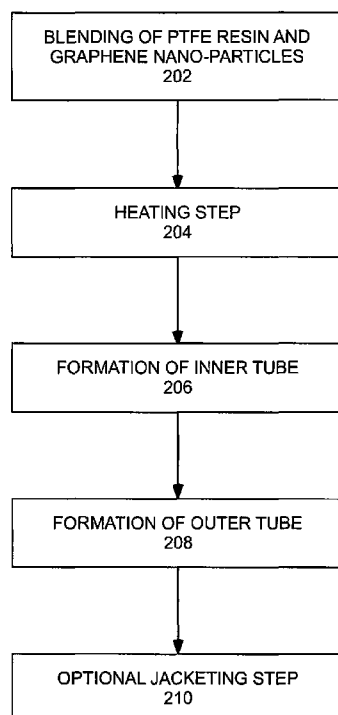




- (51) **International Patent Classification:**
F16L 11/04 (2006.01) *F16L 11/20* (2006.01)
- (21) **International Application Number:**
PCT/US2015/040925
- (22) **International Filing Date:**
17 July 2015 (17.07.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
14/334,228 17 July 2014 (17.07.2014) US
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- (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, BN, 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, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, 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, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, 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,

[Continued on next page]

(54) **Title:** HIGH PRESSURE GAS HOSE AND METHOD OF MAKING SAME**Fig. 4**

(57) **Abstract:** A high pressure gas hose and related methods of transporting high pressure gases in which gas permeability throughout a length of the high pressure gas hose is reduced. The high pressure gas hose can have an outer tube and the inner tube. The outer tube can be formed of a resistant polymer material such as PTFE. The inner tube can include a matrix formed of PTFE and graphene nano-platelets or nano-particles. The graphene nano-platelets define a tortuous path within the matrix such that gas permeability is reduced through an inner tube wall thickness. Gas permeability throughout a length of the high pressure gas hose can be less than about 20 ml/m/hr. The high pressure gas hose can find practical application in natural gas applications, automotive applications, cooling and refrigeration applications and other applications in which it is desired to have low gas permeability in high pressure applications.



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, **Published:**
GW, KM, ML, MR, NE, SN, TD, TG).

— *with international search report (Art. 21(3))*

HIGH PRESSURE GAS HOSE AND METHOD OF MAKING SAME

5

RELATED APPLICATIONS

The present application claims the benefit of U.S. Patent Application No. 14/334,228 filed July 17, 2014, which is incorporated herein in its entirety by reference.

FIELD OF THE INVENTION

10

The present invention is directed to fluoropolymer hoses such a polytetrafluoroethylene (PTFE) hoses, perfluoroalkoxy copolymer (PFA) or fluorinated ethylene propylene (FEP). More specifically, the present invention is directed to fluoropolymer hoses with reduced permeability PTFE hose for use in high pressure gas and vapor applications.

15

BACKGROUND OF THE INVENTION

Gases such as, for example, bottled industrial gases (nitrogen, argon, oxygen), refrigerants and natural gas, are frequently transported at high pressure, often exceeding 2000 PSIG. For example, bottled industrial gases are frequently at pressures exceeding 2800 PSIG and specialty bottled gases can be over 6000 PSIG. At natural gas fueling installations, natural gas can be supplied to vehicles at pressures exceeding 4000 PSIG. The molecules of natural gas are small, enhancing its ability to permeate through standard rubber or PVC hose constructions used for low pressure fluids, and the permeation of the gas is more rapid as the working pressure increases, which can cause natural gas accumulation with potentially dangerous consequences.

Traditionally, these gases have been transported in lower permeability tubing, such as hard tubing formed of metals or metallic alloys such as, for example, steel, stainless steel, copper and the like or using polymeric tubing such as, for example, nylon tubing. Such tubing must meet certain standards, such as ANSI, ASTM, and/or Underwriter Laboratories (UL®) requirements, to be used for distribution of high pressure gases. For example, hoses used for distribution of natural gas should have a maximum permeability rate of about 20 ml/m/hr.

However, conventional high pressure tubing suffers from drawbacks. For example, metallic tubing can fatigue or corrode over time, which results in catastrophic failure. Polymer hose and tubing such as, for example, Nylon tubing, on the other hand, while typically not subject to catastrophic failure, has the potential for kink formation. Furthermore, polymer hoses can degrade over time, causing an increase in their permeability until the tubing is no longer adequate for use with high pressure gases, i.e. the maximum permeability rate has been exceeded, which can go undetected. In addition, polymeric hoses may not be compatible with high temperatures such as, for example, those found in automotive applications, or low temperature conditions as found in some gas depressurizing applications. As such, it would be advantageous to improve upon existing hose and tubing options for use in transporting high pressure gases.

