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(54) **Title**: MULTI- FIBER, FIBER OPTIC CABLE FURCATION ASSEMBLIES COMPRISING CONSTRAINED OPTICAL FIBERS WITHIN AN OPTICAL FIBER SUB-UNIT

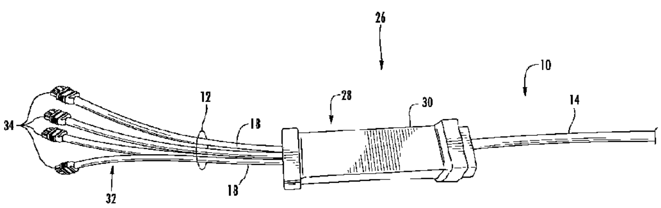

FIG. 3

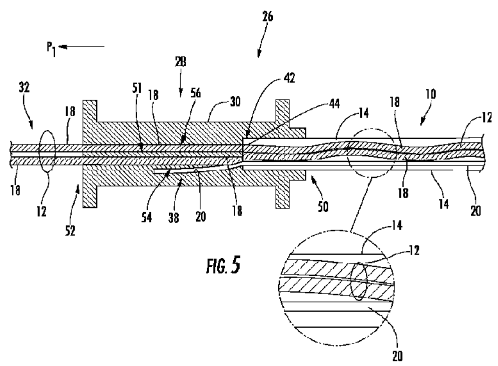

FIG. 5

(57) **Abstract**: Multi-fiber, fiber optic cable assemblies and related fiber optic components, cables, and methods providing constrained optical fibers within an optical fiber sub-unit are disclosed. The optical fiber sub-unit(s) comprises optical fibers disposed adjacent a sub-unit strength member(s) within a sub-unit jacket. Movement of optical fibers within a sub-unit jacket can be constrained. In this manner, the optical fibers in an optical fiber sub-unit can be held together within the optical fiber sub-unit as a unit. As a non-limiting example, the optical fiber sub-unit(s) may be exposed and constrained in a furcation assembly as opposed to the optical fibers, thereby reducing complexity in fiber optic cable assembly preparations. Constraining the optical fibers may also allow optical skew, reduction of entanglement between the optical fibers and the cable strength members to reduce or avoid optical attenuation, and/or allow the optical fibers to act as anti-buckling components within the fiber optic cable.

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MULTI-FIBER, FIBER OPTIC CABLE FURCATION ASSEMBLIES COMPRISING CONSTRAINED OPTICAL FIBERS WITHIN AN OPTICAL FIBER SUB-UNIT

RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. § 120 of U.S. Application Serial No. 13/165,974 filed on June 22, 2011 the content of which is relied upon and incorporated herein by reference in its entirety.

BACKGROUND

Field of the Disclosure

[0002] The technology of the disclosure relates to multi-fiber, fiber optic cables, and related fiber optic components and assemblies.

Technical Background

[0003] Benefits of optical fiber use include extremely wide bandwidth and low noise operation. Because of these advantages, optical fiber is increasingly being used for a variety of applications, including but not limited to broadband voice, video, and data transmission. As a result, fiber optic communications networks include a number of interconnection points at which multiple optical fibers are interconnected. Fiber optic communications networks also include a number of connection terminals, examples of which include, but are not limited to, network access point (NAP) enclosures, aerial closures, below grade closures, pedestals, optical network terminals (ONTs), and network interface devices (NIDs). In certain instances, the connection terminals include connector ports, typically opening through an external wall of the connection terminal. The connection terminals are used to establish optical connections between optical fibers terminated from the distribution cable and respective optical fibers of one or more pre-connectorized drop cables, extended distribution cables, tether cables or branch cables, collectively referred to herein as “drop cables.” The connection terminals are used to readily extend fiber optic communications services to a subscriber. In this regard, fiber optic networks are being developed that deliver “fiber-to-the-curb” (FTTC), “fiber-to-the-business” (FTTB), “fiber-to-the-home” (FTTH) and “fiber-to-the-premises” (FTTP), referred to generically as “FTTx.”

[0004] Use of multi-fiber distribution cables in a fiber optic communications network can present certain challenges. For example, excessive optical skew or delay can cause transmission errors. Optical fibers in multi-fiber distribution cables can be damaged if the cable is subject to excessive bending. To prevent or reduce excessive bending, cable strength members may be disposed within a cable jacket of the fiber optic cable along with the optical fibers. However, the optical fibers may engage and become entangled with the strength members thereby bending the optical fibers inside the cable jacket and attenuating the optical signals carried on the optical fibers. Further, a terminated end of the distribution cable often times must be pulled to a desired location during installation, such as to a connection terminal (e.g., a fiber distribution hub (FDH)) or to another distribution cable, through relatively small diameter conduits. Accordingly, a terminated end of the distribution cable can be provided within a pulling grip. When pulled, the pulling grip is capable of transferring a tensile load (e.g., a pulling load) to the cable jacket and/or strength members of the fiber optic cable. However, a portion of the pulling load may be transferred to the optical fibers within the fiber optic cable. Transferring excessive load to optical fibers disposed in a fiber optic cable can damage the optical fibers.

SUMMARY OF THE DETAILED DESCRIPTION

[0005] Embodiments disclosed in the detailed description include multi-fiber, fiber optic cables providing constrained optical fibers within an optical fiber sub-unit disposed in a cable jacket. Related fiber optic components and fiber optic assemblies are also disclosed. In one embodiment, one or more optical fiber sub-units can be provided that each comprises a plurality of optical fibers disposed adjacent one or more sub-unit strength members within a sub-unit jacket. Movement of optical fibers within a sub-unit jacket is constrained by an interior wall of the sub-unit jacket and/or the sub-unit strength members disposed in the sub-unit jacket. In this manner as a non-limiting example, optical fibers disposed in an optical fiber sub-unit can be held together as a unit within the optical fiber sub-unit. By providing the optical fibers constrained as a unit in optical fiber sub-units, the optical fiber sub-units may be constrained in a furcation assembly without having to expose the optical fibers within the optical fiber sub-units, thereby reducing complexity in fiber optic cable assembly preparations. Avoiding exposing optical fibers in a furcation assembly may also reduce the risk of damaging the optical fibers during furcation assembly preparations. Constraining the optical fibers within the optical fiber sub-units may also, as non-limiting examples, provide low optical skew, may reduce or eliminate entanglement between the optical fibers and the cable strength members to reduce or avoid optical attenuation, and/or may allow the optical fibers to act as anti-buckling components within the fiber optic cable.

[0006] As one non-limiting option, the optical fiber sub-units may be disposed adjacent to the cable strength members within the cable jacket in a manner that allows movement between the optical fiber sub-units and the cable strength members within the cable jacket. In this manner, the one or more optical fiber sub-units can freely move within the cable jacket in this embodiment. As a result in one non-limiting example, entanglements between the cable strength member and the optical fiber sub-units that may cause optical attenuation or broken fibers may be avoided. Stranding can cause a bend to be disposed in the optical fiber sub-units thereby attenuating optical signals carried by the optical fibers in the optical fiber sub-units.

[0007] In this regard in one embodiment, a fiber optic cable assembly is disclosed. This fiber optic cable assembly comprises a fiber optic cable comprising a cable jacket, one or more cable strength members disposed within the cable jacket, and one or more optical fiber sub-units disposed within the cable jacket. This fiber optic cable assembly also comprises an end portion of the fiber optic cable comprising end portions of optical fiber sub-units and end portions of the cable strength members both exposed from an end portion of the cable jacket. This fiber optic cable assembly also comprises a furcation assembly receiving the end portion of the fiber optic cable at a first end of the furcation assembly. The furcation assembly terminates the end portion of the cable jacket and the end portions of the cable strength members. The end portions of the optical fiber sub-units extending through and from a second end of the furcation assembly. Additionally, each of the optical fiber sub-units may comprise a plurality of optical fibers and one or more sub-unit strength members disposed adjacent to each other in a sub-unit jacket. In this regard, movement of the optical fibers within the sub-unit jacket is constrained by an interior wall of the sub-unit jacket and the sub-unit strength members.

[0008] In this embodiment, the one or more cable strength members are disposed within the cable jacket in a first length, and the one or more optical fiber sub-units are disposed within the cable jacket in a second length, the second length greater than the first length. In this manner as a non-limiting example, a tensile load (e.g., a pulling load) placed on the furcation assembly is directed more to the one or more cable strength members to avoid or reduce stress placed on the optical fibers. As a non-limiting option in this embodiment, the optical fiber sub-units are disposed adjacent to the cable strength members within the cable jacket that allows movement between the one or more optical fiber sub-units and the one or more cable strength members within the cable jacket. As another non-limiting example, the optical fiber sub-units can include tight buffered optical fibers that are disposed adjacent to strength members disposed within the sub-unit jackets, wherein movement between is allowed between the optical fiber sub-units and the one or more cable strength members within the cable jacket of the fiber optic cable.

[0009] In another embodiment, a method of assembling a fiber optic cable is disclosed. This method comprises disposing one or more cable strength members within a cable jacket of a fiber optic cable in a first length. This method also comprises disposing one or more optical fiber sub-units within the cable jacket in a second length, the second length greater than the first length. This method also comprises exposing end portions of the one or more optical fiber sub-units and end portions of the one or more cable strength members from an end portion of the cable jacket. This method also comprises receiving the end portion of the fiber optic cable at a first end of a furcation assembly. This method also comprises terminating the end portion of the cable jacket and the end portions of the one or more cable strength members in the furcation assembly.

[0010] In another embodiment, a fiber optic cable is disclosed. This fiber optic cable comprises a cable jacket. This fiber optic cable also comprises one or more cable strength members disposed within the cable jacket in a first length. This fiber optic cable also comprises one or more optical fiber sub-units disposed within the cable jacket in a second length, the second length greater than the first length. Each of the optical fiber sub-units comprises a plurality of optical fibers and one or more sub-unit strength members disposed adjacent to each other in a sub-unit jacket. In this regard, movement of the optical fibers within the sub-unit jacket is radially constrained by an interior wall of the sub-unit jacket and the sub-unit strength members, and the plurality of optical fibers are in friction contact with the one or more sub-unit strength members constraining relative longitudinal movement of the plurality of optical fibers within the sub-unit jacket. The optical fiber sub-units are disposed adjacent to the cable strength members within the cable jacket. The one or more optical fiber sub-units are disposed within the cable jacket adjacent to the one or more cable strength members to allow movement between the one or more optical fiber sub-units and the one or more cable strength members within the cable.

[0011] In any of the embodiments disclosed herein, the optical fiber sub-units can be tight buffered optical fibers without the inclusion of strength members provided within the optical fiber-subunit(s), if desired.

[0012] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments as described herein, including the detailed description that follows, the claims, as well as the appended drawings.

[0013] It is to be understood that both the foregoing general description and the following detailed description present embodiments, and are intended to provide an overview or framework for understanding the nature and character of the disclosure. The accompanying drawings are included to provide a further understanding, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments, and together with the description serve to explain the principles and operation of the concepts disclosed.

