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(71) Applicant: **CORNING OPTICAL COMMUNICATIONS LLC** [US/US]; 800 17th Street NW, Hickory, North Carolina 28601 (US).

(72) Inventors: **ISENHOUR, Micah Colen**; 1008 Park Circle, Lincolnton, North Carolina 28092 (US). **MCDONALD, Alvin John**; 1753 Orchard Drive, Lenoir, North Carolina 28645 (US). **MEEK, David Wayne**; 10038 Stoneleigh Drive, Fort Worth, Texas 76126 (US). **TRAN, Hieu Vinh**; 6017 Castlecove Rd., Charlotte, North Carolina 28278 (US).

(74) Agent: **MONTGOMERY, C. Keith**; Corning Optical Communications LLC, Intellectual Property Department SP-TI-03-1, Corning, New York 14831 (US).

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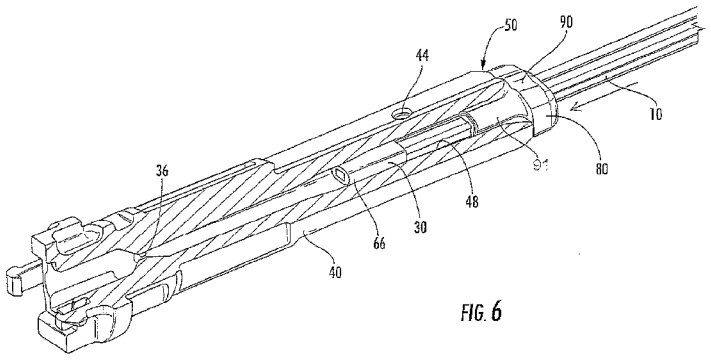


FIG. 6

(57) Abstract: A fiber optic cable assembly for terminating a cable using an interior seal component in a passage of a retention body and methods for making the same. The interior seal component inhibits a bonding material from passing through to unintended portions of the retention body, and also serves to position the cable within the retention body during termination. Embodiments may include an optional end seal for inhibiting the bonding agent from escaping the retention body.

FIBER OPTIC CABLE ASSEMBLIES FOR TERMINATING A FIBER OPTIC CABLE AND METHODS OF MAKING THE SAME

PRIORITY APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 61/991,974 filed on May 12, 2014 the content of which is relied upon and incorporated herein by reference in its entirety.

BACKGROUND

[0002] Optical fiber connectors are an integral part of optical fiber communication systems, and are used for terminating an optical transmission component such as an optical fiber of a fiber optic cable. Optical fiber connectors are widely used for providing a mating/unmating connection point in optical networks, connecting different optical fibers, and terminating optical fibers for optical connection with other devices, such as closures, multiports, optical transmitters, receivers, isolators, attenuators, amplifiers, power meters, and detectors. When terminating a fiber optic cable with a fiber optic connector, the fiber optic cable should be secured to the fiber optic connector in a suitable manner to withstand pulling and side-load forces that may be experienced during installation and use. Moreover, the termination process should be relatively quick, easy and cost-effective.

[0003] Fiber optic connectors may be designed for terminating one specific fiber optic cable design and consequently may not be easily adapted for terminating other fiber optic cable designs. For instance, fiber optic cable designs may have different cross-sectional shapes, cross-sectional dimensions and/or materials, and a fiber optic connector intended for a specific cable design may not be easily adapted for others. Even different fiber optic cables of the same design can have manufacturing variations that render it difficult to terminate that cable design with certain connectors. Moreover, customers may want to use a specific fiber optic connector for their network, but in combination with a cable design that differs from the cable designed for use with their favored connector.

SUMMARY

[0004] According to one embodiment, a method of terminating a cable comprises providing a cable having at least one optical transmission component, providing a retention body having an insertion end and a passage extending at least partially along a length of the

retention body, preparing a first end of the cable, placing an interior seal component at the first end of the cable, inserting the first end of the cable and the interior seal component into the passage, and introducing a filler agent into the passage.

[0005] According to another embodiment, cable assembly is provided. The assembly includes a cable including at least one optical transmission component and a retention body. The retention body includes an insertion end and a passage extending from an insertion end at least partially along a length of the retention body. The assembly includes an interior seal component including an aperture. A first end of the cable is at the interior seal component. The interior seal component is located within the passage, and the cable extends out of the passage from the insertion end. The filler material can contact the interior seal component.

[0006] According to another embodiment, the interior seal component can be placed within the passage and the cable then inserted into the passage.

[0007] According to one aspect, the interior seal component can prevent the passage of filler agent into a portion of the passage between the interior seal component and second, front end of the retention body opposite the insertion end.

[0008] According to another aspect, the interior seal component can act to center, secure and/or otherwise position the cable in the retention body during termination. The interior seal component can also be configured to adapt various cable types and/or sizes for use in a specific retention body, or to adapt various retention body types to work with a specific cable.

[0009] 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 the description or recognized by practicing the embodiments as described in the written description and claims hereof, as well as the appended drawings.

[0010] It is to be understood that both the foregoing general description and the following detailed description are merely exemplary, and are intended to provide an overview or framework to understand the nature and character of the claims.

[0011] The accompanying drawings are included to provide a further understanding, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain principles and operation of the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1** is a perspective cutaway view illustrating a step in terminating a cable

according to one embodiment.

[0013] **FIG. 2** is a perspective view of a subassembly of a terminated cable illustrating an end seal according to one embodiment.

[0014] **FIG. 3** is a cutaway, detailed view of subassembly illustrating an interior seal component at a cable end within a passage of a retention body.

[0015] **FIG. 4A** is a perspective view of the interior seal component illustrating a cavity in which a cable end is seated.

[0016] **FIG. 4B** is another perspective view of the interior seal component illustrating the face of the interior seal component that is inserted into a retention body passage.

[0017] **FIG. 5** is another cutaway, detailed view of a cable subassembly illustrating the passage in a retention body engaged with the interior seal component.

[0018] **FIG. 6** is a perspective cutaway view of a subassembly of a terminated cable including an end seal at the insertion end of the retention body.

[0019] **FIG. 7** illustrates perspective views of the end seal.

[0020] **FIG. 8** illustrates a step in the termination process in which the interior seal component is placed on a first end of the cable.

[0021] **FIG. 9** illustrates coupling of a fiber optic subassembly to the retention body.

[0022] **FIG. 10** is a perspective view of an interior seal component according to another embodiment.

[0023] **FIG. 11** is a perspective view of an end seal according to another embodiment.

[0024] **FIG. 12** illustrates a terminated or connectorized cable assembly terminated at a hardened fiber optic connector.

DETAILED DESCRIPTION

[0025] **FIG. 1** is a cutaway view illustrating a step in terminating a cable **10** according to a first embodiment. The cable **10** can be, for example, a fiber optical cable having, for example, one or more optical transmission components, such as one or more optical fibers **12**. Other data, voice, etc. and other information transmitting media, such as metallic conductors, for example, can be included as an alternative to or in addition to optical transmission components. In the illustrated embodiment, the optical transmission components include a plurality of optical fibers **12**. The cable **10** can also have, for example, a polymeric jacket **14**, and one or more messenger or strength members **16** (shown in **FIG. 8**).

[0026] **FIG. 2** is a perspective view of a subassembly of a terminated cable **20** (also

referred to as a 'connectorized' cable). The subassembly may ultimately be formed into a fiber optic cable assembly having a hardened fiber optic connector at its end (shown in **FIG. 12**). Referring to **FIGS. 1** and **2**, according to one aspect, an interior seal component **30** is placed at a first, insertion end of the cable **10** during the termination process, such as by inserting the cable end into the component **30**. The interior seal component **30** at least partially closes the volume between the exterior of the cable **10** and an interior surface of a passage **34** of a tubular retention body **40**. As shown in **FIG. 1**, because the interior seal component **30** surrounds the first end of the cable **10**, the exterior dimensions (e.g., length, width) of the interior seal component **30** are larger than the those of the cable **10**, and specifically, these relative sizes are cross-sections in a plane perpendicular to the longitudinal axis of the cable **10** and of the passage **34**.

[0027] During the termination process, a filler or bonding material, such as a compound comprising a glue, epoxy, or some other bonding, and/or sealing substance is introduced into a section of the passage **34** that may be referred to as the bonding chamber **48**. In general, the bonding chamber **48** is defined at one end by the seal created by end seal component **80** (discussed below) and at the other end by the seal created by the interior seal component **30**. The filler agent may be introduced in fluid form through an opening in the retention body, shown as aperture **44**, into the bonding chamber **48**. Alternatively, the filler agent may be introduced from a first, cable insertion end **50** of the retention body. The filler agent acts to bond or secure a portion of the exterior of cable **10** to the inner surface of retention body **40** that defines the passage **34**. As shown in **FIG. 1**, the aperture **44** extends radially outward from passage **34** through the retention body sidewall and through the outer surface of retention body **40** to provide an opening through which the filler agent may be introduced into passage **34**.

[0028] As will be understood, the bonding that occurs within bonding chamber **48** can be sufficiently rigid so as to fix the position of cable **10** relative to retention body **40**. Any suitable type of bonding agent may be used as a filler material. For example, the bonding agent may be radiation curable epoxy such as a visible light curable epoxy or an ultraviolet (UV) light curable epoxy, a heat curable epoxy, adhesive, resin, glue, or the like. If a radiation curable substance such as a light (e.g. UV) curable epoxy is used, then the retention body **40** should be translucent to appropriate wavelengths to allow the radiation to cure the radiation curable substance. By way of example, one suitable filler agent is a two-part heat curable epoxy available from Masterbond of Hackensack, NJ under the tradename EP62-

1TK. Another suitable filler agent having a thicker viscosity is available from Loctite of Mooresville, NC under the tradename Hysol-0151.

