the check valve 3 to close. The absence of obstructing structure within the tubular body 6 will permit the contracting packer walls to urge grouting fluid generally radially and directly toward the packer central axis and into the passage 12 and will thus allow the proper contraction of the packer even though relatively viscous grouting fluid is being discharged.

The tool may then, if desired, be raised or otherwise moved to a new location within the cavity and subsequent, grouting fluid discharging steps performed. In performing each step, of course, it is merely necessary to supply pressurized fluid to the tool to effect the inflation or distension of the packer and subsequent opening of the check valve. At the conclusion of each grouting fluid discharge step, the tool may be freed by merely reducing the pressure of fluid supplied to the conduit string 2. The unimpeded contraction of the packer body 6 enables such repeated grouting steps within a cavity to be performed with maximum rapidity and reliability.

In describing the preferred structural embodiment of the invention and its mode of operation, several advantages of the invention have been demonstrated. The tubular packer body 6, in defining a flexible coupling between the conduit string and the check valve assembly, permits axial convergence of the check valve assembly 3 relative to the conduit string 2 and permits the check valve assembly 3 to move laterally with respect to the conduit string. The possible, but not always necessarily occurring, axial contraction of the tubular packer body would tend to relieve internal packer stress and absorb mechanical shock applied to the check valve assembly.

The internally unobstructed character of the packer assembly particularly facilitates the contraction or collapse of the packer in response to an internal pressure reduction. This materially improves the ease with which the grouting tool may be relocated, reused within a passage, or removed from a passage.

The specifically described structure of the reinforced packer tube, in practice, has been found to produce a reliably operating tool capable of sustained and repeated use without undergoing meaningful and undesired deformation.

The structural characteristics of the elements and adaptors interconnecting and coupling the various tool components are such as to minimize fabrication efforts without sacrificing reliable coupling and sealing characteristics.

While the invention has been described with respect to a specific preferred embodiment, those skilled in the art,

having the benefit of its disclosure, may recognize the possibility of additions, deletions, substitutions, and modifications which would fall within the purview of the invention as defined in the appended claims.

I claim:

1. An apparatus for discharging fluid into an isolated portion of a cavity, said apparatus comprising:

conduit means adapted to be inserted into a cavity and to transmit pressurized fluid;

flexible walled, elastically and laterally, distensible and contractible packer means carried by and defining an interiorly unobstructed continuation of said conduit means; and

pressure regulating means connected with and supported by said packer means,

said packer means defining a laterally flexible, and axially contractible connection disposed between said conduit means and said pressure regulating means, with said pressure regulating means being movable laterally of said conduit means and axially convergeable with said conduit means in response to lateral distention of said packer means.

2. An apparatus for discharging fluid into an isolated portion of a cavity, said apparatus comprising:

conduit means adapted to be inserted into a cavity and to transmit pressurized fluid;

flexible walled, elastically and laterally distensible and contractible packer means carried by and defining an interiorly unobstructed continuation of said conduit means;

said packer means comprising a tubular body of elastomeric material, said tubular body having innermost and outermost ends with the innermost end being disposed axially between the outermost end and said conduit means, said tubular body further having embedded therein multiple layers of reinforcing elements, each such layer comprising a plurality of strands, the strands of one layer extending generally helically about the axis of said tubular body in one direction and the strands of another reinforcing layer extending generally helically about the axis of said tubular body in an opposite direction;

pressure regulating means connected with and supported by said packer means; and

said packer means defining a laterally flexible, and axially contractible connection disposed between said conduit means and said pressure regulating means, with said pressure regulating means being movable laterally of said conduit means and axially convergeable with said conduit means in response to lateral distention of said packer means.

3. An apparatus as described in claim 2 wherein the interior of said elastomeric, tubular body defines an axial, smooth walled passage comprising an extension of an axial passage defined by said conduit means.

