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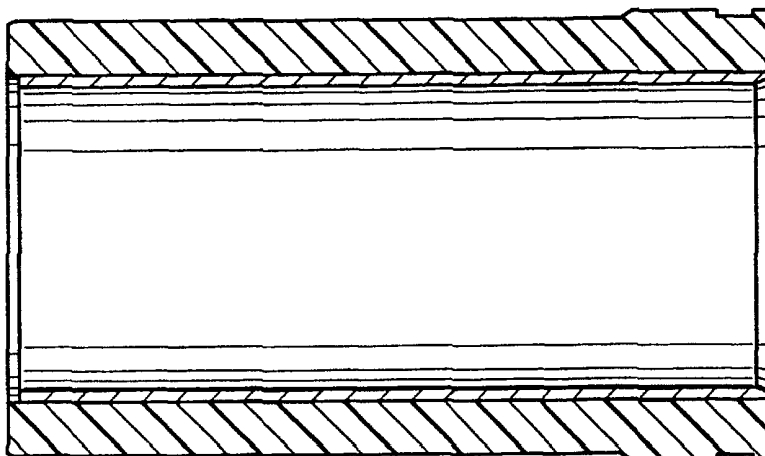
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(54) Title: PUMP LINER



(57) Abstract: A pump liner (16) comprising a tubular sleeve (22) having an inner sleeve surface (26) formed of a corrosion- and abrasion-resistant material and an outer sleeve surface (28) and a shell (24) having an outer shell surface (30) and an inner shell surface (32), the inner shell surface being in surface-to-surface engagement with the outer sleeve surface, the shell comprising a reinforcing filler supported in a polymeric matrix selected from the group consisting of thermoplastic resins, thermosetting resins, and mixtures thereof.



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PUMP LINER

Background of the Invention

Field of the Invention

The present invention relates to reciprocating pumps, such as pumps of the duplex
5 or triplex type and, more specifically, to liners for use in such pumps.

Description of the Prior Art

In certain applications, corrosive or abrasive fluids (for example, oil well drilling fluid, commonly known as "mud"), must be pumped. Pumps used in these applications are reciprocating pumps typically of the duplex or triplex type provided with two or three
10 cylinders, as the case may be, a piston being reciprocally disposed in each cylinder. Each cylinder communicates with a suction and discharge valve equipped chamber so that, as the piston is reciprocated by the piston rod, drilling fluid will be ultimately drawn into and discharged from the working chambers. Since the material pumped is of an abrasive character, and frequently corrosive as well, wear on the piston and cylinder wall is quite
15 severe, and it has been common practice, in order to more easily repair a worn pump, to provide each cylinder with a replaceable steel liner that reciprocally supports the piston in the cylinder. Nevertheless, the abrasive fluid--e.g., mud--results in a relatively short lifetime of the liner and the piston, necessitating frequent replacement. It will be apparent that because of the abrasive nature of the fluids being pumped, the liner must
20 have a hard interior surface. Additionally, because the pressures and forces that act on the liner are extreme, the liner is typically quite large and heavy.

Attempts to address the issue of making a liner that resists abrasion and corrosion and that is economical are numerous. As illustrated in U.S. Patent No. 5,617,773, incorporated herein by reference for all purposes, the industry has generally settled on a
25 dual-metal pump liner having an abrasive and corrosive-resistant inner sleeve and a machinable outer shell. One such liner is centrifugally cast, wherein a carbon steel outer shell is cast on the spinning mold and a high-chrome steel is then poured into the interior of a hot outer shell. Upon cooling, the result is a metallurgical bond between the inner sleeve and the outer shell, and the liner has a hard inner surface and a machinable outer
30 surface. However, critical spinning speeds, pour temperatures, and other parameters

make such a liner process expensive and the liners difficult to make. Another method that has been used in the manufacturing of liners is a shrink fit, wherein the carbon steel shell is heated and the high chrome sleeve is cooled. The two are then press-fitted together. Upon reaching a common temperature, the sleeve has expanded and the shell
5 has shrunk, thus creating a tight fit. Still other attempts have been made at static casting the steel shell in the sleeve; however, that method was abandoned as a failure because the brittle sleeve tended to crack.