[0029] The bonding chamber **48** is located, along an axial direction of the retention body **40**, between the interior seal component **30** and the first, cable insertion end **50** of the retention body **40**. The first, insertion end **50** is the end of the retention body **40** through which the cable **10** is inserted during cable termination, and as shown in **FIG. 2**, an upstream section of the cable **10** extends out of and away from the retention body **40** through the insertion end **50**. The interior seal component **30** may be configured to prevent and/or inhibit the passage of some, substantially all, or all of the fluid filler agent from entering into a narrowed passage section **56** of the body **40**, or otherwise moving of the filler agent towards a second, front end **60** of the retention body **40**. In one embodiment, the interior seal component **30** forms a fluid-tight seal within the passage **34** that prevents the filler agent from traversing past the seal within the passage **34**. Adhesive filler agent flowing towards the second end **60** is not desirable because it can wholly or partially encapsulate an optical fiber and/or contact a ferrule, locking it in place and resulting in a nonfunctioning connector. Adhesive can also contaminate the rear (at the insertion end **50**) of a connector, reducing the effectiveness of the strain relieving function of the connector. It is thus generally advantageous to retain the filler agent between the interior seal component **30** and the first end **50** during termination. The interior seal component **30** can be shaped and/or possess material properties (e.g., deformability, compliancy) so as to alleviate and/or obviate the need for shaving, cutting, shaping or otherwise altering the profile of the insertion end of the cable **10** so as to form the cable **10** into a shape that causes the cable **10** itself to seal the passage **34**.

[0030] The term 'seal' is used in this application to indicate a component that inhibits but must not necessarily block all filler agent flow. For example, depending upon the viscosity of the filler agent, seal components may not need to fill the entire space between the cable **10** and the passage **34**. A water-tight seal, for example, would be more than sufficient to block the flow of most contemplated filler agents. In some applications a seal may be sufficient for either end of the bonding chamber if it blocks most filler agent flow, but allows small amounts of filler agent to pass through the seals.

[0031] During termination, it is desirable that the cable **10** be relatively stable, immobile, and centered within the passage **34**. The interior seal component **30** can alleviate and/or obviate the requirement of shaping the insertion end of the cable **10** so that the cable **10** is

securely seated within the passage **34** of the retention body **40**. The interior seal component **30** can be, for example, deformable so that it deforms to fit securely (e.g., an interference fit) over the end of a variety of cable sizes and types, and also so that its exterior deforms to fit against the interior surface of passage **34**. It is also desirable for a retention body **40** to accommodate as many cable types and sizes as possible. According to the present embodiments, the seal component **30** can be sufficiently deformable so that a variety of cable types and sizes fit relatively snugly (e.g., interference fit) over the cable, as well as sufficiently deformable so that it is capable of seating snugly within a variety of retention bodies (e.g., a variety of passage sizes and configurations). According to one embodiment, a seal component can be part of an inventory of a family of seal components that are each sized to fit over a particular cable size and type, yet common to a specific retention body. This retention body family thus allows many cable types to be used with a specific retention body. Alternatively, a seal component can be part of an inventory of a family of seal components that are each sized to fit within one of variety of retention bodies, yet common to a specific cable size and type. This retention body family thus allows many retention bodies to be used with a cable type. Seal components according to the present embodiments thus provide a variety of options in alleviating or obviating the need for or the degree to which a cable end must be modified to be made suitable for use with various retention bodies.

[0032] **FIG. 3** is a cutaway, detailed view of the partially terminated cable **20**, before a filler agent is introduced into the retention body **40**. The detailed view of the narrowed passage section **56** illustrates the reduction in cross-sectional area (e.g., the dimension perpendicular to the longitudinal axis) of the passage **34** in comparison with its cross-sectional area at the insertion end **50**. The reduction of cross-sectional area can be realized, for example, by gradually reducing the height and width of the passage **34**. The passage **34** may continue to narrow toward the front end **60** and reach a minimum cross-sectional area at a section **36** proximate to the front end **60**. The optical transmission components **12** may extend through the passage **34** and pass through the section **36** for connection to a ferrule, as discussed below. The reducing cross-section of the passage **34** acts to center components during the formation of a cable assembly. The interior seal component **30** can have a tapered end **66** that is configured to abut or engage with the narrowed passage section **56** when the cable **10** has advanced a desired distance into the passage **34**. The interior seal component **30** can have a shape that is complementary with the narrowed passage section **56** such that, when fully seated in the passage **34**, it substantially or wholly closes the passage **34**. The interior

seal component **30** can, for example, form a fluid-tight seal that limits or prevents filler agent traversing past the seal, as well as securely seating the cable **10** in the retention body **40**. The seal need not necessarily be fluid-tight, and when inserted the desired distance in the retention body **40**, at the locations where the seal component engages the passage **34**, the seal component **30** can occupy at least 70 percent of a transverse (i.e., perpendicular to the long axis of the retention body **40**) cross-sectional passage area between the cable **10** and the passage **34** wall. According to another embodiment, the interior seal component **30** can occupy at least 90 percent, and further at least 95 percent of the cross-sectional area between the cable **10** and the passage **34** interior surface.

[0033] **FIGS. 4A** and **4B** are perspective views of the interior seal component **30**. The interior seal component **30** comprises a cavity **70** configured to receive an insertion end of the cable **10**, and an aperture **72** through which, for example, optical transmission components can pass toward the front end **60** of the retention body **40**. The cavity **70** is defined by an inner surface **74**. In some embodiments, a portion of the inner surface **74** engages a portion of the exterior surface of the cable **10** when the interior seal component is mounted to the cable **10**. The interior seal component **30** can be coupled to the cable **10** via, for example, an interference fit. The cavity **70** can be configured to, for example, fit a specific cable size and type, or configured to receive a variety of cable sizes and types. Referring also to **FIG. 3**, the interior seal component **30** can be formed from a relatively compressible material in order to enhance the seal with the passage **34**, and in some such embodiments, the interior seal component **30** compresses forming an interference fit with the inner surface of the passage **34**. The interior seal component **30** can be, for example, a pre-formed, molded part, that can be manually inserted by hand onto an end of the cable **10** prior to insertion into the passage **34**. Alternatively, the interior seal component **30** may be inserted into the passage **34**, and the cable **10** can subsequently be seated in the seal component as the cable end is inserted into the retention body **40**.

[0034] **FIG. 5** is another cutaway, detailed view of a step in cable termination. **FIG. 5** illustrates deformation of the exterior of the interior seal component **30** as its tapered end **66** is pressed into the narrowed section **56** of the passage **34**. The interior seal component **30** can be inserted into the passage **34** so that it deforms (e.g., under compression) and resulting in, for example, at least one percent reduction of its cross-sectional area at least one cross-section of the seal when it is seated within the passage **34**. According to another embodiment, the seal component **30** can be inserted so that it is compressed resulting in at

least a three percent reduction in its cross-sectional area at least one cross-section of the seal. According to one embodiment, the cavity **70** may have four substantially planar surfaces with projections **76** extending inwardly from the upper and lower surfaces so as to conform to one typical drop cable geometry.

[0035] **FIG. 6** is a perspective view of the cable **10** and retention body **40** ready for introduction of filler agent (not shown) into the bonding chamber **48**. According to one embodiment, an end seal component **80** can be placed at the first end **50** of the retention body **40**. The end seal component **80** may be included to substantially block and/or inhibit the filler agent from flowing from the bonding chamber **48** out of the insertion end **50** of the retention body **40** during termination. **FIG. 7** illustrates perspective views of the end seal component **80**. Referring to **FIG. 7**, the end seal component **80** includes an opening, shown as a through-hole aperture **86**, configured to receive the cable **10**. In various embodiments, the cable **10** extends through the end seal component **80** via the aperture **86**. The aperture **86** can be configured to accommodate a cable of particular cross-section so as to substantially prevent or inhibit the passage of filler agent between the cable jacket and the passage **34** during termination. The end seal component **80** may also be configured to accommodate a variety of cable types and sizes. In the exemplary embodiment, the aperture **86** is generally rectangular in cross-section, with a width **W** that is at least 20 per cent greater than its height **H**. Projections **88** can extend inwardly from the upper and lower surfaces of the aperture **86** and may be configured to generally mate with centrally located grooves extending along a length of the cables of certain cross-section.

[0036] The end seal component **80** can include a flange section **90** that is configured to engage the insertion end **50** of the retention body **40** (the engagement position is shown in **FIG. 6**). In **FIG. 6**, the flange section **90** abuts the insertion end **50**. An insertion section **91** of smaller cross-section than the flange section **90** extends from the flange section **90**. As shown in **FIG. 6**, the insertion section **91** extends into the passage **34**, and in one embodiment, the outer surface of the insertion section **91** engages and forms an interference fit with the inner surface defining the passage **34**. The end seal component **80** can be deformable so as to form a secure seal between the passage **34** and the cable **10** at the first end **50**. Thus, end seal component **80** forms a seal within passage **34** and/or at the interface with the insertion end **50** of the retention body **40**. The seal at the end can be fluid-tight, for example, with respect to the filler agent, or sufficiently fluid-tight to prevent significant filler agent from passing out of the end of the retention body during termination. In this

arrangement, the combination of the interior seal component **30** and the end seal component **80** define the opposing ends of the bonding chamber **48**. In the illustrated embodiment, the aperture **44** through which filler agent is introduced is located between the opposing inner faces of the interior seal component **30** and the end seal component **80**. If filler agent is to be introduced through the insertion end **50** as opposed to through the aperture **44**, the end seal component **80** would be slid along the cable **10** and **80** seated in the passage **34** after introducing the filler agent.

