



(51) International Patent Classification:  
*B29C 70/78* (2006.01) *F04C 2/107* (2006.01)

(21) International Application Number:  
PCT/US2011/034766

(22) International Filing Date:  
2 May 2011 (02.05.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
61/330,439 3 May 2010 (03.05.2010) US

(71) Applicant (for all designated States except US): **NATIONAL OILWELL VARCO, L.P.** [US/US]; 7909 Parkwood Circle Drive, Houston, Texas 77036 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **PRILL, Jonathan Ryan** [CA/CA]; 7603 - 16th Avenue SW, Edmonton, Alberta T6X 1M3 (CA). **VOGHELL, Mark Louis Philip** [CA/CA]; 1331 - 117 Street, Edmonton, Alberta T6J 7G1 (CA).

(74) Agents: **FALESKI, Thaddeus J.** et al.; Conley Rose, P.C., P.O. Box 3267, Houston, Texas 77253-3267 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

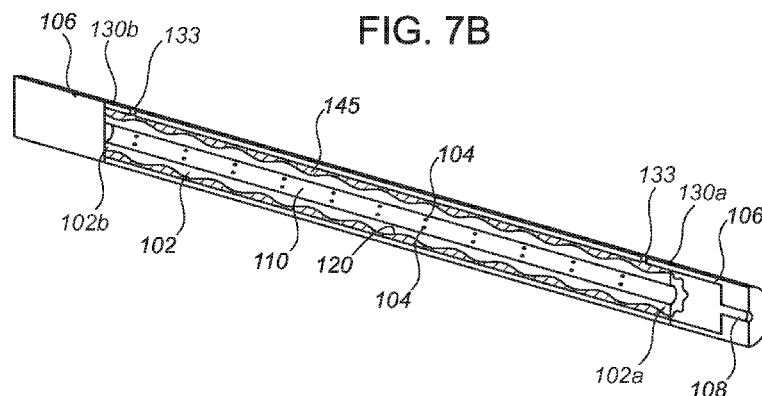
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: METHODS AND APPARATUS FOR MANUFACTURING STATORS FOR POSITIVE DISPLACEMENT MOTORS AND PROGRESSIVE CAVITY PUMPS



(57) Abstract: A method for manufacturing a stator for a PDC or PC pump comprises (a) providing an elongate mold (100) having a central axis (C102), a first end (102a), a second end (102b) opposite the first end (102a), a radially outer surface (103) extending axially between the first end (102a) and the second end (102b), and a through bore (110) extending axially from the first end (102a) to the second end (102b). The radially outer surface (103) defines a plurality of helical vanes (104a) and a plurality of helical troughs (104b), one trough (104b) being circumferentially disposed between each pair of circumferentially adjacent vanes (104a). In addition, the method comprises (b) positioning the elongate mold (100) within a tubular insert (120) to form an insert-and-mold assembly. Further, the method comprises (c) positioning the insert-and-mold assembly within a tubular stator housing (130). Still further, the method comprises (d) pulling the insert (120) radially inward into engagement with the elongate mold (100).



**METHODS AND APPARATUS FOR MANUFACTURING  
STATORS FOR POSITIVE DISPLACEMENT MOTORS  
AND PROGRESSIVE CAVITY PUMPS**

**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims benefit of U.S. provisional patent application Serial No. 61/330,439 filed May 3, 2010, and entitled "Method and Apparatus for Manufacturing Stators for Positive Displacement Motors," which is hereby incorporated herein by reference in its entirety.

**STATEMENT REGARDING FEDERALLY SPONSORED  
RESEARCH OR DEVELOPMENT**

[0002] Not applicable.

**BACKGROUND**

Field of the Invention

[0003] The present invention relates generally to the manufacture of positive displacement motors (PDMs) and progressive cavity (PC) pumps. More particularly, the invention relates to the manufacture of the elastomeric inserts for stators for PDMs and PC pumps.

Background of the Technology

[0004] Rotor-stator assemblies in PDMs and PC pumps frequently fail due to destruction of the elastomer inserts (also commonly referred to as simply "elastomers") that are essential components of the stators of PDMs and PC pumps. Mechanical failure of the elastomer can occur when the high-compression fit between the rotor and the stator causes the stress and strain limits of the elastomer to be exceeded. Thermal failure of the elastomer can occur when the temperature of the elastomer exceeds its rated temperature for a prolonged period of time. Attempts have been made to overcome these problems by creating an even-walled (i.e., uniform radial thickness) elastomer by machining the rotor and stators. However, this approach is a relatively expensive and difficult process that requires long manufacturing times and costly resources. Other attempts have been made to lessen stress on the elastomer by decreasing the eccentricity of the rotor-stator lobes (i.e., the radial offset between the central axes of the rotor and stator). While somewhat effective in reducing stress and strain in the elastomer, a decreased eccentricity also reduces the amount of torque that a PDM can deliver to a drilling attachment, thereby reducing the effectiveness of the attachment.

[0005] Accordingly, there remains a need in the art for stators for PDMs and PC pumps that offer the potential for improved resistance to mechanical and thermal failure without the drawbacks

associated with even-walled elastomers, and without reducing the rotor-stator eccentricity. In addition, there is a further need for methods and apparatus for manufacturing stators having the foregoing desirable characteristics while retaining the ease of manufacture and deployment provided by traditional elastomer inserts. There is also a need for such methods and apparatus that provide for flexibility in the choice of elastomer type and elastomer properties such as thermal characteristics. Embodiments disclosed herein are directed to these needs.

### **BRIEF SUMMARY OF THE DISCLOSURE**

[0006] These and other needs in the art are addressed in one embodiment by a method for manufacturing a stator for a PDC or PC pump. In an embodiment, the method comprises (a) providing an elongate mold having a central axis, a first end, a second end opposite the first end, a radially outer surface extending axially between the first end and the second end, and a through bore extending axially from the first end to the second end. The radially outer surface defines a plurality of helical vanes and a plurality of helical troughs, one trough being circumferentially disposed between each pair of circumferentially adjacent vanes. In addition, the method comprises (b) positioning the elongate mold within a tubular insert to form an insert-and-mold assembly. Further, the method comprises (c) positioning the insert-and-mold assembly within a tubular stator housing. Still further, the method comprises (d) pulling the insert radially inward into engagement with the elongate mold.

[0007] These and other needs in the art are addressed in another embodiment by a method for manufacturing a stator for a PDC or PC pump. In an embodiment, the method comprises (a) providing an elongate mold having a longitudinal axis. In addition, the method comprises (b) positioning the elongate mold within a tubular elastomer insert to form an insert-mold assembly. At least a portion of a radially inner surface of the insert is radially spaced from the elastomer insert. Further, the method comprises (c) positioning the insert-and-mold assembly within a tubular stator housing to form an insert-mold-housing assembly. Still further, the method comprises (d) pulling the insert radially inward into engagement with the elongate mold. Moreover, the method comprises (e) placing a filler material in an annulus positioned radially between the stator housing and the insert after (c) and (d). The method also comprises (f) withdrawing the mold from the insert after (e).

[0008] These and other needs in the art are addressed in another embodiment by an assembly for forming a stator for a PDC or PC pump. In an embodiment, the assembly comprises an elongate mold having a central axis, a first end, a second end opposite the first end, a radially outer surface extending axially between the first end and the second end, and a through bore extending axially from the first end to the second end. The radially outer surface of the mold includes a plurality of

circumferentially spaced helical vanes and a plurality of circumferentially spaced helical troughs, one trough being circumferentially disposed between each pair of circumferentially adjacent vanes. In addition, the assembly comprises an elastomer insert disposed about the mold.