Thus, there remains a need for a pump liner that is corrosion- and abrasion-resistant, that can withstand the pressures and forces exerted on the liner, and that is
10 lightweight to permit easier field installation.

Summary of the Invention

It is therefore an object of the present invention to provide a pump liner that makes use of composites.

Another object of the present invention is to provide a pump liner that is
15 lightweight relative to prior art pump liners.

The above and other objects of the present invention will become apparent from the drawings, the description given herein, and the appended claims.

In accordance with the present invention, there is provided a pump liner comprising a tubular sleeve having an inner corrosion- and abrasion-resistant sleeve
20 surface and an outer sleeve surface, and a shell having an outer shell surface and an inner shell surface, the inner shell surface being in surface-to-surface engagement with the outer sleeve surface, the shell comprising a reinforcing filler supported in a polymeric matrix selected from the group consisting of thermoplastic resins, thermosetting resins, and mixtures thereof.

25 Brief Description of the Drawings

Fig. 1 is a simplified schematic diagram, partially in section, illustrating the pump liner of the present invention in operative position in a triplex mud pump.

Fig. 2 is a sectional view taken through an axial radial plane of one embodiment of the pump liner of the present invention.

Fig. 3 is a view similar to Fig. 2 showing another embodiment of the pump liner of the present invention.

Fig. 4 is an enlarged sectional view similar to Figs. 2 and 3 showing in greater detail one form of the composite shell of the pump liner of the present invention.

5 Fig. 5 is a view similar to Fig. 4 showing in detail another form of the composite shell of the pump liner of the present invention.

Description of Preferred Embodiments

With reference first to Fig. 1, there is shown a triplex mud pump 10 having a cylinder 12 communicating with valve-equipped intake and exhaust chambers 14, which in turn are connected with mud supply lines, not shown. The cylinder 12 is equipped with a sleeve-like liner 16 projecting at one open end outwardly of the cylinder 12 in the direction of a piston rod 18 connected with a piston 20 for reciprocation in the liner 16 and pumping of mud from a mud circulating pit to a drill string, neither of which are shown.

15 With reference now to Fig. 2, the pump liner 16 is seen to comprise a generally tubular, cylindrical body having an inner sleeve 22 and an outer shell 24. Inner sleeve 22 has an inner sleeve surface 26 that is corrosion- and abrasion-resistant and an outer sleeve surface 28, whereas shell 24 has an outer shell surface 30 and an inner shell surface 32. Pump liner 16 is constructed such that inner shell surface 32 is in positive, surface-to-surface contact with outer sleeve surface 28. As also seen, shell 24 has an upset portion 34 and an annular groove 36 that permit pump liner 16 to be adapted to the pump housing. The surface 26 of sleeve 22 must be of a material that is both abrasion- and corrosion-resistant. This can be accomplished by making sleeve 22 entirely of a material that possesses such properties. In this regard, typical materials that can be used
25 include so-called white iron, which can contain alloying elements such as silicon, chromium, or nickel. For example, a cast sleeve of iron containing 23-28% chromium is frequently used as the sleeve in pump liners. Additionally, as disclosed in U.S. Patent No. 4,746,554, incorporated herein by reference for all purposes, the sleeve can be comprised of a steel tube on the internal surface on which is applied a cladding that is
30 abrasion- and corrosion-resistant. Examples of such cladding materials that can be used to form the inner corrosion- and abrasion-resistant surface of the sleeve include Stellite

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Alloy No. 1, Stellite Alloy No. 6, and Deloro 60, as well as various other metal oxides, borides, and carbides. Additionally, the entire sleeve can be made of a ceramic material such as a metal oxide, boride, or carbide. Additionally, the entire sleeve can be made of a ceramic material such as a metal oxide, boride, or carbide.

5 Prior art pump liners use the sleeve as described above to provide the abrasion- and corrosion-resistant inner surface upon which the seal on the piston rides, while the shell is typically made of either a carbon steel or a low alloy steel that has sufficient wall thickness to resist the pressures and forces acting on the pump liner. Because of this construction, the pump liners of the prior art are quite heavy and difficult to manipulate
10 in the field.