[0037] A method of terminating a cable will now be discussed with reference to **FIGS. 1-12**. A cable **10** having at least one optical transmission component, shown as one or more optical fibers **12**, is provided. The insertion end of the cable **10** is moved through the aperture **86** of the end seal component **80** (shown in **FIG. 7**) a sufficient distance from the cable end to allow for further operations on the end of the cable **10**. The insertion section **91** of the component **80** faces toward the insertion end of the cable **10**.

[0038] Referring to **FIG. 8**, the first end of the cable **10** is then prepared for termination by removing all or a portion of the cable jacket **14** at the insertion end of the cable **10** to expose the optical transmission component(s) (e.g., a coated optical fiber(s)). One or more messenger wires or strength members **16** can be cut away from a specified length at the insertion end of the cable. The end seal component **80** is not visible in **FIG. 8**.

[0039] The interior seal component **30** is then placed at the prepared, insertion end of the cable **10**, such as by mounting the interior seal component **30** on the cable **10** by pressing the cable into the cavity **70**. If optical transmission components are included in the cable **10**, they can be arranged so that they pass through the aperture **72** in the interior seal component **30**. In this type of arrangement, the optical transmission components of cable **10** extend through the interior seal component **30** and into the region of the passage **34** between the interior seal component **30** and the second end **60**. The exposed section of optical transmission components may be long enough to extend through the entire retention body **40** and past the front end **60**. In a specific embodiment, the exposed sections of optical transmission components extend from the front end **60** of the retention body **40** to interface with a ferrule as part of the connectorization process.

[0040] The cable **10**, with the interior seal component **30** on its end, is inserted into the passage **34** and advanced a desired distance to assume the position shown in **FIG. 6**. For example, the cable **10** can be advanced until the interior seal component **30** abuts and forms a relatively tight engagement with the passage **34**, such as at the narrowed passage section **56**.

The component **30** also serves to position, such as by centering, the cable **10** within the passage **34** which may facilitate alignment and coupling to the ferrule. The cable **10** and component **30** are now seated within the retention body **40**.

[0041] Still referring to **FIG. 6**, the end seal component **80** is then pushed along the cable **10** until the insertion section **91** enters the passage **34** at the insertion end **50** of the retention body **40**. The end seal component **80** can be pressed firmly into the passage **34** so as to form a good seal at the end of the passage **34**. The end seal component **80** also serves to center the cable **10** within the passage **34**.

[0042] With the interior seal component **30** engaged with and at least partially sealing the interior of the passage **34**, and the end seal component **80** at least partially sealing the insertion end **50** of the retention body, filler agent (not shown) is introduced into the passage **34** through the aperture **44**. The filler agent may be, for example, introduced in liquid form into the passage **34** under pressure, such as by injection through the aperture **44**. A vent aperture **96** (shown in **FIG. 3**) relieves pressure in the chamber **48** to allow injection of the filler agent into the bonding chamber **48**. The filler agent is allowed to cure, securing the cable **10**, the interior seal component **30**, and the end seal component **80** to the retention body **40**. The filler agent can be injected into the bonding chamber **48** so that it substantially fills the chamber, although filling less than the entire chamber space between the interior seal component **30** and the insertion end **50** may suffice to secure the cable **10** within the retention body **40**.

[0043] Referring to **FIG. 9**, the second, or front end **60** of the retention body **40**, including the optical transmission component **12**, is coupled to a fiber optic subassembly **95**. The fiber optic subassembly **95** includes a ferrule **96** and a housing **98** that houses and supports a ferrule holder **99**. The fiber optic subassembly may also include a spring for biasing the ferrule forward. Fiber optic subassembly **95** may be any suitable configuration type such as a SC-type or LC-type, but other types of fiber optic connector subassemblies are possible. The optical fiber **12** is securely retained inside ferrule **96** for inhibiting the effect of changes in optical fiber **12** length or misalignment issues when fiber optic cable **10** undergoes stress (e.g., compression, tension, side-load, etc.). During assembly, fiber optic subassembly **95** can be attached to the retention body **40**, such as by snap-fitting with interlocking fingers disposed on opposite sides of retention body **40**. US Pat. No. 8,272,792 illustrates an exemplary process for coupling a fiber optic cable subassembly to a retention body, the contents of which are hereby incorporated by reference.

[0044] Referring generally to **FIGS. 10** and **11**, an embodiment of an interior seal component, shown as interior seal component **100,** and an embodiment of an end seal component, shown as end seal component **120**, are shown. In general, the interior seal component **100** is substantially the same as the interior seal component **30** except as discussed herein, and the end seal component **120** is substantially the same as the end seal component **80** except as discussed herein.

[0045] The interior seal component **100** includes an expanded body portion **102** having a cavity that is configured and sized to receive the insertion end of the cable **10** and a reduced size section **104** that defines the front or leading surface **106** of interior seal component **100**. In the embodiment shown, a cavity of the interior seal component **100** terminates in a substantially circular aperture **108** formed through the front surface **106**. In general, the aperture **108** is shaped and sized to allow an optical transmission component of the cable **10**, such as optical fiber **12**, to extend out of the interior seal component **100** toward the second end **60** of the retention body **40**.

[0046] The interior seal component **100** includes one or more sealing ribs, shown as sealing ribs **110**, extending from reduced size section **104**. In the embodiment shown, the sealing ribs **110** extend radially outward from the reduced size section **104** and also extend completely around the perimeter of reduced size section **104**. In the specific embodiment shown, the sealing ribs **110** are substantially parallel to each other and are positioned substantially perpendicular to a longitudinal axis of the interior seal component **100**. In general, the outer dimensions of the sealing ribs **110** are sized to engage and seal against the inner surface of the passage **34**. Sealing ribs **110** are formed from a compliant deformable material that can deform as the interior seal component **100** is inserted into the passage **34** and can form a tight seal against the inner surface of the passage **34**.

[0047] In various embodiments, the sealing ribs **110** may be integrally formed with the rest of the interior seal component **100**. In other embodiments, the sealing ribs **110** may be separate components coupled around the reduced size section **104** and may be made from a material that is different from the rest of the interior seal component **100**. In the embodiment shown, the interior seal component **100** includes three sealing ribs **110**, but the interior seal component **100** may include any other numbers of ribs (e.g., 1, 2, 4, 8, 10, etc.) suitable to form a seal with the shape of a particular retention body **40**.

[0048] Referring to **FIG. 11**, the end seal component **120** includes a flange section **122** and a reduced sized insertion section **124**. The reduced sized insertion section **124** includes a rear

or insertion face **126**, and the interior channel of the end seal component **120** terminates in an opening **128** defined in the insertion face **126**. In the embodiment shown, the interior channel and opening **128** are shaped to conform to the outer surface of the cable **10**, and in the particular embodiment shown, opening **128** includes two semi-circular lobes **130** separated by upper and lower centrally located longitudinal ridges **132**.

[0049] The end seal component **120** includes one or more sealing ribs, shown as sealing ribs **134**, extending from the insertion section **124**. In the embodiment shown, the sealing ribs **134** extend radially outward from the insertion section **124** and also extend completely around the perimeter of insertion section **124**. In the specific embodiment shown, the sealing ribs **134** of insertion section **124** are substantially parallel to each other and are positioned substantially perpendicular to a longitudinal axis of the end seal component **120**. In general, the outer dimensions of the sealing ribs **134** are sized to engage and seal against the inner surface of the passage **34**. Sealing ribs **134** are formed from a compliant deformable material that deforms as the end seal component **120** is inserted into the passage **34** forming a tight seal against the inner surface of the passage **34**.

[0050] In various embodiments, the sealing ribs **134** may be integrally formed with the rest of the end seal component **120**. In other embodiments, the sealing ribs **134** may be separate components coupled around the insertion section **124** and may be made from a material that is different from the rest of the end seal component **120**. In the embodiment shown, the end seal component **120** includes three sealing ribs **134**, but the end seal component **120** may include any other numbers of ribs (e.g., 1, 2, 4, 8, 10, etc.) suitable to form a seal with the shape of a particular retention body **40**.

[0051] **FIG. 12** is a perspective view of a completed, terminated cable assembly, shown as connectorized cable assembly **140**. **FIG. 12** shows a plurality of outer protective layers and other components that surround the terminated cable end. Thus, the retention body of the terminated cable, such as retention body **40**, the ferrule and other components of the connectorized cable assembly are located within the protective structures shown in **FIG. 12**.

[0052] Cable assembly **140** includes a first heat shrink tube, shown as first heat shrink tubing **142**, is the first layer attached to the outer surface of the cable **10** at the beginning of the connector assembly. A second heat shrink tube, shown as second heat shrink tubing **144**, is attached to the outer surface of the first heat shrink tubing **142** and/or to the outer surface of the cable **10**. In general, the first heat shrink tubing **142** and the second heat shrink tubing **144** are formed from a polymer material that shrinks during heat to form a tight seal onto the

outer surface of the cable **10**.

[0053] As will be understood, the combination of the first heat shrink tubing **142** and the second heat shrink tubing **144** act to seal the insertion or upstream end of the connector assembly from water. In addition, the combination of the first heat shrink tubing **142** and the second heat shrink tubing **144** also acts to provide an increasing outer diameter onto which the adjacent components shown in **FIG. 12** can be mounted. In general, the first heat shrink tubing **142** forms a water tight seal onto the outer surface of the cable **10** which prevents liquid or moisture from traveling down the length of cable **10** into the connector assembly at the end of the terminated cable. The thickness of the first heat shrink tubing **142** also increases the outermost diameter of the terminated cable assembly, which allows the large diameter, second heat shrink tubing **144** to shrink to form a water tight seal onto the outer surface of the first heat shrink tubing **142**. In various embodiments, the two layers of heat shrink tubing disclosed here provides for water-tight sealing of the insertion or upstream side of the cable assembly while allowing the maximum outer diameter of the heat shrink sealing layers to be larger than may be easily achievable with a single layer of heat shrink tubing.