SUMMARY OF THE INVENTION

Generally, a high pressure gas hose of the present invention overcomes the deficiencies of the prior art by using an inner tube designed to have a reduced gas permeability throughout a length of the inner tube. Generally, the high pressure gas hose can comprise an outer tube and

the inner tube. The outer tube can be formed of a resistant polymer material such as, for example, PTFE. The inner tube can comprise a matrix formed of PTFE and graphene nano-platelets or nano-particles. The graphene nano-platelets can comprise a tortuous path within the matrix such that gas permeability is reduced through an inner tube wall thickness. In some
5 embodiments, gas permeability throughout a length of the high pressure gas hose can be less than 20 ml/m/hr, more particularly about 10 ml/m/hr, and more particularly from about 4 to about 8 ml/m/hr. In some embodiments, the permeability rate is reduced by an order of magnitude compared to traditional nylon hoses. The high pressure gas hose of the present invention can find practical application for use in natural gas transport, distribution, automotive applications,
10 cooling and refrigeration applications, high pressure gas transport and/or distribution, and any other application in which it is desired to have low gas permeability in high pressure applications.

In one aspect, the present invention is directed to a high pressure hose for transporting pressurized gases in excess of 2000 psig. Generally, an embodiment of the high pressure hose
15 can comprise an inner tube and an outer tube. The outer tube can be formed of a PTFE resin. The inner tube can be formed of a matrix of PTFE and graphene nano-platelets or nano-particles. In some embodiments, the matrix of PTFE and graphene nano-platelets can be defined continuously through an inner tube wall. In some embodiments, the inner tube wall and an outer tube wall can define a hose wall having a hose wall thickness. In some embodiments, the inner
20 tube wall can have an inner tube wall thickness that comprise less than or equal to 15% of a hose wall thickness. In some embodiments, the matrix defines a tortuous path within the inner tube wall that reduces gas permeability of the pressurized gas through the inner tube wall. In some

embodiments, the gas permeability of the high pressure hose is less than about 20 ml/m/hr, more particularly from about 1 to about 10 ml/m/hr, and more particularly from about 4 to about 8 ml/m/hr.

In one aspect, the present invention can be directed to a method of making a high
5 pressure hose assembly for transporting pressurized gases in excess of 2000 psig. The method can comprise, for example, combining or blending PTFE resin and graphene nano-platelets or nano-particles to form a graphene/PTFE resin or matrix. The matrix or resin can include a concentration of graphene nano-platelets or particles to define a tortuous path within the matrix of inner tube. In some embodiments, a concentration of graphene nano-platelets or nano-particles
10 is from about 0.5 to about 15 percent by weight of the resin, more particularly, from about 1 to about 10 percent by weight of the resin, and even more particularly from about 1.5 to about 5 percent by weight of the resin. The resin can contain optional additives, such as surfactants, fillers, and the like.

The resin is then extruded or molded to form an inner tube having graphene nano-
15 platelets or nano-particles distributed therethrough. Optionally, an outer tube, such as a PTFE tube, is coextruded over the inner tube, forming a high pressure tube having a tube wall thickness. Typically, the high pressure tube is capable of safely handling high pressure gases in excess of 100 PSIG. In embodiments, the inner tube comprises from about 1 to about 100 percent of the total wall thickness, more particularly from about 1 to about 50% of the total wall
20 thickness more particularly from about 5 to about 30 percent of the total wall thickness, and even more particularly about 15 percent of the total wall thickness. In an alternative embodiment, a single tube is extruded such that the graphene nano-platelets or nano-particles are distributed

throughout 100 percent of the total wall thickness. Optionally, an outer sleeve or jacket is formed or coupled to an outer surface of the high pressure tube to at least partially circumferentially surround the PTFE tube. The jacket can be formed of a plurality of plaits of fiberglass lace, wires, yarns, mono- or micro-filaments, or a combination of these, for example, as described in WO 2013/0165452 A1, entitled "Tubes and Methods of Production of Use
5 Thereof," incorporated herein by reference in its entirety.

In another aspect, the present invention can be directed to a method for transporting high pressure gasses. In a representative embodiment, the method can comprise pressurizing a gas to a pressure exceeding about 2000 PSIG followed by transporting the gas through a high pressure
10 hose having an inner tube, an optional outer tube, and an optional jacket as described above. The method can further comprise forming the inner tube of a matrix of PTFE and graphene nano-platelets while the optional outer tube is formed of PTFE, as described above. In some embodiments, the matrix can be formed to define a tortuous path within the matrix of inner tube. In some embodiments, the matrix can be formed by combining the graphene nano-particles to the
15 PTFE resin prior to formation of the inner tube. In some embodiments, the inner tube and the outer tube can be formed simultaneously. In some embodiments, the tortuous path within the matrix limits gas permeability through the high pressure hose to less than about 20 ml/m/hr, more particularly about 10 ml/m/hr, and more particularly from about 4 to about 8 ml/m/hr.