BRIEF DESCRIPTION OF THE FIGURES

[0014] **FIG. 1** is an end view of a cross-section of an exemplary multi-fiber, fiber optic cable comprised of a plurality of optical fiber sub-units disposed within a cable jacket, each of the plurality of optical fiber sub-units comprising a plurality of optical fibers and one or more sub-unit strength members disposed in a sub-unit jacket;

[0015] **FIG. 2** is an end view of a cross-section of one optical fiber sub-unit disposed inside the cable jacket of the fiber optic cable in **FIG. 1**;

[0016] **FIG. 3** is a top perspective view of an exemplary fiber optic cable assembly comprised of a portion of end portions of the optical fiber sub-units (“optical fiber sub-unit end portions”) and a portion of end portions of cable strength member(s) (“cable strength member end portion(s)”) exposed from the cable jacket of an end portion of the fiber optic cable of **FIG. 1** secured inside a furcation plug of a furcation assembly;

[0017] **FIG. 4** illustrates an end portion of the fiber optic cable in **FIG. 1** cut to a desired length with a portion of an end portion of the cable jacket removed to expose the optical fiber sub-unit end portions and cable strength member end portions from the end portion of the cable jacket to prepare for providing the furcation assembly, including the furcation plug in **FIG. 3**;

[0018] **FIG. 5** is a schematic side view of a cross-section of the fiber optic cable assembly in **FIG. 3** illustrating the optical fiber sub-units disposed in the cable jacket of the fiber optic cable adjacent to the one or more cable strength members to allow movement between the one or more optical fiber sub-units and the one or more cable strength members within the cable jacket;

[0019] **FIG. 6** is a schematic side view of a cross-section of the fiber optic cable assembly of **FIG. 3** illustrating an optional exemplary strain relief member and optional exemplary spiral-wound tubing securing the optical fiber sub-units;

[0020] **FIG. 7** is a top perspective view of the fiber optic cable assembly in **FIG. 3**, wherein the furcation plug is arranged to be enclosed with an exemplary pulling grip sub-assembly for pulling the fiber optic cable;

[0021] **FIG. 8** illustrates the fiber optic cable assembly in **FIG. 7** with the furcation plug enclosed in the pulling grip sub-assembly and enclosed in an exemplary pulling bag for pulling the fiber optic cable;

[0022] **FIG. 9** is a top perspective view of the fiber optic cable assembly of **FIG. 3** with an alternative exemplary furcation plug;

[0023] **FIG. 10A** illustrates an alternative fiber optic cable assembly comprised of optical fiber sub-unit end portions and cable strength member end portion(s) exposed from the cable jacket of an end portion of the fiber optic cable of **FIG. 1**, wherein a cable strength member pulling loop is formed from disposing and securing a loop disposed in the cable strength member end portion on the cable jacket;

[0024] **FIG. 10B** illustrates the fiber optic cable assembly in **FIG. 10A** with the cable strength member pulling loop fully assembled;

[0025] **FIG. 11** illustrates the fiber optic cable assembly in **FIGS. 10A** and **10B**, wherein the cable strength member pulling loop is not disposed in a strength member tube;

[0026] **FIG. 12** illustrates an alternate exemplary fiber optic cable assembly comprised of a cable strength member pulling loop formed by disposing the cable strength member end portion through first and second heat shrink tubes and looping the end of the cable strength member end portion back through the first heat shrink tube adjacent to the cable jacket;

[0027] **FIG. 13** illustrates the cable strength member pulling loop of the fiber optic cable assembly in **FIG. 12** with the exposed cable strength member end portion trimmed and fanned around the cable jacket of the fiber optic cable;

[0028] **FIG. 14** illustrates disposing a cable jacket heat shrink tube over the cable strength member pulling loop in the fiber optic cable assembly in **FIG. 13** to form an exemplary cable strength member pulling loop; and

[0029] **FIG. 15** illustrates the cable strength member pulling loop in the fiber optic cable assembly in **FIG. 14** after exposing the cable jacket heat shrink tube to secure the cable strength member pulling loop to the cable jacket.

DETAILED DESCRIPTION

[0030] Reference will now be made in detail to the embodiments, examples of which are illustrated in the accompanying drawings, in which some, but not all embodiments are shown. Indeed, the concepts may be embodied in many different forms and should not be construed as limiting herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Whenever possible, like reference numbers will be used to refer to like components or parts.

[0031] Embodiments disclosed in the detailed description include multi-fiber, fiber optic cables providing constrained optical fibers within an optical fiber sub-unit disposed in a cable jacket. Related fiber optic components and fiber optic assemblies are also disclosed. In one embodiment, one or more optical fiber sub-units can be provided that each comprises a plurality of optical fibers disposed adjacent one or more sub-unit strength members within a sub-unit jacket. Movement of optical fibers within a sub-unit jacket is constrained by an interior wall of the sub-unit jacket and/or the sub-unit strength members disposed in the sub-unit jacket. In this manner as a non-limiting example, optical fibers disposed in an optical fiber sub-unit can be held together as a unit within the optical fiber sub-unit. By providing the optical fibers constrained as a unit in optical fiber sub-units, the optical fiber sub-units may be constrained in a furcation assembly without having to expose the optical fibers within the optical fiber sub-units, thereby reducing complexity in fiber optic cable assembly preparations. Avoiding exposing optical fibers in a furcation assembly may also reduce the risk of damaging the optical fibers during furcation assembly preparations. Constraining the optical fibers within the optical fiber sub-units may also, as non-limiting examples, provide low optical skew, may reduce or eliminate entanglement between the optical fibers and the cable strength members to reduce or avoid optical attenuation, and/or may allow the optical fibers to act as anti-buckling components within the fiber optic cable.

[0032] In this regard, **FIG. 1** is an end view of a cross-section of one exemplary multi-fiber, fiber optic cable **10**. The fiber optic cable **10** may be used as a distribution cable or drop cable as non-limiting examples. With continuing reference to **FIG. 1**, the fiber optic cable **10** is comprised of a plurality of optical fiber sub-units **12** disposed longitudinally within a cable jacket **14**. **FIG. 2** is an end view of a cross-section of one optical fiber sub-unit **12** disposed inside the cable jacket **14** of the fiber optic cable **10** in **FIG. 1**. With reference back to **FIG. 1**, the plurality of optical fiber sub-units **12** are disposed in the cable jacket **14**, but only one optical fiber sub-unit **12** could be disposed in the cable jacket **14** if desired as well. Each optical fiber sub-unit **12** disposed in the cable jacket **14** of the fiber optic cable **10** in this embodiment includes a plurality of optical fibers **16** disposed within a sub-unit jacket **18**. The optical fibers **16** may be buffered or not buffered. As a non-limiting example, twelve (12) optical fibers **16** may be disposed within each sub-unit jacket **18** of each optical fiber sub-unit **12** to provide multi-fibered optical fiber sub-units **12**. Any number of the optical fibers **16** may be disposed in each optical fiber sub-unit **12**. Further, different optical fiber sub-units **12** may contain different counts of optical fibers **16**, if desired. As will be discussed in more detail below, end portions of the optical fibers **16** may be connectorized or pre-connectorized with fiber optic connectors for establishing fiber optic connections with the optical fibers **16** in the fiber optic cable **10**.

[0033] With continuing reference to **FIG. 1**, a cable strength member **20** is also disposed longitudinally inside the cable jacket **14** adjacent to the optical fiber sub-units **12**. The cable strength member **20** provides strength support in the fiber optic cable **10** to resist excessive elongation to prevent or reduce the risk of damage to the optical fibers **16** and/or to reduce or avoid optical attenuation. One or more cable strength members **20** may be disposed inside the cable jacket **14**. As a non-limiting example, the cable strength member **20** may be provided as one or more tensile yarns. As another non-limiting example, the cable strength member **20** may be manufactured from aramid, such as Kevlar®. Other examples of materials that may be employed for the cable strength member **20** include, but are not limited to fiberglass, ultra high molecular weight polyethylene (UHMWPE) such as Dyneema® for example, paraaramid copolymers such as Technora® for example, or other such tensile yarns.

[0034] With continuing reference to **FIG. 1**, in this embodiment, the optical fiber sub-units **12** are optionally loosely disposed in the cable jacket **14** adjacent to the cable strength member **20**. In this manner, the optical fiber sub-units **12** can move between each other and with respect to the cable strength member **20** and the cable jacket **14**. In one embodiment, the optical fiber sub-units **12** may be exposed from the cable jacket **14** to provide furcation legs from the fiber optic cable **10**. Disposing the optical fiber sub-units **12** loosely in the cable jacket **14** can allow for a furcation assembly that directs a tensile load (e.g., a pulling load) primarily to the cable strength member **20** and/or the cable jacket **14** as opposed to the optical fiber sub-units **12** to protect the optical fibers **16** from damage. As another non-limiting example, disposing the optical fiber sub-units **12** loosely within the cable jacket **14** may also avoid the need for stranding between the optical fiber sub-units **12** and the cable strength member **20**, which can reduce manufacturing complexity. Stranding may also cause the cable strength members **20** to be longer than the optical fiber sub-units **12** such that tensile loads applied to the fiber optic cable **10** are firstly or primarily borne by the optical fiber sub-units **12** and then secondly or secondarily by the cable strength member **20**. The cable strength member **20**

may also be disposed loosely within the cable jacket **14** to allow further freedom of relative movement between the optical fiber sub-units **12** and the cable strength member **20** within the cable jacket **14**.

[0035] With continuing reference to **FIG. 1**, an inner diameter **ID_1** of the cable jacket **14** may be greater than an outer diameter **OD_1** of the collective grouping of the optical fiber sub-units **12** and cable strength member **20** disposed inside the cable jacket **14** to allow relative freedom of movement between the optical fiber sub-units **12**, and the cable strength member **20** and/or the cable jacket **14**. As one non-limiting example, the inner diameter **ID_1** of the cable jacket **14** may be 3.0 mm to 12.5 mm depending on the number optical fiber sub-units **12** included in the fiber optic cable **10**. As other non-limiting examples, as illustrated in **FIG. 2**, an outer diameter **OD_2** of the optical fiber sub-unit **12** may be less than 3.1 millimeters (mm), and may be 3.0 mm, 2.0 mm, or 1.6 mm as examples. As another non-limiting example, the inner diameter **ID_1** of the cable jacket **14** may be at least 0.5 mm greater than the collective outer diameter **OD_1** of the optical fiber sub-units **12** and cable strength member **20**.

[0036] With reference back to **FIG. 1**, the optical fiber sub-units **12** may be disposed loosely inside the cable jacket **14** over the entire longitudinal length of the fiber optic cable **10**. Alternatively or in addition, the optical fiber sub-units **12** may be disposed at an end portion of the fiber optic cable **10**. If the optical fiber sub-units **12** are disposed loosely over the entire longitudinal length of the fiber optic cable **10**, this disposition may be accomplished during manufacturing of the fiber optic cable **10**. If the optical fiber sub-units **12** are disposed loosely at an end portion of the fiber optic cable **10**, this disposition may be accomplished post manufacturing of the fiber optic cable **10**. Examples of these techniques will be discussed in more detail below.

[0037] With continuing reference to **FIGS. 1** and **2**, the optical fiber sub-units **12** disposed in the fiber optic cable **10** also have the feature of constraining movement of the optical fibers **16** disposed therein. In this regard with reference to **FIG. 2**, the optical fibers **16** are disposed within the sub-unit jacket **18** of the optical fiber sub-unit **12**. One or more sub-unit strength members **22** are also disposed within the sub-unit jacket **18** adjacent the optical fibers **16**. The sub-unit strength members **22** may be manufactured from the same or different material than the cable strength member **20**. Also, the optical fibers **16** could be tight buffered within the sub-unit jackets **18** either adjacent to one or more sub-unit strength members **22** also provide within a sub-unit jacket **18** or in a sub-unit jacket **18** that does not include the sub-unit strength member **22**.