[0009] Thus, embodiments described herein comprise a combination of features and advantages intended to address various shortcomings associated with certain prior devices, systems, and methods. The various characteristics described above, as well as other features, will be readily apparent to those skilled in the art upon reading the following detailed description, and by referring to the accompanying drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a detailed description of the preferred embodiments of the invention, reference will now be made to the accompanying drawings, in which numerical references denote like parts, and in which:

[0011] Figure 1 is a transverse cross-section through a conventional positive displacement motor (PDM) having a two-lobe rotor and a three-lobe stator cavity.

[0012] Figure 2 is a transverse cross-section through a conventional PDM having a four-lobe rotor and a five-lobe stator cavity.

[0013] Figure 3A is a perspective view of an embodiment of a mold for an eight-lobe stator in accordance with the principles described herein.

[0014] Figure 3B is an enlarged cross-sectional perspective view of the mold of Figure 3A.

[0015] Figure 4A is a perspective, partial cutaway view of the mold of Figure 3A with a cylindrical elastomer insert disposed therearound.

[0016] Figure 4B is an enlarged cross-sectional perspective view of the mold and elastomer insert shown in Figure 4A.

[0017] Figure 5 is a perspective, partial cutaway view of the mold-and-insert assembly of Figures 4A and 4B inserted into a stator housing.

[0018] Figure 6A is a perspective, partial cutaway view of the mold and insert assembly of Figure 5 after application of vacuum to the elastomer mold.

[0019] Figure 6B is an enlarged cross-sectional perspective of the mold and insert assembly of Figure 6A after application of vacuum.

[0020] Figure 7A is a longitudinal cross-sectional perspective view of the assembly of Figure 5 after application of vacuum, and illustrating the annulus between the elastomer and the stator housing.

[0021] Figure 7B is a longitudinal cross-sectional perspective view of the assembly of Figure 7A after injection of hard plastic into the circumferential cavity between the elastomer and the stator housing.

[0022] Figure 8A is a perspective of the assembly of Figure 7B after removal of the elastomer mold.

[0023] Figure 8B is an enlarged cross-sectional perspective view of the assembly of Figure 8A.

[0024] Figure 8C is a partial longitudinal cross-sectional perspective view through the assembly of Figure 8A.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

[0025] The following discussion is directed to various embodiments of the invention. Although one or more of these embodiments may be preferred, the embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. In addition, one skilled in the art will understand that the following description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to intimate that the scope of the disclosure, including the claims, is limited to that embodiment.

[0026] Certain terms are used throughout the following description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function. The drawing figures are not necessarily to scale. Certain features and components herein may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in interest of clarity and conciseness.

[0027] In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to... ." Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection, or through an indirect connection via other devices, components, and connections. In addition, as used herein, the terms "axial" and "axially" generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms "radial" and "radially" generally mean perpendicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a radial distance means a distance measured perpendicular to the central axis.

[0028] Figures 1 and 2 illustrate examples of conventional positive displacement motors (PDMs) and progressive cavity (PC) pumps, the basic construction and workings of which are well known in the art and do not require detailed explanation for purposes of this disclosure. Figure 1 shows a PDM (or PC motor) 50 having a rotor 55 disposed within a stator 60, which comprises an elastomer 62 disposed within a cylindrical stator housing 65. Rotor 55 in Figure 1 is ovate in cross-section, with a central or longitudinal axis  $C_R$ , and defines two helical rotor lobes 57. Elastomer 62 defines a helically-lobate cavity 64 defining three helical stator lobes 66. Typically, the number of stator lobes (e.g., lobes 66) in a PDM is one greater than the number of rotor lobes (e.g., lobes 57). This is further illustrated by the example of Figure 2, which illustrates a PDM (or PC motor) 70 having a rotor 75 with four rotor lobes 77 and a stator 80 having an elastomer 82 disposed within a stator housing 85, with elastomer 82 having a helically-lobate cavity defining five stator lobes 86. As may be appreciated from Figures 1 and 2, the central or longitudinal axis  $C_R$  of the rotor 55, 75 is radially offset from the longitudinal central or longitudinal axis  $C_S$  of the stator by fixed value known as the "eccentricity," labelled as "E" in Figures 1 and 2.

[0029] Embodiments disclosed herein teach new methods and apparatus for manufacturing stators for PDMs and PC pumps, which may be understood with reference to the remaining Figures. Figures 3A and 3B illustrate a mold 100 for use with one embodiment of the method disclosed herein. Mold 100 has an elongate body or core 102 having a central or longitudinal axis  $C_{102}$ , a first end 102a, a second end 102b opposite end 102a, and a radially outer surface 103 extending axially between ends 102a, b. Outer surface 103 includes a plurality of circumferentially spaced helical vanes 104a corresponding in shape and number of lobes desired for the particular stator being manufactured, and a plurality of circumferentially spaced helical troughs 104b. One helical trough 104b is circumferentially disposed between each pair of circumferentially adjacent vanes 104a.

[0030] Core 102 also includes a continuous longitudinal through bore 110 extending axially between ends 102a, b and defining a radially inner surface 112. Longitudinal bore 110 is shown in Figures 3A and 3B as a cylindrical bore, but could be of a different geometric configuration (e.g., square bore, etc.). In this embodiment, a plurality of transverse channels 105 extend (radially or otherwise) through core 102 from inner surface 112 to outer surface 103. The size, number, and spacing of transverse channels 105 may be selected to suit the requirements of particular embodiments. In Figures 3A and 3B, transverse channels 105 are shown terminating at the peaks of helical vanes 104a, but this is exemplary only; any one or more transverse channels 105 could also terminate in troughs 104b between helical vanes 104a, as may be desirable to suit particular embodiments.

[0031] An end member 106 of suitable configuration is provided at each end 102a, b of core 102. One end member 106 (e.g., end member 106 at end 102a) includes a vacuum port 108 in fluid communication with bore 110 and each trough 104b. In the illustrated embodiments, vacuum port 108 is shown as a channel coaxially aligned with longitudinal bore 110, however, in other embodiments, vacuum port 108 may be of a different configuration and/or orientation.

[0032] Referring now to Figures 4A and 4B, a tubular elastomer liner or insert 120 is coaxially disposed about core 102 of elastomer mold 100. Insert 120 has a central or longitudinal axis  $C_{120}$ , a first end 120a, a second end 120b opposite end 120a, a cylindrical radially inner surface 121 extending axially between ends 120a, b, and a cylindrical outer surface 122 extending axially between ends 120a, b. Elastomer insert 120 preferably has an inner diameter that is the same or slightly greater than the outer diameter of core 102 defined by the peaks of vanes 104a. Thus, inner surface 121 may slidably engage the peaks of vanes 104a. In this embodiment, inner surface 121 is disposed at the same diameter as the radially outermost surface on each vane 104a, and thus, surface 121 slidably engages vanes 104a. However, troughs 104b are radially spaced from inner surface 121. As a result, a plurality of helical passages 123 are radially disposed between elastomer insert 120 and troughs 104b and circumferentially positioned between circumferentially adjacent vanes 104a. Ends 120a, b of elastomer insert 120 are axially aligned with ends 102a, b of core 102. Thus, elastomer insert 120 has the same axial length as core 102.

