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(54) **EXPANDABLE PLUG AND CONTROL METHOD**

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ORGANE D'OBTURATION EXPANSIBLE ET PROCEDE DE COMMANDE

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EP 0 738 379 B9

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Description

BACKGROUND OF INVENTION

[0001] The present invention relates to an expandable plug adapted to seal or to regulate pressure or flow within a tube, and also to a method of control.

[0002] Expandable plugs of this general type find application in cases where normal valving of flow is inappropriate for some reason, for example because the position of the desired seal or regulation is not fixed with respect to the tube, the desired seal is temporary, or the exterior of the tube is inaccessible.

[0003] The general approach to the design and construction of expandable plugs involves the use of an elastomeric cylinder or bladder, which is caused to increase in diameter. This may be done by a variety of mechanical means, or by application of internal pressure.

[0004] In use the plug will need to withstand diametral expansion and axial thrust, the latter being due to friction (in cases where the plug moves relative to the tube) and the differential tube fluid pressure across the plug.

[0005] Mechanically expanded plugs are suitable only for relatively small ratios of expansion and/or low axial thrusts. Larger expansion ratios may be required in cases for example where undue hydraulic obstruction of the tube cannot be tolerated when the plug is not expanded, or where the tube may vary in diameter or be caused to expand by fluid pressure behind the plug. For such applications, expansion by internal pressure is preferred.

[0006] U.S. patent No. US-A-4883094. **[deletion(s)]** The Vetter device is specifically designed to seal a pipe and provides no means of controlling its internal pressure to allow controlled passage of lubricating fluid past the device in use.

[0007] U.S. patent 2,794,197 discloses a pipe cleaning tool which includes a spheroidal-body (B) having a number of reinforcement ribs (50) thereabout. A rope (20) is used to draw the body (B) along the pipe (P) whereupon the fluid upstream of the body passes through apertures (12) to inflate the body (B) so as to force the ribs (50) against the internal surface of the pipe for cleaning purposes. There is no means of finely adjusting the internal pressure of the body (B) by means external of the pipe (P). **[deletion(s)]**

[0008] The drawback of these prior art systems are solved by the characterising features of claims 1 and 11.

[0009] Further preferred embodiments or method variants are subject of dependent claims 2-10 and 12.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Further preferred embodiments of the invention shall now be described with reference to the accompanying drawings, in which:

Fig. 1 is a schematic side view, partly in cross sec-

tion, of a preferred plug construction;

Fig. 2 is a perspective view of a portion of the bladder with the sheath removed to reveal the helical reinforcing cord arrangement;

Figs. 3 and 4 schematically illustrate the spreading of the cords as the plug is inflated; and

Figs. 5 to 7 are schematic view illustrating the control method according to the second aspect of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] The plug generally consists of a pair of end cap members 10 between which a cylindrical bladder 12 extends. The upstream end cap member 10a has a fluid inlet means 14 for entry of liquid or gas or end members (10,10a) to inflate the bladder. In practice, the end caps may be identical and the downstream end cap blocked off or restricted to provide back pressure. At least one of the end caps is physically connected to an external support to provide reactive support against axial thrust on the plug. This support may conveniently be provided by the pipe (not shown) which provides the inflation fluid.

[0012] The bladder 12 should be formed of a tube of elastomeric material with a high strain capability and low stiffness, in order to accept diametral expansion without rupture. This is particularly important where a high expansion ratio is required.

[0013] The elastomeric bladder is fixed to the end caps (10,10a) by compression seals 16 or other suitable means. Each seal is compressed between a compression flange 18 and a spacer block 20 as nut 22 on the shaft 24 of the compression flange is tightened.

[0014] The reinforcing envelope 26 is formed of flexible cords 28 which surround the outer surface of the bladder, the cords being better shown in Fig. 2. The cord may be fixed by winding about a series of angled anchor pins 30 (shown in Fig. 1) attached to each end cap (10, 10a). The cords, of non-elastomeric material, encase the bladder, offering little or no resistance to diametral expansion. It will be appreciated that the gap between the cords will tend to increase as the plug circumference expands. Within this gap the elastomeric bladder is unsupported, and therefore numerous, closely positioned cords should be used. The cords may be protected by a second elastomeric sheath 34 over the outside of the plug if necessary.