[0054] In various embodiments, first heat shrink tubing **142** is configured to provide for improved watertight sealing onto a contoured outer surface of the cable **10**. As noted above, in various embodiments cable **10** includes one or more longitudinally extending grooves **146** on the upper surface of the cable **10** and may also include a corresponding longitudinal groove located on the lower surface of cable **10**. In such embodiments, the inner surface of heat shrink tubing **142** may be defined by a layer of meltable adhesive material. In such embodiments, when heat is applied to shrink first heat shrink tubing **142** the inner layer of meltable adhesive melts and flows into the longitudinal grooves of the cable **10**. When the meltable adhesive solidifies the adhesive has closely conformed to the contours of the outer surface of cable **10** and has filled the longitudinal grooves facilitating the formation of the watertight seal.

[0055] In various embodiments, heat shrink tubing **142** and **144** may be installed onto the cable **10** as part of a method of terminating a cable. In such methods, the cable **10** is passed through a central opening or channel of heat shrink tubing **142** after coupling of cable **10** to the retention body **40**. Next, heat shrink tubing **142** is coupled to and sealed onto the outer surface of the cable **10** at a position upstream along the cable from retention body **40**. Next, the cable **10** is passed through a central opening or channel of heat shrink tubing **144**, and heat shrink tubing **144** is coupled and sealed onto the outer surface of the cable **10** and/or heat

shrink tubing **142** also at a position upstream along the cable from retention body **40**. In various embodiments, the seals formed by heat shrink tubing **142** and **144** are fluid-tight or watertight seals. In various embodiments, sealing the first heat shrink tubing **142** onto the cable **10** includes melting the meltable adhesive located within heat shrink tubing **142** to conform to the outer surface of the cable **10** during heating.

[0056] Still referring to **FIG. 12**, a covering or boot, shown as boot **148**, is coupled to the second heat shrink tube **144**. In general, the boot **148** is formed from a flexible plastic material and controls flexibility at the cable connector and may also be configured to provide strain relief. A cap, shown as dust cap **150**, is located at the end of the terminated cable, and a coupling nut **152** is located between the boot **148** and the dust cap **150**. In general, coupling nut **152** facilitates coupling to the appropriate network equipment (e.g., network service panel). Dust cap **150** protects the end of the fiber optic connector located within the dust cap **150**. Dust cap **150** also includes a ring or loop, shown as attachment loop **154**, located at the second or downstream end of dust cap **150**. Loop **154** facilitates coupling to a tool, such as a pulling tool, that may be used during installation and deployment of the terminated cable.

[0057] As an alternative to placing a molded seal component **30** onto the end of the insertion end of the cable, the interior seal component may be a highly viscous liquid or a semi-solid sealing compound that is placed on the end of the cable prior to insertion into the retention body **40**. In such embodiments, the interior sealing compound can be, for example, an adhesive material that is applied to the insertion end of the cable **10**. In this embodiment, applying the interior sealing compound can replace the step of applying the interior seal component **30**. The interior sealing compound can be allowed to cure after insertion into the retention body **40** such that a seal is formed between the adhesive injection aperture **44** and the second end **60** of the retention body **40**. In some exemplary embodiments, the interior sealing compound may be sufficiently viscous (e.g., may have a putty-like consistency) so as to center and seal the cable within the retention body **40**. When the filler agent is introduced into the bonding chamber **48**, the interior sealing compound acts to limit or prevent the passage of filler agent past the seal toward the second, front end **60** of the retention body as it is injected into the passage **34** through the aperture **44**.

[0058] According to another embodiment, the interior sealing component **30** and the end seal component **80** can be formed as a single component. The component can be configured for attached as a single unit to the cable **10**, and configured to seal both the interior of the retention body **40** and its end. The end seal and interior seal component could be connected

by, for example, a web matrix, longitudinally extending strips of material, or other means.

[0059] In the embodiments discussed herein, it is desirable to retain the filler agent within the passage **34**. It is not necessary, however, to form a perfect seal at the interior and exterior seal components. It may be sufficient, for example, if less than five percent of the filler agent introduced into the retention body **40** moves out of the bonding chamber toward the front end of the retention body **40**. According to another embodiment, it may be sufficient that at least 90 percent of the filler agent introduced into the retention body is maintained between the end seal component and the interior seal component.

[0060] The interior seal components disclosed herein can be made from deformable materials of sufficient rigidity to hold the cable relatively securely within the retention body during termination. For example, urethanes or other deformable plastics can be used to form molded pieces to serve as the seal components. The end seal component can be formed from similar materials. In various embodiments, various components discussed herein, including the interior seal component and/or the end seal component, may be made from materials such as styrene butadiene rubber (SBR), liquid silicone rubber (LSR), and styrene ethylene butylene styrene (SEBS) block copolymers. One exemplary set of materials used to form the interior seal component and/or the end seal has a Shore hardness in the range of 20-50.

[0061] The strength members according to the present embodiments can be, for example, elongate rigid elements extending along the length of a cable. Examples of rigid strength components include dielectric rods, metallic rods, metallic wires and similar materials. In one embodiment, the strength members can be glass reinforced plastic (GRP) rods. Strength members can also include one or more tensile yarns extending along the length of a cable. In one embodiment, the strength members are aramid yarns, such as yarns available under the brand name KEVLAR®, disposed within or inside or the cable jacket.

[0062] The cable jackets disclosed herein can be generally described as 'polymeric.' In this specification, the terms "polymer" and "polymeric" indicate materials comprised primarily of extrudable polymer materials such as, for example, copolymers, but allows for the presence of non-polymer materials such as additives and fillers. An example of polymers suitable for use in cable jackets according to the present embodiments includes polyethylene.

[0063] The fiber optic cable **10** may be of any desired length. The upstream end fiber optic cable **10** comprising part of the cable assembly **140**, which is not illustrated, may be, for example, connectorized as shown in the figures, may be a simple section of cable, or may be otherwise connected.

[0064] The retention body can be constructed from any relatively rigid material, such as plastics and metals. In the illustrated embodiment, the retention body is made from an engineering thermoplastic.

[0065] The seals according to the illustrated embodiments are shown as continuous tubular shapes without interruption or discontinuity in the tubular cross-sections of the seals. For ease of installation, a slit, for example, may be cut into the cross-sections so that a seal may be opened and inserted onto a cable exterior. Any interruption in the cross-section of a seal should be calibrated so as to allow the seal to achieve to a desired level of liquid seal to be obtained for the termination process.

[0066] Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that any particular order be inferred.

[0067] It will be apparent to those skilled in the art that various modifications and variations can be made without departing from the spirit or scope of the invention. Since modifications combinations, sub-combinations and variations of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method of terminating a cable, comprising:

providing a cable having at least one optical transmission component;

providing a retention body having an insertion end and a passage extending at least partially through a length of the retention body;

preparing a first end of the cable;

inserting the first end of the cable and the interior seal component into the passage so that the interior seal component is located at the first end of the cable; and

introducing a filler material into the passage.

2. The method of claim 1, further comprising, prior to inserting the first end of the cable and the interior seal component into the passage, placing the interior seal component at the first end of the cable.

3. The method of claim 1 or 2, further comprising coupling a fiber optic subassembly to the retention body, the fiber optic subassembly including a ferrule housing, and a ferrule for connection to the at least one optical transmission component.

4. The method of any of claims 1 through 3, wherein preparing the first end of the cable comprises removing at least a portion of a jacket of the cable, wherein removing at least a portion of the jacket at least partially exposes at least one optical transmission component of the cable.

5. The method of claim 4, wherein preparing the first end of the cable comprises removing at least a portion of a strength component of the cable, the strength component comprising a component selected from the group consisting of elongate metallic components, elongate glass-reinforced plastic components, and aramid fibers.

6. The method of any of claims 1 through 5, further comprising:

passing the cable through a first tube;

placing the first tube onto an outer surface of the cable at a position upstream from the retention body along the cable; and

placing a second tube onto an outer surface of the first tube at a position upstream

along the cable from the retention body.

7. The method of any of claims 1 through 6, wherein placing an interior seal component at the first end of the cable comprises extending the at least one optical transmission component through an aperture in the interior seal component.

8. The method of claim 7, wherein the at least one optical transmission component is pulled manually through the aperture in the interior seal component, and the interior seal component is placed manually over the first end of the cable.

9. The method of any of claims 1 through 8, wherein the interior seal component has an exterior width that is larger than an exterior width of the cable, and wherein the interior seal component has an exterior height that is larger than an exterior height of the cable.

10. The method of claim 9, wherein inserting the first end of the cable and the interior seal component into the passage causes at least one of the width and height of the interior seal component to reduce by at least one percent where it contacts the passage.

11. The method of any of claims 1 through 10, wherein inserting the first end of the cable and the interior seal component into the passage causes the interior seal component to form a seal in the passage to prevent a substantial portion of filler material from passing between the interior seal component and an interior surface of the passage.

12. The method of any of claims 1 through 11, wherein the passage has a first cross-sectional area at the insertion end, and a second cross-sectional area at a narrowed section of the passage, the second cross-sectional area being smaller than the first cross-sectional area, and wherein inserting the first end of the cable and the interior seal component into the passage causes the interior seal component to abut an interior surface of the narrowed section of the passage.

13. The method of any of claims 1 through 12, wherein introducing the filler material into the passage comprises introducing the filler material through an aperture in the retention body, the aperture opening into the passage at a location between the interior seal component

and the insertion end of the retention body.

14. The method of any of claims 1 through 13, wherein inserting the first end of the cable and the interior seal component into the passage causes at least one outwardly extending rib of the interior seal component to engage the passage.

15. The method of any of claims 2 through 14, wherein placing the interior seal component at the first end of the cable comprises inserting at least a portion of the first end of the cable in a cavity of the interior seal component.

16. The method of any of claims 1 through 15, further comprising placing an end seal component on the cable so that the cable extends through an aperture in the end seal component.