[0033] In general, elastomer insert 120 may be made from any suitable elastomeric material(s) including, without limitation, highly saturated nitrile rubber or other highly elastic and erosion resistant material. In this embodiment, elastomer insert 120 is preferably a two-part construction comprising a radially inner layer made from a highly abrasion-resistant high-temperature-resistant compound (such as a hard rubber) backed by a radially outer layer made from a high-temperature deformable compound (such as silicone). As a general rule, though, the materials and construction details of elastomer insert 120 can be selectively engineered to provide specific tolerances and properties to suit specific in-service conditions.

[0034] Referring now to Figure 5, the next step is to coaxially dispose the insert-and-mold assembly (i.e., tubular elastomeric insert 120 disposed about core 102) within a tubular stator housing 130 (e.g., heat-treated steel tube). Housing 130 has a central or longitudinal axis  $C_{130}$ , a first end 130a, a second end 130b opposite end 130a, a cylindrical radially inner surface 131 extending axially between ends 130a, b, and a cylindrical outer surface 132 extending axially between ends 130a, b. Housing 130 has an inner diameter that is greater than the outer diameter of elastomer insert 120. Thus, inner surface 131 is radially spaced from elastomer insert 120, thereby defining an annulus between housing 130 and elastomer insert 120 coaxially disposed therein. As will be described in more detail below, insert 120 is attached housing 130 with a

filler material that is positioned radially between insert 120 and housing 130. The annulus between insert 120 and housing 130 offers the potential to ensure proper adhesion of insert 120 to housing 130 with the filler material. Ends 130a, b of housing 130 are axially aligned with ends 120a, b of elastomer insert 120. Thus, housing 130 has the same axial length as elastomer insert 120. As a result, housing 130 encloses the full length of core 102 of elastomer mold 100.

[0035] Each end 130a, b of stator housing 130 axially abuts and sealingly engages one end member 106 of mold 100. In particular, an annular vacuum-tight seal is formed between each end 130a, b and its corresponding member 106. In general, such annular seals may be formed by any suitable means including, without limitation, annular O-ring seals, polypacks, or other elastomeric sealing device.

[0036] Next, the pressure within bore 110 and passages 123 is reduced by applying a vacuum to bore 110, passages 123, and channels 105 via port 108 (i.e., in accordance with known vacuum molding techniques). As best shown in Figures 6A and 6B, as result, tubular elastomer insert 120 is pulled radially inward, deforms, and conforms to the contours of the outer surface of core 102 of elastomer mold 100. Thus, inner surface 121 of elastomer insert 120 transitions from a cylindrical surface to a surface including a plurality of circumferentially spaced helical vanes 121a and a plurality of circumferentially spaced helical troughs 121b, wherein one trough 121b is circumferentially disposed between each pair of circumferentially adjacent vanes 121a. Further since elastomer insert 120 has a substantially uniform radial thickness, outer surface 122 of elastomer insert 120 transitions from a cylindrical surface to a surface including a plurality of circumferentially spaced helical vanes 122a and a plurality of circumferentially spaced helical troughs 122b, wherein one trough 122b is circumferentially disposed between each pair of circumferentially adjacent vanes 122a. As best shown in Figure 7A, an annulus or cavity 140 extending axially between ends 120a, b and 130a, b is formed radially between elastomer insert 120 and stator housing 130.

[0037] Although the insert-and-mold assembly is disposed within housing 130 before reducing the pressure in bore 110, passages 123, and channels 105 in this embodiment. It should be appreciated, that the pressure in bore 110, passages 123, channels 105, or combinations thereof may be reduced to pull elastomer insert 120 radially inward into engagement with core 102 before placing the insert-and-mold assembly within stator housing 130.

[0038] Moving now to Figure 7B, the next step in the method is to introduce a suitable filler material into annulus 140 to form a solid stator core section 145 enclosed by and bonded to elastomer insert 120 and stator housing 130, with elastomer insert 120 defining the surface of the helically-lobate stator cavity of the finished stator section. Thus, core section 145 is radially disposed between stator housing 130 and elastomer insert 120. In general, the filler material may

comprises any suitable material capable of being flowed into annulus 140 in a liquid form and allowed to cure and/or harden such as a polymer, plastic, or epoxy. The filler material may be introduced into cavity 140 through injection ports 133 at selected locations in the cylindrical wall of stator housing 130, as shown in Figure 7B. However, embodiments disclosed herein are not restricted to the use of any particular method or means for introducing filler material into cavity 140 to form stator core section 145; persons skilled in the art will appreciate that other such means may be devised and used.

[0039] The final step in the method is to withdraw elastomer mold 100 from stator housing 130, core section 145, and elastomer insert 120, thereby forming a helically-lobate stator cavity 165, bounded and defined by the vacuum-deformed elastomer insert 120. This step is may be accomplished by disconnecting one end member 106 from core 102 of elastomer mold 100 so that core 102 can be rotated and thus withdrawn (i.e., by effectively "unscrewing" mold 100 from elastomer insert 120). Withdrawal of elastomer mold 100 is preferably facilitated by applying a suitable lubricant to core 102 of elastomer mold 100 prior to the step of disposing elastomer insert 120 around core 102. Figures 8A, 8B, and 8C illustrate a finished stator section 160 manufactured in accordance with embodiments disclosed herein.

[0040] One potential advantage of embodiments of the stator manufacturing method disclosed herein is that the elastomer insert can be engineered from very specific materials to provide improved abrasion resistance, reduced thermal expansion, increased service life, and better resistance to chemical corrosion. Another potential advantage is that unlike conventional pressure injection molding methods, the methods disclosed herein do not require the use of high-temperature liquid plastics and rubbers, which can be difficult and hazardous to work with. Additionally, vacuum forming technologies, as used in the present method, are relatively simple compared to injection molding technologies, and typically do not require specialized high-temperature or pressurizing equipment.

[0041] Since vacuum forming methods are well understood, and because the stator manufacturing methods disclosed herein allow the properties of the elastomer to be selectively engineered, such embodiments offer the potential to be more cost-effective, simple, and faster than known methods. Embodiments described herein thus offer the potential to provide advantages in time and cost versus the manufacture of stators with even-walled elastomers, as well as cost and service life advantages over the elastomer inserts of conventional PDMs and PC pumps. Manufacturing time may also reduced, since the construction of the elastomer is carried out within the stator housing, and the final process of the construction results in a fully assembled stator. This is in contrast with conventional manufacturing methods, in which the elastomer is typically manufactured in a separate process and then inserted into the stator housing.

[0042] While preferred embodiments have been shown and described, modifications thereof can be made by one skilled in the art without departing from the scope or teachings herein. The embodiments described herein are exemplary only and are not limiting. Many variations and modifications of the systems, apparatus, and processes described herein are possible and are within the scope of the invention. For example, the relative dimensions of various parts, the materials from which the various parts are made, and other parameters can be varied. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims.

**CLAIMS**

What is claimed is:

1. A method for manufacturing a stator for a PDC or PC pump, the method comprising:
  - (a) providing an elongate mold having a central axis, a first end, a second end opposite the first end, a radially outer surface extending axially between the first end and the second end, and a through bore extending axially from the first end to the second end, wherein the radially outer surface defines a plurality of helical vanes and a plurality of helical troughs, one trough being circumferentially disposed between each pair of circumferentially adjacent vanes;
  - (b) positioning the elongate mold within a tubular insert to form an insert-and-mold assembly;
  - (c) positioning the insert-and-mold assembly within a tubular stator housing; and
  - (d) pulling the insert radially inward into engagement with the elongate mold.
2. The method of claim 1, further comprising:
  - (e) placing a filler material in an annulus positioned radially between the stator housing and the insert.
3. The method of claim 2, wherein (e) is performed after (d).
4. The method of claim 3, wherein (d) is performed after (e).
5. The method of claim 4, wherein (c) is performed after (b).
6. The method of claim 2, further comprising:
  - (f) withdrawing the mold from the stator housing after (e).
7. The method of claim 6, wherein (f) comprises:  
rotating the mold about the central axis; and  
unscrewing the mold from the insert.
8. The method of claim 6, wherein (d) comprises:  
applying a vacuum to a plurality of helical passages radially positioned between the insert and the troughs.