[0015] In the embodiment of Fig. 2, the cords are laid at a small helix angle, for example less than 15°, to the axis of the plug, with two or more layers 32a,32b of cords with opposing helices. This assists in the positioning of the cords during expansion, although at the cost of a slight increase in diametral resistance due to the circumferential component of the cord direction.

[0016] Most commercially available reinforcing cord is made by twisting together a large number of individual strands. The twist prevents spreading of the cord and provides greater resilience. However, the Applicant has found that in this particular application the normal twisted cord is undesirable, as the cords cause intense local stresses in the elastomer and tend to cut the bladder. The Applicant has found that by using untwisted cord the strands move laterally over the expanding surface of the bladder, spreading the load and thus preventing cutting of the bladder.

[0017] Figs. 3 and 4 illustrate this lateral movement of the strands during inflation. Fig. 3 shows a parallel cord configuration of an uninflated plug. Fig. 4 shows the same plug when inflated. It can be seen that the width of the untwisted cords increases as the bladder expands. For the sake of clarity, Figs. 3 and 4 show the cords widely separated. In practice, the cords are preferably more tightly packed with little or no gap.

[0018] In principle the cords can be of any material with appropriate characteristics, in general high tensile strength, high elastic modulus, high flexibility, and suitable chemical compatibility with the fluid involved. Cotton, metal, or synthetic fibre cords could be used. Very successful plugs have been constructed using aramid cords, which consist of a very large number of very fine strands, and can be obtained in untwisted form.

[0019] It is important in the construction of the plug that the cords be all equal in tension and length. One cord slightly looser than others will be displaced on expansion and leave an unsupported gap on the elastomeric bladder. A method by which equal tension may be achieved is to fix cord anchor rings on an appropriate rigid frame, and wind the cords using a counter weight to ensure constant tension.

[0020] In an alternative embodiment, the reinforcing envelope may be integrally formed with the elastomeric material of the bladder or sheath. The use of the untwisted cords allows lateral movement of the strands, reducing the tendency of the cords to tear the elastomer matrix of the composite material during expansion.

[0021] The construction according to the invention provides a plug with highly anisotropic properties, namely:

1. the ability to accept diametral expansion without rupture and without requiring excessive pressure, that is, a high strain capability in the circumferential direction and a low stiffness; and
2. the ability to carry axial loading resulting from the pressure differential across the plug, that is, very high strength and high stiffness in the axial direction.

[0022] The diametral expansion properties of the plug result in a relatively low free expansion pressure, that is, the pressure needed to expand the plug to the tube

diameter without confinement. This allows fine control of the plug inflation pressure, thus allowing control of the upstream pressure or flow in the tube as described below.

[0023] Surprisingly, the Applicant has found that a precise and predictable relationship exists between the pressure applied internally to an expandable plug and the pressure which may be retained behind the plug, as described in the following equation:

$$P_p = \Delta P + P_d$$

where

- P_p = Pressure applied to plug
 ΔP = Pressure differential across plug
 P_d = Pressure to expand plug to diameter d without confinement (free expansion pressure)
 d = diameter of confining tube

[0024] Figs. 5 to 7 illustrate the parameters of the control method. Fig. 5 shows the unexpanded plug, with atmospheric pressure both inside and outside the plug. In Fig. 6 the plug is expanded to diameter d without a constraining tube, by application of the free expansion pressure P_d to the inside of the plug. In Fig. 7 the plug is expanded inside a tube 36 of internal diameter d and the volume inside the tube upstream of the plug is pressurised to ΔP . The minimum plug pressure, P_p , needed to maintain the pressure differential ΔP may be calculated is the sum of the free expansion pressure and the pressure differential.

[0025] The Applicant has found that, by controlling the internal pressure in the plug substantially according to the above equation, the tube pressure upstream of the plug can be controlled precisely as fluid will begin to leak past the plug at pressure differentials exceeding ΔP . Controlling the plug pressure substantially according to the above equation is also particularly useful in applications where there is relative movement between the plug and the tube. In such applications, the retained fluid can be caused to flow past the surface of the plug forming a thin film, thus lubricating the relative movement and reducing friction forces on the outer surface of the plug.

[0026] The sensitivity of the control depends on the free expansion pressure of the plug. If this is very large, then a large plug pressure is required to effect a seal, which inhibits fine control of the system. It is desired therefore that the free expansion pressure be kept as low as possible, which object is achieved by the plug construction according to the first aspect of the invention.

