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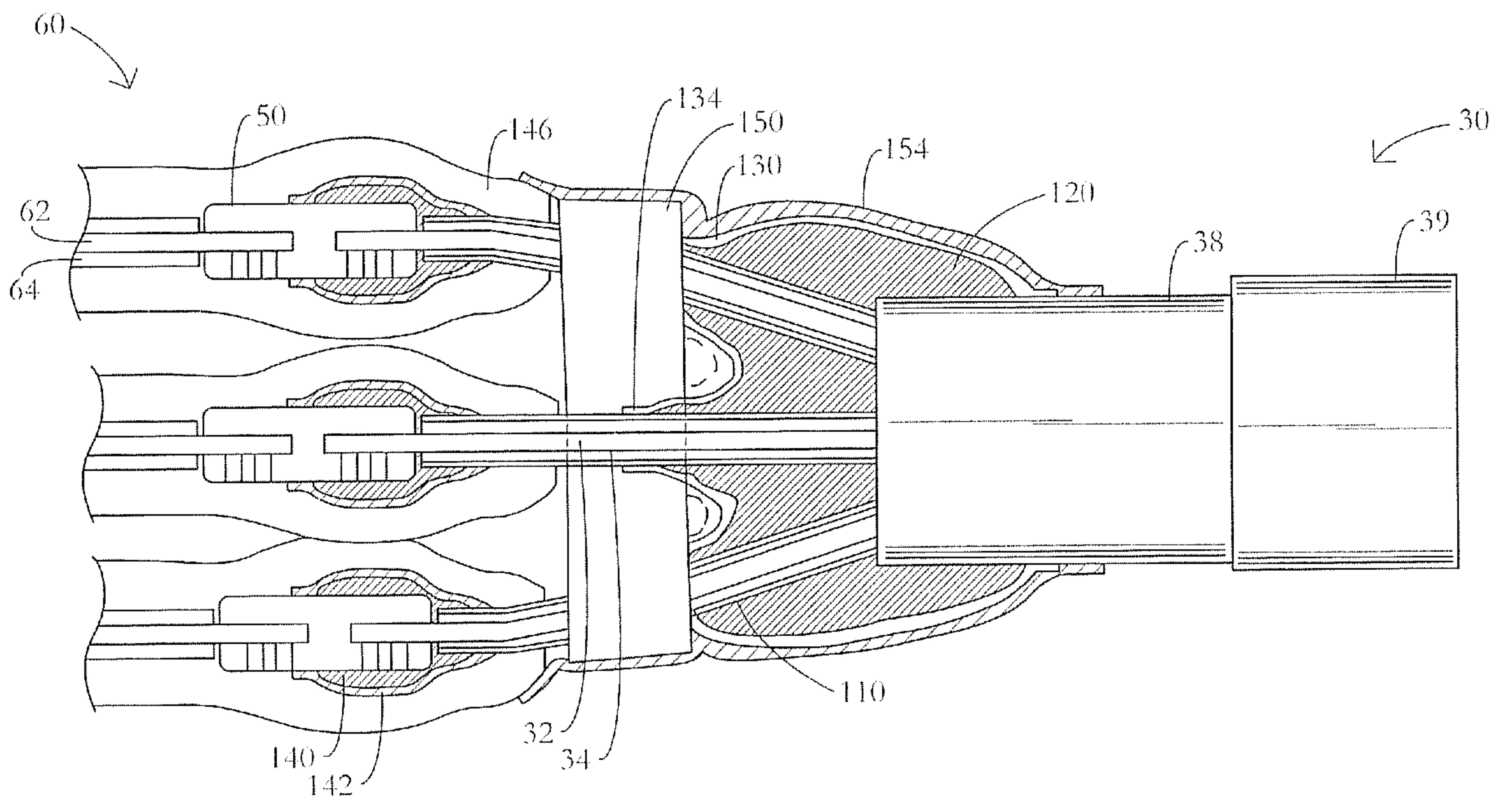
(54) **Titre : ENSEMBLES CABLES RECOUVERTS ET PROCEDES ET SYSTEMES PERMETTANT DE FORMER CEUX-CI**
(54) **Title: COVERED CABLE ASSEMBLIES AND METHODS AND SYSTEMS FOR FORMING THE SAME**



(57) **Abrégé/Abstract:**
A covered cable assembly includes a cable and a sealing assembly. The cable includes a metal sheath and a cable core. The metal sheath has a sheath terminal edge defining a sheath opening. The cable core extends through the metal sheath. The cable core includes an electrical conductor and an oil-impregnated paper insulation layer surrounding the electrical conductor. An extended cable core section of the cable core extends through the sheath opening and beyond the sheath terminal edge. The sealing assembly includes an oil barrier tube, a sealing mastic and a pressure retention tape. The oil barrier tube surrounds the extended cable core section. The sealing mastic surrounds the cable about the sheath terminal edge and overlaps portions of the metal sheath and the oil barrier tube adjacent the sheath terminal edge to effect an oil barrier seal between the metal sheath and the cable core at the sheath opening. The pressure retention tape surrounds the sealing mastic to limit displacement of the sealing mastic.

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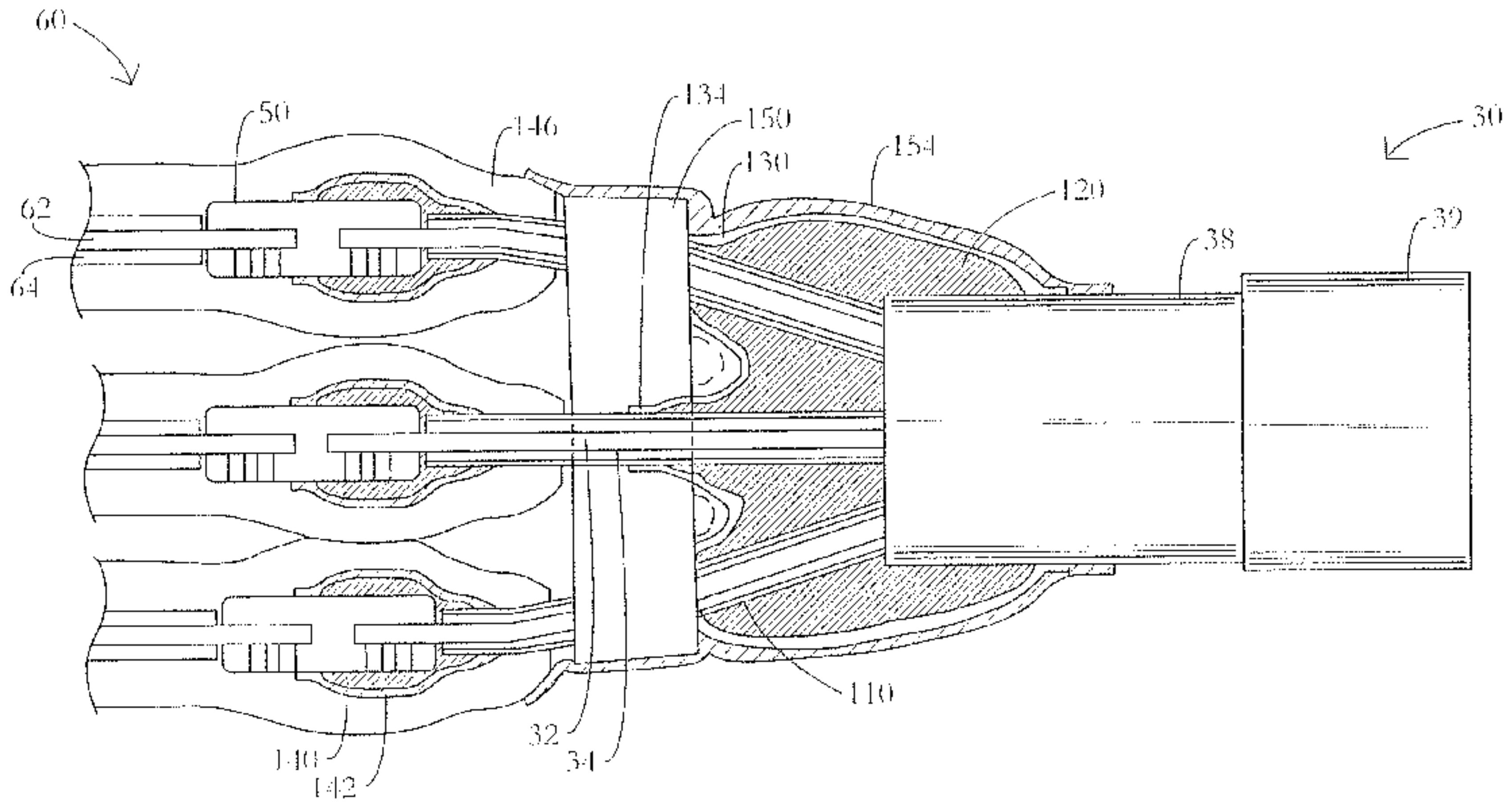

FIG. 19B

(57) **Abstract**: A covered cable assembly includes a cable and a sealing assembly. The cable includes a metal sheath and a cable core. The metal sheath has a sheath terminal edge defining a sheath opening. The cable core extends through the metal sheath. The cable core includes an electrical conductor and an oil-impregnated paper insulation layer surrounding the electrical conductor. An extended cable core section of the cable core extends through the sheath opening and beyond the sheath terminal edge. The sealing assembly includes an oil barrier tube, a sealing mastic and a pressure retention tape. The oil barrier tube surrounds the extended cable core section. The sealing mastic surrounds the cable about the sheath terminal edge and overlaps portions of the metal sheath and the oil barrier tube adjacent the sheath terminal edge to effect an oil barrier seal between the metal sheath and the cable core at the sheath opening. The pressure retention tape surrounds the sealing mastic to limit displacement of the sealing mastic.

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COVERED CABLE ASSEMBLIES AND METHODS AND SYSTEMS FOR FORMING THE SAME

Field of the Invention

[001] The present invention relates to electrical cables and, more particularly, to covers for electrical cables having oil-impregnated paper insulation.

Background of the Invention

[002] Covers are commonly employed to protect or shield electrical power cables and connections (*e.g.*, low voltage cables up to about 1000V and medium voltage cables up to about 65 kV). One application for such covers is for splice connections of metal-sheathed, paper-insulated cables such as paper-insulated lead cable (PILC). A PILC typically includes at least one conductor surrounded by an oil-impregnated paper insulation layer, and a lead sheath surrounding the conductor and insulation layer. Alternatively, the metal sheath may be formed of aluminum. In some cases, it is necessary to contain the oil. It is known to use a heat shrinkable sleeve made of a polymer that does not swell when exposed to the oil. Examples of such heat shrinkable sleeves include heat shrinkable oil barrier tubes (OBT) available from Tyco Electronics Corporation of Fuquay-Varina, NC. The sleeve is placed over the oil impregnated paper and heat is applied to contract the sleeve about the insulation layer. Mastic or other sealant material may be used at each end of the sleeve to ensure an adequate seal and containment of the oil.