 In the pump liner of the present invention, the shell is a composite comprised of a reinforcing filler supported in a polymeric matrix selected from the group consisting of thermoplastic resins, thermosetting resins, and mixtures thereof. As used herein, the term "composite" means a reinforcement, referred to herein as a filler, such as fibers or
15 particles encapsulated in and/or supported by a suitable matrix or binder material such as a thermosetting and/or thermoplastic polymeric material. Generally speaking, composites of the type used herein have a discontinuous phase formed by the filler--e.g., fiber, particles, or the like--that is stiffer and stronger than the continuous matrix phase--e.g., the thermosetting or thermoplastic resin. Generally speaking, the filler will be
20 present in the composite in an amount of 7% or greater. The fillers or reinforcements that make up the composite can be fibrous, laminar, or particulate in nature. The fiber reinforcements can in turn be divided into those containing discontinuous or continuous fibers or filaments. Fiber-reinforced composites contain fillers having lengths much greater than their cross-sectional dimensions. As noted, the fibrous filler can be of the
25 discontinuous or continuous type, a discontinuous fiber being one in which its properties vary with its length. On the other hand, a continuous fiber or filament can be considered one in which, in general, any further increase in its length does not further increase certain physical properties, e.g., the elastic modulus. Continuous reinforcing fibers or fillers are available in many product forms ranging from monofilament to multi-filament
30 fiber bundles, and from unidirectional ribbons to single-layer fabrics and multi-layer fabric mats. Particulates are not generally useful as reinforcements in and by themselves but can be used with fiber fillers as reinforcements. Composites that are useful in the

present invention are discussed in *Engineered Materials Handbook, Vol. 1: Composites*, ASM International, 1987, incorporated herein by reference for all purposes.

Non-limiting examples of fibrous fillers, be they discontinuous or continuous, include glass fibers, carbon fibers, aramid fibers, polybenzimidazole fibers, boron fibers,
5 silicon carbide fibers, aluminum oxide fibers, graphite fibers, metallic fibers, etc.

In addition to a filler or reinforcement, the composites used in the pump liners of the present invention include, as a matrix or binder, a thermosetting resin, a thermoplastic resin, or mixtures thereof. Non-limiting examples of thermosetting resins include epoxy resins, bismaleimide resins, polyimide resins, phenolic resins, polyurethanes, etc., and
10 mixtures thereof. Non-limiting examples of thermoplastic resins that can be used in the composites of the present invention include polyether etherketones, polyphenylene sulfides, polyetherimides, polyamideimides, polypropylenes, polyurethanes, etc., and mixtures thereof. It will also be appreciated that in certain cases it may be possible to use mixtures of thermoplastic and thermosetting resins, just as it is possible to use more than
15 one type of filler or reinforcement in the composites used to make the pump liners of the present invention.

Returning to Fig. 2, shell 24, in one form, can be formed as a composite comprising windings of a suitable continuous filament coated or impregnated with a suitable thermosetting resin. For example, continuous filaments such as carbon fiber or
20 glass fiber coated or impregnated with epoxy can be wound around sleeve 22 in successive layers until the desired radial thickness to form shell 24 is achieved. Following this, the pump liner blank can be cured to harden the epoxy matrix, following which the shell can be machined, for example, such that the upset 34 and groove 36 are formed. It will be appreciated that by using successive layers of windings as described
25 above, a pump liner can be formed wherein the shell exhibits a very high hoop force to resist forces acting against and radially outward of the inner surface.

With reference to Fig. 5, there is shown an enlarged section of the pump liner of the present invention wherein continuous windings consisting of a suitable fibrous reinforcement have been wound around sleeve 22 to form successive layers, the layers
30 being placed one upon the other until the desired radial thickness, indicated as D, has been achieved. It will be appreciated that the windings 50 are essentially surrounded by a suitable thermosetting or thermoplastic matrix such that the windings 50 in combination

with the matrix essentially form a monolithic structure, the reinforcements or windings being primarily responsible for the structural strength, the matrix being responsible for bonding together the windings such that the shell retains its overall structural integrity.