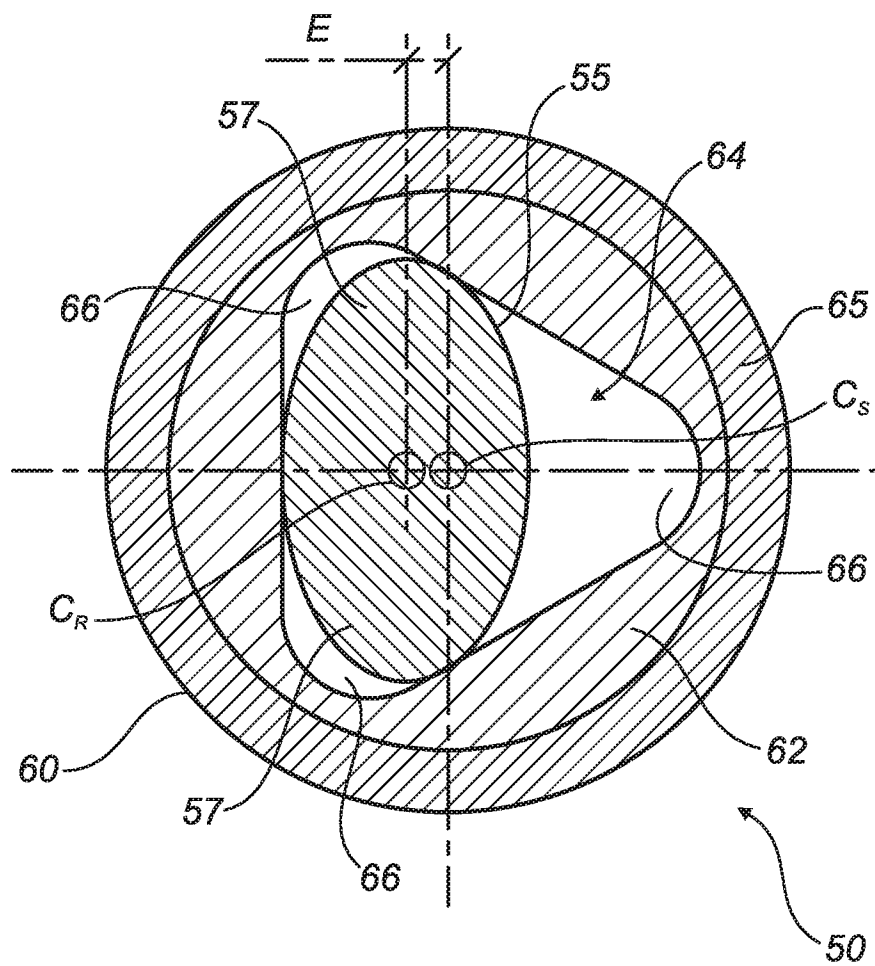
9. The method of claim 6, wherein the mold further comprises a plurality of channels extending from the through bore to the radially outer surface; and  
wherein (d) comprises applying a vacuum to the through bore of the mold and the channels.
10. The method of claim 1, wherein the insert comprises an elastomeric material.
11. The method of claim 10, wherein the insert comprises a radially inner layer made from a highly abrasion-resistant high-temperature-resistant compound backed by a radially outer layer made from a high-temperature deformable compound.
12. A method for manufacturing a stator for a PDC or PC pump, the method comprising:  
(a) providing an elongate mold having a longitudinal axis;  
(b) positioning the elongate mold within a tubular elastomer insert to form an insert-mold assembly, wherein at least a portion of a radially inner surface of the insert is radially spaced from the elastomer insert;  
(c) positioning the insert-and-mold assembly within a tubular stator housing to form an insert-mold-housing assembly; and  
(d) pulling the insert radially inward into engagement with the elongate mold;  
(e) placing a filler material in an annulus positioned radially between the stator housing and the insert after (c) and (d); and  
(f) withdrawing the mold from the insert after (e).
13. The method of claim 12, wherein the filler material is injected into the annulus through one or more ports in the stator housing.
14. The method of claim 12, wherein (e) comprises:  
(e1) flowing the filler material into the annulus; and  
(e2) allowing the filler material to harden after (e1).
15. The method of claim 14, wherein the filler material is a polymer or epoxy.
16. The method of claim 12, wherein (f) further comprises forming the stator having a radially inner surface including a plurality of circumferentially spaced helical vanes and a

plurality of circumferentially spaced helical troughs, wherein one trough is circumferentially positioned between each pair of circumferentially adjacent vanes.

17. An assembly for forming a stator for a PDC or PC pump, the assembly comprising:  
an elongate mold having a central axis, a first end, a second end opposite the first end, a radially outer surface extending axially between the first end and the second end, and a through bore extending axially from the first end to the second end;  
wherein the radially outer surface of the mold includes a plurality of circumferentially spaced helical vanes and a plurality of circumferentially spaced helical troughs, one trough being circumferentially disposed between each pair of circumferentially adjacent vanes; and  
an elastomer insert disposed about the mold.
18. The assembly of claim 17, wherein the elastomer insert is a tubular having a cylindrical radially inner surface and a cylindrical radially outer surface.
19. The assembly of claim 17, further comprising:  
a tubular stator housing disposed about the elastomer insert.
20. The assembly of claim 19, further comprising:  
a filler material radially disposed between the elastomer insert and the stator housing.
21. The assembly of claim 20, wherein the elastomer insert has a radially inner surface engaging the radially outer surface of the mold.
22. The assembly of claim 21, wherein the elastomer insert has a radially outer surface including a plurality of circumferentially spaced helical vanes and a plurality of circumferentially spaced helical troughs, one trough being circumferentially disposed between each pair of circumferentially adjacent vanes.