[0038] The quantity of strength members can be described by axial rigidity, which is the modulus of elasticity times the cross sectional area of a material. For a composite material such as a cable, the axial rigidity is the sum of the axial rigidity of the individual elements of the cable. For each component of a cable, the axial rigidity can be the load bearing area times the modulus of elasticity for the material. In this regard with reference to **FIG. 1**, the total axial rigidity of the fiber optic cable **10** may be the sum of the axial rigidity of the optical fiber sub-units **12**, the cable strength members **20**, the cable jacket **14**, and any other components of the fiber optic cable **10**. Likewise, the axial rigidity of each of the optical fiber sub-units **12** would be the sum of the axial rigidity of the sub-unit strength members **22**, the sub-unit jacket **18**, and any other components of the optical fiber sub-unit **12**. The total axial rigidity of the optical fiber sub-units **12** would be the sum of the axial rigidity of all the individual optical fiber sub-units **12**. In one embodiment, the strength of the optical fibers **16** is not included in the total axial rigidity of each of the optical fiber sub-units **12**, because the fiber optic cable **10** is designed to reduce the strain on the optical fibers **16**. In another embodiment, the strength of the optical fibers **16** can be included in the total axial rigidity of each of the optical fiber sub-units **12**. Further, the axial rigidity of the cable jacket **14** and the sub-unit jackets **18** as well as any fiber coatings on the optical fibers **16** may be insignificant enough to be ignored in an axial rigidity calculation.

[0039] As a non-limiting example, axial rigidity may be calculated as follows:

$$Axial\_Rigidity = \sum_i E_i A_i \text{, where:}$$

E_i is the elastic modulus of material i; and

A_i is the load bearing area of component i.

[0040] As an example, for a 380 grams denier (i.e., gram weight for 9000 meters) aramid yarn strength member, the sum of EA may be 3.33 kiloNewtons (kN). For a 1420 grams denier aramid yarn strength member, the EA may be 12.63 kN. In one embodiment, each optical fiber sub-units **12** may have four (4) 380 grams denier aramid yarns strength members **22**, providing for the total axial rigidity (i.e., ∑ EA) of the sub-unit strength members **22** to be 4 x 3.33 kN = 13.32 kN. The amount of cable strength member **20** provided in the fiber optic cable **10** located outside the sub-unit jackets **18** may vary based on the total optical fiber **16** count provided in the fiber optic cable **10**. The following table provides exemplary calculations for the axial rigidity of cable strength members **20** and the sub-unit strength members **22** of various possible fiber optic cable **10** designs in accordance with embodiments disclosed herein.

Fiber optic cable (10)	Number of optical fiber sub-units (12)	Sum of optical fiber sub-unit (12) EA	Number of 1420 grams denier aramid yarns (200 outside optical fiber sub-units (12)	EA outside optical fiber sub-units (12)	Total EA	% total EA in one optical fiber sub-unit (12)	% total EA in all optical fiber sub-units (12)
12 f	1	13.3	8	101.0	114.4	11.6%	12%
24 f	2	26.6	12	151.6	178.2	7.5%	15%
48 f	4	53.3	12	151.6	204.8	6.5%	26%
72 f	6	79.9	16	202.1	282.0	4.7%	28%
96 f	8	106.6	16	202.1	308.6	4.3%	35%
144 f	12	159.8	16	202.1	361.9	3.7%	44%

[0041] The same non-limiting examples provided above with regard to the cable strength member **20** are also applicable as non-limiting examples for the sub-unit strength members **22**. As additional non-limiting examples, the axial rigidity of each of the optical fiber sub-units **12** can be less than fifteen percent (15%) of the total axial rigidity of the one or more cable strength members **20** and the sub-unit strength members **22** of the fiber optic cable **10**. The combined axial rigidity of all of the sub-unit strength members **22** of the optical fiber sub-units **12** can be less than fifty percent (50%) of the total axial rigidity of the cable strength members **20** and the sub-unit strength members **22** of the fiber optic cable **10**.

[0042] With continuing reference to **FIG. 2**, the sub-unit strength members **22** are disposed longitudinally adjacent to the optical fibers **16** along the length of the optical fiber sub-units **12**. The optical fibers **16** are disposed inside the sub-unit jacket **18** such that movement of the optical fibers **16** is contained by an interior wall **24** of the sub-unit jacket **18** and/or the sub-unit strength members **22**. The optical fibers **16** may be constrained by friction themselves, which constrains the relative longitudinal movement of the optical fibers **16** relative to each other. For example, the group of optical fibers **16** inside each sub-unit jacket **18** may have an effective diameter of 1.0 mm inside a 1.4 mm inner diameter sub-unit jacket **18**. The sub-unit strength members **22** may be about 0.1 mm in thickness as an example. Thus, the optical fiber **16** to optical fiber **16** contact is provided by the limited free space within the optical fiber sub-unit **12** that enables the friction between the optical fibers **16** to limit relative longitudinal movement between the optical fibers **16**. The ability to produce low skew optical fiber sub-units **12** can be determined in the ability to limit the relative longitudinal movement of the individual optical fibers **16** within an optical fiber sub-unit **12**.

[0043] Constraining the optical fibers **16** within the optical fiber sub-units **12** may allow the optical fibers **16** disposed within a given optical fiber sub-unit **12** to be held together as a unit within the optical fiber sub-unit **12**. As will be discussed in more detail below, by providing the optical fibers constrained as a unit in optical fiber sub-units, the optical fiber sub-units may be exposed and constrained in a furcation assembly without exposing the optical fibers contained in the optical fiber sub-units. This feature may reduce complexity and labor costs in furcation assembly preparations. Further, the optical fibers may be subjected to less risk of damage if not exposed in a furcation assembly.

[0044] Constraining the optical fibers **16** within the optical fiber sub-units **12** may also provide low optical skew of the fiber optic cable **10** acting as a parallel optic system with multiple optical fibers **16** disposed in each optical fiber sub-unit **12**. As non-limiting examples, constraining the optical fibers **16** in the optical fiber sub-units **12** may provide an optical skew less than 6.1 picoseconds (ps) per meter (m) (ps/m). As another non-limiting example, constraining the optical fibers **16** in the optical fiber sub-units **12** may provide an optical skew less than 3.6 ps/m. As non-limiting examples, constraining the optical fibers **16** in the optical fiber sub-units **12** may also allow the optical fibers **16** within each optical fiber sub-unit **12** to act as anti-buckling components within the fiber optic cable **10** to resist bending and avoid optical attenuation that would result from such bending.

[0045] The fiber optic cable **10** in **FIG. 1** can be furcated to expose the optical fiber sub-units as furcation legs for connecting the optical fibers to other connectors, adapters, or fiber optic equipment. In this regard, **FIG. 3** illustrates a top perspective view of an exemplary fiber optic cable assembly **26** that includes the fiber optic cable **10** in **FIG. 1**. As illustrated in **FIG. 3**, the fiber optic cable assembly **26** includes a furcation assembly **28**. In this embodiment, the furcation assembly **28** is a furcation plug **30**, but the furcation assembly **28** may be comprised of alternative furcation assemblies as will be discussed in more detail below. End portions **32** of the optical fiber sub-units **12** extend from the furcation plug **30** to provide furcated legs. The optical fiber sub-units **12** can provide furcated legs without the need for additional furcation tubing. The optical fiber sub-units **12** in this embodiment do not have preferential bend. As a non-limiting example, this may allow the optical fiber sub-units **12** acting as furcated legs to be about 2.0 mm to 3.0 mm in outer diameter, which may reduce congestion of furcated legs in fiber optic equipment. The end portions **32** of the optical fiber sub-units **12** are connectorized with fiber optic connectors **34** to provide connection access to the optical fibers **16** contained in the optical fiber sub-units **12**. For example, the fiber optic connectors may be multi-fiber termination push-on (MTP) style fiber optic connectors, but other fiber optic connector types are also possible, including but not limited to SC, FC, LC, ST, and duplex connectors.

[0046] As will be discussed in more detail below, providing the optical fibers **16** constrained in the optical fiber sub-units **12** while providing for movement of the optical fiber sub-units **12** within the cable jacket **14** relative to the cable jacket **14** and/or the cable strength member **20** can provide certain non-limiting advantages. One advantage includes the furcation assembly **28** directing tensile load (e.g., a pulling load) away from the optical fibers **16** and to the cable jacket **14** and/or the cable strength member **20**. Another advantage includes not having to expose the optical fibers **16** from within the sub-unit jacket **18** in the furcation assembly **28** to secure the optical fibers **16** therein. Because the optical fibers **16** are constrained within the sub-unit jacket **18**, constraining of the sub-unit jackets **18** can provide sufficient securing of the optical fibers **16** in the furcation assembly **28**. The process of exposing optical fibers **16** within a sub-unit jacket **18** can be more costly in terms of time and labor costs than the ability to secure the sub-unit jackets **18** in the furcation assembly **28** without having to expose the optical fibers **16**.

[0047] Prior to providing the furcation assembly **28** in **FIG. 3**, the fiber optic cable **10** undergoes certain preparations. In this regard, **FIG. 4** is provided. **FIG. 4** illustrates an end portion **36** of the fiber optic cable **10** in **FIG. 1**. The end portion **36** of the fiber optic cable **10** is cut to a desired length. Thereafter, a portion of the cable jacket **14** is windowed or removed to expose end portions **32** of the optical fiber sub-units **12** and an end portion **38** of the cable strength member **20**. As a result, a transition interface **42** is provided between an end **44** of the cable jacket **14** and the optical fiber sub-units **12** and cable strength member **20**. The end portion **38** of the cable strength member **20** may be optionally twisted, as illustrated in **FIG. 4**, prior to preparing a furcation assembly in the end portion **36** of the fiber optic cable **10** to enhance the strength of the cable strength member **20** when disposed in a furcation assembly. To retain the twist in the end portion **38** of the cable strength member **20**, tape **48** or other securing means may be disposed around an end **46** of the cable strength member **20**.

[0048] **FIG. 5** is a side view of a cross-section of the fiber optic cable assembly **26** in **FIG. 3** illustrating the optical fiber sub-units **12** and cable strength member **20** disposed in the furcation plug **30** to provide the furcation assembly **28**. The end portions **32** of the optical fiber sub-units **12** are disposed through a first end **50** of the furcation plug **30**, into an interior chamber **51** of the furcation plug **30**, and extend out from a second end **52** of the furcation plug **30**. Note that optical fibers **16** are not exposed from the optical fiber sub-units **12** in the interior chamber **51** of the furcation plug **30**, because the optical fibers **16** are constrained in the sub-unit jackets **18**. The end portion **38** of the cable strength member **20** is also disposed through the first end **50** of the furcation plug **30**.

[0049] With continuing reference to **FIG. 5**, the cable strength member **20** is cut so that an end **54** of the cable strength member **20** does not extend through the second end **52** of the furcation plug. The end **54** of the cable strength member **20** is retained inside the interior chamber **51** of the furcation plug **30**. The end **44** of the cable jacket **14** is terminated inside the interior chamber **51** of the furcation plug **30**. A potting compound or epoxy **56** can be disposed in the interior chamber **51** of the furcation plug **30** to secure the portion of end portion **38** of the cable strength member **20** and portions of the end portion **32** of the optical fiber sub-units **12** in the furcation plug **30**. In this manner, when a tensile or tensile load (e.g., a pulling load) $\mathbf{P_1}$ is placed on the furcation plug **30**, the tensile load $\mathbf{P_1}$ can be translated to the cable strength member **20** and/or cable jacket **14** secured inside the interior chamber **51** of the furcation plug **30**.