The above summary of the various representative embodiments of the invention is not
20 intended to describe each illustrated embodiment or every implementation of the invention. Rather, the embodiments are chosen and described so that others skilled in the art can appreciate

and understand the principles and practices of the invention. The figures in the detailed description that follow more particularly exemplify these embodiments.

5

BRIEF DESCRIPTION OF THE DRAWINGS

A specific embodiment is now described by way of example to further the understanding of the present disclosure, with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of a length of high pressure gas hose according to an embodiment of the present invention.

10

Figure 2 is a section view of the high pressure gas hose taken at line 2-2 of Figure 1

Figure 3a is a detailed view of the high pressure gas hose of Figure 1 taken at Detail 3 of Figure 2.

Figure 3b is a detailed view of a high pressure gas hose according to an alternative embodiment of the present invention.

15

Figure 4 is a schematic illustration of a method of making a high pressure gas according to an embodiment of the present invention.

Figure 5 is a perspective view of a permeability rate testing apparatus according to an embodiment of the invention.

20

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents,

and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE DRAWINGS

A representative length of hose 100 according to an embodiment of the present invention is illustrated generally in Figures 1, 2, and 3a . Hose 100 is generally defined between a first end 102 and a second end 104. Hose 100 generally has a hose wall 106 defining a circular cross-section 108. Hose wall 106 is generally defined by an outer tube 110 and an inner tube 112. Hose wall 106 generally has a wall thickness 113 defined by an outer tube thickness 114 and an inner tube thickness 116. Hose 100 has a hose diameter 118 defined by the outer tube thickness 114, the inner tube thickness 116 and an internal diameter 120.

Hose 100 is generally formed by co-extruding the outer tube 110 and inner tube 112. Outer tube 110 is generally formed of a fluoropolymer 122, such as, for example, polytetrafluoroethylene (PTFE), perfluoroalkoxy copolymer (PFA) or fluorinated ethylene propylene (FEP), so as to be chemically resistant and compatible with environmental surroundings. In some embodiments, outer tube 110 can further include a braided or jacketed sleeve (not shown) to supply extra strength and support to hose 100. The sleeve can be formed or coupled to an outer surface of outer tube 110 to at least partially circumferentially surround outer tube 110 and inner tube 112. As discussed previously, the jacket can be formed, for example, of a plurality of plaits of fiberglass lace, wires, yarns, mono- or micro-filaments, or a combination of these as described in WO 2013/0165452 A1, entitled "Tubes and Methods of Production of Use Thereof," incorporated above by reference in its entirety.

As seen in Figure 2, inner tube 112 is generally formed of a matrix 124 comprising PTFE 122 and graphene nanoparticles or nano-platelets 126. Graphene is a desirable material to blend with PTFE because of its similar aspect ratio to PTFE, allowing it to blend easily.

Furthermore, graphene is an efficient conductor of heat and electricity such that the inner tube 112 efficiently dissipates to avoid build up of electrical charge or heat, which can otherwise have potentially dangerous consequences. Particularly with respect to nano-platelets, the nano-platelets, due to their large surface area, create a sufficiently tortuous path for natural gas particles to escape, thereby significantly decreasing permeability of the tube. In addition, the nano-platelets or particles can provide other structure advantages including increasing the stiffness of the inner tube 112 as well as enhancing impact, mar and flame resistance.

The graphene nanoparticles or nano-platelets can be incorporated into the PTFE resin prior to the extrusion process. In some embodiments, a concentration of graphene nano-platelets or nano-particles is from about 0.5 to about 15 percent by weight of the matrix 124, more particularly, from about 1 to about 10 percent by weight of the matrix 124, and even more particularly from about 1.5 to about 5 percent by weight of the matrix 124. The matrix 124 can contain optional additives, such as surfactants, fillers, and the like.

Within the matrix 124, the graphene nanoparticles or nano-platelets 126 define a tortuous path 128 between an innermost surface 130 and an outermost surface 132. In embodiments, the inner tube comprises from about 1 to about 50 percent of the total wall thickness, more particularly from about 5 to about 30 percent of the total wall thickness. In one representative non-limiting embodiment, inner tube thickness 116 comprises 15% or less of the wall thickness 113.

In an alternative embodiment not shown, an inner tube is formed of PTFE, while an outer tube comprises the graphene nano-platelet or nano-particle matrix. In yet another embodiment

shown in Fig. 3b, the hose comprises a single tube 112 formed from the graphene nano-platelet or particle matrix 124 forming the entire thickness of the hose wall.

In operation, hose 100 can be utilized for transporting gas at pressures exceeding about 2000 psig. A representative method 200 for making a high pressure gas hose is illustrated generally in Figure 4 and can comprise a blending step 202 in which a PTFE resin is blended with the nano-particles or nano-platelets, such as by metering, at concentrations described above using a ribbon blender, paddle mixer, baffles, V-blenders, rolling mixers or any of a variety of blending techniques known in the art.