[0027] For pressure control applications, a further important feature of such a plug relates to its length to diameter (L/D) ratio. It will be appreciated that the maximum expanded diameter of the plug occurs when the cords form a sphere. After this point is reached, further

increases in pressure cannot result in a further increase in diameter. (With a pressure differential across the plug in fact, this point can never be reached). This therefore sets a lower limit on the length of the plug. As this lower limit is approached, the sensitivity of the plug decreases, that is, the free plug expansion pressure increases, and in the limit, to infinity. It would therefore seem desirable to have a very long plug. However, it has been discovered that a stability problem arises if the plug is too long, whereby the plug collapses progressively from the upstream to the downstream end, and the retained fluid is released in spurts. The critical upper L/D ratio depends on a number of factors, including the compliance of the pressurisation system (controlled by the volume and elasticity of pipe work and pumps, as well as the nature of the fluid being retained and the inflation fluid. For water, successful L/D ratios for the plug have been found below about 8:1.

Claims

1. Inflatable plug for regulating pressure or flow within a tube, comprising an inflatable bladder (12) adapted for diametral expansion by application of internal fluid pressure, fluid inlet means (14) communicating with the interior of the bladder (12) for connection to a source of inflating fluid and reinforcement means (26) including a plurality of flexible reinforcing cords (28) **which form an envelope surrounding an outer surface of the bladder and** which provide axial reinforcement to the plug and diametral support to the bladder (12), **each reinforcing cord (28) comprising a plurality of strands, characterised in that said strands are not twisted together so that they spread out laterally over the surface of the bladder (12) as the bladder (12) is inflated.**
2. The inflatable plug of claim 1, **characterised in that** said reinforcing cords (28) are closely positioned so as to substantially wholly support the outer surface of the bladder (12).
3. The inflatable plug of claim 1, **characterised in that** said reinforcing cords (28) extend between opposite axial ends of the bladder (12).
4. The inflatable plug of claim 1, **characterised in that** said reinforcing cords (28) extend helically about said outer surface of the bladder (12).
5. The inflatable plug of claim 4, **characterised in that** said reinforcing cords (28) extend at a helix angle of less than 15° to the axis of the plug.
6. The inflatable plug of claim 4, **characterised in that** said plug comprises at least two layers of cords (28)

extending in opposite helices.

7. The inflatable plug of claim 1, **characterised in that** said reinforcing cords (28) are of substantially equal tension and length.
8. The inflatable plug of claim 1, **characterised in that** said plug further comprises upstream and downstream end members (10, 10a) at respective opposite ends of said bladder (12), at least one of said members including said fluid inlet means (14) and means for connection to an external support.
9. The inflatable plug of claim 1, **characterised in that** said plug has a length-to-diameter ratio of less than 8:1.
10. The inflatable plug of claim 1, **characterised in that** said plug further comprises a sheath (34) outside said reinforcing cords (28).
11. A method of maintaining a desired pressure differential ΔP across the inflatable plug **according to any one of claims 1-10** positioned in a tube of internal diameter d , **characterised by** inflating the plug by applying and maintaining an internal pressure P_p in the plug substantially according to the equation

$$P_p = \Delta P + P_d$$

where P_d is the internal pressure required to expand the plug to tube diameter d without confinement.

12. Method **according to claim 11, characterised in that**, the plug and the tube being in relative movement, **it further allows** leakage of a lubricating flow past the plug of fluid within the tube to occur.

Patentansprüche

1. Aufblasbarer Stopfen für die Regelung des Druckes oder der Strömung im Innern eines Rohres, welcher enthält: - einen aufblasbaren Balg (12), der für eine Ausdehnung seines Durchmessers durch die Anlegung eines inneren Druckes mit einem Fluid ausgelegt ist, und - eine Einlassöffnung (14) für das Fluid, die mit dem Innern des Balges (12) in Verbindung steht für den Anschluss an eine Quelle mit einem zum Aufblasen dienenden Fluid und - ein Verstärkungsmittel (26), das eine Vielzahl von flexiblen Verstärkungsschnüren (28) aufweist, welche eine Hülle bilden, die eine äußere Oberfläche des Balges umschließt, und welche eine axiale Verstärkung für den Stopfen und eine Abstützung für den Durchmesser des Balges (12) gewährleisten, wobei

eine jede Verstärkungsschnur (28) aus einer Vielzahl von Litzen besteht, **dadurch gekennzeichnet, dass** die Litzen nicht zusammen verdreht sind, so dass sie sich seitlich über die Oberfläche des Balges (12) ausdehnen, wenn der Balg (12) aufgeblasen wird.