[0050] **FIG. 6** illustrates the fiber optic cable assembly **26** of **FIG. 5**, but an optional strain relief device **60** and cable wrap **62** are provided. The strain relief device **60** interfaces between the cable jacket **14** and the first end **50** of the furcation plug **30** to provide strain relief when the cable jacket **14** is bent about the furcation plug **30**. The strain relief device **60** may be a boot, and may be a separate or integral component to the furcation plug **30**. The cable wrap **62** may be disposed around the optical fiber sub-unit **12** to group the optical fiber sub-units **12** together extending from the second end **52** of the furcation plug **30**. An end **64** of the cable wrap **62** may be secured inside the furcating plug **30**.

[0051] To further improve the pulling characteristics of the furcation assembly **28** in **FIGS. 5** and **6** to direct tensile load (e.g., a pulling load) away from the optical fibers **16**, the features of the fiber optic cable **10** can be employed. Specifically, the end portion **38** of the cable strength member **20** can be pulled taut prior to securing the end portion **38** in the furcation plug **30**, as illustrated in **FIG. 5**. Because the optical fiber sub-units **12** can be loosely disposed in the cable jacket **14** of the fiber optic cable **10**, the length of the optical fiber sub-units **12** with the cable jacket **14** can be made longer than the length of the cable strength member **20**. The length of the cable strength member **20** is greater than the length of the optical fiber sub-units **12** in the cross-section of the cable jacket **14** adjacent to the transition interface **42** in this embodiment. The length of the cable strength member **20** can also be greater than the length of the optical fiber sub-units **12** in the cross-section of the cable jacket **14** in any portion of the fiber optic cable **10** if the optical fiber sub-units **12** are provided longer than the cable strength member **20** over the entire length of the fiber optic cable **10** during manufacturing of the fiber optic cable **10**.

[0052] As one non-limiting example, the relative longitudinal movement of the optical fiber sub-units **12** within the end **44** of the cable jacket **14** can be greater than four (4) mm. In another non-limiting example, the relative longitudinal movement of the optical fiber sub-units **12** within the end **44** of the cable jacket **14** can be greater than ten

(10) mm. In this regard, when the tensile load (e.g., a pulling load) $\mathbf{P_1}$ is placed on the furcation plug **30**, the tensile load $\mathbf{P_1}$ is directed primarily to the taut cable strength member **20** as opposed to primarily the optical fiber sub-units **12** and optical fibers **16** disposed therein. The cable strength member **20** will carry the bulk of the tensile load $\mathbf{P_1}$ while directing less of the tensile load $\mathbf{P_1}$ to the optical fiber sub-units **12**. The tensile load $\mathbf{P_1}$ may be directed away from the optical fiber sub-units **12** and optical fibers **16** disposed therein. In this manner, damage to the optical fibers **16** is reduced or eliminated as a result of pulling the fiber optic cable **10**.

[0053] Providing the cable strength member **20** in the cable jacket **14** of the fiber optic cable **10** of a length shorter than the optical fiber sub-units **12** can be accomplished in at least two methods. In one method, end portions **32** of the optical fiber sub-units **12** can be pushed into the end **44** of the cable jacket **14**, as illustrated in **FIGS. 5** and **6**. The end portion **38** of the cable strength member **20** is pulled taut from the end **44** of the cable jacket **14** so that the length of the cable strength member **20** is shorter than the length of the optical fiber sub-units **12**.

[0054] The length of the optical fiber sub-units **12** can also be provided longer within the cable jacket **14** than the cable strength member **20** during manufacture of the fiber optic cable **10**. The tension at which the optical fiber sub-units **12** may be fed may be lower than the tension in which the cable strength member **20** may be fed during manufacture of the fiber optic cable **10** resulting in longer length optical fiber sub-units **12**. For example, the length of the cable strength member **20** disposed in the cable jacket **14** may be shorter than the length of the optical fiber sub-units **12** by 1.0 mm to 6.0 mm per meter (mm/m) length of the cable jacket **14** or more. As another example, the length of the cable strength member **20** disposed in the cable jacket **14** may be shorter than the length of the optical fiber sub-units **12** up to 1 percent (1%), or 0.5 percent (0.5%), or even 0.1 percent (0.1%).In this regard, **FIG. 7** is a top perspective view of the fiber optic cable assembly **26** in **FIG. 5**, wherein the furcation plug **30** is arranged to be enclosed with an exemplary pulling grip sub-assembly **66** comprised of two shells **68A, 68B** adapted to be disposed on each other to secure the furcation plug **30** therebetween for pulling the fiber optic cable **10**. **FIG. 8** illustrates the fiber optic cable assembly **26** in **FIG. 7** with the furcation plug **30** enclosed in the pulling grip sub-assembly **66** and enclosed in an exemplary pulling bag **70** for pulling the fiber optic cable **10**. A loop **72** is disposed on an end **74** of the pulling bag **70** opposite of an end **76** retaining the pulling grip sub-assembly **66** for pulling the fiber optic cable **10**. **FIG. 9** is a top perspective view of a fiber optic cable assembly that is similar to the fiber optic cable assembly **26** of **FIG. 3**, but employing an alternative exemplary furcation plug **80**. A pulling grip sub-assembly can be designed to retain the furcation plug **80**, which can be disposed in the pulling bag **70** in **FIG. 8** to pull the fiber optic cable.

[0055] In one embodiment, the furcation plug **30** does not transfer the tensile load $\mathbf{P_1}$ placed on the furcation plug **30** to the optical fiber sub-units **12**. In another embodiment, the furcation plug **30** is configured to sustain a tensile load of at least 100 pounds (lbs.) while producing less than 0.3% strain on the optical fiber sub-unit **12**. In another embodiment, the furcation plug **30** is configured to sustain a tensile load of at least 150 lbs. while producing less than 0.2% strain on the optical fiber sub-units **12**.

[0056] Other furcation assemblies can be provided that employ the fiber optic cable **10** in **FIG. 1** or a fiber optic cable that contains some or all features provided in the fiber optic cable **10** in **FIG. 1**. In this regard, **FIG. 10A** illustrates an alternative fiber optic cable assembly **90**. The fiber optic cable assembly **90** includes a furcation assembly **92** that furcates the optical fiber sub-units **12** and provides a cable strength member pulling loop **94**, as opposed to a furcation plug, for pulling the fiber optic cable **10**. **FIG. 10B** illustrates the fiber optic cable assembly **90** in **FIG. 10A** with the cable strength member pulling loop **94** fully assembled. As illustrated in **FIG. 10A**, the cable strength member pulling loop **94** is formed by looping a first end **97** of a cable strength member end portion **96** back onto itself and towards a cable jacket tube **98** of the fiber optic cable **10**. In this manner, the cable strength member pulling loop **94** can be pulled to pull the fiber optic cable **10**, wherein the tensile load (e.g., a pulling load) is directed onto the cable strength member pulling loop **94**, which is formed from the cable strength member **20** disposed inside the fiber optic cable **10**. Any size of cable strength member pulling loop **94** may be formed as desired. Because the cable strength member pulling loop **94** transfers tensile load directly to the cable strength member **20**, the cable strength member pulling loop **94** does not transfer the tensile load to the optical fiber sub-units **12**.

[0057] As one non-limiting example, the cable strength member pulling loop **94** may be two (2) to three (3) inches in circumference. The first end **97** of the cable strength member end portion **96** is secured to the cable jacket **14** to secure the formation of the cable strength member pulling loop **94** in this embodiment. **FIG. 10B** illustrates the cable jacket tube **98** after being heat shrunk onto the cable strength member pulling loop **94** and the cable jacket **14** of the fiber optic cable **10** to secure the cable strength member pulling loop **94** to the cable jacket **14**. As one non-limiting example, the cable jacket tube **98** may be heated to a temperature between 100 and 200 degrees Celsius for between two (2) and four (4) minutes to heat shrink and secure the cable jacket tube **98** to the cable strength member end portion **96** and the cable jacket **14**. The cable strength member pulling loop **94** may further be disposed with a heat shrink tube **100**, as illustrated in **FIG. 10B**, or may only consist of the cable strength member **20** without additional tubing, as illustrated in **FIG. 11**.

[0058] **FIGS. 12-15** illustrate another exemplary fiber optic cable assembly **102** that may include a furcation assembly **101** disposed in a fiber optic cable **10**, including the fiber optic cable **10** in **FIG. 1**. In this embodiment, a cable strength member pulling loop **103** is formed by the cable strength member end portion **96** disposed in two strength member tubes **104A, 104B** to form an additional neck portion **106** in the cable strength member pulling loop **103**. Providing a neck portion **106** in the cable strength member pulling loop **103** may assist in translating a tensile load (e.g., a pulling load) applied to the cable strength member pulling loop **103** in alignment with the longitudinal axis of the cable strength member **20** disposed inside the fiber optic cable **10**. This may allow a greater tensile load to be applied to the cable strength member end portion **96**. Because the cable strength member pulling loop **103** transfers tensile load directly to the cable strength member **20**, the cable strength member pulling loop **103** does not transfer tensile load to the optical fiber sub-units **12**.

[0059] The strength member tubes **104A, 104B** may be heat shrink tubes. In this regard, heat can be applied to the strength member tubes **104A, 104B** to heat shrink the strength member tubes **104A, 104B** to be secured in place onto the cable strength member end portion **96** to form the neck portion **106** and a loop portion **108** in the cable strength member pulling loop **103**, as illustrated in **FIGS. 12** and **13**. A tensile load placed on the loop portion **108** is translated to the neck portion **106**, which is disposed along a longitudinal axis $\mathbf{A_1}$ as illustrated in **FIG. 13**. Thus, if the neck portion **106** is disposed along a longitudinal axis $\mathbf{A_2}$ of the fiber optic cable **10**, the tensile load will be directed to the cable strength member **20** without the cable strength member **20** applying a force onto or expanding the cable jacket **14**. As one non-limiting example, the strength member tubes **104A, 104B** in **FIG. 13** may be heated to a temperature between 100 and 200 degrees Celsius for between two (2) and four (4) minutes to heat shrink and secure the strength member tubes **104A, 104B** to the cable strength member end portion **96** to form the cable strength member pulling loop **103**. As also illustrated in **FIG. 13**, a first end **110** of the cable strength member end portion **96** can be pulled back onto and fanned about the cable jacket **14** of the fiber optic cable **10** to distribute the first end **110** onto the cable jacket **14**. The first end **110** of the cable strength member end portion **96** can be secured to the cable jacket **14**, such as with tape **112** or other securing means, as illustrated in **FIG. 13**.

[0060] With reference to **FIG. 14**, to secure the first end **110** of the cable strength member end portion **96**, a cable jacket tube **114** is provided as illustrated in **FIGS. 14** and **25**. The cable jacket tube **114** is used to secure the cable strength member pulling loop **103** to the cable jacket **14** of the fiber optic cable **10**. **FIG. 14** illustrates the cable jacket tube **114** before being heat shrunk onto the first end **110** of the cable strength member end portion **96** and the cable jacket **14** of the fiber optic cable **10**. **FIG. 15** illustrates the cable jacket tube **114** after being heat shrunk onto the first end **110** and the cable jacket **14** of the fiber optic cable **10**. With reference to **FIG. 14**, the cable jacket tube **114** is disposed over the first end **110** of the cable strength member end portion **96** and the cable jacket **14** of the fiber optic cable **10** before the cable strength member pulling loop **103** is secured.

[0061] For example, the cable jacket tube **114** may be a heat shrink tube. In this regard, the cable jacket tube **114** is heated to heat shrink the cable jacket tube **114** onto the first end **110** of the cable strength member end portion **96** and the cable jacket **14** to secure the formed cable strength member pulling loop **103**, as illustrated in **FIG. 15**. As one non-limiting example, the cable strength member pulling loop **103** may be heated to a temperature between 100 and 200 degrees Celsius for between two (2) and four (4) minutes to heat shrink and secure the cable jacket tube **114** to the cable strength member end portion **96** and the cable jacket **14**. A pressing force may be applied to the cable jacket tube **114** to promote adhesion between the cable jacket tube **114** and the cable strength member end portion **96** to secure the cable strength member pulling loop **103** to the cable jacket **14** of the fiber optic cable **10**.