17. The method of claim 16, further comprising moving the end seal component to a position abutting the insertion end of the retention body to inhibit a flow of filler material from passing out of the retention body.

18. The method of any of claims 1 through 17, wherein the retention body is an elongate tubular body and the passage extends through at least half a length of the retention body.

19. The method of any of claims 1 through 17, wherein the retention body is an elongate tubular body and the passage extends through the full length of the retention body.

20. The method of any of claims 1 through 19, wherein the interior seal component is a molded piece and the first end of the cable forms an interference fit with the interior seal component.

21. The method of any of claims 1 through 20, wherein an outer surface of the interior seal component forms an interference fit with an interior surface of the passage.

22. The method of any of claims 1 through 21, wherein the retention body is made from a rigid thermoplastic.

23. The method of any of claims 1 through 22, wherein the interior seal component is a deformable component having a Shore hardness in the range of 20-50.

24. The method of any of claims 3 through 23, wherein the at least one optical transmission component includes an optical fiber having an end disposed within the ferrule.

25. The method of any of claims 1 through 24, wherein the filler material is introduced as a liquid into the passage and is selected from the group consisting of epoxy, adhesive, resin, and glue.

26. A fiber optic cable assembly, comprising:

a fiber optic cable including at least one optical transmission component;

a retention body having an insertion end and a passage extending from the insertion end at least partially through a length of the retention body; and

an interior seal component located within the passage at a first end of the cable and abutting an interior surface of the passage; and

a filler material located within the passage and surrounding a portion of the cable and contacting the interior seal component,

wherein the fiber optic cable extends out of the passage from the insertion end, and the at least one optical transmission component extends through the passage to a front end of the retention body.

27. The fiber optic cable assembly of claim 26, further comprising a fiber optic subassembly coupled to the retention body, the fiber optic subassembly including a ferrule housing and a ferrule, an end of the optical transmission component being disposed within the ferrule.

28. The fiber optic cable assembly of any of claims 26 through 27, further comprising:

a first tube surrounding an outer surface of the cable upstream along the cable from the retention body; and

a second tube disposed on an outer surface of the first tube at a position upstream along the cable from the retention body,

wherein the first tube includes a meltable adhesive located within the first tube configured to melt and conform to the outer surface of the cable during heating.

29. The fiber optic cable assembly of any of claims 26 through 28, wherein the interior seal component includes a cavity and the first end of the cable is received in the cavity, in part coupling the interior seal component to the first end of the cable.

30. The fiber optic cable assembly of any of claims 26 through 29, wherein an outer surface of the interior seal component forms an interference fit with an interior surface of the passage.

31. The fiber optic cable assembly of claim 30, wherein the passage includes a tapered section having a cross-sectional area that decreases as the distance from the insertion end increases, wherein the interference fit is formed at the tapered section of the passage.

32. The fiber optic cable assembly of any of claims 26 through 31, wherein the interior seal component is formed from a polymer material and surrounds the first end of the cable, wherein the polymer material is under compression to form the interference fit within the passage.

33. The fiber optic cable assembly of any of claims 26 through 32, further comprising an end seal component located at the insertion end of the retention body, wherein the cable extends through the end seal component.

34. The fiber optic cable assembly of claim 33, wherein the passage, the end seal component and the interior seal component in part define a bonding chamber within a portion of the passage, at least 90 percent of the filler material introduced into the retention body being located between the end seal component and the interior seal component.

35. The fiber optic cable assembly of any of claims 27 through 34, wherein the at least one optical transmission component extends through the passage away from the first end of the cable and terminates at the ferrule.

36. The fiber optic cable assembly of any of claims 33 through 35, wherein the end seal component abuts the insertion end of the retention body and a reduced sized insertion section extends into the passage and contacts the filler material.

37. The fiber optic cable assembly of any of claims 26 through 36, wherein the retention body is an elongate tubular body and the passage extends through the full length of the body.

38. The fiber optic cable assembly of any of claims 26 through 37, wherein the interior seal component is a molded piece and wherein the retention body is made from a thermoplastic.

39. The fiber optic cable assembly of any of claims 26 through 38, wherein the interior seal component is a deformable component having a Shore hardness in the range of 20-50.

40. The fiber optic cable assembly of any of claims 26 through 39, wherein the filler material is selected from the group consisting of epoxy, adhesive, resin, and glue.

41. A fiber optic cable assembly, comprising:

a fiber optic cable including at least one optical fiber;

a retention body having an insertion end and a passage extending from the insertion through a length of the retention body; and

an interior seal component located within the passage and abutting an interior surface of the passage;

a filler material located within the passage and surrounding a portion of the cable; and

a fiber optic subassembly coupled to a front end of the retention body, the fiber optic subassembly including a ferrule housing and a ferrule, an end of the optical fiber being disposed within the ferrule, wherein

the fiber optic cable extends out of the passage from the insertion end, and the at least one optical fiber extends through the passage to the front end of the retention body.

42. The fiber optic cable assembly of claim 41, comprising an end seal component at the insertion end of the retention body.