Alternatively, the windings of a continuous filament such as a carbon fiber or
5 glass fiber that has been coated or impregnated with a suitable thermosetting or thermoplastic resin can be wound in various other patterns around sleeve 22 again to the desired radial thickness, whereupon the pump liner blank can then be cured and the outer surface machined.

With reference now to Fig. 3, there is shown another embodiment of the pump
10 liner of the present invention. In the embodiment shown in Fig. 3, the pump liner shown generally as 16a has a sleeve 22 as described above; but unlike the pump liner shown in Fig. 2, the outer shell is comprised of two concentric cylindrical portions, an innermost cylindrical portion 38, and an outermost cylindrical portion 40. As can be seen, the inner surface 42 of inner cylindrical portion 38 is in surface-to-surface contact with the outer
15 surface 28 of sleeve 22, while the outer surface 44 of inner cylindrical portion 38 is in contact with the inner cylindrical surface 46 of second or outer cylindrical portion 40. The outer surface 48 of second cylindrical portion 40, as surface 30 in the pump liner shown in the embodiment in Fig. 2, can be machined to form the upset 34 and the recess 36. Pump liner 16a, in one embodiment, could be constructed such that first or inner
20 cylindrical portion 38 is formed of a high modulus, continuous carbon filament using an epoxy matrix, while outer or second cylindrical portion 40 could be formed of a medium modulus continuous glass filament using an epoxy matrix. As described above with respect to the embodiments shown in Figs. 2 and 5, the respective cylindrical portions 38 and 40 could be formed in a variety of ways. For example, both cylindrical portions 38 and 40 could be formed using windings of a continuous filament to form successive
25 layers to achieve the desired radial thickness of cylindrical portion 38 or 40, as the case may be. Alternatively, one of the cylindrical portions--e.g., cylindrical portion 38--could be of layered windings, such as shown in Fig. 5, while the outer cylindrical portion 40 could be of windings of a continuous filament in a different form.

30 With reference to Fig. 4, the shell is shown as being comprised of discontinuous fibers 60 of a suitable material embedded in a suitable polymeric matrix 62, the discontinuous fibers 60 having a length to diameter ratio so as to provide structural

integrity to the shell. Returning to the embodiment of Fig. 3, inner cylindrical portion 38 could be formed of windings, as shown in Fig. 5, to gain the requisite hoop force, while outer cylindrical portion 40 could be formed of discontinuous fibers in the manner shown in Fig. 4. And in still further variations, cylindrical portions 38 and 40 could be formed in the manner shown in Fig. 4, cylindrical portion 38 using one type of discontinuous fiber and one type of thermosetting or thermoplastic resin, while outer cylindrical portion 40 is formed of a different discontinuous fiber and a different thermosetting or thermoplastic resin. It will be apparent that numerous variations of the various embodiments described with respect to Figs. 2-5 can be employed.

In addition to windings of continuous filament fillers or reinforcements, the pump liners of the present invention could be formed by compression molding or ejection or transfer molding of a suitable composite around the inner sleeve. Such a composite could use discontinuous fibers in a suitable polymeric matrix. Additionally, a flowable thermosetting resin could be transferred into a fiber-packed mold and cured around the sleeve.

In a specific method of making the pump liner of the present invention, a continuous filament--e.g., carbon, glass, or the like--is coated or impregnated with a thermosetting resin such as an epoxy resin, the coated filament being wrapped around the inner sleeve to the appropriate outer dimension--i.e., radial thickness. This preform is then placed in an oven at the appropriate temperature for a specified time to achieve a full cure. Following cooling, the pump liner preform is machined to the appropriate dimensions to fit the appropriate pump.