Paste extruded PTFE blends are formed into a billet or preformed and extruded into a tubular shape and heated to dry any lubricant the heat is then increased until the material sinters at temperature of 600-700° F.

The melt extrudable polymers of PFA blends, FEP blends, and/or PTFE blends are heated at step 204 to temperatures of 600-700°F (melting temperature of PTFE is about 620.3°F) such that the resin is flowable. The flowable resin is then extruded or molded during a formation step 206 in which the inner tube 112 is formed such that the matrix 124 is defined continuously through the inner tube thickness 116. The formation step 206 can include forming the inner tube thickness 116 such that the inner tube thickness 116 is from about 1 to about 100 percent of the total wall thickness 113, more particularly from about 5 to about 30 percent of the total wall thickness 113, and even more particularly about 15 percent of the total wall thickness 113.

In some embodiments, the tortuous path 128 can be created by adding the graphene nano-particle 128 to the PTFE resin 122 prior to the formation step 206. In some embodiments, the method can include a formation step 208 in which the outer tube 110 is formed of a PTFE resin

extruded or molded over outer surface of inner tube 112. In some embodiments, formation step 206 and formation step 208 can be accomplished simultaneously, for example, through simultaneous extrusion of the inner tube 112 and outer tube 110 to form hose 100. Optional step 210 includes coupling a sleeve or jacket, such as a braided fiberglass lace, wires, yarns, mono- or micro-filaments, or a combination of these to form a jacket as described above, over an outer periphery of outer tube 110. In some embodiments, the method 200 results in hose 100 having a gas permeability of less than about 20 ml/m/hr, more particularly about 10 ml/m/hr, and more particularly from about 4 to about 8 ml/m/hr.

Hose 100 can be used in a variety of applications in which it is desirable to transport and/or distribute gas at high pressures. For example, hose 100 can find practical application for use in natural gas transport or distribution, automotive applications, cooling and refrigeration applications, and other applications in which it is desired to have low gas permeability in high pressure applications. Hose 100 generally satisfies a variety of standards for the transportation of high pressure gas, such as, for example, various ASTM and ANSI standards including, for example, ANSI/CSA NGV-3.1 and ANSI/CSA NGV-4.2 for vehicles fueled by natural gas. Use of hose 100 can be especially beneficial in the transport of flammable gasses or gas mixtures such as, for example, natural gas lines and oxygen service lines.

Permeation Testing

In order to verify the advantages of the presently claimed invention, a series of tests were conducted to compare the performance of hose 100 to conventional products. In conducting the tests, a testing apparatus 300 as illustrated in Figure 5 was constructed. Testing apparatus 300

generally comprises a liquid bath 302 including a mounting assembly 304. Mounting assembly 304 generally comprises a lower mounting member 306, a positioning member 308 and a clamp assembly 310 and a graduated cylinder 311. Liquid bath 302 is generally filled with a suitable liquid 312 such as, for example, water. A length of hose 100 has the first end 102 plugged with
5 second end 304 being fluidly coupled to a high pressure gas source. Hose 100 is filled with a pressurized gas 316 and allowed to normalize and come to equilibrium within the liquid bath 302 for a period of at least 72 hours. Using positioning member 308 and hose clamp assembly 310, the graduated cylinder 311 is positioned upside down within the liquid bath 302 below a surface 314 of the liquid 312 such that the graduated cylinder 311 is filled with liquid 312 and is
10 positioned over the hose 100. Amounts of pressurized gas 316 that escape from the filled hose 100 are captured and retained within the graduated cylinder wherein the volume can be measured over a period of time so as to come up with a diffusion rate.

In conducting the testing, three different samples of hose 212 were evaluated. The testing was conducted at ambient temperature (25°C). Hose 212 was filled with pressurized gas 316 at
15 3400 psig. Pressurized gas 316 generally comprised dry nitrogen. Each hose 100 had a length of 0.33 m. The results of the testing were as contained in Table 1 below:

Table 1

Tubing Description	Start Time	Finish Time	Elapsed Time (hours)	Gas Collected (ml)	Permeation Rate (ml/m/hr)
PTFE with 5% Nano Platelets with cb conductive line	8:58	12:05	4.12	6	4.6 ml/m/hr
Post sinter air cooled (PTFE, no nano-platelets)	13:47	16:40	2.88	14	15.4
Highly Crystalline PTFE Oven cooled (PTFE, no nano-platelets)	7:42	10:48	3.10	21	21.7

While a specific embodiment has been described above by way of illustration, it will be appreciated that the described principles are equally applicable to a wide range of popcorn popper products and configurations. More generally, numerous adaptations, modifications, combinations and juxtapositions of the features described above may be made without departing from the principles of the presently disclosed invention.