4. An apparatus as described in claim 3 wherein said packer means includes two concentric layers of reinforcing elements and wherein strands in each reinforcing layer, extending between ends of said tubular body, are inclined with respect to the direction of the longitudinal axis of said tubular body at an angle of approximately five degrees.

5. An apparatus as described in claim 4 wherein said reinforcing elements are embedded within said tubular body such that the thickness of elastomeric material between the outermost reinforcing element layer and the tubular body exterior exceeds the thickness of the layer of elastomeric material between the innermost reinforcing element layer and the tubular body interior.

6. An apparatus as described in claim 2 wherein said innermost end of said tubular body is connected to said conduit means by first coupling means and wherein said outermost end of said tubular body is connected to said pressure regulating means by second coupling means;

said first coupling means comprising a cylindrical portion embedded within said innermost end of said tubular body and a female coupling portion threadably connected to said conduit means;

said second coupling means comprising a cylindrical portion embedded within said outermost end of said tubular body and a female coupling portion threadably connected to said pressure regulating means;

said conduit means including a cylindrical portion extending into the interior of said innermost end of said tubular body and compressing an annular portion of said innermost tubular body end against said cylindrical portion of said first coupling means; and said pressure regulating means including a cylindrical portion extending into the interior of said outermost end of said tubular body and compressing an annular portion of said outermost tubular body end against said cylindrical portion of said second coupling means.

7. An apparatus as described in claim 6 wherein said cylindrical portion of said conduit means extends coaxially through said first coupling means into sealing engagement with said innermost end of said tubular body and wherein said cylindrical portion of said pressure regulating means extends coaxially through said second coupling means into sealing engagement with said outermost tubular body end.

8. An apparatus as described in claim 2 wherein said pressure regulating means comprises:

generally cylindrical casing means;

hollow piston means having one end open and facing said elastomeric tubular body and having another end closed, said hollow piston means being telescopically mounted within an axial opening in said casing means;

coil spring means encircling said piston means and contained within said casing means, said coil spring means engaging an annular shoulder on the exterior of said piston and engaging an annular shoulder on the interior of said casing means so as to bias said piston toward said elastomeric tubular body; and said piston including transverse openings extending laterally through side wall portion thereof, said openings being adapted to communicate with the exterior of said casing when fluid pressure within said casing exerts a force against said piston means sufficient to overcome the biasing force of said coil spring means and move said piston means outwardly of said casing means through said axial opening thereof.

9. An apparatus as described in claim 4 wherein the innermost end of said tubular body is connected to said conduit means by first coupling means and wherein an outermost end of said tubular body is connected to said pressure regulating means by second coupling means;

said first coupling means comprising a cylindrical portion embedded within said innermost end of said tubular body and a female coupling portion threadably connected to said conduit means;

said second coupling means comprising a cylindrical portion embedded within an outermost end of said tubular body and a female coupling portion threadably connected to said pressure regulating means;

said conduit means including a cylindrical portion extending into the interior of said innermost end of said tubular body and compressing an annular portion of said innermost tubular body end against said cylindrical portion of said first coupling means; and said pressure regulating means including a cylindrical portion extending into the interior of said outermost end of said tubular body and compressing an annular portion of said outermost tubular body end against said cylindrical portion of said second coupling means.

10. An apparatus as described in claim 9 wherein said pressure regulating means comprises:

generally cylindrical casing means;

9

hollow piston means having one end open and facing said elastomeric tubular body and having another end closed, said hollow piston means being telescopingly mounted within an axial opening in said casing means;

coil spring means encircling said piston means and contained within said casing means, said coil spring means engaging an annular shoulder on the exterior of said piston and engaging an annular shoulder on the interior of said casing means so as to bias said piston toward said elastomeric tubular body; and

said piston including transverse openings extending laterally through side wall portions thereof, said openings being adapted to communicate with the exterior of said casing when fluid pressure within casing exerts a force against said piston means sufficient to over-

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come the biasing force of said coil spring means and move said piston means outwardly of said casing means through said axial opening thereof.

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