Summary of the Invention

[003] According to embodiments of the present invention, a covered cable assembly includes a cable and a sealing assembly. The cable includes a metal sheath and a cable core. The metal sheath has a sheath terminal edge defining a sheath opening. The cable core extends through the metal sheath. The cable core includes an electrical conductor and an oil-impregnated paper insulation layer surrounding the electrical conductor. An extended cable

core section of the cable core extends through the sheath opening and beyond the sheath terminal edge. The sealing assembly includes an oil barrier tube. a sealing mastic and a pressure retention tape. The oil barrier tube surrounds the extended cable core section. The sealing mastic surrounds the cable about the sheath terminal edge and overlaps portions of the metal sheath and the oil barrier tube adjacent the sheath terminal edge to effect an oil barrier seal between the metal sheath and the cable core at the sheath opening. The pressure retention tape surrounds the sealing mastic adjacent to the sheath terminal edge to limit displacement of the sealing mastic.

[004] According to method embodiments of the present invention, a method for forming a covered cable assembly includes providing a cable including: a metal sheath having a sheath terminal edge defining a sheath opening: and a cable core extending through the metal sheath. The cable core including an electrical conductor and an oil-impregnated paper insulation layer surrounding the electrical conductor; wherein an extended cable core section of the cable core extends through the sheath opening and beyond the sheath terminal edge. The method further includes: mounting an oil barrier tube on the extended cable core section such that the oil barrier tube surrounds the extended cable core section: applying a sealing mastic to the cable such that the sealing mastic surrounds the cable about the sheath terminal edge and overlaps portions of the metal sheath and the oil barrier tube adjacent the sheath terminal edge to effect an oil barrier seal between the metal sheath and the cable core at the sheath opening; and applying a pressure retention tape to surround the sealing mastic to limit displacement of the sealing mastic.

[005] According to further embodiments of the present invention, a cover system for covering a cable including a metal outer sheath and multiple cable cores, each cable core including an electrical conductor surrounded by an oil-impregnated paper insulation, includes: a plurality of oil barrier tubes each configured to be mounted on a respective one of the cable cores: a sealing mastic to be mounted on the oil barrier tubes and the metal sheath to effect an oil barrier seal between the metal sheath and the cable cores at an opening of the metal sheath; an elastomeric breakout having a main tubular body to receive the metal sheath and a plurality of tubular fingers integral with the main tubular body and configured to receive respective

ones of the cable cores; an insert member, the insert member having a plurality of legs configured to be interposed between the first, second and third tubular fingers; and a pressure retention tape to surround the breakout and the insert member to limit displacement of the sealing mastic.

[006] According to embodiments of the present invention, a covered cable assembly

includes a cable, an electrically conductive connector, and a sealing assembly. The cable includes: a metal sheath having a sheath terminal edge defining a sheath opening; and a cable core extending through the metal sheath, the cable core including an electrical conductor and an oil-impregnated paper insulation layer surrounding the electrical conductor. An extended cable core section of the cable core extends through the sheath opening and beyond the sheath terminal edge. The electrically conductive connector is mounted on the electrical conductor. The sealing assembly includes an oil barrier tube, a connector mastic, and a connector pressure retention tape. The oil barrier tube surrounds the extended cable core section. The connector mastic surrounds and engages each of the connector and the oil barrier tube adjacent an interface between the connector and the oil barrier tube to effect an oil barrier seal about the cable core. The connector pressure retention tape surrounds the cable and the connector mastic and includes first and second opposed end portions extending axially beyond the connector mastic. The first end portion overlaps and adheres to the connector and the second end portion overlaps and adheres to the oil barrier tube.

Brief Description of the Drawings

[007] **Figures 1-21** illustrate methods for forming a covered cable assembly according to embodiments of the present invention using a cover system according to embodiments of the present invention.

[008] **Figures 22-32** illustrate methods according to further embodiments of the present invention for forming a covered cable assembly according to embodiments of the present invention using a cover system according to embodiments of the present invention.

Detailed Description of Embodiments of the Invention

[009] The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which illustrative embodiments of the invention are shown. In the drawings, the relative sizes of regions or features may be exaggerated for clarity. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0010] It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present invention.

[0011] Spatially relative terms, such as "beneath", "below", "lower", "above", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90° or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0012] As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless expressly stated otherwise. It will be further understood that the terms "includes," "comprises," "including" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0013] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0014] As used herein, "cold shrink" or "cold shrink cover" means that the cover or component can be shrunk or contracted about a substrate (*e.g.*, a cable) without requiring the use of applied heat.

[0015] With reference to **Figure 21**, a cover system **101** according to some embodiments of the present invention is shown therein. The cover system **101** can be used to form a cover assembly **102** as shown in **Figure 21**. The cover assembly **102** can be a cold-applied transition joint about a connection between an oil-containing cable **30** having a metal sheath and an oil-impregnated paper insulation and a polymeric cable **60**, as discussed in more detail below, to form a covered cable assembly **103** (**Figure 21**). In some embodiments, the cover system **101** is provided as a pre-packaged kit of components for subsequent assembly by an installer (*e.g.*, a field installer) using a method as described herein.

[0016] The cable **30** (**Figure 1**) as illustrated is a three-phase cable including three electrical conductors **32**, which may be formed of any suitable material such as copper, and may be solid or stranded. Each conductor **32** is surrounded by a respective oil-impregnated paper insulation layer **34**. The oil impregnating each layer **34** may be any suitable oil such as a mineral oil. A respective metal screen **36** may surround each paper layer **34**. A metal sheath **38** surrounds the three conductors **32**, collectively. According to some embodiments, the metal sheath **38** is a lead sheath and the cable **30** may be commonly referred to as a paper-insulated lead cable (PILC). According to other embodiments, the metal sheath **38** is formed of aluminum. A polymeric jacket **39** surrounds the metal sheath **38**.

[0017] The polymeric cable **60** (**Figure 13**) includes three conductors **62**, each surrounded by a respective polymeric insulation **64** and a respective semiconductive elastomer **66**. A metal shield layer **68** collectively surrounds the conductors **62**. A polymeric jacket **69** surrounds the shield layer **68**.

[0018] The cover system **101** includes three tubular oil barrier tubes (OBTs), an electrically conductive metal mesh **114**, a dual layer mastic tape **116**, a vinyl tape **118**, an oil barrier mastic (OBM) insert **120**, mastic patches **122**, **124**, **126**, a breakout **130** (initially mounted on a main holdout **133** and three finger holdouts **135**), a dual layer mastic tape **140**, a connector pressure retention tape **142**, a vinyl tape **144**, a tubular cold shrink joint (CSJ) body **146** (initially mounted on a holdout **147**), a spacer or insert member **150**, and a breakout pressure retention tape **154**.

[0019] Each OBT **110 (Figure 2)** may be formed of any suitable material. According to some embodiments. each OBT **110** is formed of an electrically insulative material and may include an electrically conductive semiconductive layer HOA. According to some embodiments. each OBT is formed of an electrically expandable mateṙ aL which may be an elastomeric material. Suitable materials for the OBTs may include EPDM. neoprene. butyl or polyurethane. Each OBT **110** may be initially mounted on a holdout (not shown). The holdouts may be formed of any suitable material. According to some embodiments. the holdouts are formed of plastic with a surface lubricant to assist in removal from the OBT **110.**

[0020] The breakout **130 (Figures 11. 12** and 18C) includes a main tubular body **132** and three circumferentially distributed tubular fingers **134** integral with the main body 132. The breakout **130** may be formed of any suitable material. According to some embodiments. the breakout **130** is formed of an elastically insulative material. According to some embodiments. the breakout **130** is formed of an elastically expandable material such as an elastomeric material. Suitable materials may include EPDM. neoprene. but\I or polyurethane. The holdouts **133. 135** may be formed of an)· suitable material. According to some embodiments. the holdouts **135** are formed of plastic with a release lubricant. According to some embodiments. the holdout **133** is a spirally wound holdout.

[0021] Each of the dual layer mastic tapes **116 (Figure 6A). 140** (Figure **14)** includes an inner layer of sealing mastic carried by an outer substrate or layer of an elastic material. The inner layer is deformable. resistant to chemical attack from oil. and resistant to migration of oil therethrough. The outer layer can be elastically elongated. Each tape **116. 140** is a self-amalgamating tape such that. when wrapped upon itself, the inner layer of mastic will fuse with itself. Suitable dual layer mastic tapes may include tapes as disclosed in U.S. Patent Application Publication No. 2008/0277139 AL. Suitable dual layer mastic tapes may include the EPPA-225 tape available from Tyco Electronics Corporation.

[0022] The connector pressure retention tape **142** (Figure **15)** may include any suitable self-amalgamating sealing tape. According to some embodiments. the connector pressure retention tape **142** includes a silicone tape impregnated with a substrate (in some embodiments. a fabric mesh) that limits the permitted extent of elongation of the tape **142.** In some embodiments. elongation of the tape **142** is limited to from about 5 to 25%. Suitable connector pressure retention tapes may include EXRM-3020 tape available from Tyco Electronics Corporation

[0023] The OBM insert **120** (**Figures 5A** and **5B**) may be formed of any suitable sealing mastic. According to some embodiments, the OBM insert **120** is formed of nitrile rubber, epichlorhydrin rubber, or fluorinated rubber. The OBM insert **120** includes three generally planar walls or legs **120A** joined at their inner ends and circumferentially spaced apart. Suitable mastic materials include S1340 mastic available from Tyco Electronics Corporation.

[0024] The mastic patches **122**, **124**, **126** (**Figures** 7-9) may be formed of any suitable sealing mastic and, according to some embodiments, are formed of the same material as the OBM insert **120**. The mastic patches **122**, **124**, **126** are generally planar members.

[0025] The CSJ body **146** (**Figures 17** and **18A**) may be of any suitable construction and materials. The CSJ body **146** may include a tubular elastomeric, electrically insulative layer and one or more internal electrically semiconductive layers, for example, as known in the art for controlling electrical stresses, providing electrical shielding and bridging the electrically semi-conductive layers **36**, **66** of the cables **30**, **60**. Suitable materials for the CSJ body **146** may include silicone rubber, for example. The CSJ body **146** can be initially mounted on a holdout **147**.

[0026] The spacer or insert member **150** (**Figures 18A-18C**) may be formed of any suitable resiliently deformable material. According to some embodiments, the insert member **150** is formed of an elastomeric material. Suitable elastomeric materials may include ethylene-propylene-diene-monomer (EPDM) rubber, silicone rubber, butyl rubber or nitrile rubber. According to some embodiments, the insert member **150** has a modulus of elasticity in the range of from about 30 to 100 psi and, in some embodiments, from about 68 to 76 psi. The insert member **150** includes three generally planar legs **152** joined along their inner ends and circumferentially spaced apart.

[0027] The breakout pressure retention tape **154** may be any suitable self-amalgamating tape. According to some embodiments, the tape **154** is a fusible silicone tape. In some embodiments, the tape **154** has a maximum elastic elongation in the range of from about 50 to 600% and, in some embodiments, from about 50 to 200%. Suitable tapes for the tape **154** may include MVFT tape available from Tyco Electronics Corporation, for example.