CLAIMS

1. A high pressure gas hose, comprising:
 - an inner tube; and
 - 5 an outer tube formed of PTFE,
 - wherein the inner tube is formed of a matrix of PTFE and graphene nano-platelets, wherein the matrix is defined continuously through an inner tube wall, and
 - wherein a permeability of the hose is less than about 20 ml/m/hr.
- 10 2. The high pressure gas hose of claim 1, wherein the inner tube wall and an outer tube wall define a hose wall having a hose wall thickness, and wherein an inner tube wall thickness is from about 1 to about 99.9% of the hose wall thickness.
3. The high pressure gas hose of claim 2, wherein the inner tube wall thickness is from
15 about 5 to about 30% of the hose wall thickness.
4. The high pressure gas hose of claim 3, wherein the inner tube wall thickness is about 15% of the hose wall thickness.
- 20 5. The high pressure gas hose of any of the preceding claims, wherein the gas permeability is from about 1 to about 10 ml/m/hr.

6. The high pressure gas hose of claim 5, wherein the gas permeability is from about 4 to about 8 ml/m/hr.

7. The high pressure gas hose of any of the preceding claims, wherein the inner tube
5 comprises a concentration of graphene nano-platelets in a range of about .5 to about 15 percent by weight of the matrix.

8. The high pressure gas hose of claim 7, wherein the concentration of graphene nano-platelets is in a range of about 1 to about 10 percent by weight of the matrix.

10

9. The high pressure gas hose of claim 8, wherein the concentration of graphene nano-platelets is in a range of about 1.5 to about 5 percent by weight of the matrix.

10. A method for making a high pressure gas hose, the method comprising:

15 combining PTFE resin and a concentration of graphene nano-platelets to form a PTFE/graphene nano-platelet resin; and

forming an inner tube of the hose from the PTFE/graphene nano-platelet resin, the inner tube having an inner tube wall thickness; and

forming an outer tube of the hose over the inner tube from a PTFE resin, the outer
20 tube having an outer tube wall thickness.

11. The method of claim 10, wherein the concentration of graphene nano-platelets in a range of about .5 to about 15 percent by weight of the resin.

12. The method of claim 11, wherein the concentration of graphene nano-platelets in a range
5 of about 1 to about 10 percent by weight of the resin.

13. The method of claim 12, wherein the concentration of graphene nano-platelets in a range of about 1.5 to about 5 percent by weight of the resin.

10 14. The method of any of claims 10-13, wherein the inner tube wall thickness and the outer tube wall thickness define a hose wall thickness, and wherein an inner tube wall thickness is from about 1 to about 100% of the hose wall thickness.

15. The method of claim 14, wherein the inner tube wall thickness is from about 5 to about
15 30% of the hose wall thickness.

16. The method of claim 15, wherein inner tube wall thickness is about 15 % of the hose wall thickness.

20 17. The method of any of claims 10-16, wherein forming the inner tube comprises extruding the PTFE/graphene nano-platelet resin.

18. The method of claim 17, wherein forming the outer tube comprises extruding a PTFE resin, and wherein the outer tube and the inner tube are co-extruded simultaneously.

19. The method of any of claims 10-18, wherein a gas permeability of the hose is less than
5 about 20 ml/m/hr.

20. The method of claim 19, wherein the gas permeability is from about 1 to about 10 ml/m/hr.

10 21. The method of claim 20, wherein the gas permeability is from about 4 to about 8 ml/m/hr.

22. The method of any of claims 10-21, further comprising:

coupling a braided jacket to an outer surface of the outer tube, the braided jacket including multiple layers of fiberglass lace, metal wires, yarns, microfilaments, or
15 monofilaments, or combinations thereof.

23. A high pressure gas hose, comprising:

a fluoropolymer tube defining a tube wall, the tube wall including a matrix of fluoropolymer and graphene nano-platelets, wherein the matrix is defined continuously
20 through the tube wall such that the hose has a gas permeability of less than about 20 ml/m/hr.