[0062] As used herein, it is intended that terms "fiber optic cables" and/or "optical fibers" include all types of single mode and multi-mode light waveguides, including one or more optical fibers that may be up-coated, colored, buffered, ribbonized and/or have other organizing or protective structure in a cable such as one or more tubes, strength members, jackets or the like. The optical fibers disclosed herein can be single mode or multi-mode optical fibers. Likewise, other types of suitable optical fibers include bend-insensitive optical fibers, or any other expedient of a medium for transmitting light signals. An example of a bend-insensitive, or bend resistant, optical fiber is ClearCurve® Multimode fiber commercially available from Corning Incorporated. Suitable fibers of this type are disclosed, for example, in U.S. Patent Application Publication Nos. 2008/0166094 and 2009/0169163.

[0063] Many modifications and other embodiments of the embodiments set forth herein will come to mind to one skilled in the art to which the embodiments pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. As non-limiting examples, the number of optical fiber sub-units, the number of optical fibers provided within each optical fiber sub-unit, and the number of cable strength members provided in the fiber optic cable can vary as desired. The number of sub-unit strength members provided in each sub-unit jacket of an optical fiber sub-unit can vary as desired. The optical fibers can be buffered or non-buffered. The optical fibers can be tight buffered, such as within an optical fiber sub-unit cable either adjacent to one or more strength members in a sub-unit jacket or in a sub-unit jacket that does not include any strength members. Any type of furcation assembly desired can be employed to provide a furcation of the optical fiber sub-units from the fiber optic cable. The dimensions of any of the components disclosed herein can vary or be set as desired.

[0064] Therefore, it is to be understood that the description and claims are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. It is intended that the embodiments cover the modifications and variations of the embodiments provided they come within the scope of the appended claims and their equivalents. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

1. A fiber optic cable assembly, comprising:

a fiber optic cable comprising a cable jacket, one or more cable strength members disposed within the cable jacket, and one or more optical fiber sub-units disposed within the cable jacket;

an end portion of the fiber optic cable comprising end portions of the one or more optical fiber sub-units and end portions of the one or more cable strength members both exposed from an end portion of the cable jacket; and

a furcation assembly receiving the end portion of the fiber optic cable at a first end of the furcation assembly, the furcation assembly terminating the end portion of the cable jacket and the end portions of the one or more cable strength members, and the end portions of the one or more optical fiber sub-units extending through and from a second end of the furcation assembly;

the one or more cable strength members are disposed within the cable jacket in a first length, and the one or more optical fiber sub-units are disposed within the cable jacket in a second length, the second length greater than the first length.

2. The fiber optic cable assembly of claim 1, further comprising a plurality of optical fibers and one or more sub-unit strength members disposed adjacent to each other in a sub-unit jacket in each of the one or more optical fiber sub-units such that movement of the plurality of optical fibers is constrained by an interior wall of the sub-unit jacket and the one or more sub-unit strength members.

3. The fiber optic cable assembly of claim 2, wherein the plurality of optical fibers are in friction contact with the one or more sub-unit strength members constraining relative longitudinal movement of the plurality of optical fibers within the sub-unit jacket.

4. The fiber optic cable assembly of claims 1-3, wherein the one or more optical fiber sub-units comprise tight buffered optical fibers disposed within the sub-unit jacket with no strength members disposed in the sub-unit jacket.

5. The fiber optic cable assembly of claims 1-4, wherein the one or more optical fiber sub-units are disposed adjacent to the one or more cable strength members within the cable jacket allowing movement between the one or more optical fiber sub-units and the one or more cable strength members within the cable jacket.

6. The fiber optic cable assembly of claims 1-5, wherein the furcation assembly transfers at least a portion of tensile load placed on the furcation assembly to the one or more cable strength members.

7. The fiber optic cable assembly of claims 1-6, wherein the furcation assembly preferentially transfers at least a portion of tensile load placed on the furcation assembly to the one or more cable strength members.

8. The fiber optic cable assembly of claim 7, wherein the furcation assembly preferentially transfers a majority tensile load placed on the furcation assembly to the one or more cable strength members.

9. The fiber optic cable assembly of claims 1-8, wherein the furcation assembly limits the tensile load transferred to the optical fiber sub-units.

10. The fiber optic cable assembly of claims 1-9, wherein the end portions of the one or more cable strength members are pulled taut from the end portion of the cable jacket in the furcation assembly.

11. The fiber optic cable assembly of claims 1-9, wherein the end portions of the one or more optical fiber sub-units are pushed into the end portion of the cable jacket.

12. The fiber optic cable assembly of claims 1-9, wherein a relative longitudinal movement of the one or more optical fiber sub-units within the cable jacket is greater than 4 mm.

13. The fiber optic cable assembly of claims 1-9, wherein a relative longitudinal movement of the one or more optical fiber sub-units within the cable jacket is greater than 10 mm.

14. The fiber optic cable assembly of claims 1-9, wherein each of the plurality of optical fibers disposed in the one or more optical fiber sub-units are not exposed outside of the sub-unit jackets within the assembly.

15. A method of assembling a fiber optic cable assembly, comprising:

disposing one or more cable strength members within a cable jacket of a fiber optic cable in a first length;

disposing one or more optical fiber sub-units within the cable jacket in a second length, the second length greater than the first length;

exposing end portions of the one or more optical fiber sub-units and end portions of the one or more cable strength members from an end portion of the cable jacket;

receiving the end portion of the fiber optic cable at a first end of a furcation assembly; and

terminating the end portion of the cable jacket and the end portions of the one or more cable strength members in the furcation assembly.

extending the end portions of the one or more optical fiber sub-units through the furcation assembly and from a second end of the furcation assembly;

16. The method of claim 15, further comprising disposing a plurality of optical fibers and one or more sub-unit strength members adjacent to each other in a sub-unit jacket in each of the one or more optical fiber sub-units such that movement of the plurality of optical fibers is constrained by an interior wall of the sub-unit jacket and the one or more sub-unit strength members.

17. The method of claim 16, further comprising disposing the plurality of optical fibers in friction contact with the one or more sub-unit strength members constraining

relative longitudinal movement of the plurality of optical fibers within the sub-unit jacket.

18. The method of claims 15-17, further comprising tightly buffering optical fibers within the sub-unit jacket with no strength members disposed in the sub-unit jacket.

19. The method of claims 15-18, wherein disposing the one or more cable strength members within the cable jacket of the fiber optic cable in the first length comprises pulling the end portions of the one or more cable strength members taut from the end portion of the cable jacket in the furcation assembly.

20. The method of claims 15-18, wherein disposing the one or more optical fiber sub-units within the cable jacket in a second length comprises pushing the end portions of the one or more optical fiber sub-units into the end portion of the cable jacket.

21. The method of claims 15-18, further comprising not exposing each of the plurality of optical fibers disposed in the one or more optical fiber sub-units outside of the sub-unit jackets within the furcation assembly.

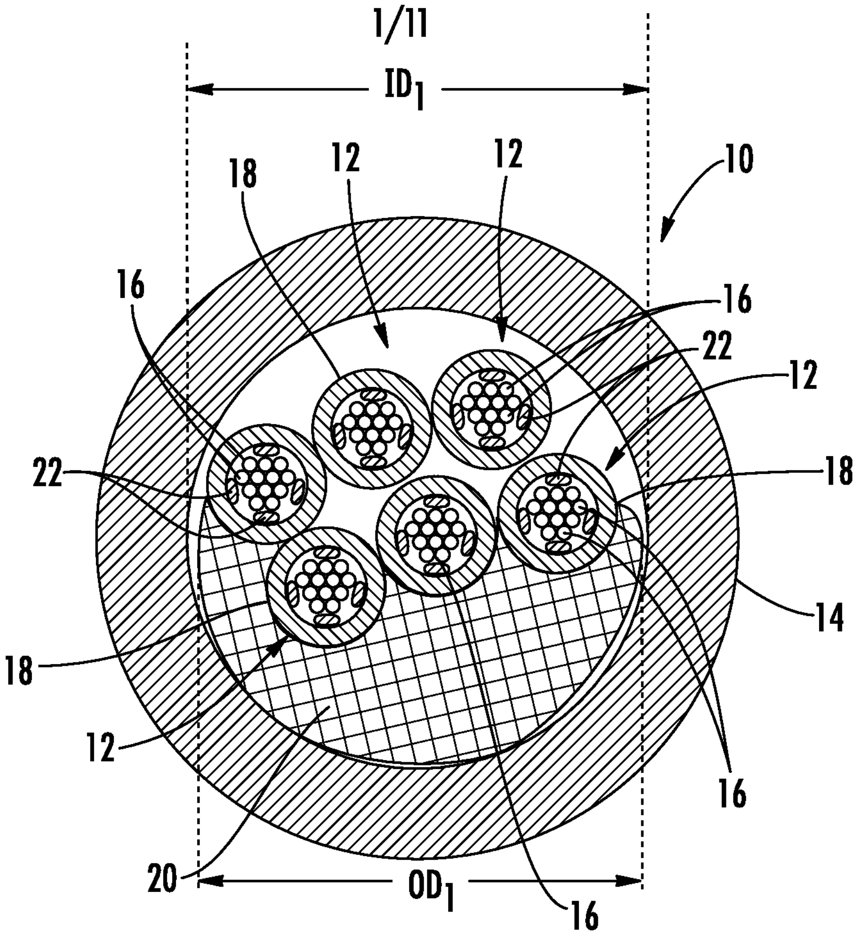
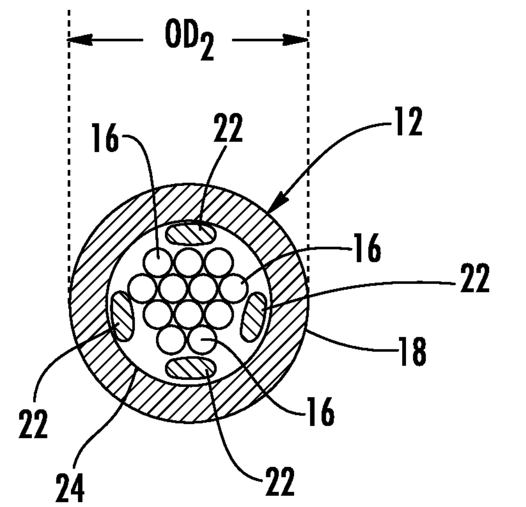

ID1
10
12
12
18
16
16
22
12
22
18
14
18
12
16
20
OD1
16

FIG. 1


OD2
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22
12
16
22
18
22
16
24
22