[0028] The construction of the cover assembly **102** may be further appreciated in view of methods for forming the cover assembly **102** according to embodiments of the present invention, as discussed in further detail below. However, it will be appreciated that, in some embodiments, certain of the steps and components disclosed hereinbelow may be altered or omitted in accordance with further embodiments of the invention.

[0029] With reference to **Figure 1**, the cable **30** is prepared by progressively trimming back or removing end sections of the jacket **39**, the metal sheath **38**, and the metal screen **36** as shown. The paper insulation **34** of each conductor **32** may also be trimmed back or may be subsequently trimmed prior to installing the connectors **50** as shown in **Figure 13**. Each conductor **32** and the paper insulation **34** surrounding the conductor **32** may be referred to herein as a cable core **40**. The metal sheath **38** has a terminal edge **38A** defining an end opening **38B** through which extended sections **42** of the three cable cores **40** extend.

[0030] As shown in **Figure 2**, an OBT **110** is mounted on each cable core **40** such that a gap **G1** is defined between the adjacent edges of the OBT **110** and the metal sheath **38**. According to some embodiments, the gap **G1** has a length of between about 0.8 inch (20mm) and 1.2 inches (30mm).

[0031] As shown in **Figure 3**, the metal sheath **114** is wrapped about the gap **G1** such that the metal mesh **114** contacts the exposed portions of the metal screens **36** and overlaps and contacts the metal sheath **38** and the semiconductive section **110A** of each OBT **110**.

[0032] Referring to **Figure 4**, the dual layer mastic tape **116** is wrapped about the metal mesh **114** with its mastic layer down (*i.e.*, inward). The tape **116** overlaps and contacts each of the metal sheath **38** and the OBT semiconductive section **110A**. According to some embodiments, the tape **116** overlaps the metal sheath **38** a distance **C1** beyond the metal mesh **114** in the range of from about 0.2 inch (5mm) to 0.75 inch (19mm). According to some embodiments, the tape **116** overlaps the OBT section **110A** a distance **C2** beyond the metal mesh **114** in the range of from about 0.25 inch (19mm) to 0.5 inch (13mm). According to some embodiments, the tape **116** is elastically elongated.

[0033] With reference to **Figures 5A** and **5B**, the OBM insert **120** is mounted in the crotch of the cable cores **40** such that each leg **120A** is interposed between respective adjacent ones of the cable cores **40**. Then, as shown in **Figures 6A** and **6B**, each **120A** is wrapped clockwise around the adjacent cable core **40** such that the free edge of each leg **120A** merges with the adjacent leg **120A**.

[0034] Referring to **Figure 7**, the mastic patch **122** is wrapped about the cable **30** with its inner edge butted to the terminal edge **38A** of the metal sheath **38**. The mastic patch **124** is then wrapped about the cable **30** such that it overlaps each of the mastic patch **122** and the OBM insert **120** (**Figure 8**). The mastic patch **126** is then wrapped about the cable **30** such that it overlaps the mastic patch **124** and further overlaps the OBM insert **120** (**Figure 9**). The vinyl tape **118** is then wrapped about the distal edge of the mastic patch **126** as shown in **Figure 10**. According to some embodiments, the mastic patch **122** overlaps the metal sheath **38** a distance **D** (**Figure 7**) beyond the tape **116** in the range of from about 0.4 inch (10mm) to 0.6 inch (15mm). In some embodiments, the mastic patches **124** and **126** overlap the mastic patches **122** and **124**, respectively, by a distance of between about 0.4 inch (10mm) and 0.6 inch (15mm).

[0035] The finger holdouts **135** can be pre-activated by twisting the holdouts **135** in the fingers **134** of the breakout **130** as shown in **Figure 11** but not yet withdrawing the holdouts **135**. Twisting the holdouts **135** distributes the lubricant between the holdouts **135** and the fingers **134** so that the holdouts **135** can be more easily slid axially with respect to the fingers **134**.

[0036] The breakout **130**, with the holdouts **133**, **135** still installed therein, is slid over the cable cores **40** such that the cable cores **40** extend through the fingers **134**. The vinyl tape **118** helps to prevent the breakout **130** from being caught on or disrupting the mastic patch **126**. The breakout **130** is slid into the crotch of the cable **30** as far as possible and the pre-activated finger holdouts **135** may be partially axially displaced or ejected as a result. In this position, the main body **132** of the breakout **130** overlaps the metal sheath **38**.

[0037] The finger holdouts **135** are then removed, permitting the fingers **134** to contract and capture respective ones of the cable cores **40**. Then, the holdout **133** is removed from the main body **132** of the breakout **130**, permitting the main body **132** to contract and capture the crotch of the cable **30** and an end portion of the metal sheath **38** as shown in **Figure 12**.

[0038] The following procedure can be executed for each of the cable cores **40** in turn. The paper insulation **34** of a selected cable core **40** can be trimmed back as shown in **Figure 13** to expose a terminal section of the conductor **32**. The conductor **32** is thereafter mechanically and electrically connected to a corresponding conductor **32** of the polymeric cable **60** by a connector **50**. In some embodiments, the connector **50** is an oil stop connector having a pair of opposed bores to receive respective ones of the conductors **32**, **62** and being fluidly separated from one another by a separator wall. Shear bolts **52** may be provided to secure the connector **50** to the conductors **32**, **62**.

[0039] The dual layer mastic tape **140** is then wrapped about the cable core **40** and the connector **50** with the mastic side down (**Figure 14**). The tape **140** is wound onto the cable core **40** and the connector **50** such that the tape **140** overlaps each of the cable core **40** and the connector **50**. According to some embodiments, the tape **140** overlaps the connector **50** by a distance **H1** (**Figure 14**) in the range of from about 1.8 inches (45mm) to 2.2 inches (56mm). According to some embodiments, the tape **140** overlaps the OBT **110** by a distance **H3** in the range of from about 0.4 inch (10mm) to 0.6 inch (15mm). In some embodiments, the tape **140** is elastically elongated so that, once applied to the cable **30**, the tape **140** continues to persistently apply a radially compressive load to the underlying components (*i.e.*, a hoop stress is retained in the tape **140**).

[0040] As shown in **Figure 15**, the connector pressure retention tape **142** is then wrapped over the connector **50**, the cable core **40**, and the tape **140**. In some embodiments, two complete wraps are made of the tape **142** about the cable core **40** and the connector **50**. According to some embodiments, the tape **142** extends beyond the tape **140** on either end thereof and overlaps, engages and adheres to the connector **50** and the OBT **110**. The tape **142** can thereby provide a gasket-type seal to prevent, limit or inhibit displacement or extrusion of the mastic of the tape **140** away from the joint between the connector **50** and the OBT **110** under internal pressure from the oil of the cable **30**. In some embodiments, the tape **142** is elastically elongated such that it applies a persistent radially compressive load on the underlying components after installation. According to some embodiments, the tape **142** overlaps each of the connector **50** and the OBT **110** a distance **I1**, **I2** (**Figure 15**) in the range of from about 0.8 inch (20mm) to 1.2 inches (30mm). According to some embodiments, the tape **142** applies a persistent radially compressive load in the range of from about 40 to 26 psi.

[0041] The vinyl tape **144** is then wrapped over the connector pressure retention tape **142** as shown in **Figure 16**.

[0042] **Figure 17** shows the cable **30** with all three cable cores **40** having been connected to their associated polymeric cable **60** and prepared with the tapes **140**, **142**, **144**. A CSJ body **146**, which may have been previously parked on the associated polymeric cable

60 is slid into place over each connector **50**. The holdout **147** is removed to permit the CSJ body **146** to contract about and sealingly engage the polymeric insulation **64** of the polymeric cable **60** and the OBT **110** (at a distance from the terminal end of the breakout finger **134**). The CSJ body **146** thus spans and encapsulates the connector **50** and the tapes **140**, **142**, **144**. A section **110B** of the OBT **110** extending between the adjacent ends of the CSJ body **146** and the breakout finger **134** remains exposed.

[0043] Once CSJ bodies **146** have been installed on all three cable cores **40** as shown in **Figure 18A**, the insert member **150** is inserted into the crotch of the PILC cable **30** and the breakout **130** as shown in **Figures 18A-18C**. The legs **152** of the insert member **150** are interposed between adjacent ones of the fingers **134** and extend from the bases of the fingers **134** (*i.e.*, the outer end of the main body **132**) to closely adjacent the proximal ends of the CSJ bodies **146**. A vinyl tape **153** may be wrapped about the cables **60** to temporarily secure the insert member **150** in place.

[0044] The breakout pressure retention tape **154** is then wrapped about the components **50** (collectively), the cable cores **40** (collectively), and an end portion of the metal sheath **38** as shown in **Figures 19A** and **19B** (**Figure 19B** is an enlarged, fragmentary, cross-sectional view). The tape **154** overlaps, engages and adheres to an end portion of each CSJ body **146** as well as the end portion of the metal sheath **38** and continuously spans therebetween. In some embodiments, the tape **154** overlaps the CSJ bodies **146** a distance **J1** (**Figure 19A**) in the range of from about 0.5 inch (13mm) to 3 inches (75mm). According to some embodiments, the tape **154** overlaps the metal sheath **38** beyond the breakout **130** by a distance **J2** (**Figure 19A**) in the range of from about 0.5 inch (13mm) to 3 inches (75mm). The tape **154** provides a gasket-type seal to prevent, limit or inhibit displacement or extrusion of the mastic **116**, **120**, **122**, **124**, **126** out of the breakout **130** and away from the joint between the metal sheath **38** and the cable cores **40** under internal pressure from the oil of the cable **30**. The tape **154** is elastically elongated so that, once applied to the cable **30**, the tape **154** continues to persistently apply a radially compressive load to the underlying components (*i.e.*, a hoop stress is retained in the tape **154**.) This compressive loading deforms the insert member **150** into intimate and compressive contact with and about the breakout fingers **134**. In this manner, the engagement and thereby the seal between each finger **134** and its associated OBT **110** are maintained and reinforced. The insert member **150** remains solid but conforms around the fingers **134** to prevent migration of mastic contained in the breakout **130**

through the interface between the cable cores **40** and the fingers **134**. The secured insert member **150** also serves to resist axial displacement of the breakout **130** away from the metal sheath **38**. The tape **154** also serves to reinforce the exposed section **110B** of each OBT **110** to resist bulging of the section **110B** due to internal pressure from the oil of the cable **30**. According to some embodiments, the tape **154** applies a persistent radially compressive load in the range of from about 6 to 16 psi.

[0045] In the foregoing manner, a reliable and robust oil stop seal can be formed at the joint between the metal sheath **38** and the cable cores **40** and at the joint between each cable core **40** and its connector **50**. The cover assembly **102** can serve to retain the oil in the PILC cable **30** even when relatively high oil internal pressures are induced, such as by increases in temperature or placement of the connection at lower elevation than other parts of the cable **30**.