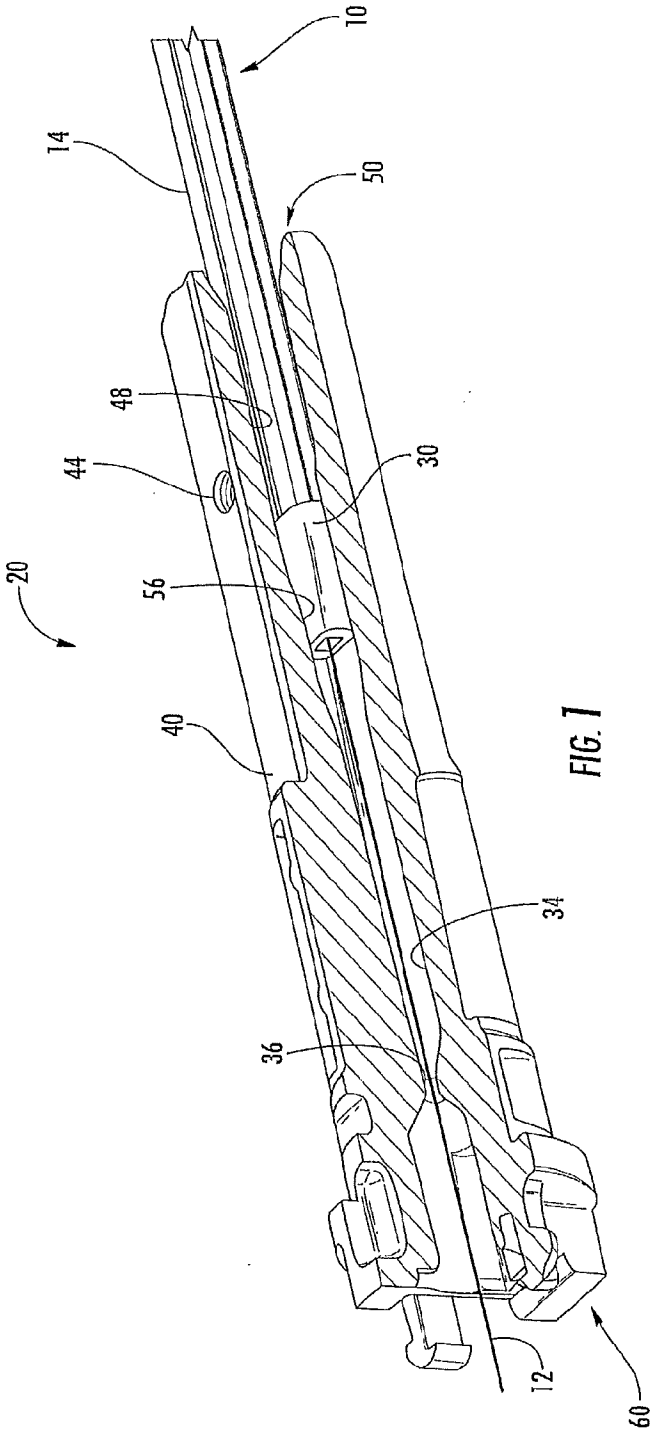


FIG. 1

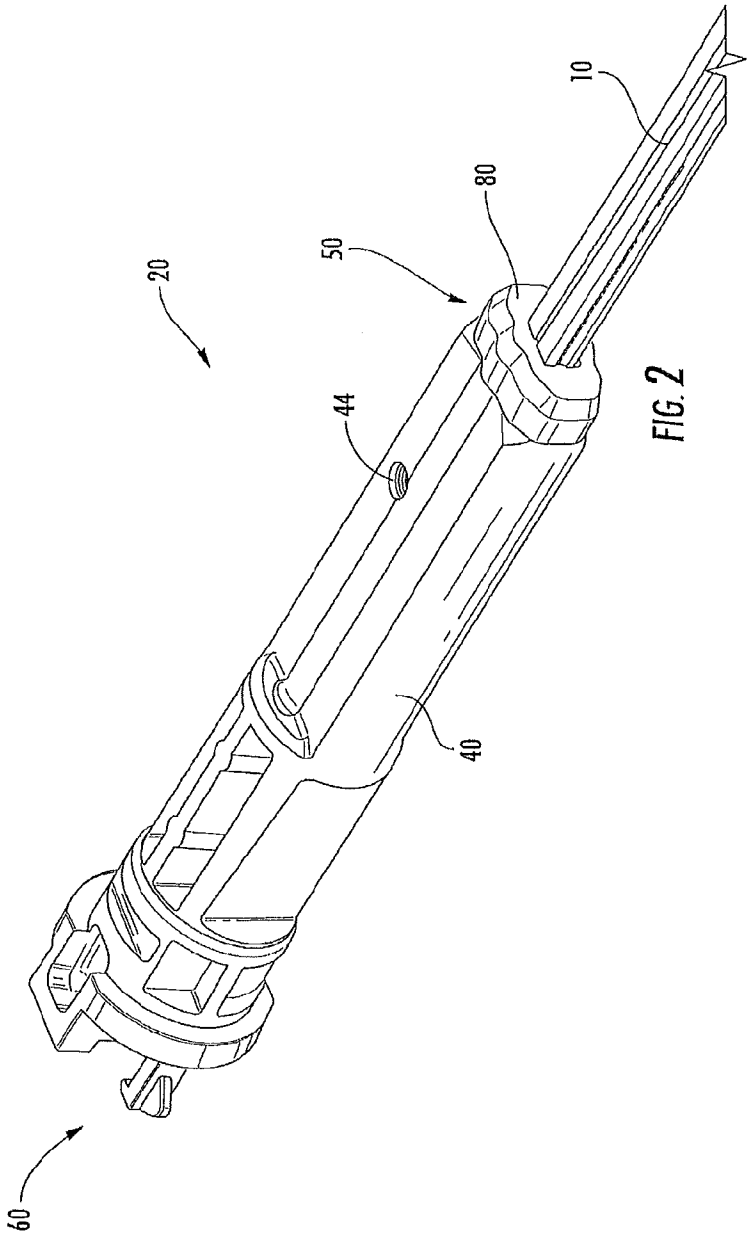


FIG. 2

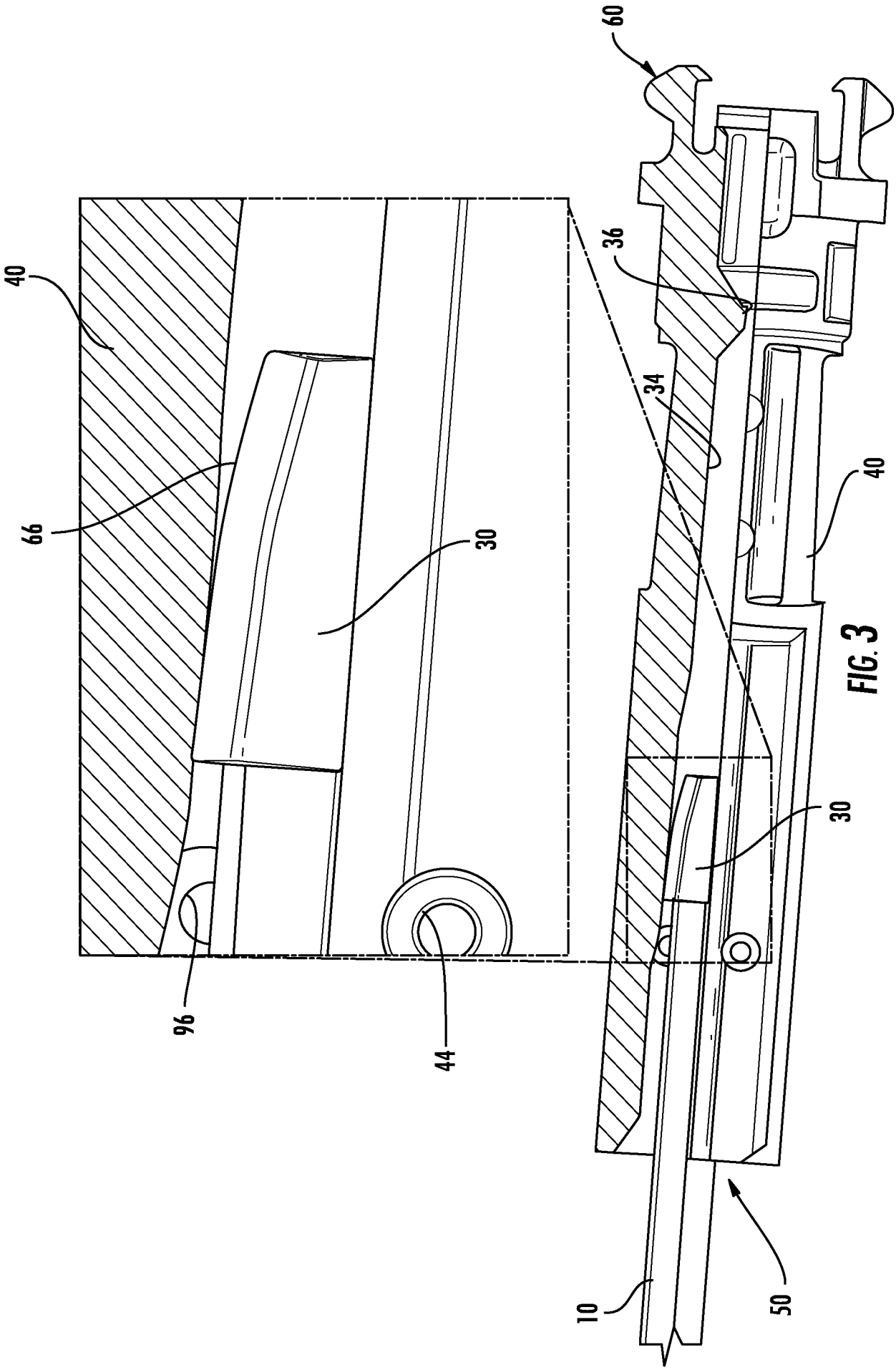


FIG. 3

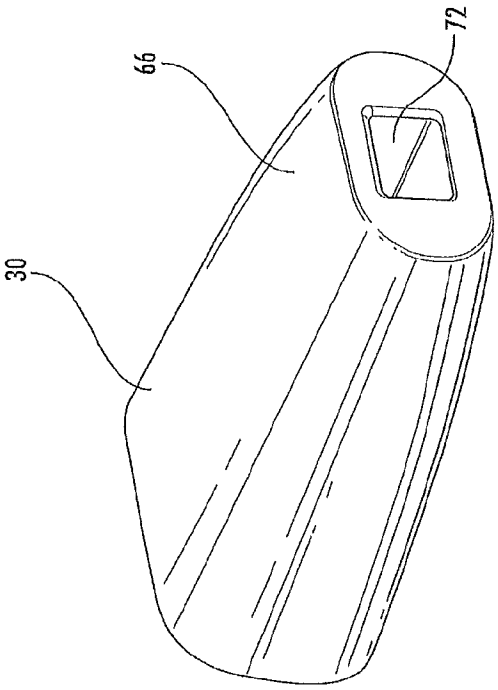


FIG. 4B

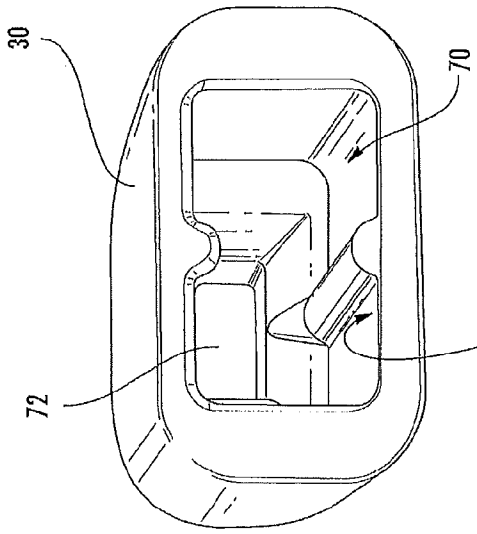
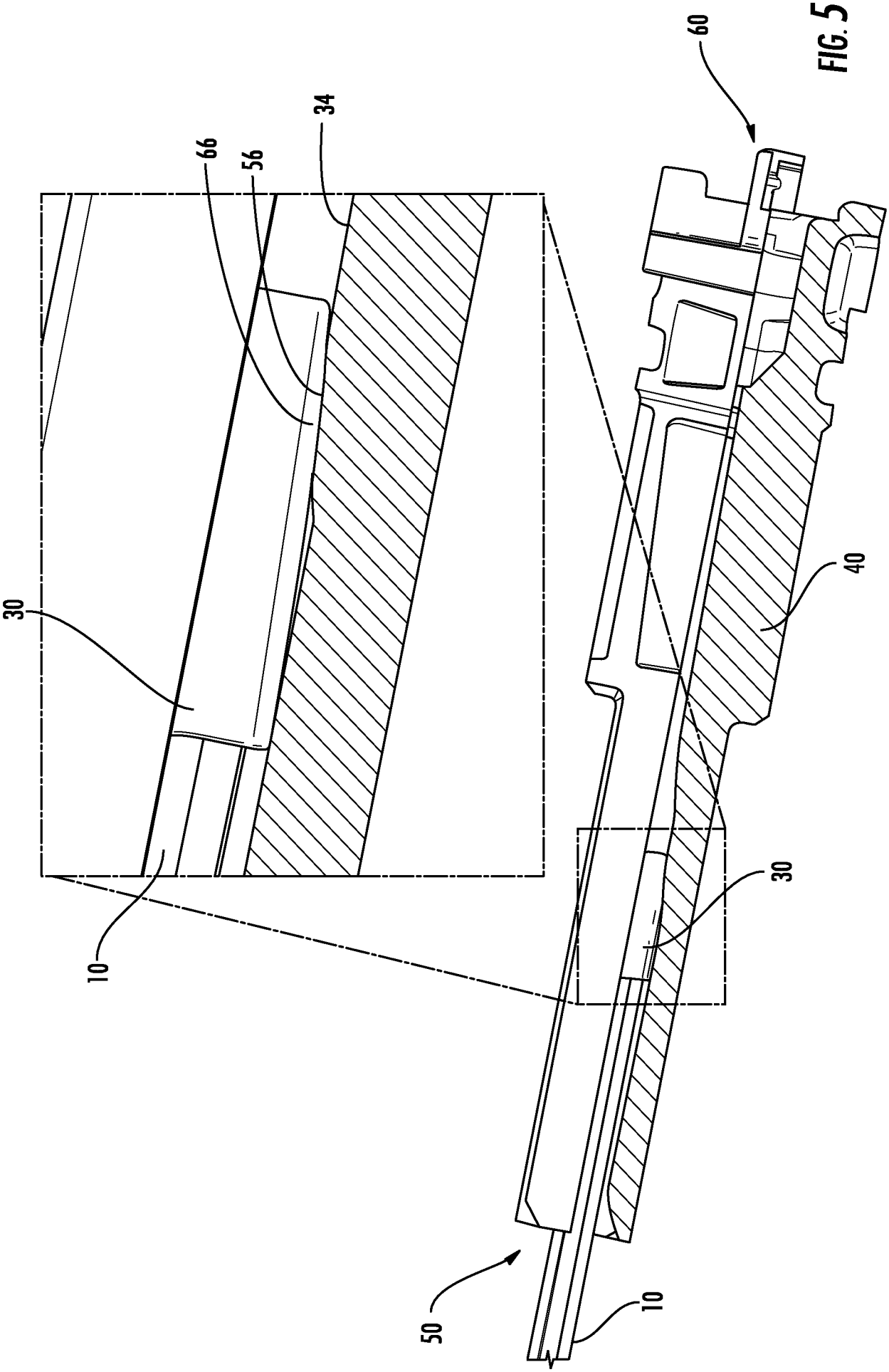