In another specific technique that has been employed, a thermoplastic matrix has been employed. In this technique, a suitable continuous filament such as carbon, glass, or the like is coated or impregnated with a thermoplastic resin that has been heated so as to stay in a molten or flowable state while the continuous, coated filament is wrapped around the inner sleeve. Following cooling, the composite sets and the shell can be machined to its final dimension. It will also be apparent that the pump liner could be formed by first wrapping the sleeve with the appropriate reinforcement--e.g., a continuous fiber wound around to the desired thickness--to form a preform, which could then be placed into a mold and a thermoplastic or thermosetting resin added to the mold, which would then be cured in the appropriate fashion, depending upon whether the

plastic matrix was thermosetting or thermoplastic in nature. Once the composite is cured, the outer surface of the shell could then be machined to the desired configuration and dimension. In this last method of forming the pump liner--more specifically, the shell--it will be appreciated that the filler is not coated or impregnated with the thermoplastic or thermosetting resin in the more conventional fashion wherein, for example, the continuous filament of the reinforcement is calendered through a bath of the resin and then wound around the sleeve. Nonetheless, the thermosetting or thermoplastic resin would still support the reinforcement, e.g., the continuous filament.

The term "support" as used herein, and with reference to the relationship between the filler/reinforcement and the polymeric matrix, is intended to encompass impregnation or coating of the filler prior to forming the shell, winding a matrix-free, continuous filament around the sleeve to the desired radial thickness, and then adding the polymeric matrix in a mold; filling a mold with discontinuous fibers, and then adding a suitable polymeric matrix, etc. In general, the word "support" is intended to encompass any structural relationship between the filler/ reinforcement and the polymeric matrix wherein the filler/reinforcement is essentially immobilized in the shell once the shell has been cured. For example, in the embodiment shown in Fig. 5, where a continuous filament is wound around the sleeve in successive layers, it will be apparent that if the filament were coated with a thermosetting resin, the thermosetting resin would be in the interstices between the individual windings. Likewise, in a case where uncoated windings were layered around the sleeve to obtain the desired radial thickness, after which a thermoplastic or thermosetting resin were added as described above using a mold, the windings would be essentially immobilized, either by virtue of the fact that the polymeric matrix would permeate the interstices between the individual winding or, if full permeation were not achieved, sufficient permeation of the outermost layers of windings would occur such that the innermost, substantially uncoated windings would be essentially immobilized so as to provide the structural support necessary to withstand the pressures and forces acting upon the liner. Thus, the polymeric matrix can be considered a binder that tends to hold the shell together in a cohesive, structurally intact form.

It will be appreciate that the outer sleeve surface can be a smooth, cylindrical surface or, more preferably, can have formations that serve to grip the inner surface of the shell to prevent relative movement between the sleeve and the shell. Thus, for

example, the outer surface of the sleeve could be provided with serrations, threads, or other such projections that would effectively mechanically grip the shell, preventing any relative rotation or longitudinal movement between the shell and the sleeve.

As noted above, one of the drawbacks of conventional pump liners that are used
5 in mud pumps is their weight, and the concomitant difficulty is replacing the pump liners in the field. A conventional six-inch pump liner weighs approximately 75 to 80 lbs., whereas a pump liner of the same dimension made in accordance with the present invention would weigh approximately 40 lbs. The advantages of such a dramatic reduction in weight are obvious. Additionally, in conventional pump liners, while the
10 inner sleeve is corrosion-resistant, the shell that is normally made of carbon steel is not corrosion-resistant. However, with the pump liners of the present invention, both the sleeve and the shell would be corrosion-resistant.

The foregoing description and examples illustrate selected embodiments of the present invention. In light thereof, variations and modifications will be suggested to one
15 skilled in the art, all of which are in the spirit and purview of this invention.

What is claimed is:

1. A pump liner comprising:
a tubular sleeve having an inner sleeve surface of a corrosion- and abrasion-resistant material and an outer sleeve surface; and
5 a shell having an outer shell surface and an inner shell surface, said inner shell surface being in surface-to-surface engagement with said outer sleeve surface, said shell comprising a reinforcing filler supported in a polymeric matrix selected from the group consisting of thermoplastic resins, thermosetting resins, and mixtures thereof.
- 10 2. The pump liner of Claim 1 wherein said shell comprises a first cylindrical portion defining said inner shell surface and a second cylindrical portion defining said outer shell surface.
3. The pump liner of Claim 2 wherein said first cylindrical portion has a higher modulus than said second cylindrical portion.
- 15 4. The pump liner of Claim 1 wherein said first cylindrical portion comprises windings of a first filament coated with a first thermosetting resin, the coated windings of said first filament being wound around said first sleeve to achieve a first, desired radial thickness, said first thermosetting resin being cured after the desired number of windings of said first filament have been wound around said sleeve.
- 20 5. The pump liner of Claim 4 wherein said second cylindrical portion comprises windings of a second filament coated with a second thermosetting resin the coated windings of said second filament being wound around said first cylindrical portion to achieve a second desired radial thickness, said second thermosetting resin being cured after said desired number of windings of said second filament have been wound around said first cylindrical portion.
- 25 6. The pump liner of Claim 4 wherein said first filament comprises a carbon fiber and said first thermosetting resin comprises an epoxy resin.