[0046] The covered cable assembly **10** can thereafter be grounded, shielded and re-jacketed in known manner, for example. Referring to **Figure 20**, grounding braids **160** can be connected to the shield layers **68** of the polymeric cables **60** and the metal sheath **30** by clamps **162**, **164** as shown therein, for example. Metal shielding mesh (not shown) can be wrapped from the clamps **162** to the clamps **164**. A sealing breakout boot (not shown) may be installed on the joint between the shielding mesh and the polymeric cables **60**. The entire joint assembly, including the cover assembly **102**, can be covered by a re-jacketing sleeve **166** (**Figure 21**), which overlaps the jacket **39**. Suitable re-jacketing sleeves may include the GelWrap Rejacketing Sleeve available from Tyco Electronics Corporation, for example.

[0047] With reference to **Figure 32**, a cover system **201** according to further embodiments of the present invention is shown therein. The cover system **201** can be used to form a cover assembly **202** as shown in **Figure 32**. The cover assembly **202** can be a cold-applied transition joint about a connection between an oil-containing cable **70** having a metal sheath and an oil-impregnated paper insulation and a polymeric cable **60** to form a covered cable assembly **203**. In some embodiments, the cover system **201** is provided as a pre-packaged kit of components for subsequent assembly by an installer (*e.g.*, a field installer) using a method as described herein.

[0048] The cable **70** (**Figure 22**) as illustrated is a single-phase cable including a conductor **72**, an oil-impregnated paper insulation **74**, a metal sheath **78**, and a jacket **79** corresponding to components **32**, **34**, **38** and **39**, respectively, of the cable **30**. The cable **70** differs from the cable **30** in that the cable **70** includes only a single cable core **40** extending through the metal sheath **78**.

[0049] The cover system **201** includes: an OBT **210** (which may be initially mounted on a holdout **111**) corresponding to the OBT **110**; a dual layer mastic tape **216** corresponding to the tape **116**; a metal mesh tape **214**; a joint pressure retention tape **254** corresponding to the tape **154**; a vinyl tape **218**; a CSJ body **246**; a dual layer mastic tape **240** corresponding to the tape **140**; a connector pressure retention tape **242** corresponding to the tape **142**; and a re-jacketing sleeve **266**.

[0050] Methods according to embodiments of the present invention for installing the cover system **201** to construct the cover assembly **202** and the covered cable assembly **203** will now be described. The cables **60**, **70** are prepared as described above. The prepared PILC cable **60** is illustrated in **Figure 22**.

[0051] With reference to **Figure 23**, the OBT **210** is installed on the cable core **40** (*e.g.*, from a holdout) such that a gap **G2** is defined between the adjacent ends of the OBT **210** and the metal sheath **78**. According to some embodiments, the gap **G2** has a length in the range of from about 0.04 inch (1mm) to 0.5 inch (13mm). A portion of the cable core **40** is exposed in the gap **G2**.

[0052] With reference to **Figure 24**, the dual layer mastic tape **216** is wrapped about the OBT **210** and the cable core **40** such that the tape **216** overlaps and engages each of the OBT **210** and the metal sheath **78**. In some embodiments, the tape **216** overlaps the metal sheath **78** by a distance **L1** in the range of from about 0.3 inch (8mm) to 0.7 inch (18mm). According to some embodiments, the tape **216** overlaps the OBT **210** by a distance **L2** in the range of from about 0.3 inch (8mm) to 0.7 inch (18mm). In some embodiments, the tape **216** is elastically elongated so that, once applied to the cable **70**, the tape **216** continues to persistently apply a compression load to the underlying components (*i.e.*, a hoop stress is retained in the tape **216**).

[0053] Referring to **Figure 25**, the metal mesh tape **214** is wrapped over the dual layer mastic tape **216**. The metal mesh tape **214** extends beyond the tape **216** on either end to overlap and engage each of the metal sheath **78** and a semiconductive portion **210A** of the OBT **210**.

[0054] The joint pressure retention tape **254** is wrapped about the metal mesh tape **214** as shown in **Figure 26**. The joint pressure retention tape **254** extends beyond the tapes

214, **216** on either end and overlaps, engages and adheres to each of the OBT **210** and the metal sheath **78**. The tape **254** is elastically elongated such that, once applied to the cable **70**, the tape **254** continues to persistently apply a radially compressive load to the underlying components (*i.e.*, a hoop stress is retained in the tape **254**). In some embodiments, two complete wraps of the tape **254** are applied.

[0055] As shown in **Figure 27**, the vinyl tape **218** can be wrapped over the inner end of the joint pressure retention tape **254** to reduce subsequent interference with the CSJ body **246**.

[0056] As shown in **Figure 28**, the conductors **62**, **72** of the cables **60**, **70** are joined by a connector **50** as discussed above with reference to **Figure 13**. Referring to **Figures 29**, **30A** and **30B**, the dual layer mastic tape **240** and the connector pressure retention tape **242** are thereafter applied to the connector **50** and the cable **70** as described above with regard to **Figures 14** and **15** and tapes **140**, **142**. **Figure 30B** is an enlarged, fragmentary, cross-sectional view of the construction of **Figures 29** and **30A**.

[0057] The CSJ body **246** (**Figure 31**) can then be installed over the connector **50** and the metal sheath joint as shown in **Figure 31**. The metal sheath **78** and the polymeric cable **60** can be suitably coupled for grounding and shielding.

[0058] The re-jacketing sleeve **266** can then be installed over the CSJ body **246** as shown in **Figure 32**. Suitable re-jacketing sleeves may include the CSJA available from Tyco Electronics Corporation.

[0059] Cover assemblies according to embodiments of the invention may be used for any suitable cables and connections. Such cable assemblies may be adapted for use, for example, with connections of low voltage cables up to about 1000V and medium voltage cables up to about 65 kV.

[0060] While the connections to PILCs have been described herein with reference to PILC-to-polymeric cable transition splices, cover assemblies as disclosed herein may also be used in PILC-to-PILC splices.

[0061] The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the invention.

CLAIMS:

1. A covered cable assembly comprising:

a) a cable including:

a metal sheath having a sheath terminal edge defining a sheath opening; and

a cable core extending through the metal sheath, the cable core including an electrical conductor and an oil-impregnated paper insulation layer surrounding the electrical conductor;

wherein an extended cable core section of the cable core extends through the sheath opening and beyond the sheath terminal edge; and

b) a sealing assembly including:

an oil barrier tube surrounding the extended cable core section;

a sealing mastic surrounding the cable about the sheath terminal edge engaging and overlapping portions of the metal sheath and the oil barrier tube adjacent the sheath terminal edge to effect an oil barrier seal between the metal sheath and the cable core at the sheath opening; and

a pressure retention tape surrounding the sealing mastic adjacent the sheath terminal edge to limit displacement of the sealing mastic.

2. The covered cable assembly of claim 1 wherein the pressure retention tape applies and maintains a persistent radially compressive load on the sealing mastic.

3. The covered cable assembly of claim 2 wherein a hoop stress is retained in the pressure retention tape and the pressure retention tape applies and maintains a persistent radially compressive load on the underlying sealing mastic.

4. The covered cable assembly of claim 1 wherein the pressure retention tape overlaps and adheres to the metal sheath and to the oil barrier tube.

5. The covered cable assembly of claim 1 wherein the pressure retention tape is in direct contact with the sealing mastic.

6. The covered cable assembly of claim 5 wherein the pressure retention tape is a self-amalgamating tape including a mass of a tape sealant on a fabric substrate, and the fabric substrate limits elongation of the retention tape.

7. The covered cable assembly of claim 1 wherein:

a) the cable further includes second and third cable cores extending through the metal sheath, the first and second cable cores having first and second extended cable core sections, respectively, extending through the sheath opening and beyond the sheath terminal edge;

b) the sealing assembly further includes:

a second elastomeric oil barrier tube surrounding the second extended cable core section;

a third elastomeric oil barrier tube surrounding the third extended cable core section;

c) the sealing mastic surrounds the cable about the sheath terminal edge and engages and overlaps portions of the metal sheath and each of the first, second and third oil barrier tubes adjacent the sheath terminal edge to effect an oil barrier seal between the metal sheath and each of the first, second and third cable cores at the sheath opening; and

d) the pressure retention tape surrounds each of the first, second and third oil barrier tubes, collectively.

8. The covered cable assembly of claim 7 wherein the sealing mastic includes:

a first mastic portion wrapped fully around the first oil barrier tube;

a second mastic portion wrapped fully around the second oil barrier tube;

a third mastic portion wrapped fully around the third oil barrier tube; and

a sheath mastic portion wrapped fully around the metal sheath at the sheath terminal edge.

9. The covered cable assembly of claim 7 wherein:

the sealing assembly further includes an elastomeric breakout having a main tubular body and first, second and third tubular fingers integral with the main tubular body;

the metal sheath is disposed in the main tubular body;

the first, second and third extended cable core sections and the first, second and third oil barrier tubes extend through the first, second and third tubular fingers, respectively;

the sealing mastic is disposed in the breakout; and

the pressure retention tape surrounds the breakout.

10. The covered cable assembly of claim 9 wherein the breakout directly engages the sealing mastic.

11. The covered cable assembly of claim 9 wherein:

the sealing assembly further includes an insert member, the insert member having a plurality of legs interposed between the first, second and third tubular fingers; and

the pressure retention tape surrounds the insert member.

12. The covered cable assembly of claim 11 wherein the pressure retention tape compressively loads the insert member such that the insert member conforms to and loads the first, second and third tubular fingers.

13. The covered cable assembly of claim 11 including first, second and third cold shrink joint bodies each mounted on a respective one of the first, second and third extended cable core sections, wherein the insert member has a length extending from bases of the first,

second and third tubular fingers to closely adjacent proximal ends of the cold shrink joints.

14. The covered cable assembly of claim 7 wherein the pressure retention tape is a self-amalgamating silicone tape.

15. The covered cable assembly of claim 1 including:

an electrically conductive connector mounted on the electrical conductor;

a connector mastic surrounding and engaging each of the connector and the oil barrier tube adjacent an interface between the connector and the oil barrier tube to effect an oil barrier seal about the cable core; and

a connector pressure retention tape surrounding the cable and the connector mastic and including first and second opposed end portions extending axially beyond the connector mastic, wherein the first end portion overlaps and adheres to the connector and the second end portion overlaps and adheres to the oil barrier tube.

16. The covered cable assembly of claim 15 wherein the connector pressure retention tape is a self-amalgamating tape including a mass of a tape sealant on a fabric substrate, and the fabric substrate limits elongation of the connector pressure retention tape.

17. The covered cable assembly of claim 15 including:

a second cable core connected to the first cable core by the connector; and

a cold shrink joint body surrounding the connector, the connector mastic, and the connector pressure retention tape, and overlapping each of the second cable core and the oil barrier tube.

18. A method for forming a covered cable assembly, the method comprising:

providing a cable including:

a metal sheath having a sheath terminal edge defining a sheath opening; and a cable core extending through the metal sheath, the cable core including an electrical conductor and an oil-impregnated paper insulation layer surrounding the electrical conductor;

wherein an extended cable core section of the cable core extends through the sheath opening and beyond the sheath terminal edge;

mounting an oil barrier tube on the extended cable core section such that the oil barrier tube surrounds the extended cable core section;

applying a sealing mastic to the cable such that the sealing mastic surrounds the cable about the sheath terminal edge and engages and overlaps portions of the metal sheath and the oil barrier tube adjacent the sheath terminal edge to effect an oil barrier seal between the metal sheath and the cable core at the sheath opening; and

applying a pressure retention tape to surround the sealing mastic_adjacent the sheath terminal edge to limit displacement of the sealing mastic.