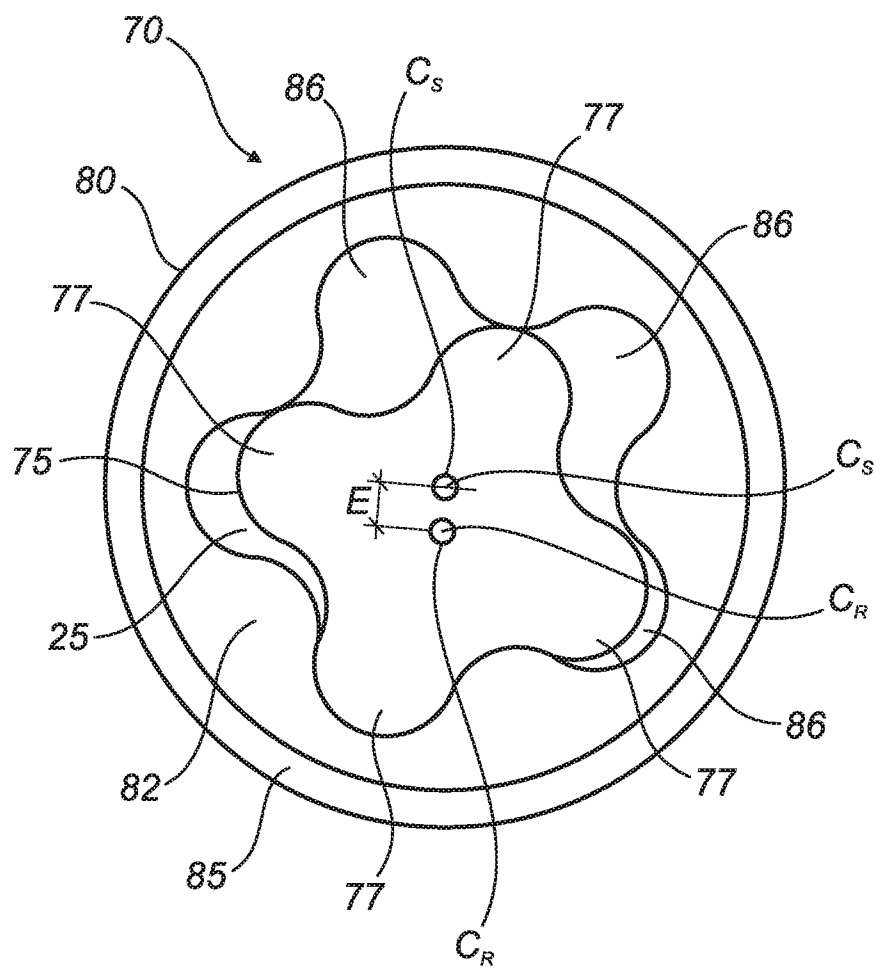
1/10

FIG. 1  
(Prior Art)



2/10

FIG. 2  
(Prior Art)



3/10

FIG. 3A

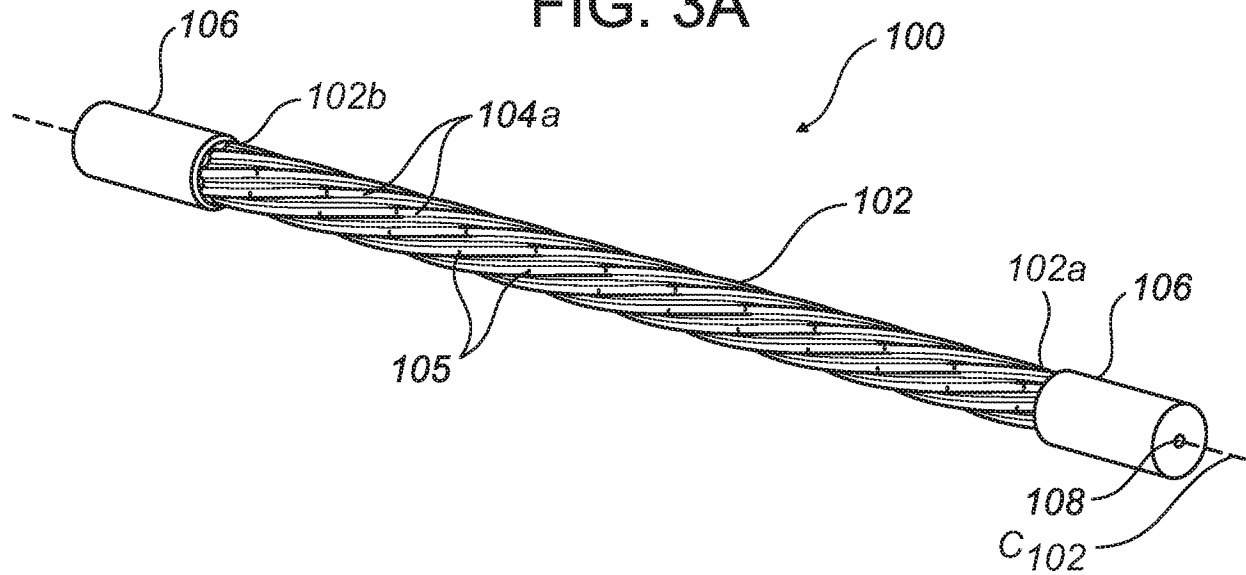