2. Aufblasbarer Stopfen gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die Verstärkungsschnüre (28) nahe beieinander angeordnet sind, so dass sie im wesentlichen die äußere Oberfläche des Balges (12) ganz abstützen.

3. Aufblasbarer Stopfen gemäß Anspruch 1, **dadurch gekennzeichnet, dass** sich die Verstärkungsschnüre (28) zwischen den gegenüberliegenden axialen Enden des Balges (12) erstrecken.

4. Aufblasbarer Stopfen gemäß Anspruch 1, **dadurch gekennzeichnet, dass** sich die Verstärkungsschnüre (28) spiralförmig über die äußere Oberfläche des Balges (12) erstrecken.

5. Aufblasbarer Stopfen gemäß Anspruch 4, **dadurch gekennzeichnet, dass** die Verstärkungsschnüre (28) sich unter einem Spiralwinkel von weniger als 15° gegenüber der Achse des Stopfens erstrecken.

6. Aufblasbarer Stopfen gemäß Anspruch 4, **dadurch gekennzeichnet, dass** der Stopfen mindestens zwei Lagen von Schnüren (28) enthält, die sich in entgegengesetzten Spiralen erstrecken.

7. Aufblasbarer Stopfen gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die Verstärkungsschnüre (28) im wesentlichen unter der gleichen Spannung stehen und von derselben Länge sind.

8. Aufblasbarer Stopfen gemäß Anspruch 1, **dadurch gekennzeichnet, dass** der Stopfen ferner aufwärts und abwärts gelegene Endelemente (10, 10a) an den jeweiligen entgegengesetzten Enden des Balges (12) aufweist, wobei mindestens eines der besagten Elemente die Einlassöffnungen für das Fluid (14) enthält sowie ein Mittel für die Verbindung mit einer externen Abstützung.

9. Aufblasbarer Stopfen gemäß Anspruch 1, **dadurch gekennzeichnet, dass** der Stopfen ein Verhältnis von Längen zu Durchmesser von weniger als 8:1 aufweist.

10. Aufblasbarer Stopfen gemäß Anspruch 1, **dadurch gekennzeichnet, dass** der Stopfen ferner einen Mantel (34) auf der Außenseite der Verstärkungsschnüre (28) aufweist.

11. Verfahren, um eine gewünschte Druckdifferenz ΔP

quer über den aufblasbaren Stopfen gemäß irgendeinem der Ansprüche 1-10 aufrechtzuerhalten, wobei der Stopfen sich in einem Rohr mit einem inneren Durchmesser d befindet, **dadurch gekennzeichnet, dass** der Stopfen aufgeblasen wird durch Anlegung und Aufrechterhaltung eines inneren Druckes P_p in dem Stopfen, im wesentlichen gemäß der Gleichung :

$$P_p = \Delta P + P_d,$$

in welcher P_d der innere Druck ist, der erforderlich ist, um den Stopfen bis auf den Durchmesser des Rohres d auszudehnen, dies ohne festhaltendes Einschließen.

12. Verfahren gemäß Anspruch 11, **dadurch gekennzeichnet, dass** es, während der Stopfen und das Rohr in relativer Bewegung zueinander stehen, ferner ein Lecken eines schmierenden Stromes eines Fluids innerhalb des Rohres an dem Stopfen vorbei gestattet.

Revendications

1. Obturateur gonflable pour régler la pression ou le débit à l'intérieur d'un tube, comprenant une vessie gonflable (12) qui est à même d'augmenter son diamètre par application d'une pression de fluide interne, un moyen d'entrée de fluide (14) communiquant avec l'intérieur de la vessie (12) pour se raccorder à une source de fluide de gonflage et un moyen de renfort (26) comprenant une pluralité de cordons de renfort flexibles (28) qui forment une enveloppe entourant une surface externe de la vessie et assurent un renfort axial à l'obturateur et un support diamétral à la vessie (12), chaque cordon de renfort (28) comprenant une pluralité de brins, **caractérisé en ce que** lesdits brins ne sont pas retordus ensemble si bien qu'ils s'étalent latéralement sur la surface de la vessie (12) lorsque la vessie (12) est gonflée.