19. The method of claim 18 wherein applying the pressure retention tape includes mounting the pressure retention tape in direct contact with the sealing mastic.

20. The method of claim 18 wherein:

the cable further includes second and third cable cores extending through the metal sheath, the first and second cable cores having first and second extended cable core sections, respectively, extending through the sheath opening and beyond the sheath terminal edge; and

the method further includes:

mounting a second elastomeric oil barrier tube on the second extended cable core section such that the second oil barrier tube surrounds the second extended cable core section;

mounting a third elastomeric oil barrier tube on the third extended cable core section such that the third oil barrier tube surrounds the third extended cable core section;

applying the sealing mastic includes applying the sealing mastic to the cable such that the sealing mastic surrounds the cable about the sheath terminal edge and engages and overlaps portions of the metal sheath and each of the first, second and third oil barrier tubes adjacent the sheath terminal edge to effect an oil barrier seal between the metal sheath and each of the first, second and third cable cores at the sheath opening; and

applying the pressure retention tape includes mounting the pressure retention tape to surround each of the first, second and third oil barrier tubes, collectively.

21. The method of claim 20 further including mounting an elastomeric breakout having a main tubular body and first, second and third tubular fingers integral with the main tubular body on the cable such that:

the metal sheath is disposed in the main tubular body;

the first, second and third extended cable core sections and the first, second and third oil barrier tubes extend through the first, second and third tubular fingers, respectively; and

the sealing mastic is disposed in the breakout;

wherein applying the pressure retention tape includes mounting the pressure retention tape to surround the breakout.

22. A cover system for covering a cable including a metal outer sheath and multiple cable cores, each cable core including an electrical conductor surrounded by an oil-impregnated paper insulation, the cover system including:

a) a plurality of oil barrier tubes each configured to be mounted on a respective one of the cable cores;

b) a sealing mastic to be mounted on the oil barrier tubes and the metal sheath to effect an oil barrier seal between the metal sheath and the cable cores at an opening of the metal sheath;

c) an elastomeric breakout having a main tubular body to receive the metal sheath and a plurality of tubular fingers integral with the main tubular body and configured to receive respective ones of the cable cores;

d) an insert member, the insert member having a plurality of legs configured to be interposed between the first, second and third tubular fingers; and

e) a pressure retention tape to surround the sealing mastic, the breakout and the insert member to limit displacement of the sealing mastic.

23. The cover system of claim 22 wherein the insert member is formed of a resiliently deformable material.

24. The cover system of claim 23 wherein the insert member is formed of a resiliently deformable elastomeric material.

25. A covered cable assembly comprising:

a) a cable including:

a metal sheath having a sheath terminal edge defining a sheath opening; and

a cable core extending through the metal sheath, the cable core including an electrical conductor and an oil-impregnated paper insulation layer surrounding the electrical conductor;

wherein an extended cable core section of the cable core extends through the sheath opening and beyond the sheath terminal edge;

b) an electrically conductive connector mounted on the electrical conductor; and

c) a sealing assembly including:

an oil barrier tube surrounding the extended cable core section;

a connector mastic surrounding and engaging each of the connector and the oil barrier tube adjacent an interface between the connector and the oil barrier tube to effect an oil barrier seal about the cable core; and

a connector pressure retention tape surrounding the cable and the connector mastic and including first and second opposed end portions extending axially beyond the connector mastic, wherein the first end portion overlaps and adheres to the connector and the second end portion overlaps and adheres to the oil barrier tube.

26. The covered cable assembly of claim 25 including:

a vinyl tape wrapped around the connector pressure retention tape; and

a cold shrink body encapsulating the connector pressure retention tape, the connector mastic, and the vinyl tape.