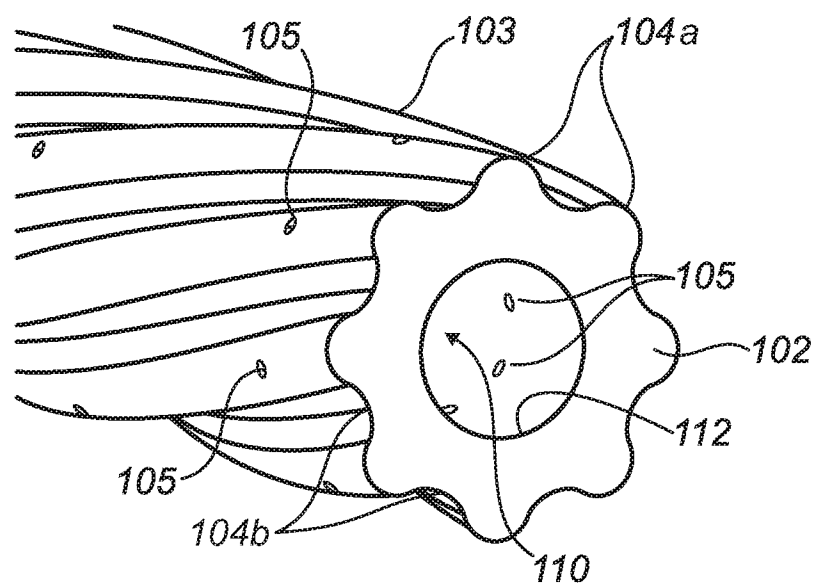
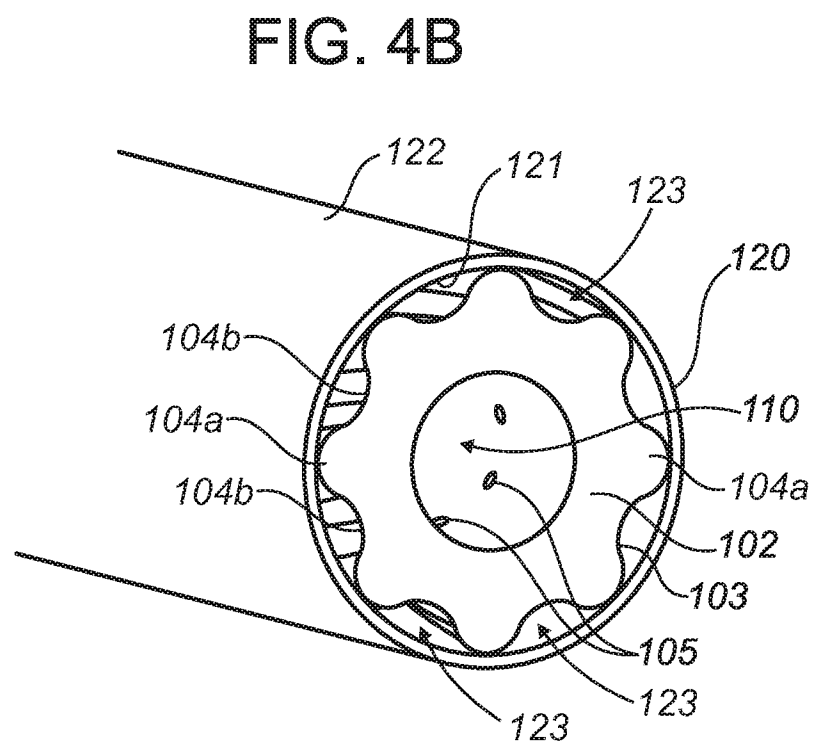
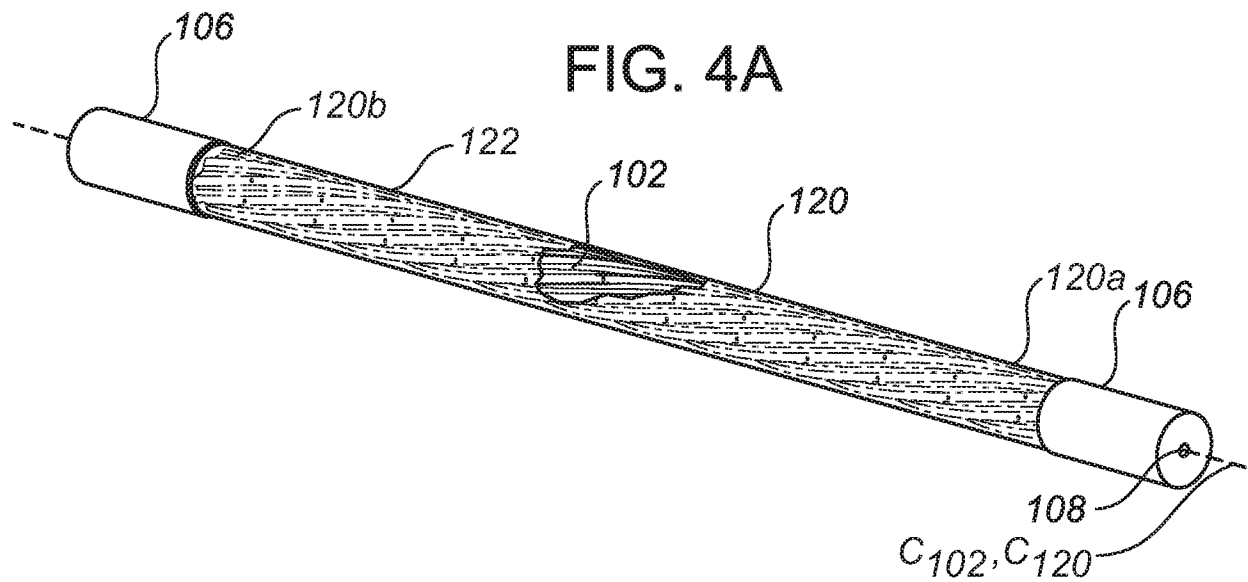