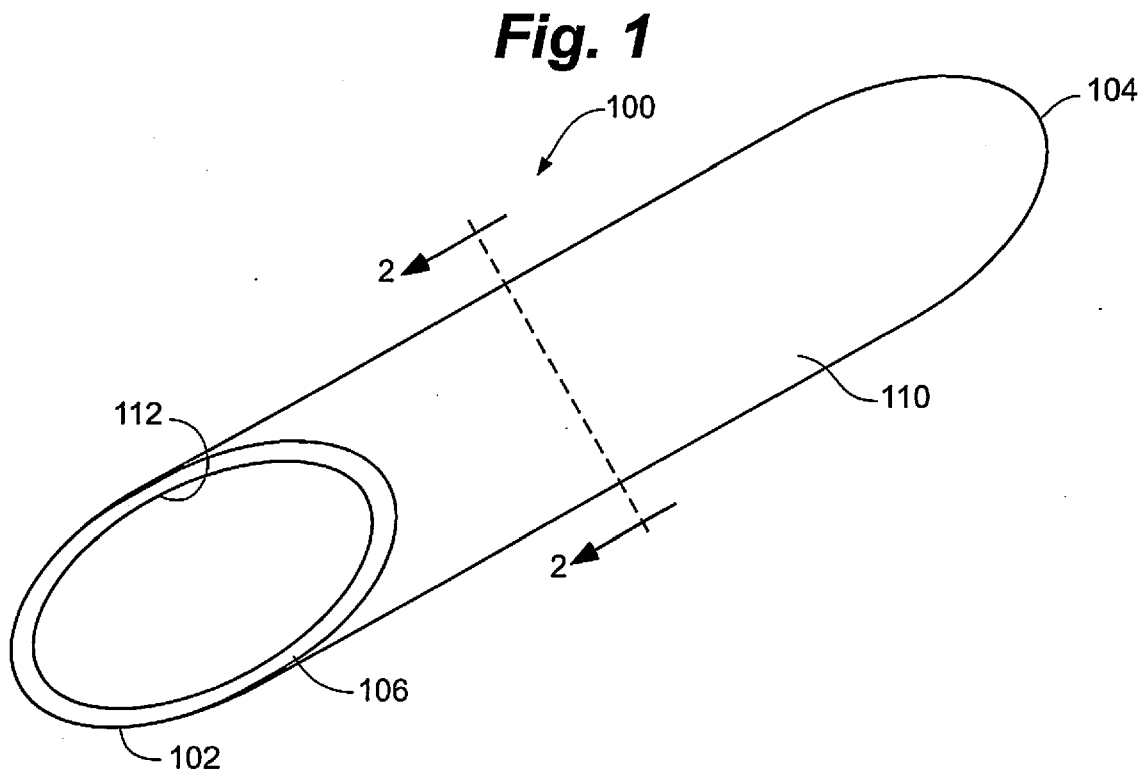


Fig. 2

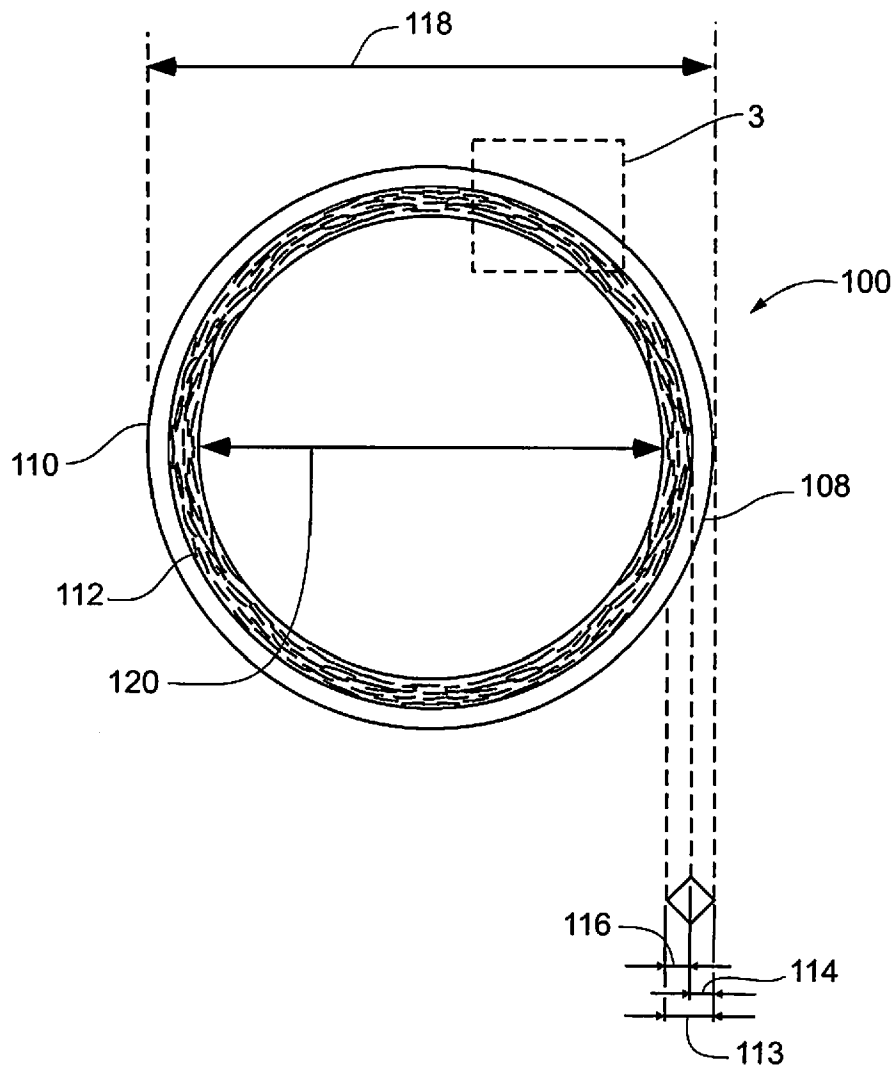


Fig. 3A

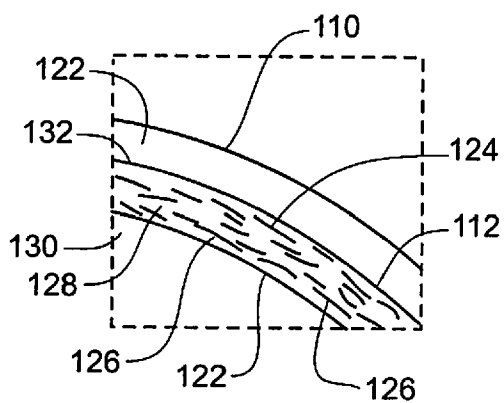