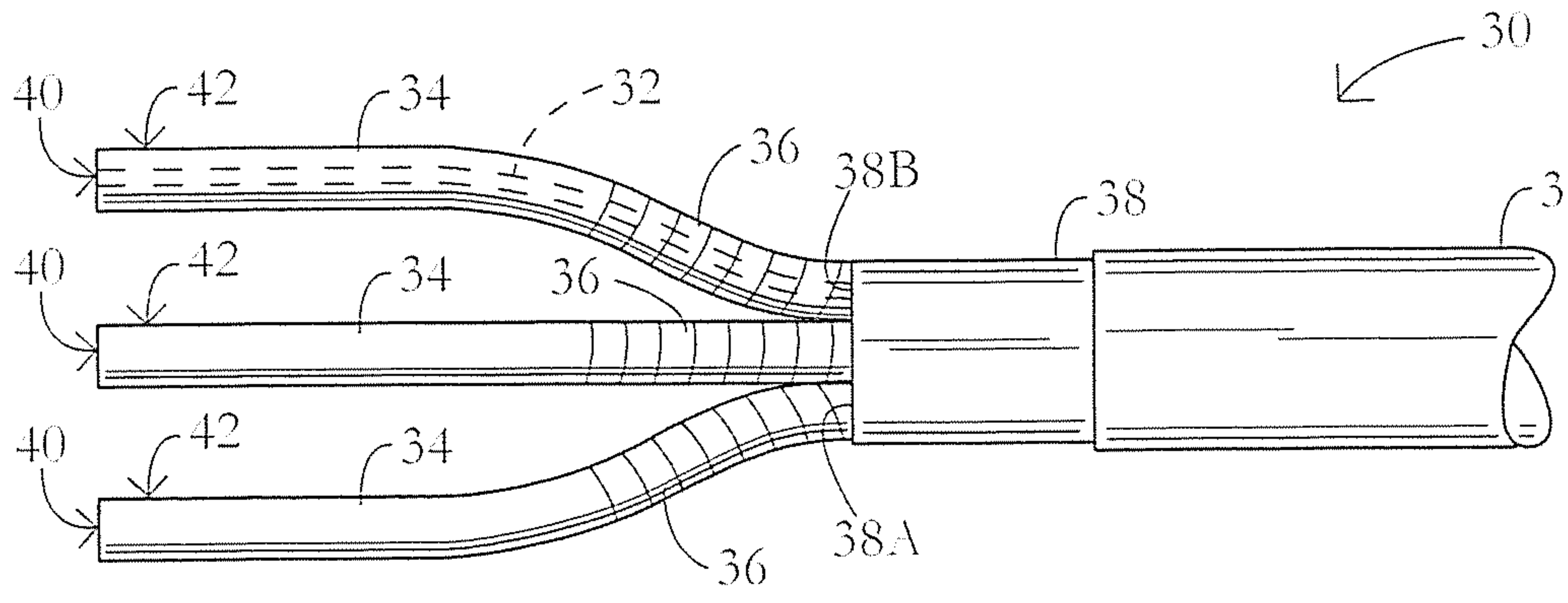


FIG. 1

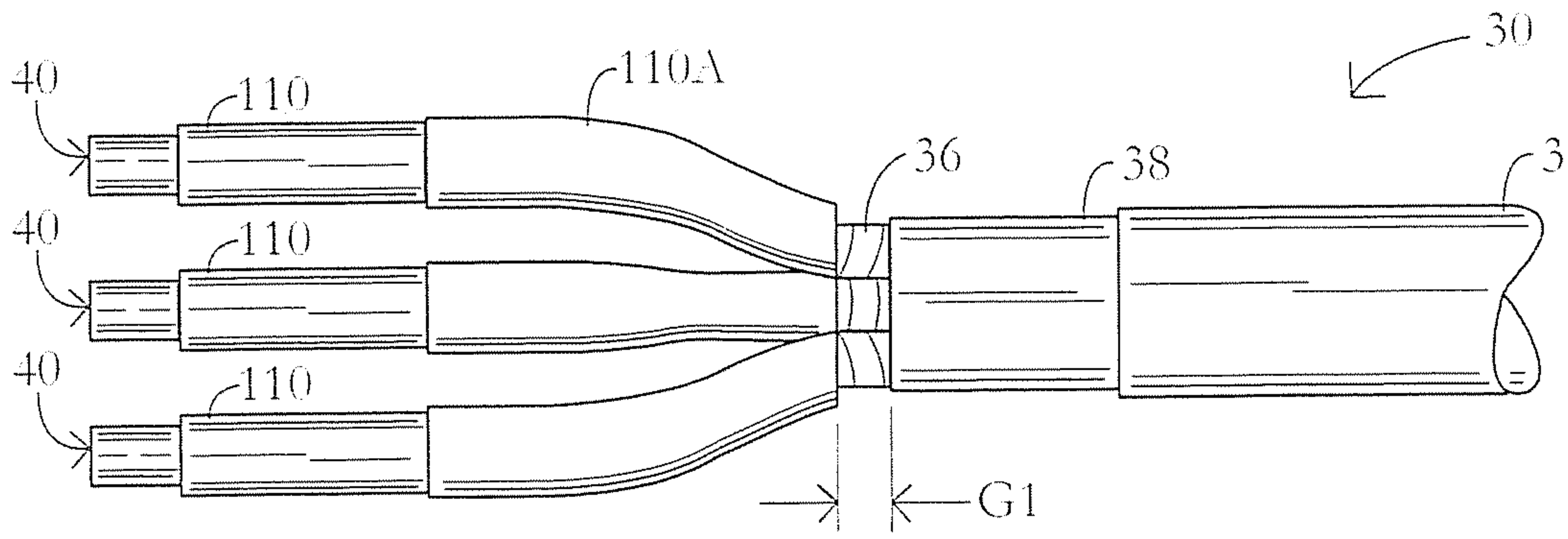


FIG. 2

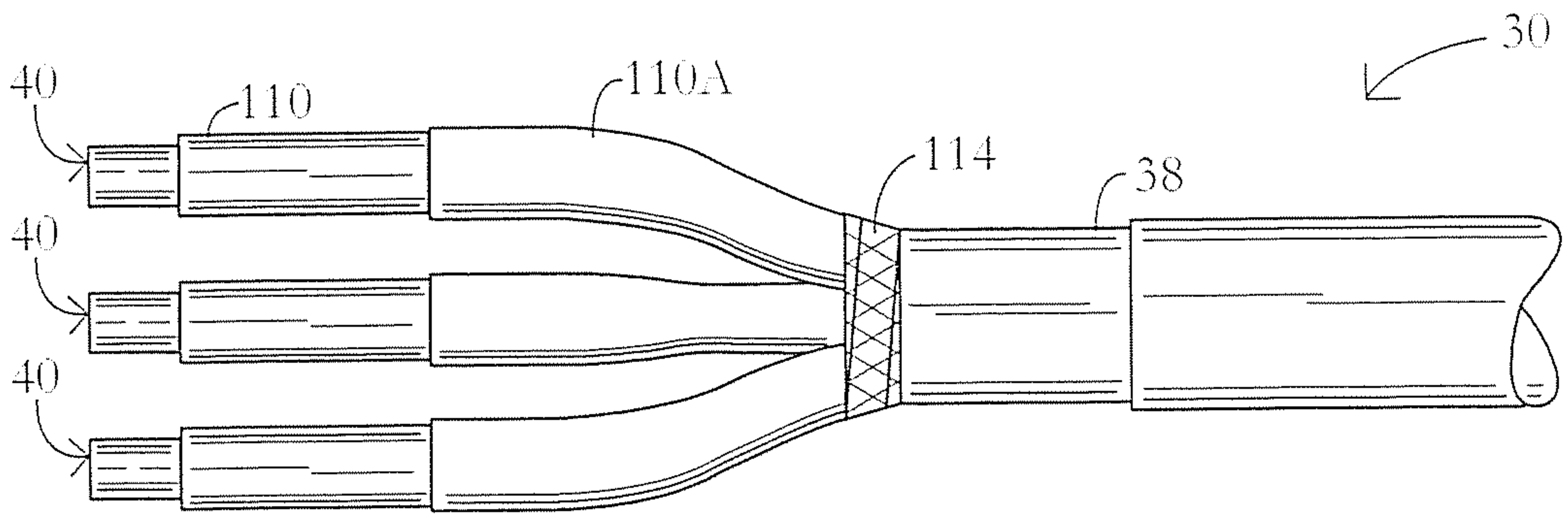


FIG. 3

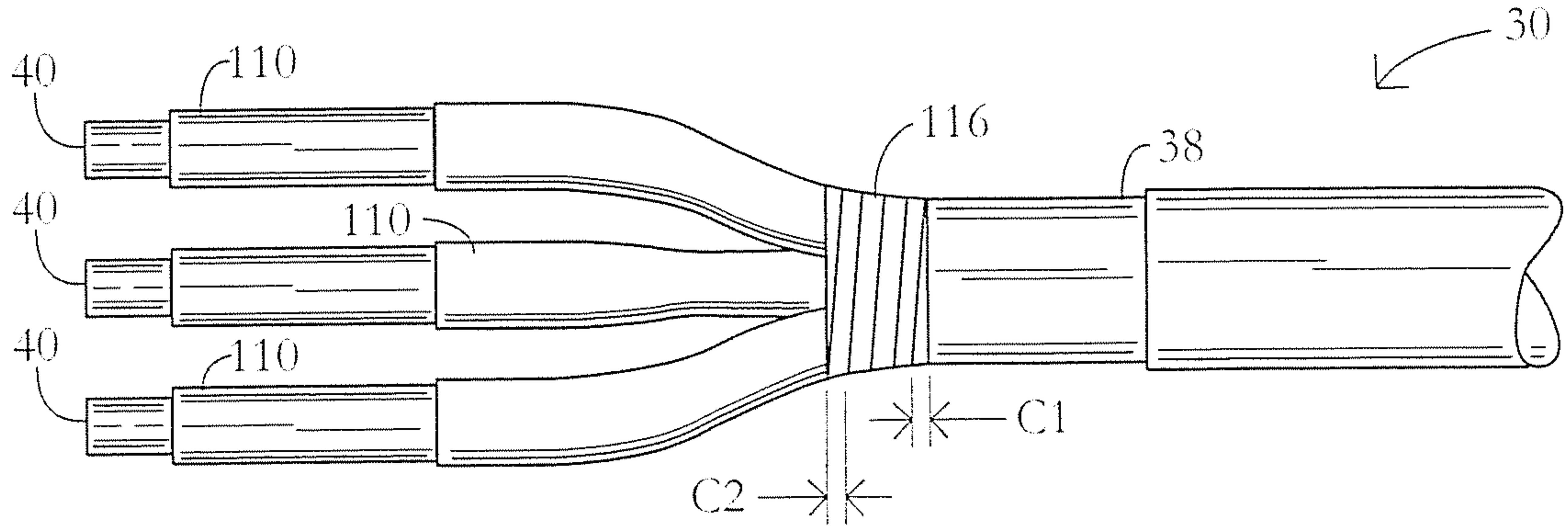


FIG. 4

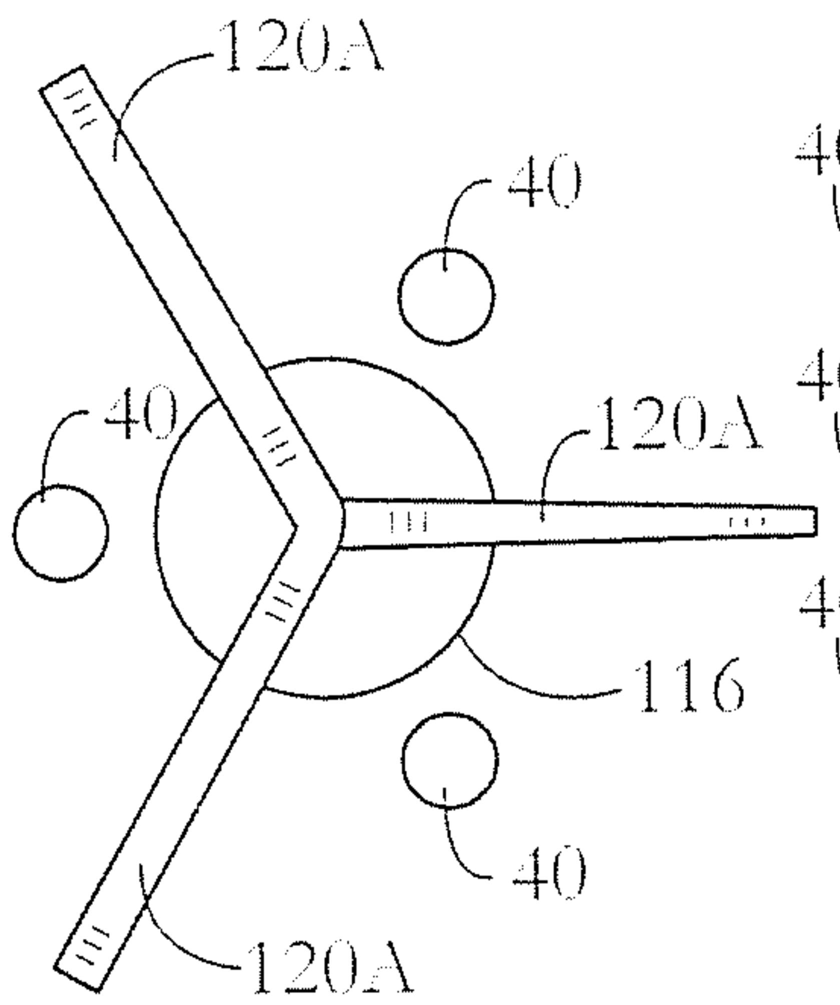