FIG. 2

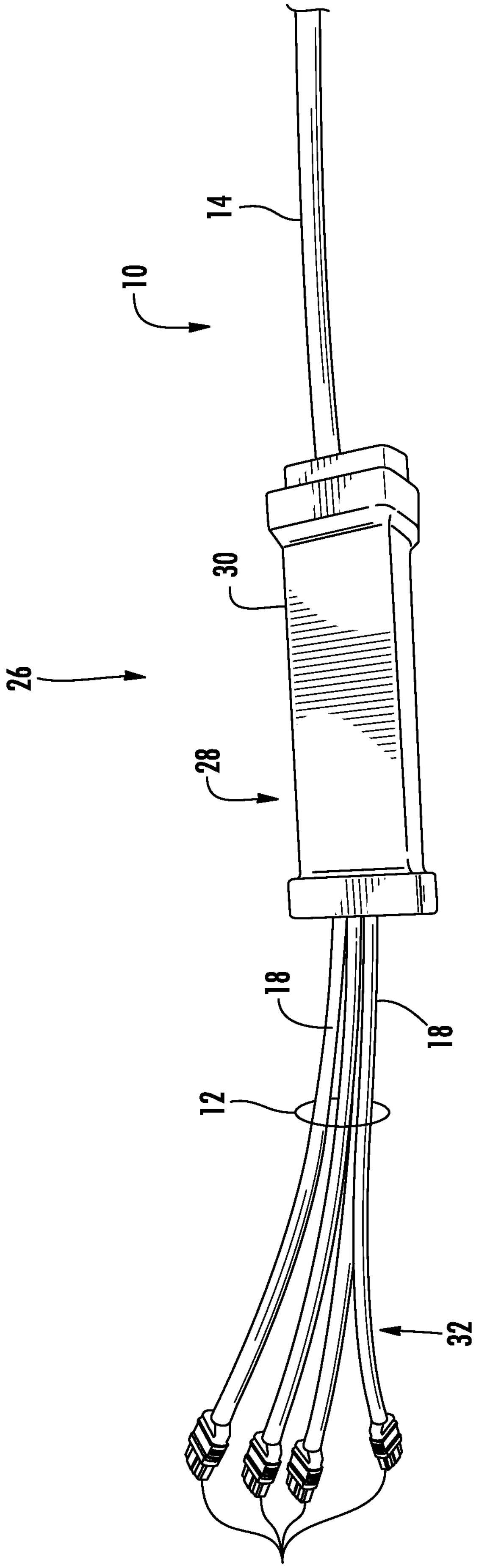

FIG. 3

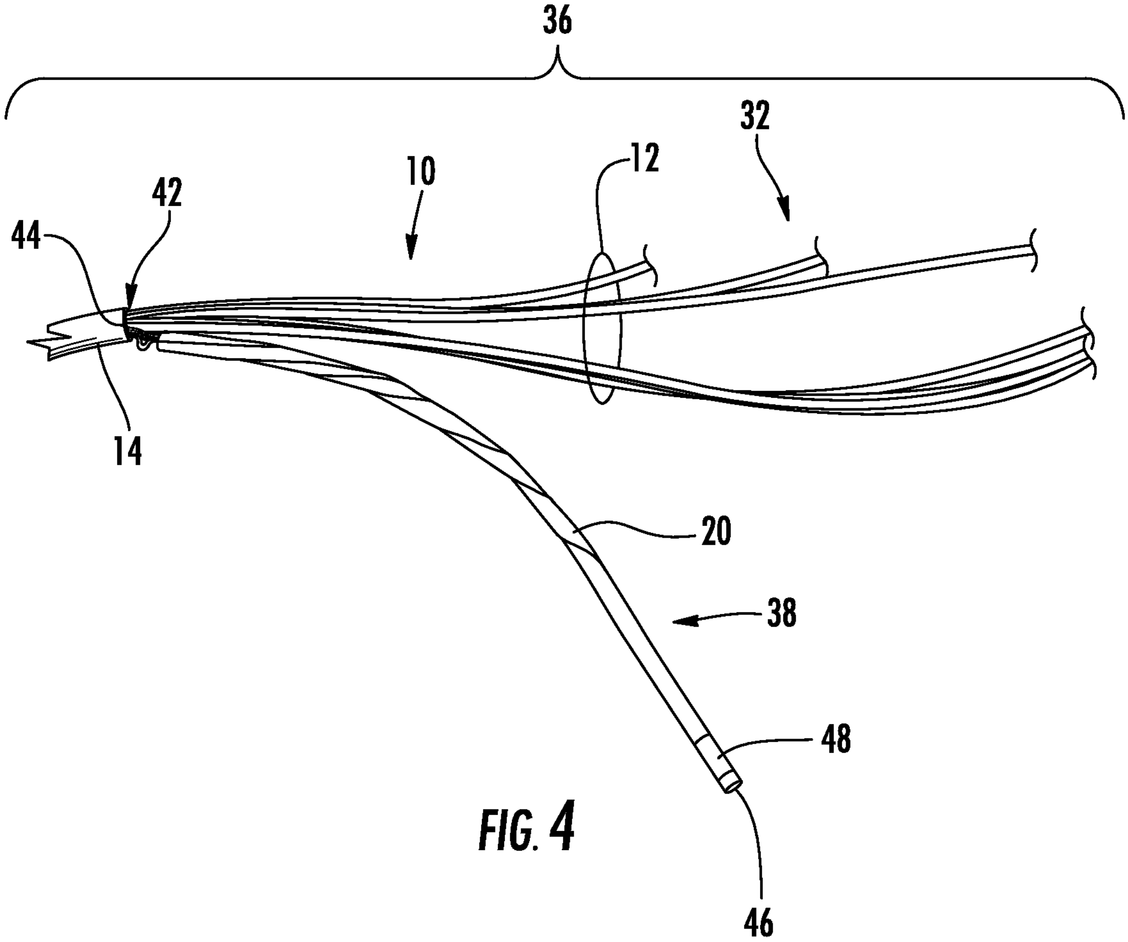

FIG. 4

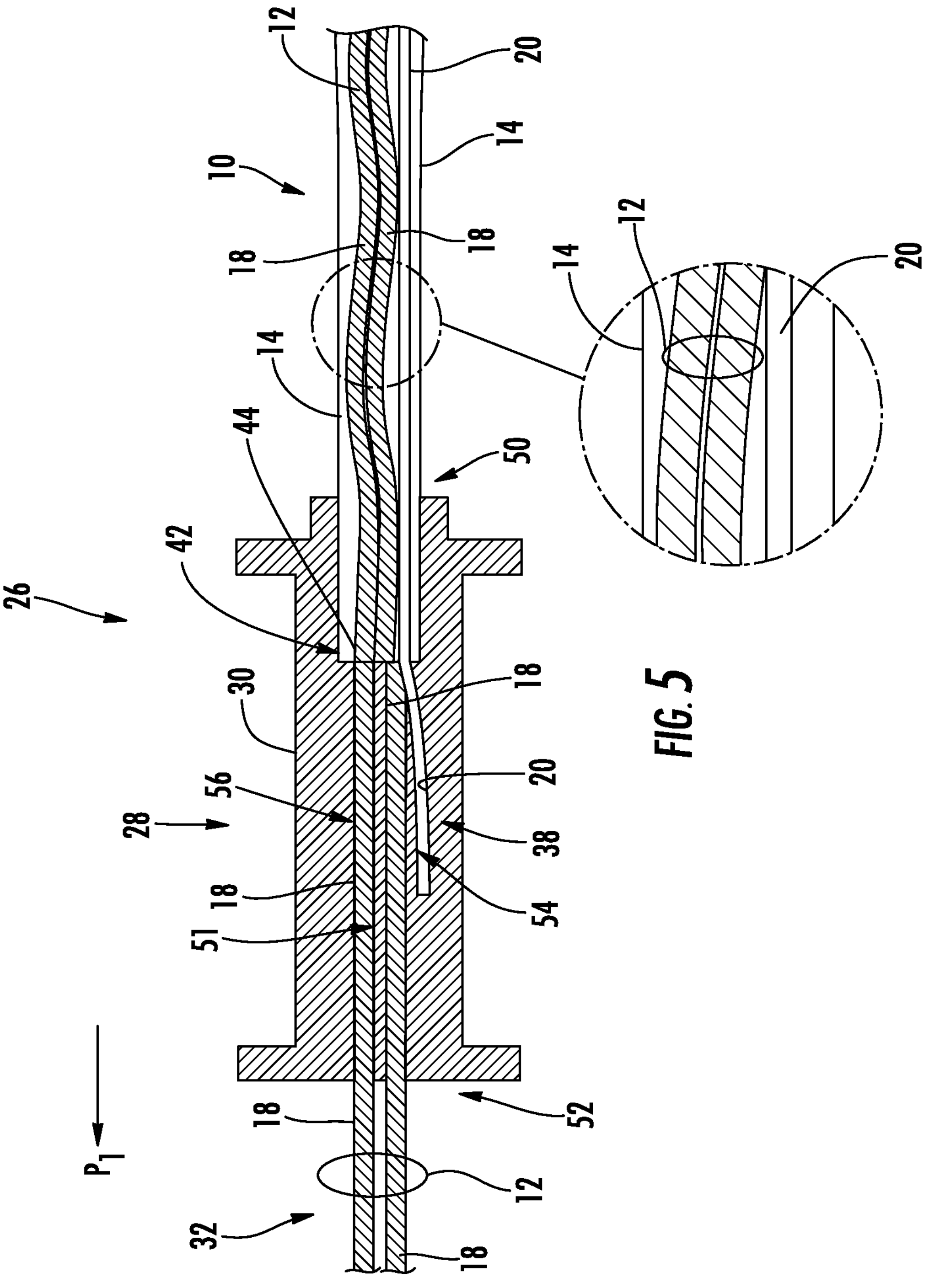
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FIG. 5