FIG. 4A

FIG. 5



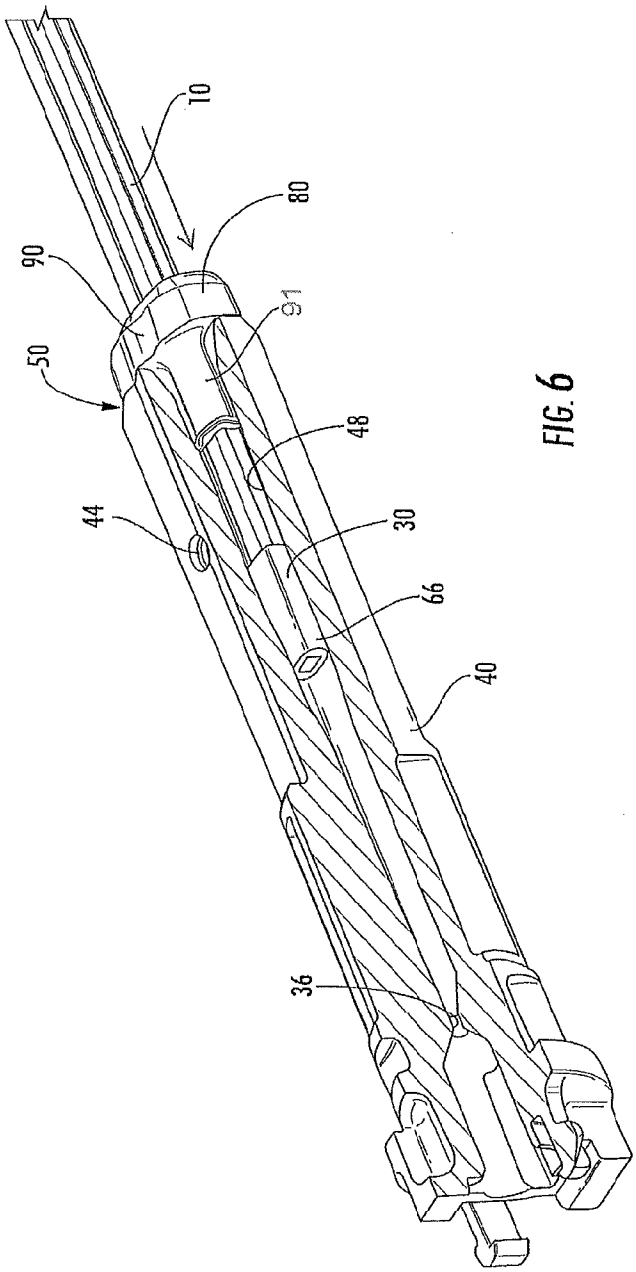


FIG. 6

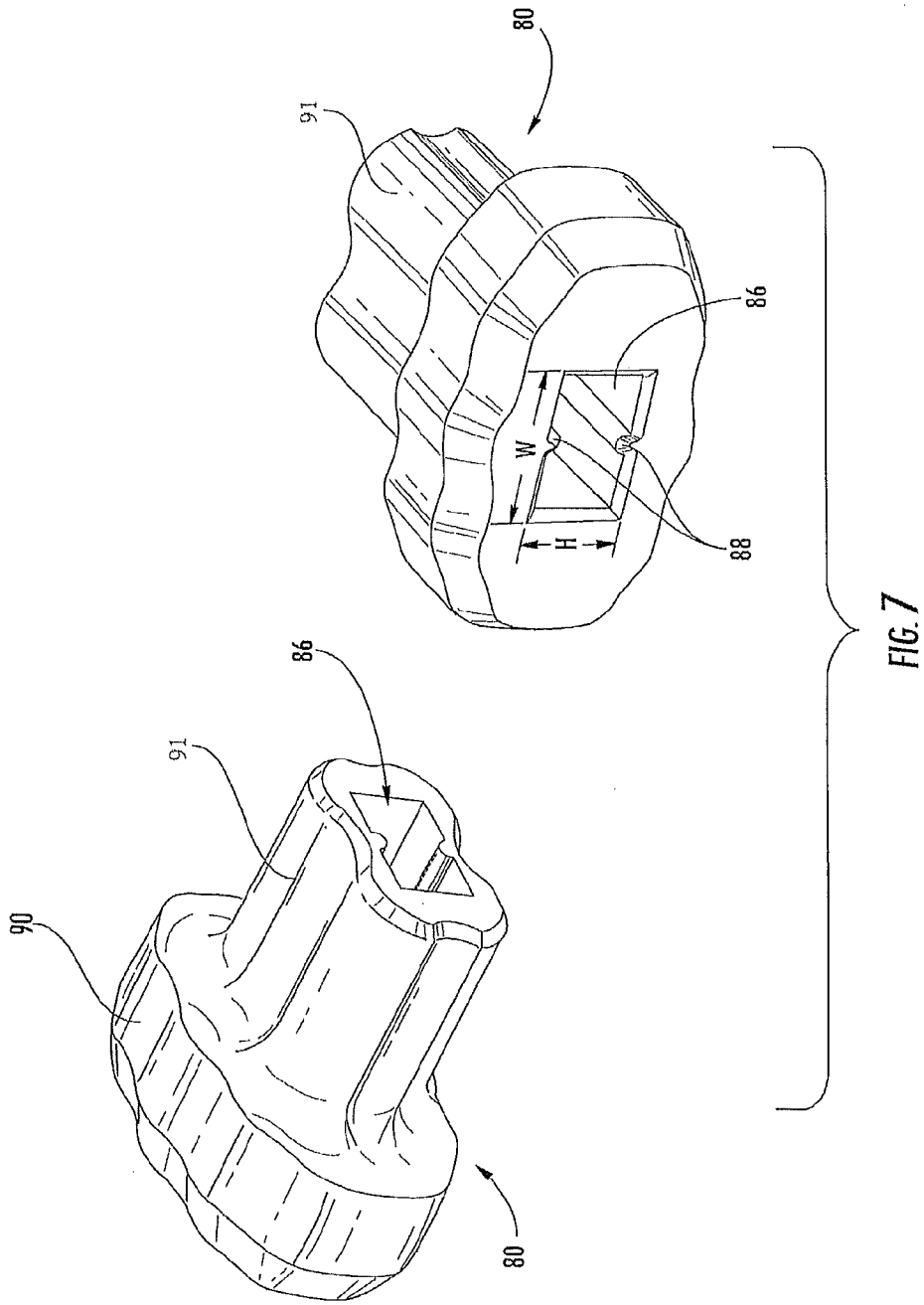


FIG. 7

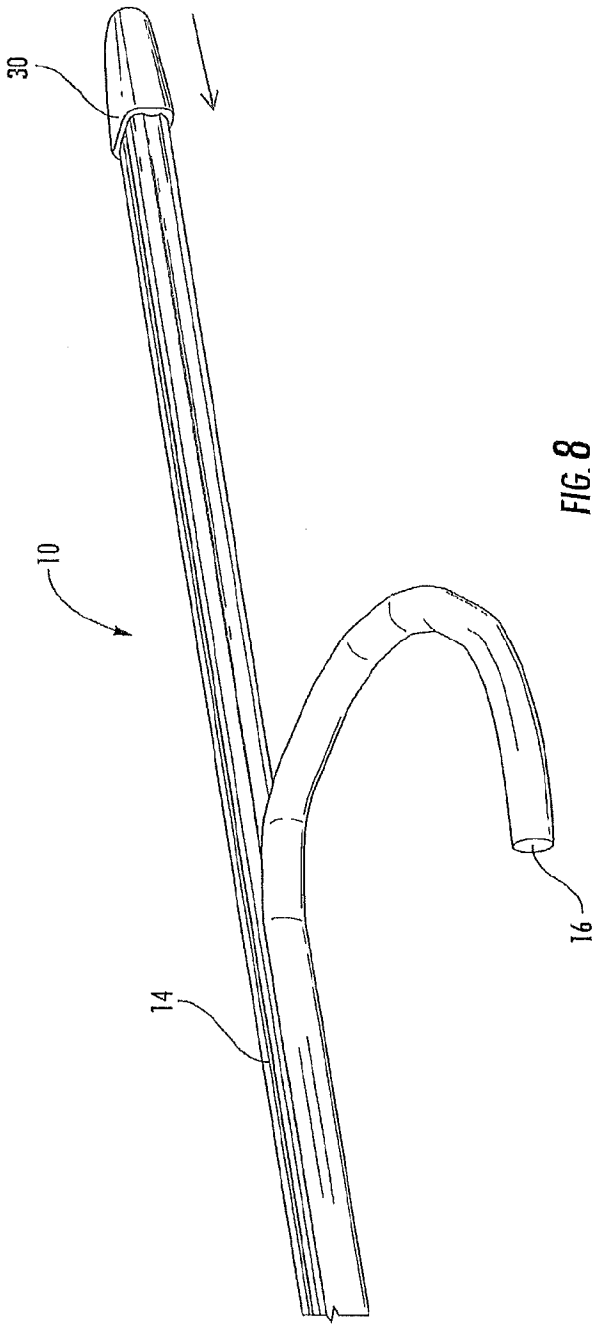


FIG. 8

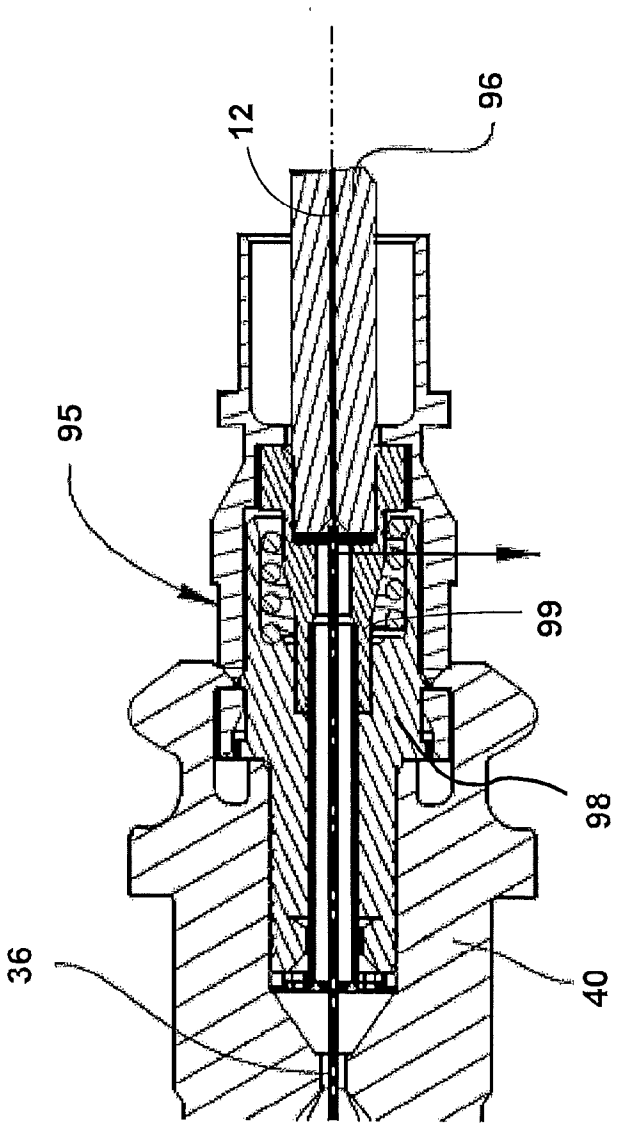


FIG. 9

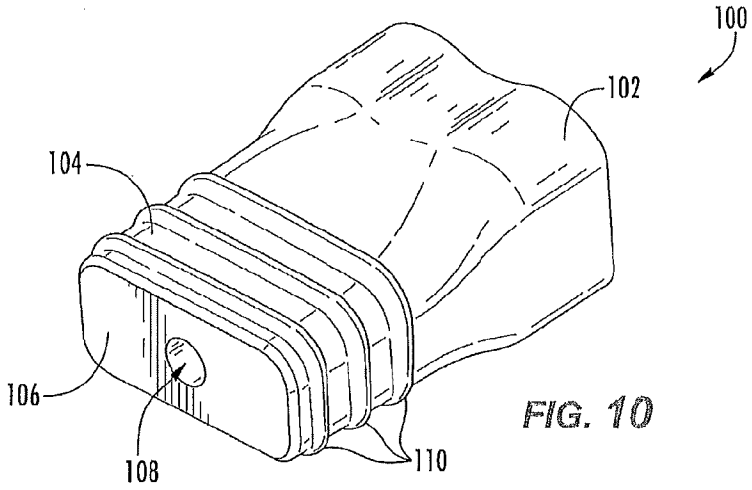


FIG. 10

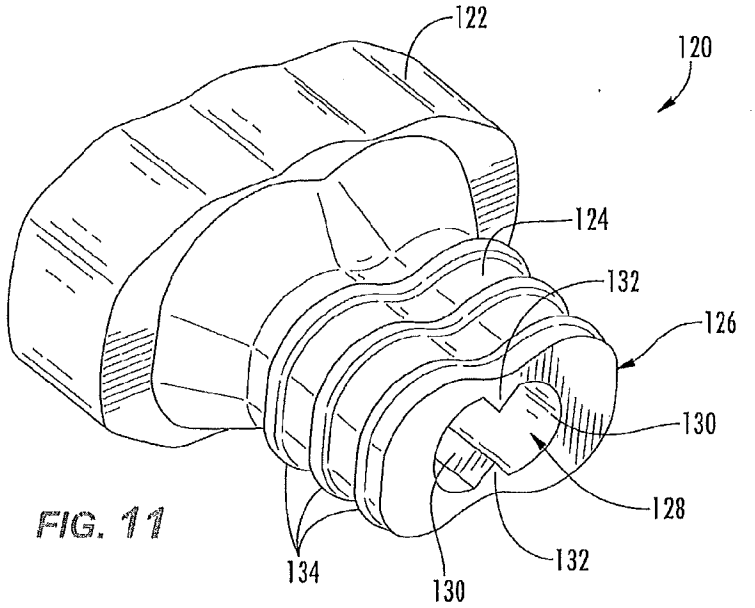


FIG. 11

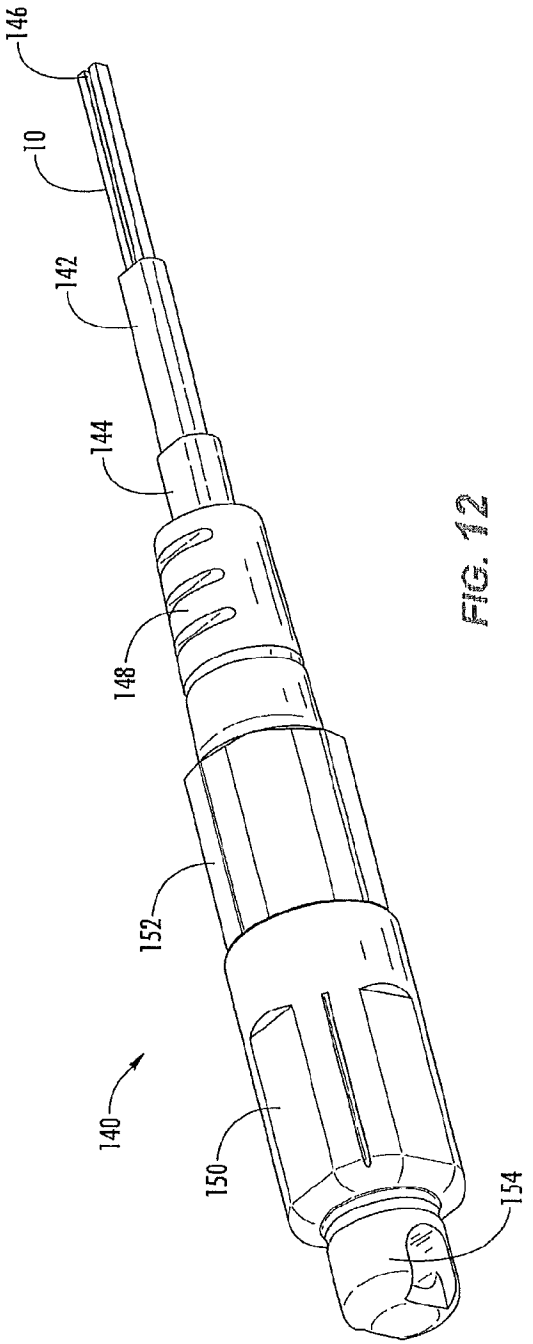


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/030060

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/38
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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014/063154 A1 (LICHOULAS TED [US]) 24 April 2014 (2014-04-24) figures 4,5 paragraph [0056] paragraph [0060] -----	1-10, 12-33, 35-42
Y	US 2006/115229 A1 (SHIMAZU HIDETO [JP] ET AL) 1 June 2006 (2006-06-01) figures 1,4,5 paragraph [0037] -----	1-10, 12-33, 35-42
A	WO 2010/039837 A1 (CORNING CABLE SYS LLC [US]; COLEMAN CASEY A [US]; THEUERKORN THOMAS [U) 8 April 2010 (2010-04-08) ----- -/--	1-42

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

[X] See patent family annex.

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

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

"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	Date of mailing of the international search report
28 August 2015	08/09/2015

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	Verbandt, Yves

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/030060

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2008/310798 A1 (CODY JOSEPH TODD [US] ET AL) 18 December 2008 (2008-12-18)	1-42
A	EP 2 053 433 A1 (SUMITOMO ELECTRIC INDUSTRIES [JP]) 29 April 2009 (2009-04-29)	1-42
A	WO 2010/102081 A2 (ADC TELECOMMUNICATIONS INC [US]; BRAN DE LEON OSCAR FERNANDO [US]; SOL) 10 September 2010 (2010-09-10)	1-42
A	GB 2 013 922 A (BOWTHORPE HELLERMANN LTD) 15 August 1979 (1979-08-15)	1-42
A	EP 0 526 108 A2 (AMERICAN TELEPHONE & TELEGRAPH [US]) 3 February 1993 (1993-02-03)	1-42

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/030060

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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