Fig. 3B

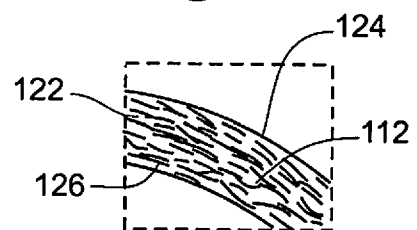


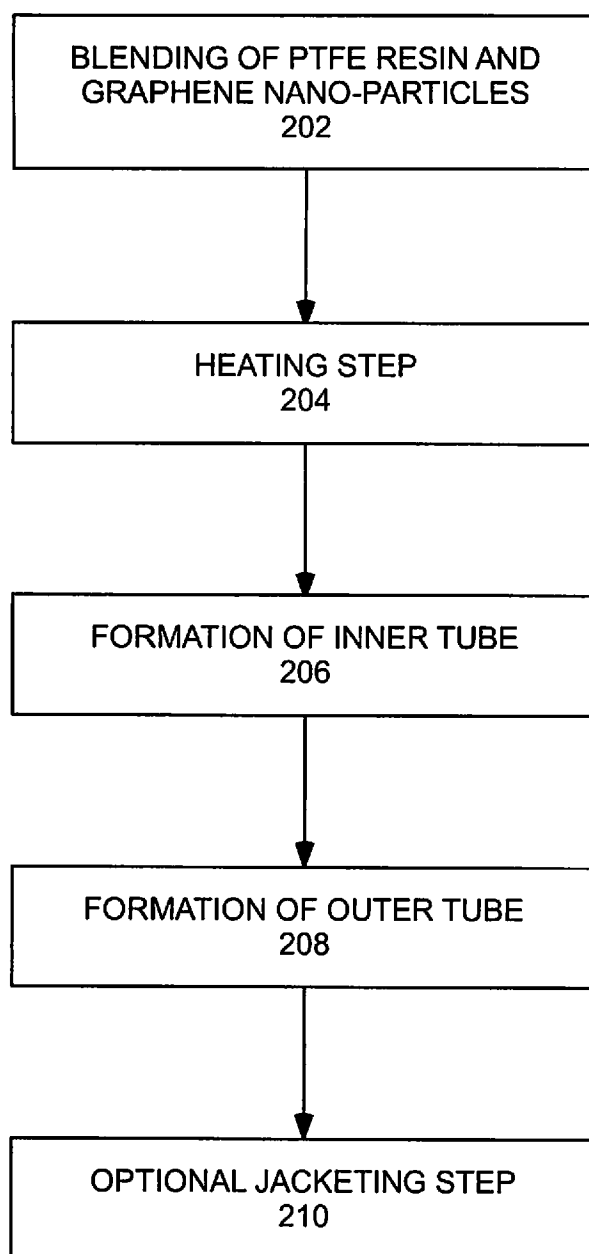
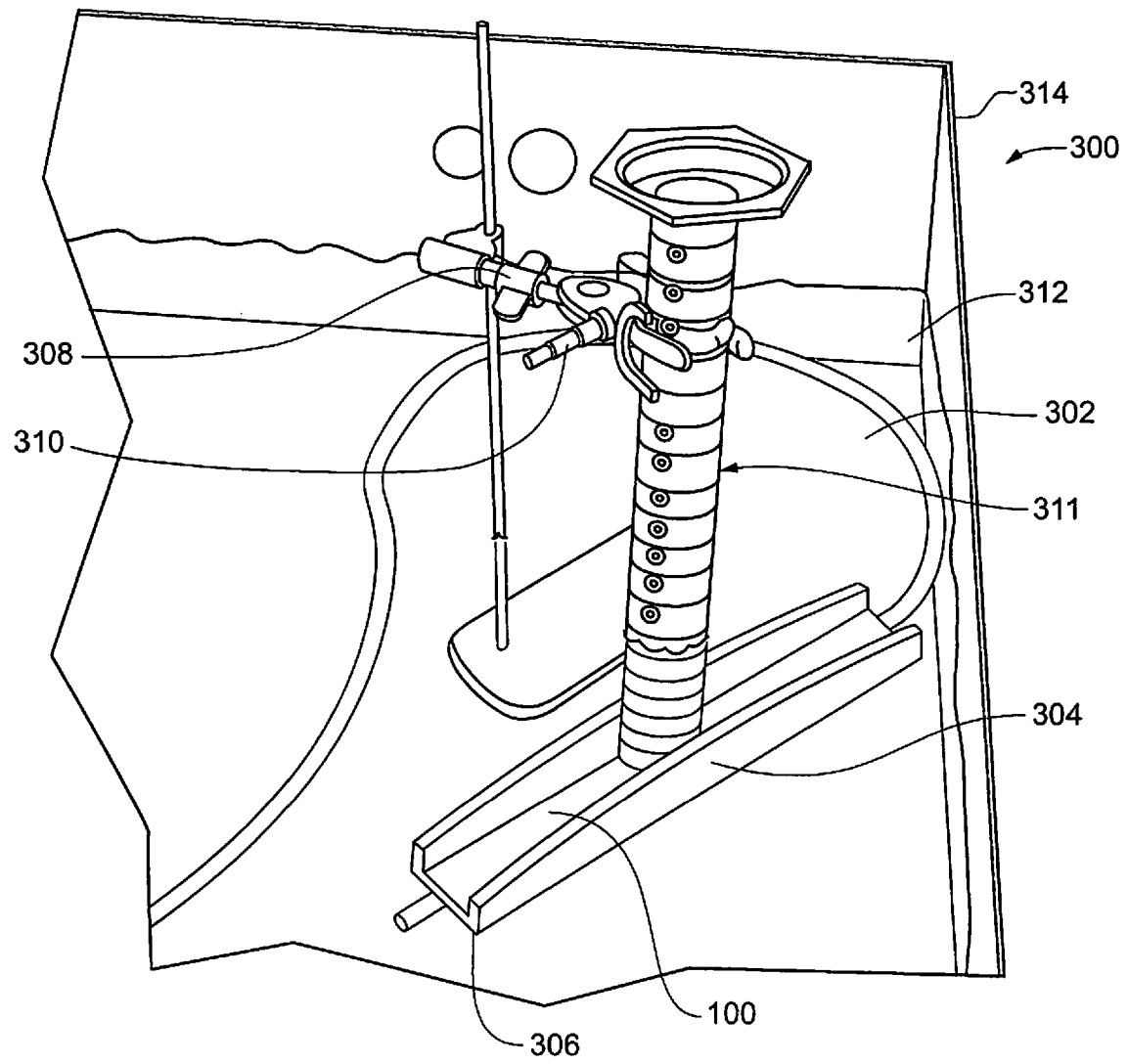
Fig. 4