2. Obturateur gonflable selon la revendication 1, **caractérisé en ce que** lesdits cordons de renfort (28) sont positionnés étroitement de manière à supporter sensiblement en totalité la surface externe de la vessie (12).

3. Obturateur gonflable selon la revendication 1, **caractérisé en ce que** lesdits cordons de renfort (28) s'étendent entre les extrémités axiales opposées de la vessie (12).

4. Obturateur gonflable selon la revendication 1, **caractérisé en ce que** lesdits cordons de renfort (28) s'étendent en hélice autour de ladite surface exter-

ne de la vessie (12).

5. Obturateur gonflable selon la revendication 4, **caractérisé en ce que** lesdits cordons de renfort (28) s'étendent selon un angle d'hélice de moins de 15° par rapport à l'axe de l'obturateur. 5
6. Obturateur gonflable selon la revendication 4, **caractérisé en ce que** ledit obturateur comprend au moins deux couches de cordons (28) s'étendant selon des hélices opposées. 10
7. Obturateur gonflable selon la revendication 1, **caractérisé en ce que** lesdits cordons de renfort (28) ont une tension et une longueur sensiblement égales. 15
8. Obturateur gonflable selon la revendication 1, **caractérisé en ce que** ledit obturateur comprend en outre des éléments terminaux amont et aval (10, 10a) aux extrémités opposées respectives de ladite vessie (12), au moins l'un desdits éléments comprenant ledit moyen d'entrée de fluide (14) et le moyen de raccordement à un support externe. 20
25
9. Obturateur gonflable selon la revendication 1, **caractérisé en ce que** ledit obturateur a un rapport de la longueur au diamètre inférieur à 8:1.
10. Obturateur gonflable selon la revendication 1, **caractérisé en ce que** ledit obturateur comprend en outre une gaine (34) à l'extérieur de dits cordons de renfort (28). 30
11. Procédé de maintien d'une différence de pression souhaitée ΔP en travers de l'obturateur gonflable selon l'une quelconque des revendications 1-10 positionné dans un tube de diamètre interne d , **caractérisé en ce que** l'on gonfle l'obturateur en appliquant et en maintenant une pression interne P_p dans l'obturateur sensiblement selon l'équation : 35
40

$$P_p = \Delta P + P_d$$

45

dans laquelle P_d est la pression interne requise pour dilater l'obturateur au diamètre d du tube sans confinement.

12. Procédé selon la revendication 11, **caractérisé en ce que**, l'obturateur et le tube étant en mouvement relatif, il permet encore une fuite d'un flux lubrifiant dans l'obturateur de fluide à l'intérieur du tube. 50

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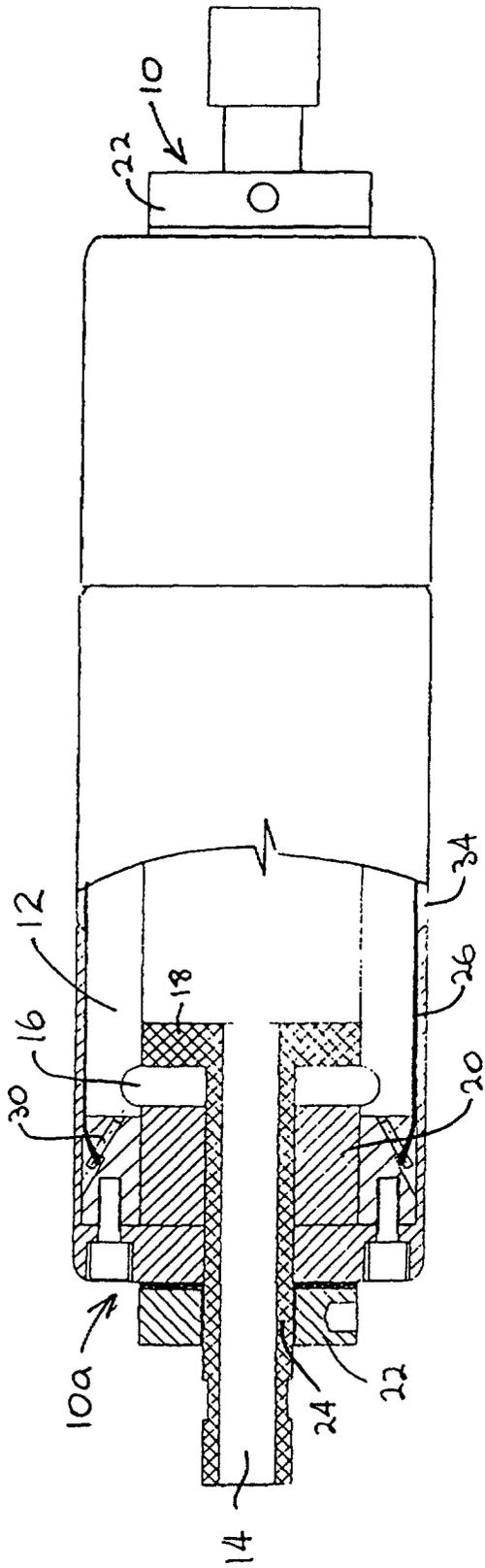