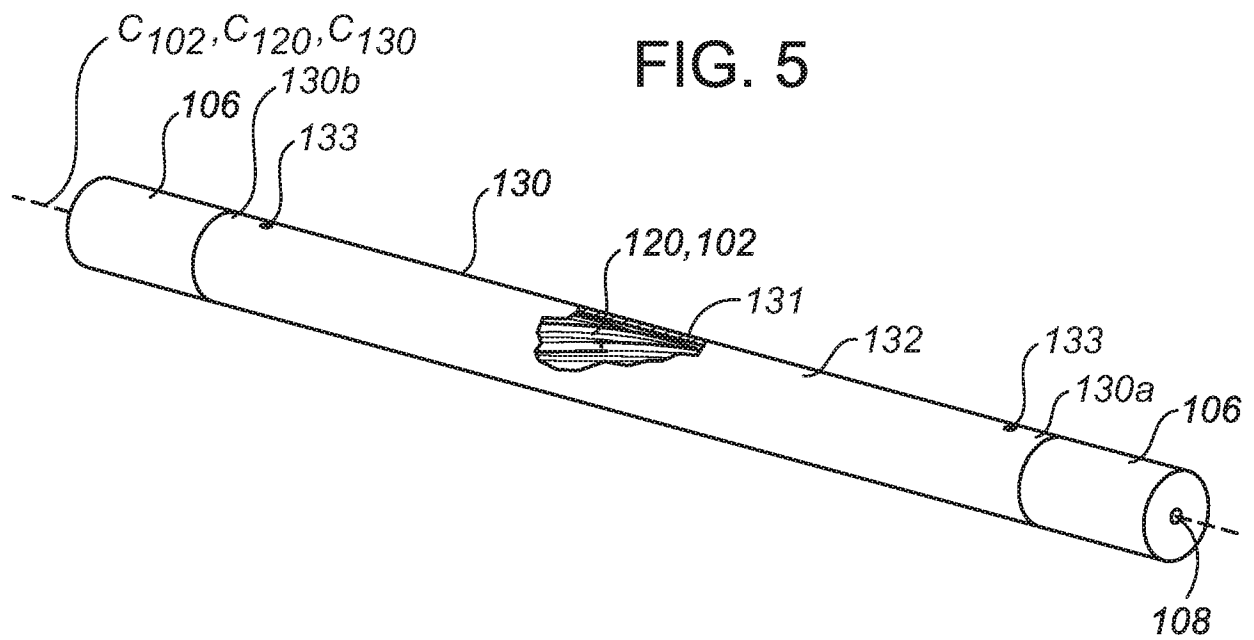
FIG. 3B



4/10



5/10



6/10

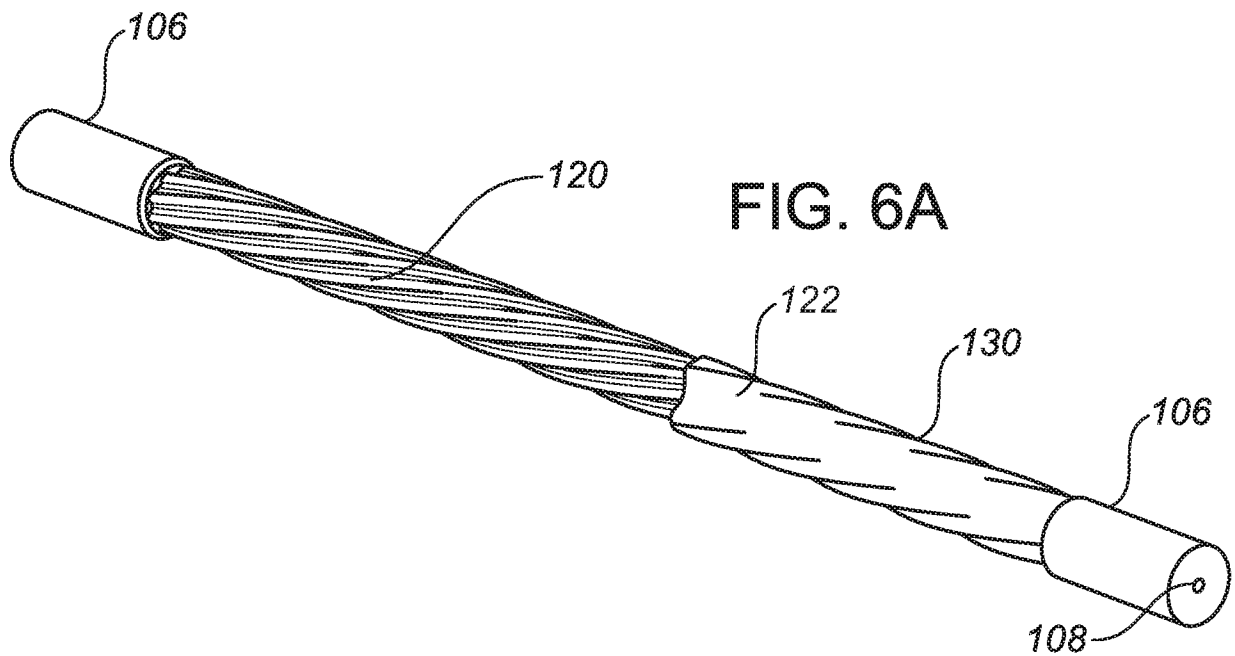
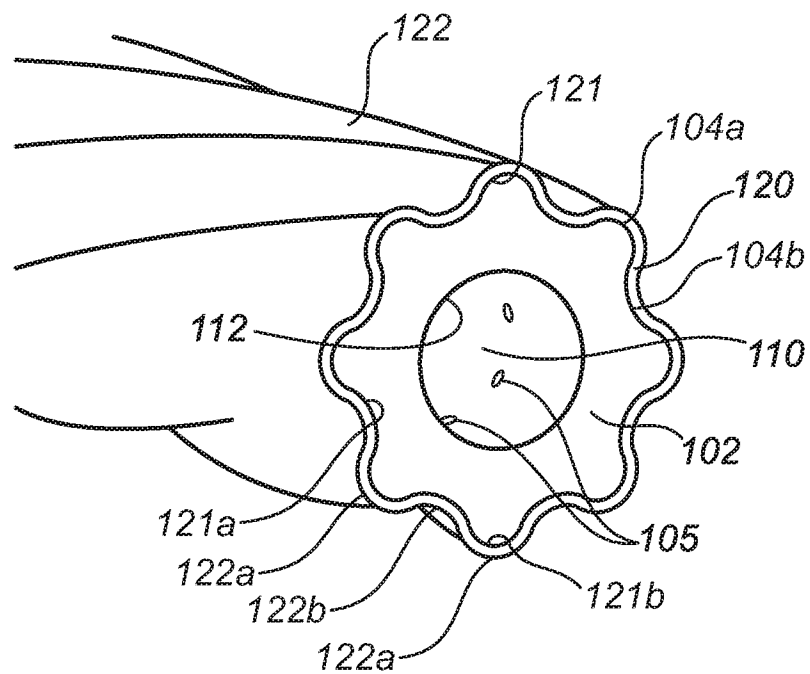
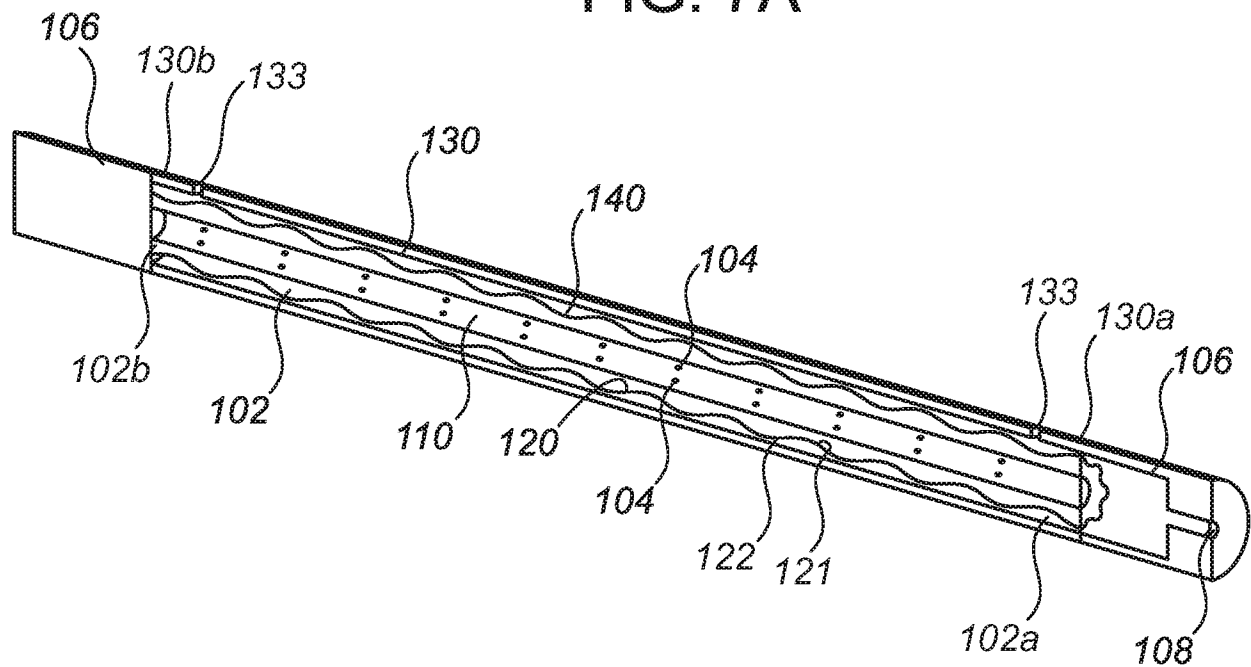