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/040925**A. CLASSIFICATION OF SUBJECT MATTER****F16L 11/04(2006.01)i, F16L 11/20(2006.01)i**

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)

F16L 11/04; F16L 11/12; B32B 1/08; B29D 7/24; F16L 9/16; F16L 9/14; F16L 11/24; B32B 1/00; F16L 11/00; F16L 11/20

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: gas, hose, fluoropolymer, PTFE, graphene, permeability, inner tube, and jacket

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4478898 A (KATO, HIROSHI) 23 October 1984 See abstract, column 2, lines 15-39, claims 4, 8-9, and figure 1.	10-16
Y		1-6, 23
Y	US 2006-0137757 A1 (MCKEEN et al.) 29 June 2006 See abstract and claims 1-3.	1-6, 23
A	WO 2013-165452 A1 (TITEFLEX COMMERCIAL INC. et al.) 07 November 2013 See abstract, page 4, line 6 - page 5, line 7, and figures 1-2B.	1-6, 10-16, 23
A	EP 1741549 A1 (UBE INDUSTRIES, LTD. et al.) 10 January 2007 See abstract and claims 1-7.	1-6, 10-16, 23
A	US 2008-0302437 A1 (LOVETT et al.) 11 December 2008 See abstract, paragraphs [0023]-[0024], and figure 2A.	1-6, 10-16, 23



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 application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 September 2015 (23.09.2015)

Date of mailing of the international search report

24 September 2015 (24.09.2015)

Name and mailing address of the ISA/KR

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 8-9,18,20-21
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 8-9,18,20-21 are unclear, because they refer to multiple dependent claims which do not comply with PCT Rule 6.4(a). Therefore, claims 8-9, 18, 20-21 do not meet the requirement of PCT Article 6.
3. ☒ Claims Nos.: 7,17,19,22
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

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

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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