Fig 1

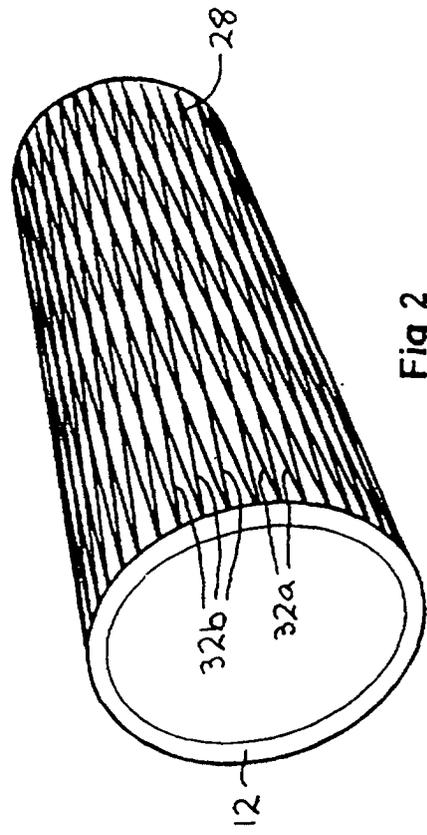


Fig 2

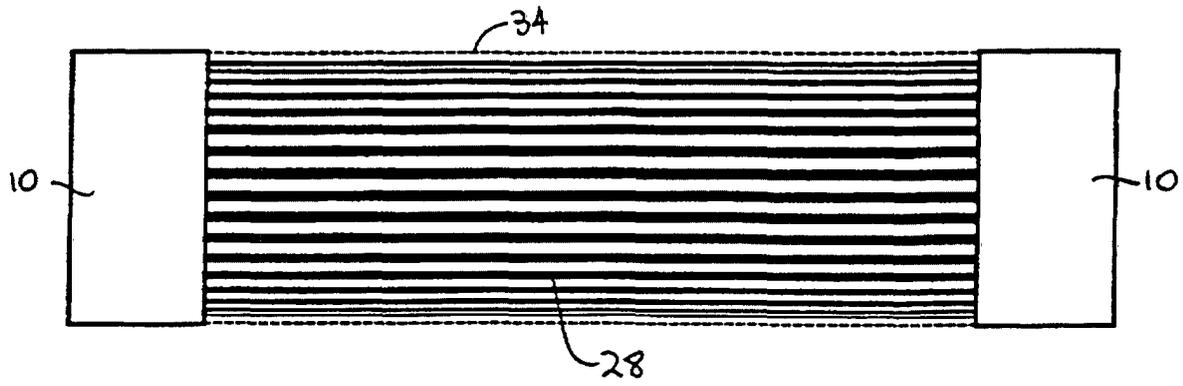


Fig 3

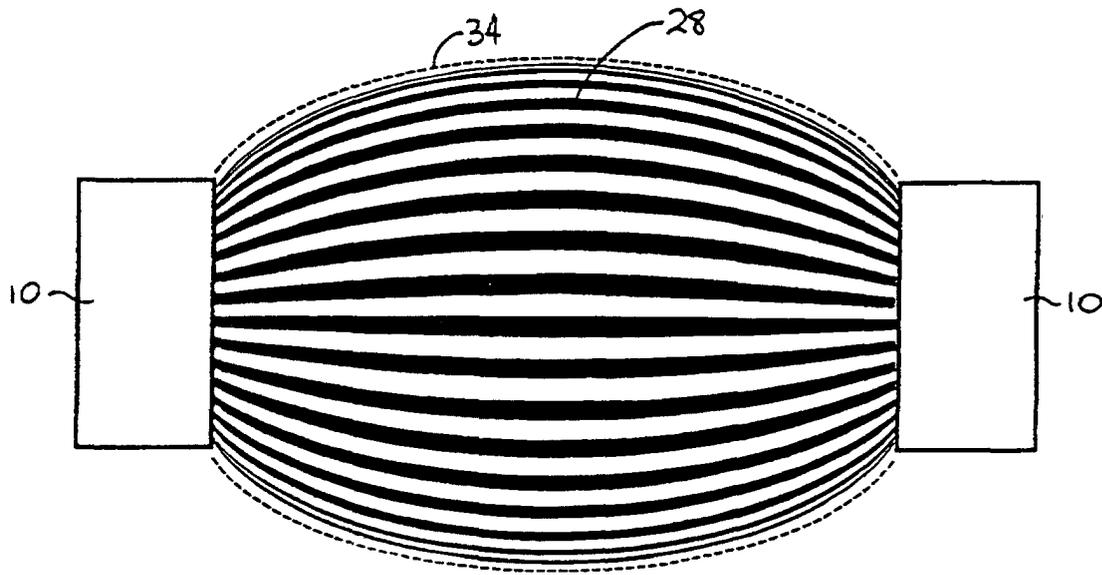