7. The pump liner of Claim 5 wherein said second filament comprises a glass fiber and said second thermosetting resin comprises an epoxy resin.

8. The pump liner of Claim 1 wherein said reinforcing filler comprises windings of a filament wound around said sleeve to achieve a desired radial thickness.

5 9. The pump liner of Claim 1 wherein said filler comprises discrete segments of a fibrous material.

10 10. The pump liner of Claim 1 wherein said filler is selected from the group consisting of carbon fibers, glass fibers, aramid fibers, polybenzimidazole fibers, boron fibers, silicon carbide fibers, aluminum oxide fibers, graphite fibers, metallic fibers, and mixtures thereof.

11. The pump liner of Claim 1 wherein said thermosetting resin is selected from the group consisting of polyester resins, vinyl ester resins, epoxy resins, bismaleimide resins, polyimide resins, phenolic resins, polyurethanes, and mixtures thereof.

15 12. The pump liner of Claim 1 wherein said thermoplastic resin is selected from the group consisting of polyether etherketone, polyphenylene sulfide, polyetherimide, polyamideimide, polypropylene, polyamides, polyurethanes, and mixtures thereof.

20 13. The pump liner of Claim 1 wherein said sleeve is made entirely of a corrosion- and abrasion-resistant material.

14. The pump liner of Claim 1 wherein said inner sleeve surface is formed of a layer of corrosion- and abrasion-resistant material on a metal, tubular substrate that is more susceptible to corrosion and/or abrasion.