FIG. 5B

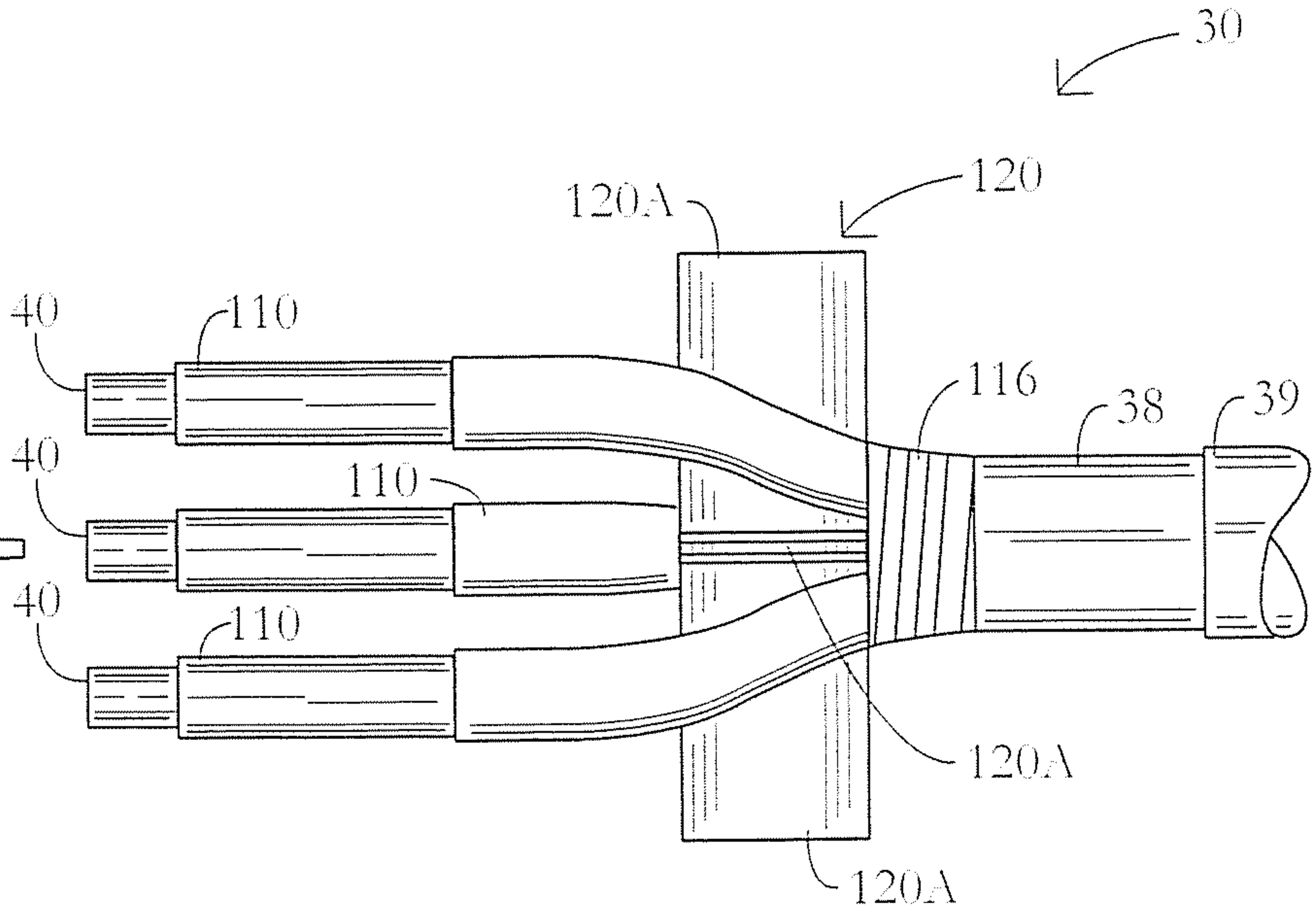


FIG. 5A

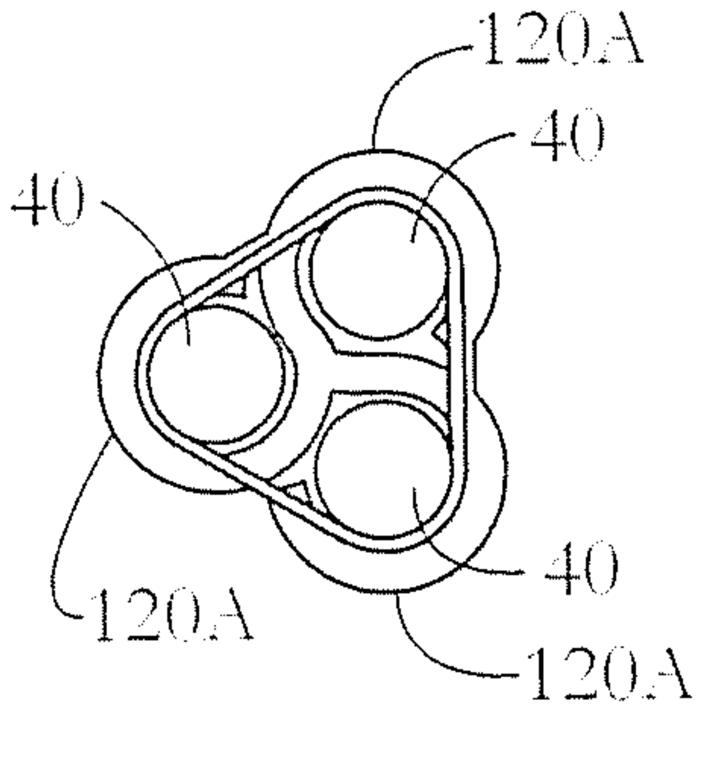


FIG. 6B

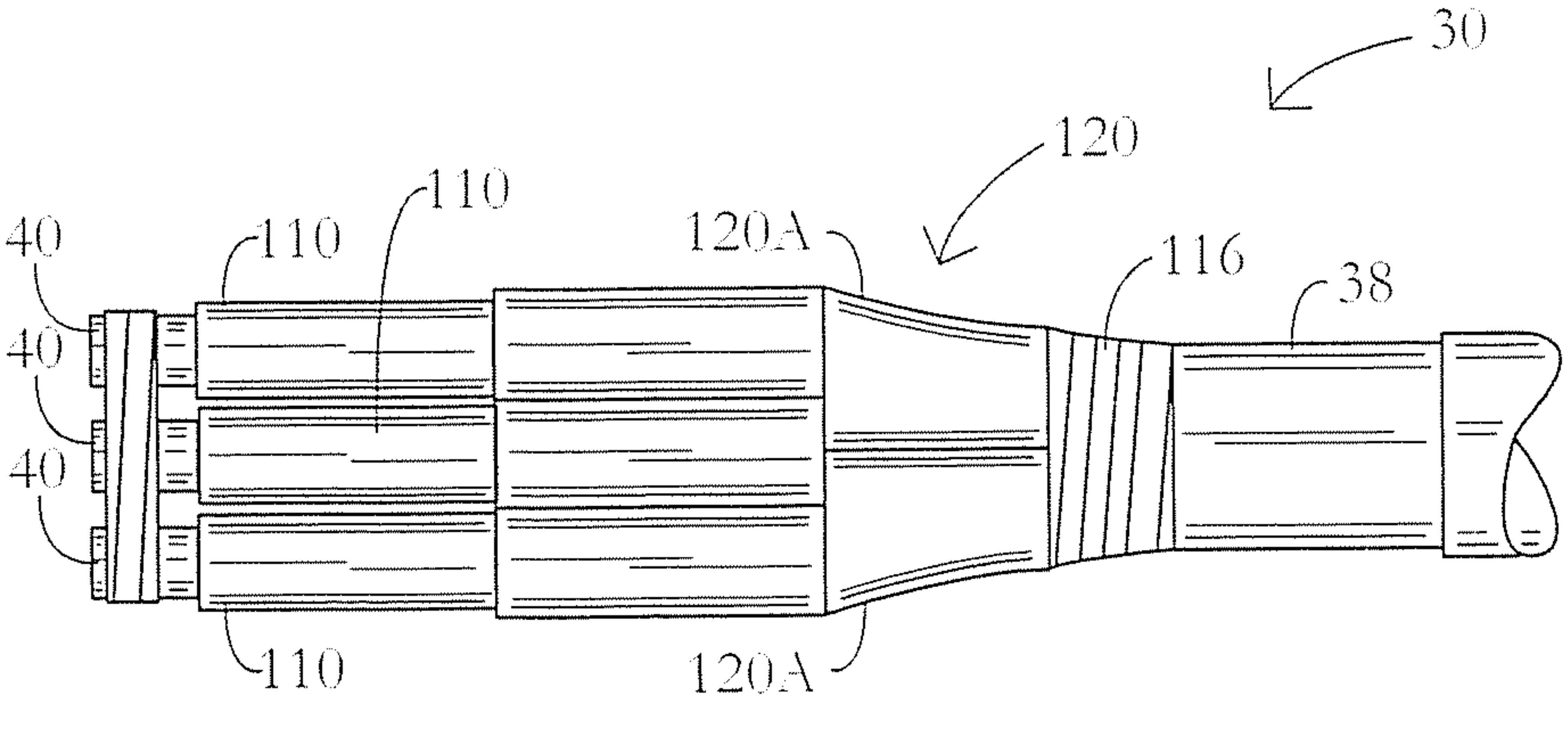


FIG. 6A

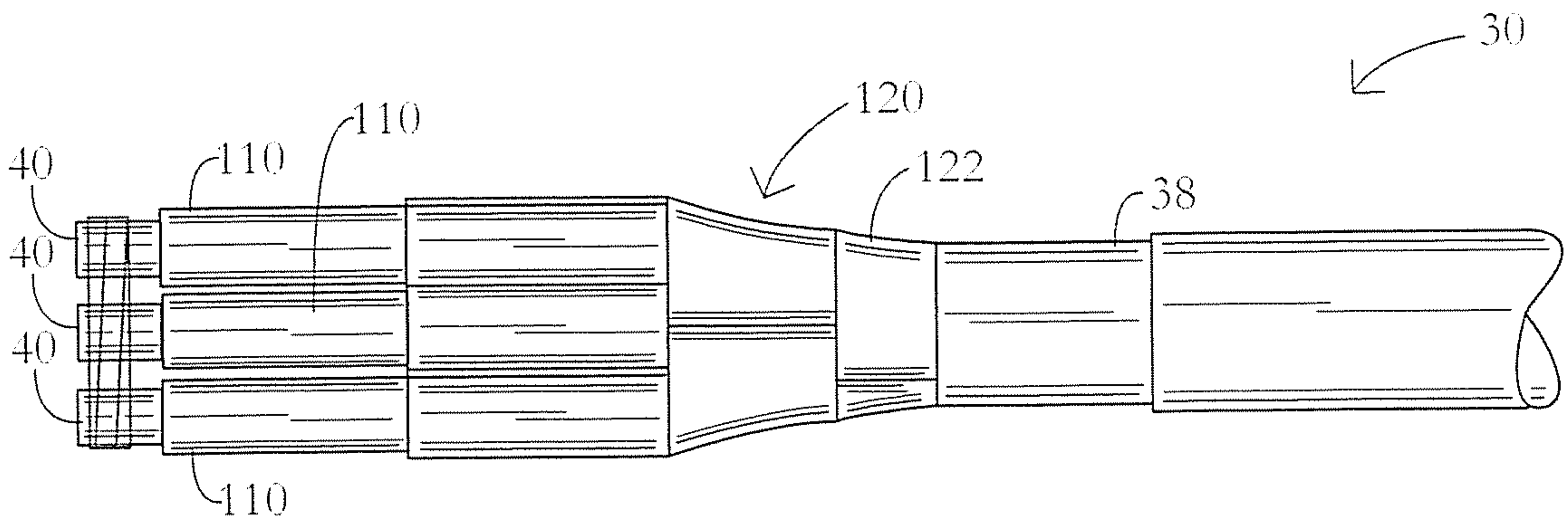


FIG. 7

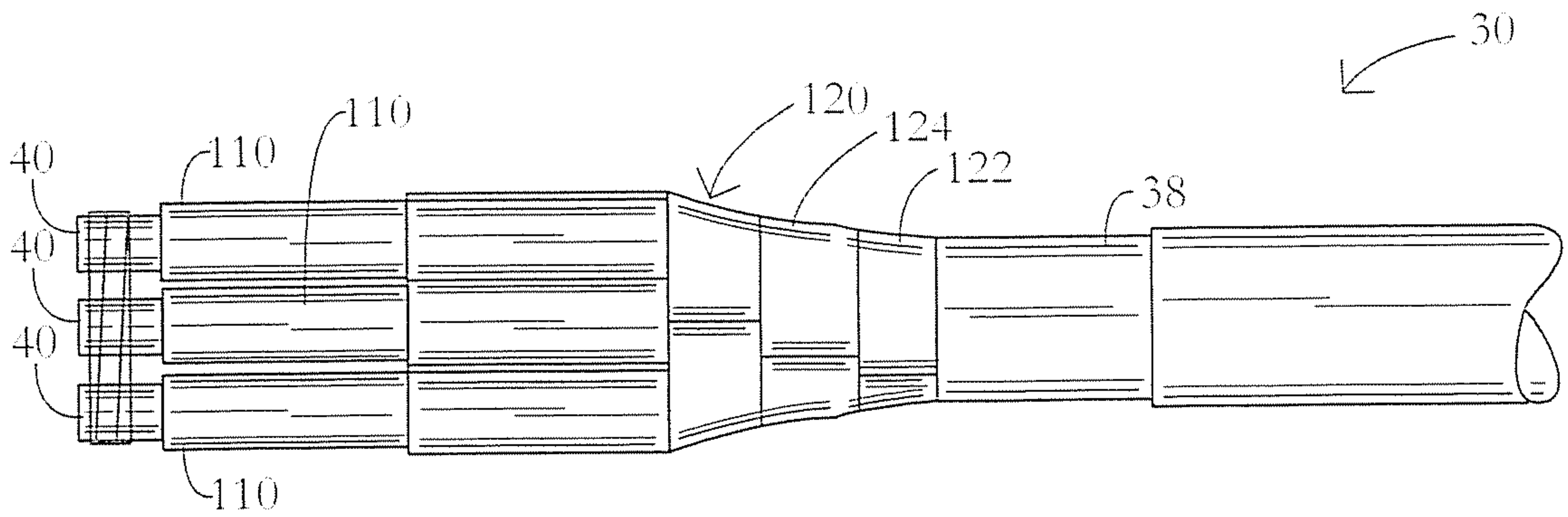