Fig 4

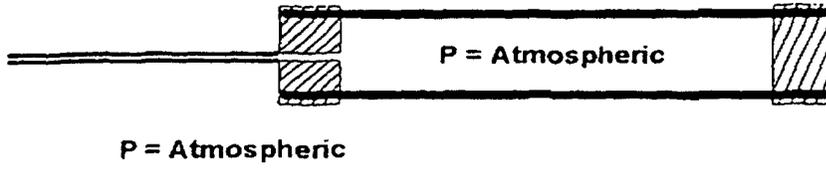


Fig 5

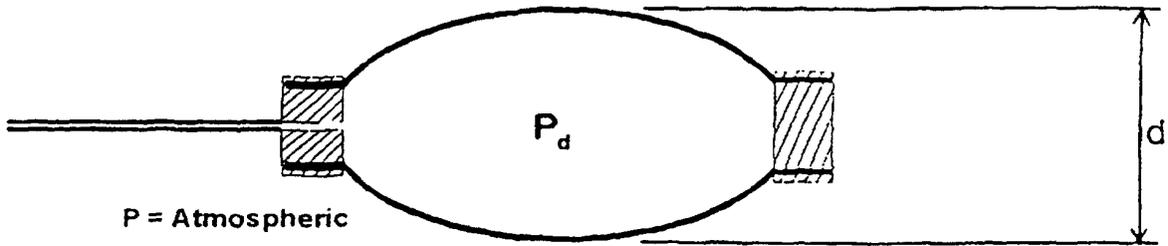


Fig 6

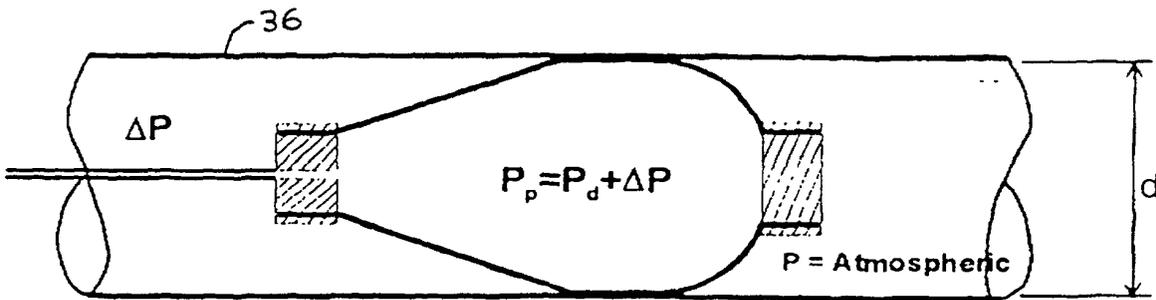


Fig 7