FIG. 6B



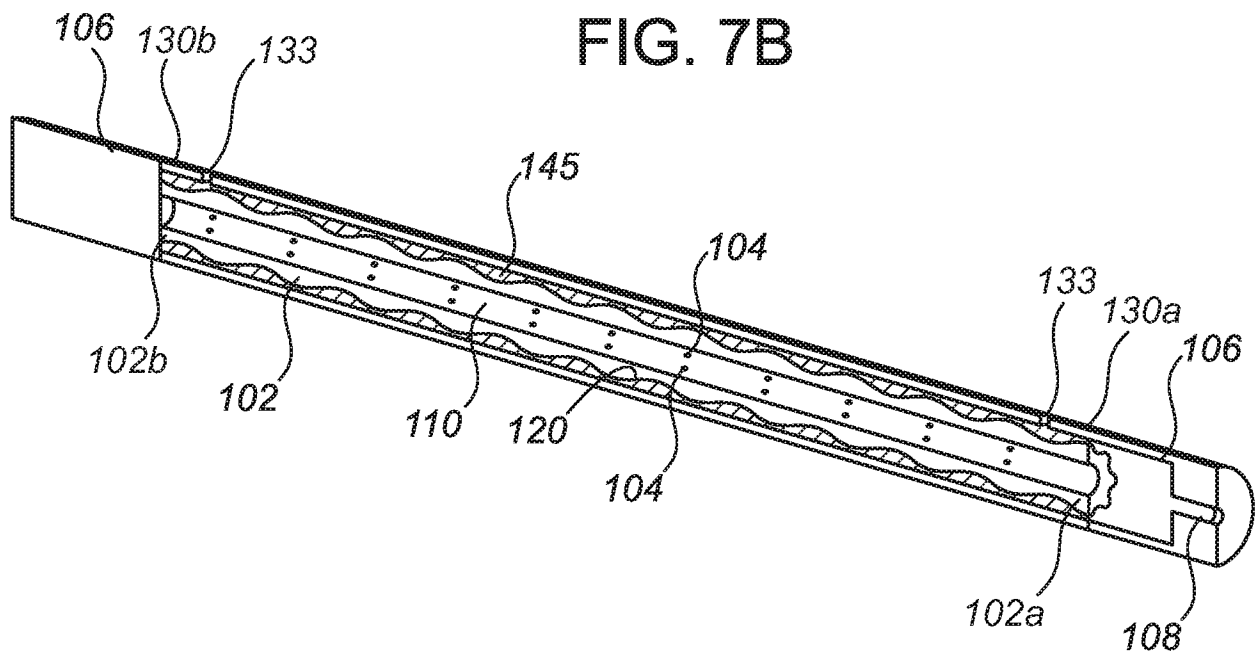
7/10

FIG. 7A

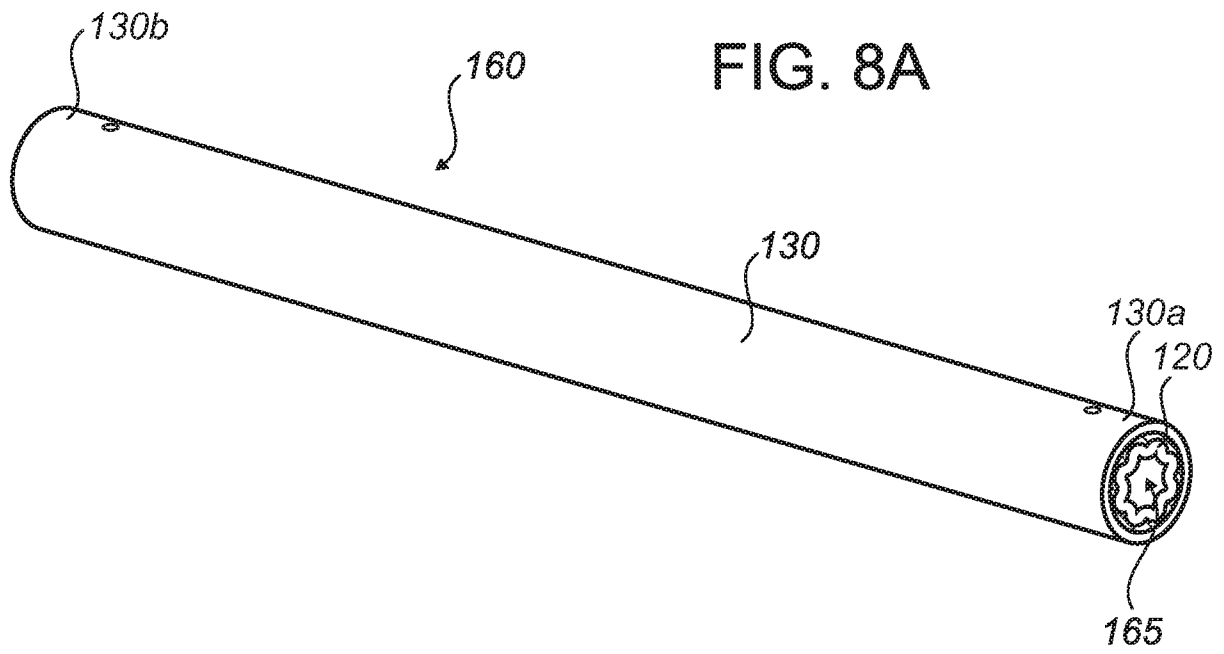


8/10

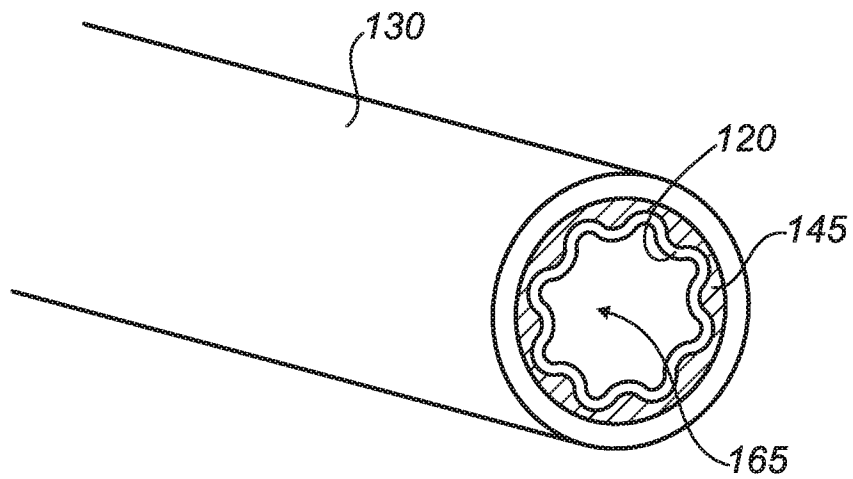
FIG. 7B



9/10

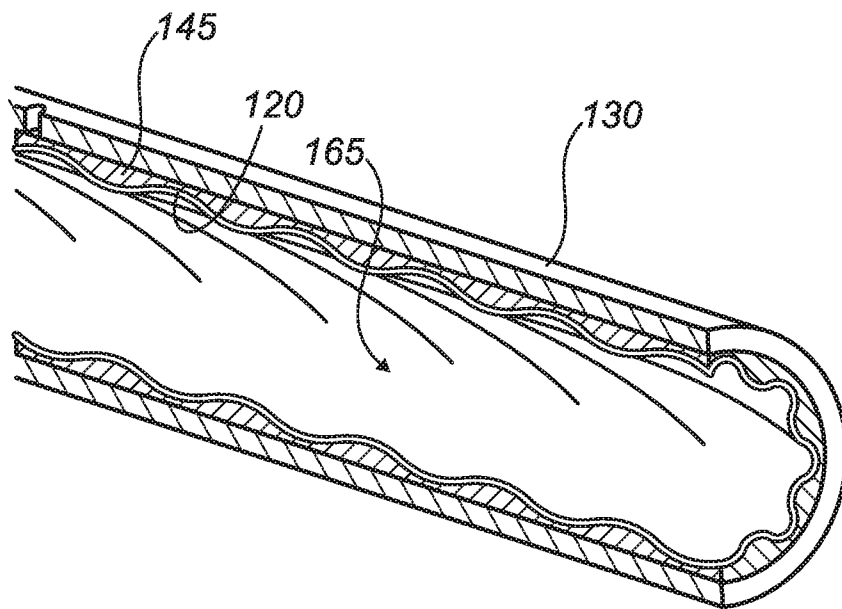


**FIG. 8B**



10/10

FIG. 8C



## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/034766

A. CLASSIFICATION OF SUBJECT MATTER  
 INV. B29C70/78 F04C2/107  
 ADD.

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)

B29C F04C E21B

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 practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                       | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | GB 2 424 452 A (SCHLUMBERGER HOLDINGS [VG]) 27 September 2006 (2006-09-27)                                                                                                                                                                                                               | 17-19                 |
| A         | figures 4, 6<br>page 4, lines 1-4<br>page 9, line 6                                                                                                                                                                                                                                      | 1-16,<br>20-22        |
| X         | US 2008/025859 A1 (LEE LAWRENCE [GB] ET AL) 31 January 2008 (2008-01-31)<br>figure 6<br>page 1, paragraph [0001]<br>page 4, paragraph [0054]<br>page 5, paragraph [0068]<br>page 6, column 2, lines 5-7<br>page 6, paragraphs [0069], [0070], [0071], [0076]<br>page 7, paragraph [0084] | 1-22                  |



Further documents are listed in the continuation of Box C.



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 document 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

6 September 2011

Date of mailing of the international search report

12/09/2011

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
 NL - 2280 HV Rijswijk  
 Tel. (+31-70) 340-2040,  
 Fax: (+31-70) 340-3016

Authorized officer

Gasner, Benoit

## INTERNATIONAL SEARCH REPORT

### Information on patent family members

International application No

PCT/US2011/034766

| Patent document<br>cited in search report |    | Publication<br>date |    | Patent family<br>member(s) |  | Publication<br>date |
|-------------------------------------------|----|---------------------|----|----------------------------|--|---------------------|
| GB 2424452                                | A  | 27-09-2006          | CA | 2540437 A1                 |  | 22-09-2006          |
|                                           |    |                     | US | 2006216178 A1              |  | 28-09-2006          |
| -----                                     |    |                     |    |                            |  |                     |
| US 2008025859                             | A1 | 31-01-2008          | CA | 2595181 A1                 |  | 31-01-2008          |
|                                           |    |                     | GB | 2441406 A                  |  | 05-03-2008          |
| -----                                     |    |                     |    |                            |  |                     |