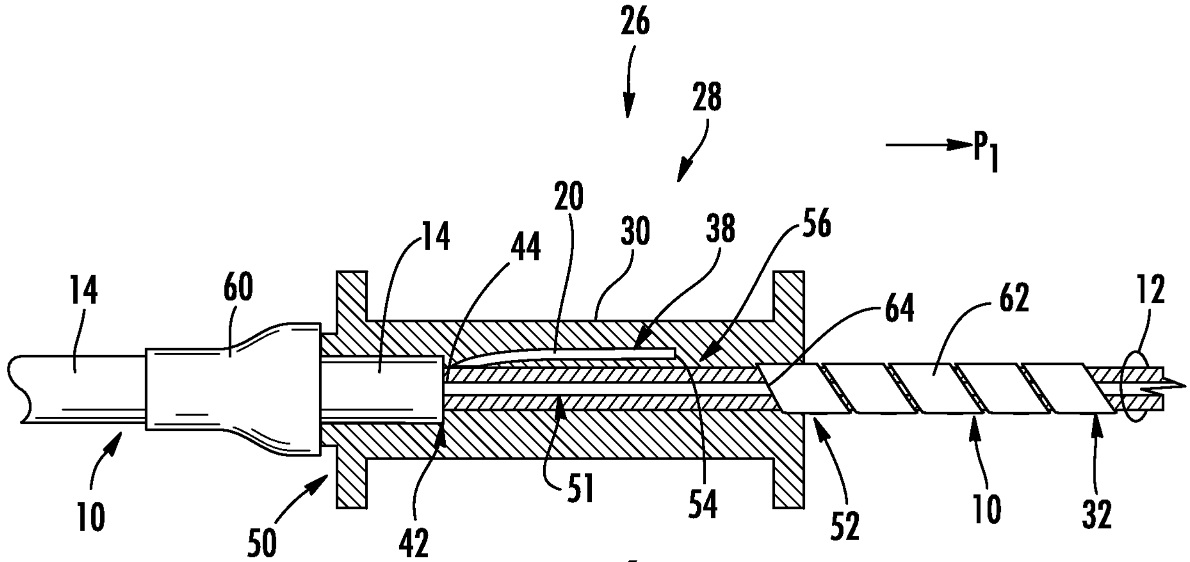

FIG. 6

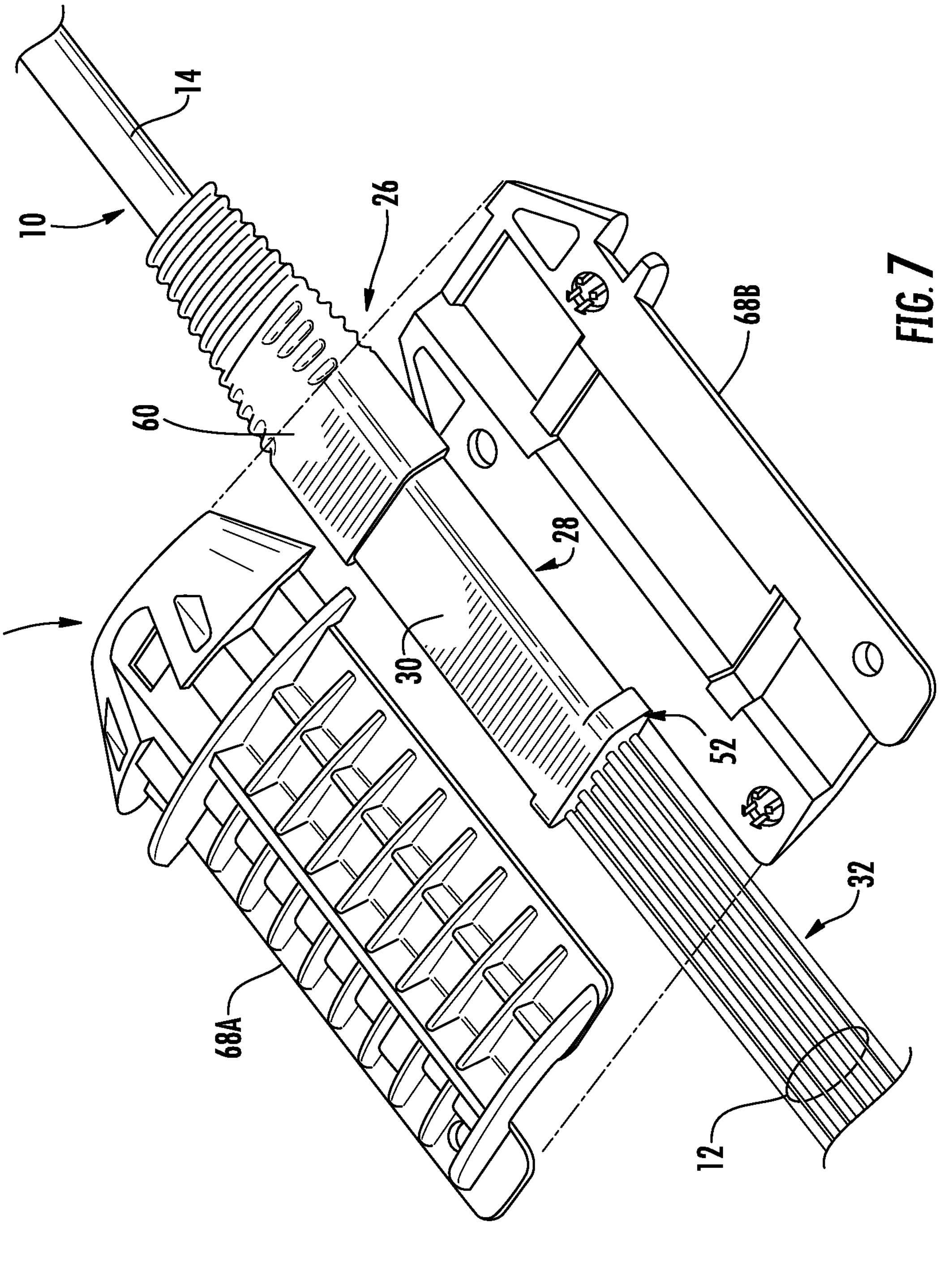

FIG. 7

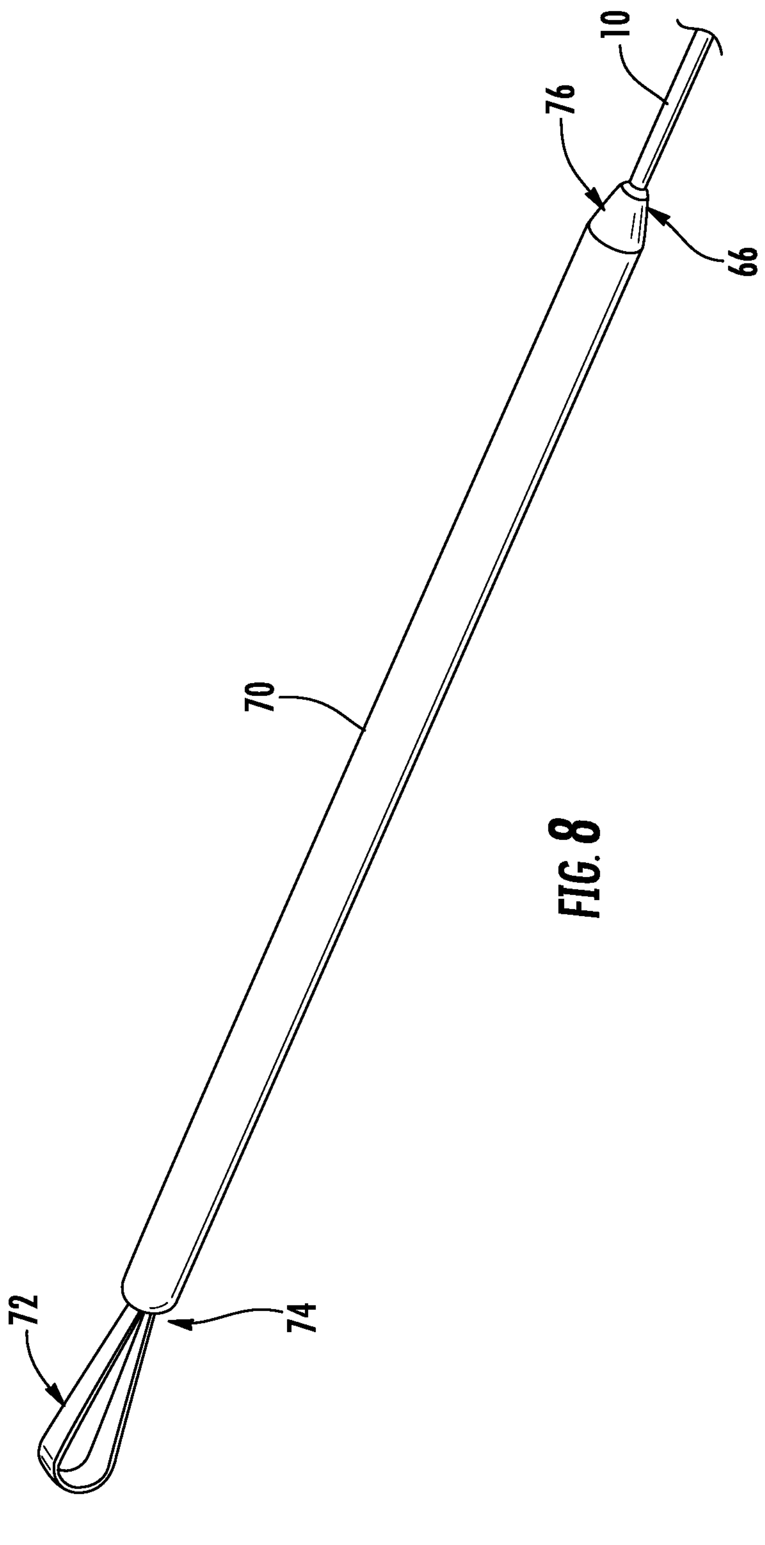

FIG. 8

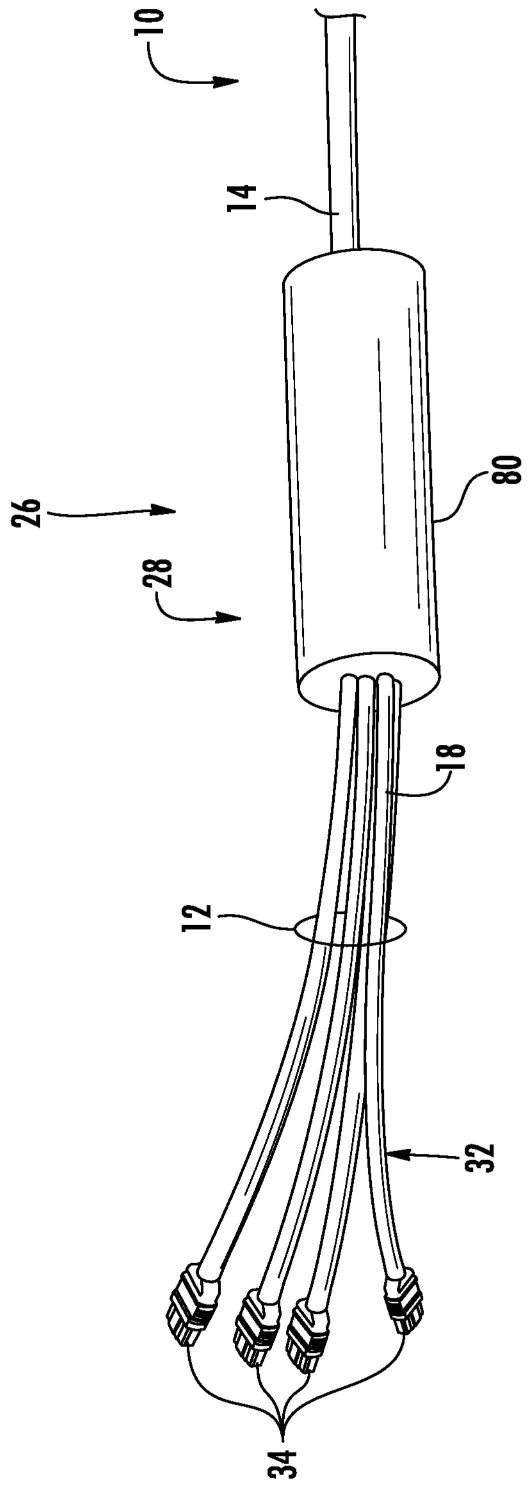

FIG. 9

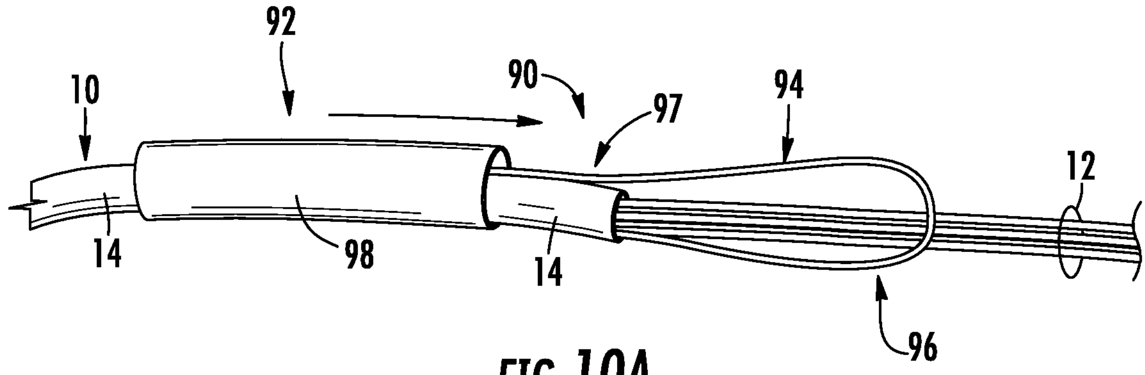

FIG. 10A

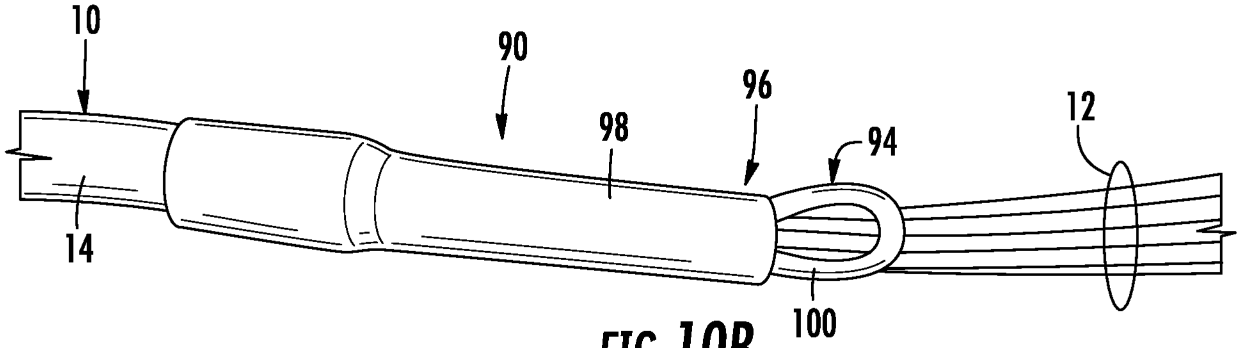

FIG. 10B

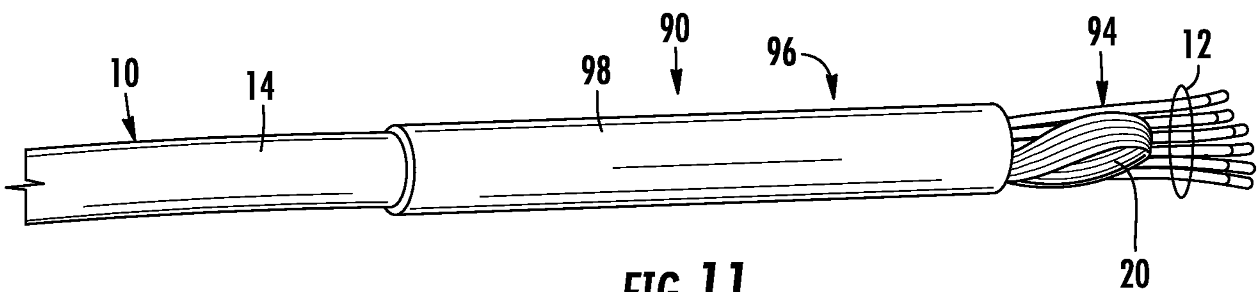

FIG. 11

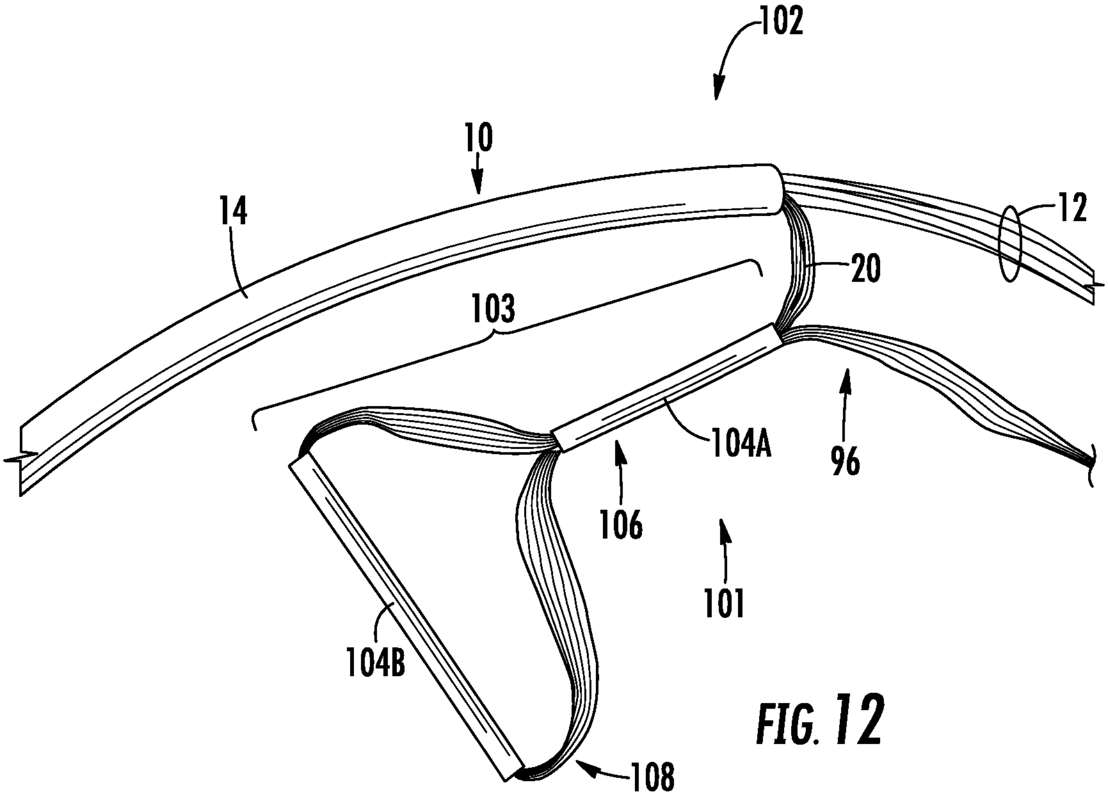

FIG. 12

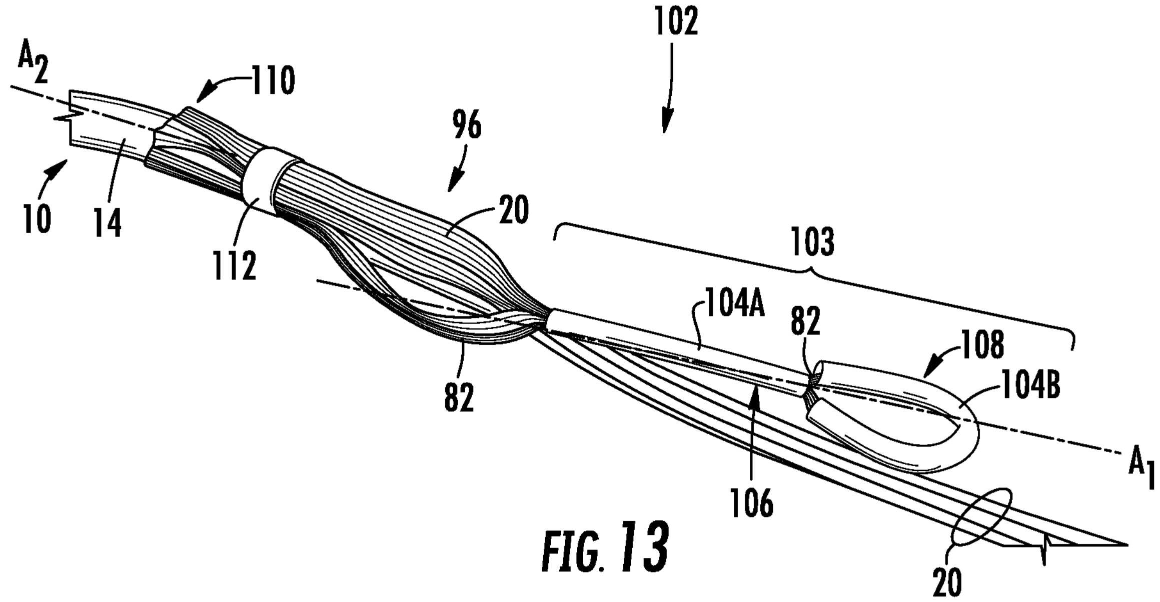

FIG. 13

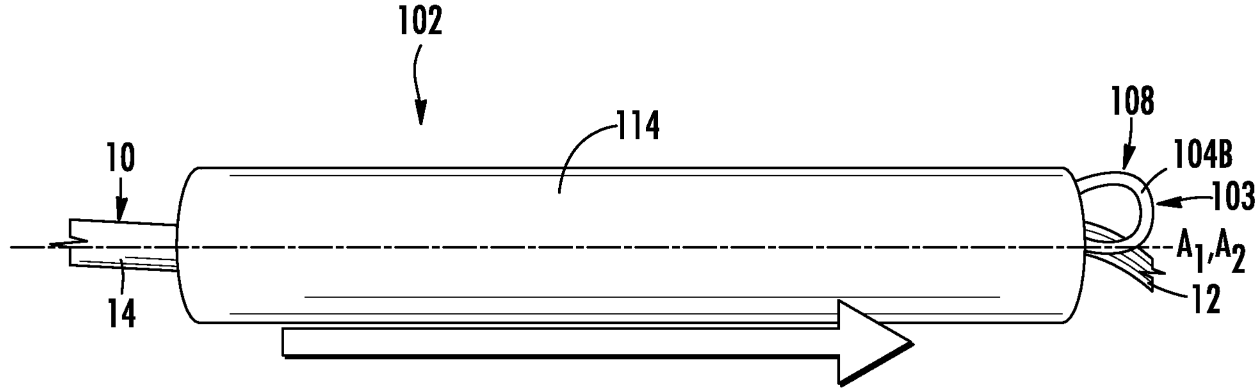

FIG. 14

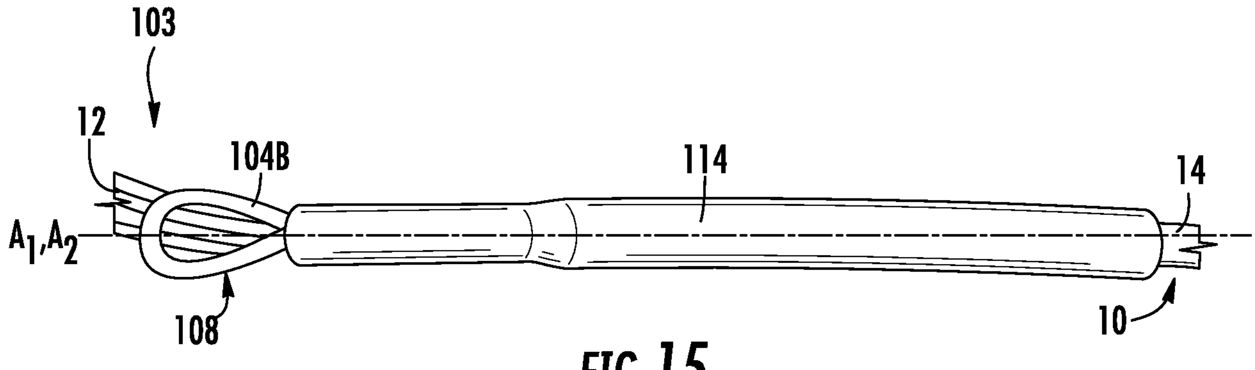

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/042417

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/44
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)
G02B

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 6 374 023 B1 (PARRIS DONALD R [US]) 16 April 2002 (2002-04-16) column 9, line 28 - column 10, line 16	1,14
A	US 2 434 793 A (FEASTER EDWARD B) 20 January 1948 (1948-01-20) column 2, line 19 - column 3, line 10	1,14
A	US 5 163 116 A (OESTREICH ULRICH [DE] ET AL) 10 November 1992 (1992-11-10) column 1, line 20 - column 3, line 37	1,14

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 August 2012	31/08/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cohen, Adam

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/042417

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2010/098386 A1 (KLEEBERGER TERRY M [US]) 22 April 2010 (2010-04-22) abstract paragraphs [0003] - [0020]; claim 1; figures 2,3	1-21

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2012/042417

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