FIG.1

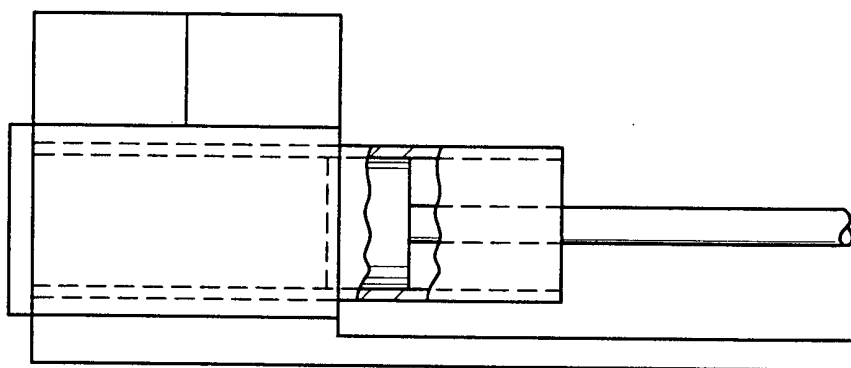


FIG.2

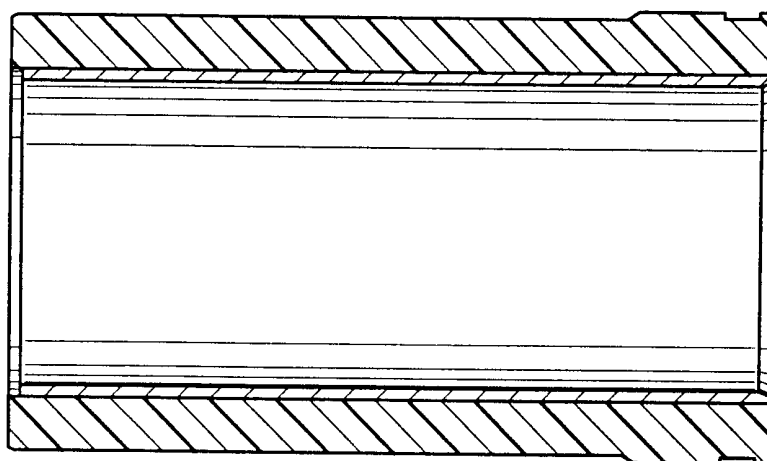
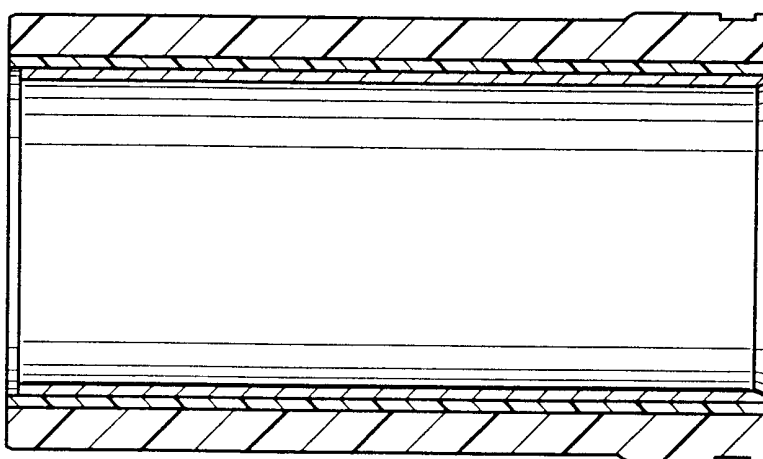
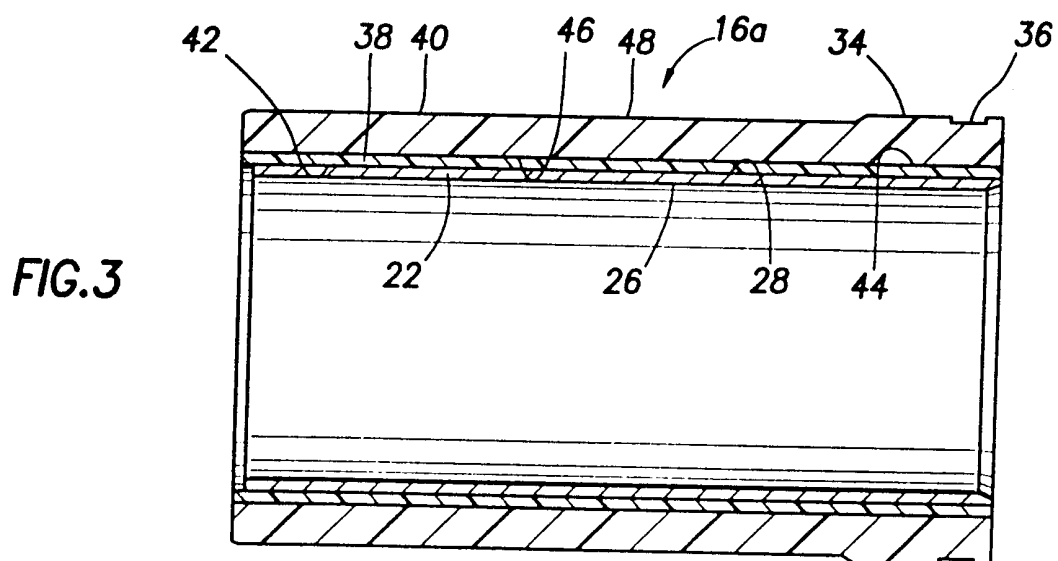
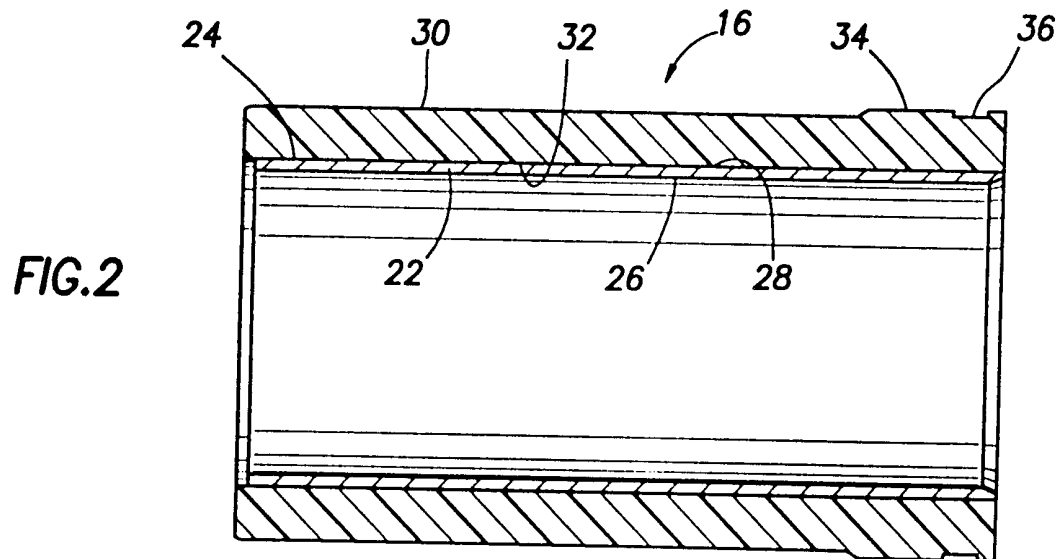
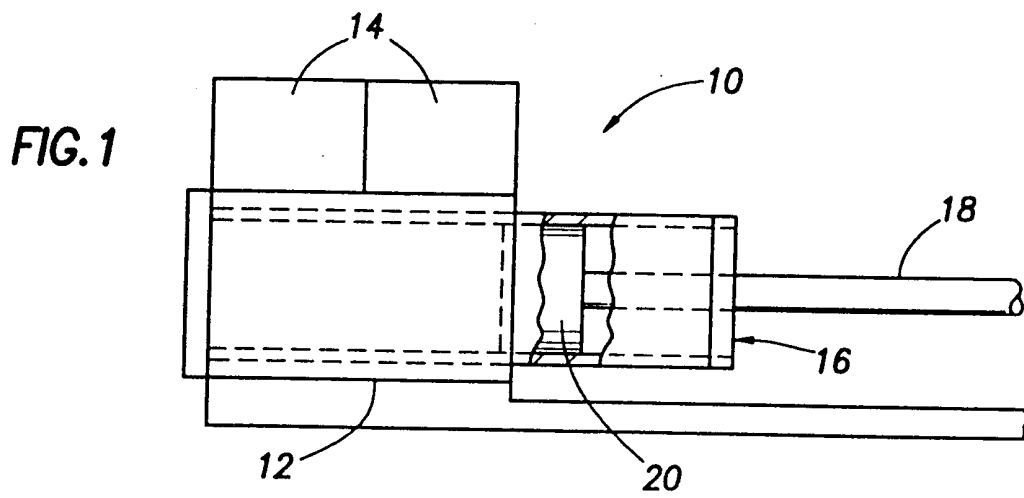


FIG.3





INTERNATIONAL SEARCH REPORT

 International application No.
PCT/US00/15846
A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :F01B 11/02

US CL :92/169.4

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)

U.S. : 92/169.1, 169.2, 169.3, 169.4, 170.1, 171.1

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)

USPTO EAST database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,740,788 A (ATMUR et al) 21 April 1998, Fig. 1.	1, 8-13
X	US 4,971,846 A (LUNDY) 20 November 1990, Fig. 1.	1,8-13
Y	US 5,829,405 A (GODEL) 03 November 1998, Fig. 1.	14
Y	US 4,746,554 A (ECER) 24 May 1988, Fig. 1.	14
A	US 4,516,479 A (VADASZ) 14 May 1985, Abstract.	14
A	US 3,678,811 A (PENWELL) 25 July 1972, Abstract.	1,14

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

* Special categories of cited documents:	*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
A document defining the general state of the art which is not considered to be of particular relevance	*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
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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	

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/15846

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,466,399, A (HINZ et al) 21 August 1984, Fig. 1.	1,14
A	US 5,415,079 A (CHING) 16 May 1995, Fig. 2.	2