FIG. 8

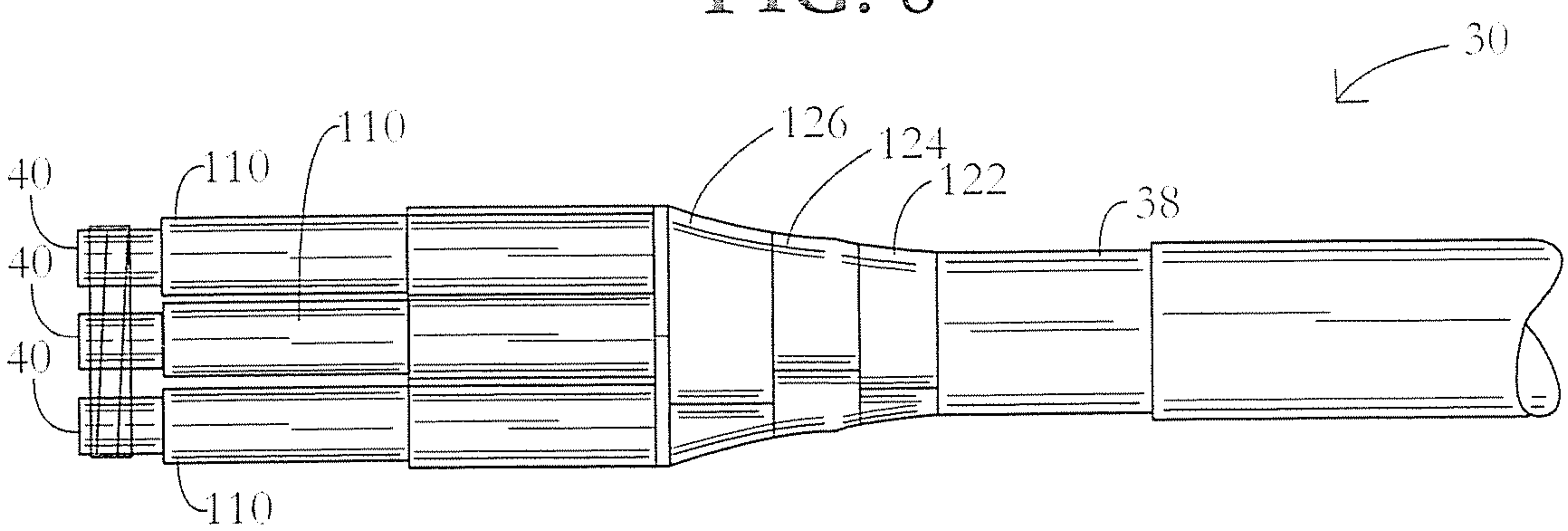


FIG. 9

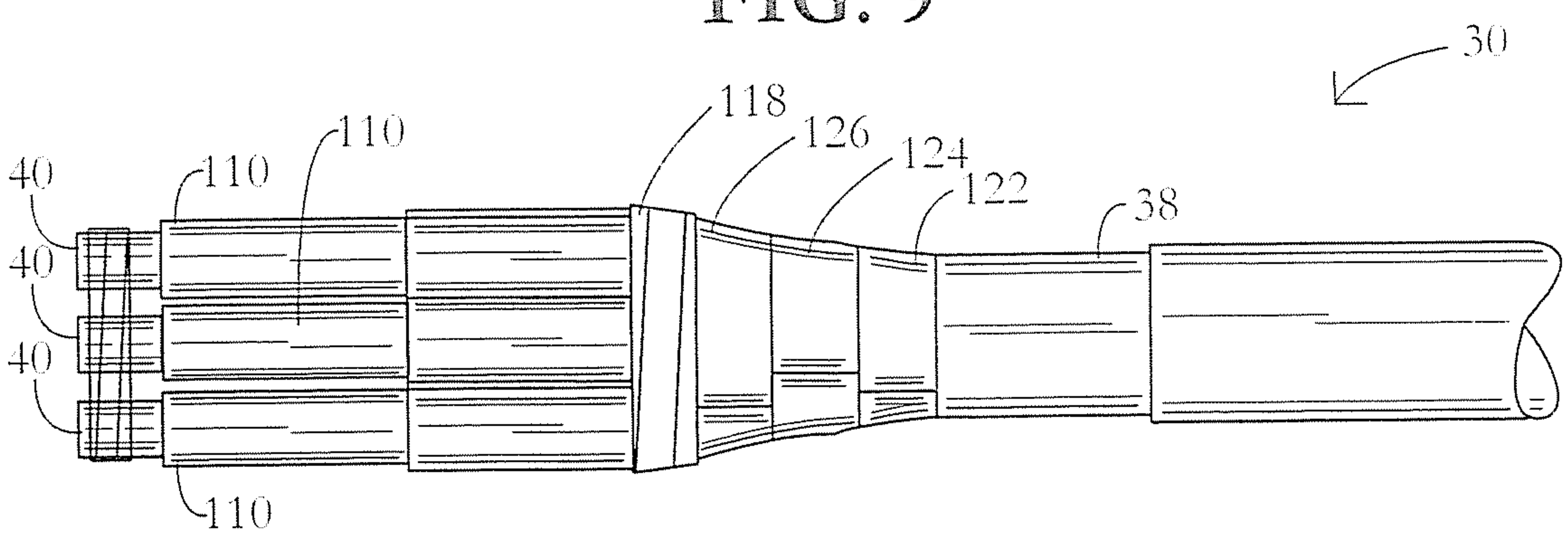


FIG. 10

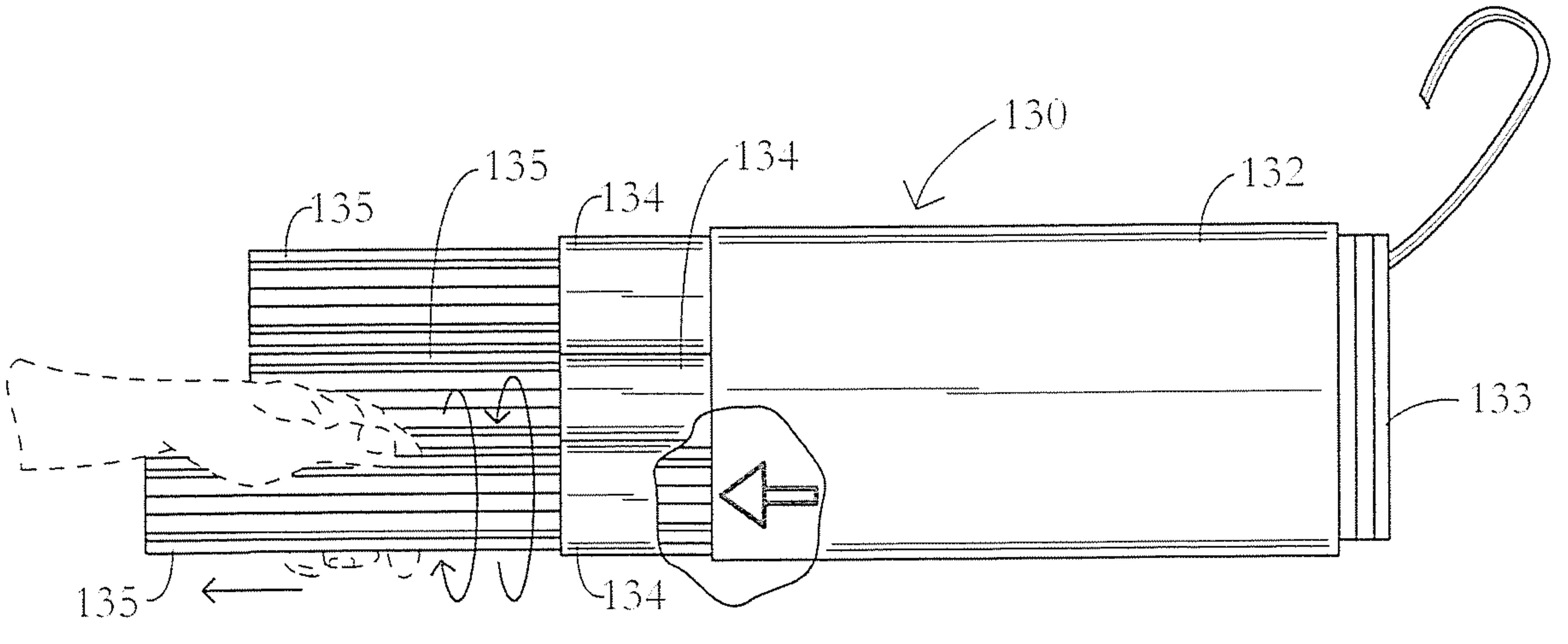

130
135
135
134
134
132
135
133
135
134

FIG. 11

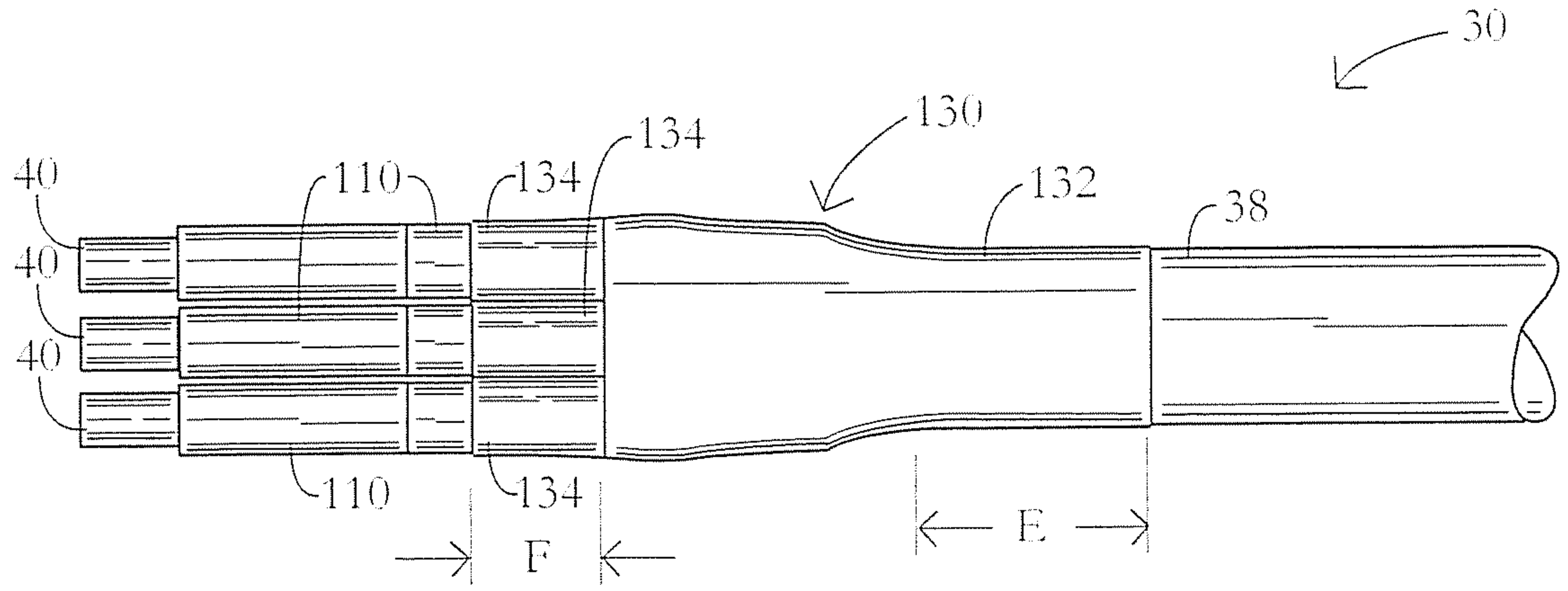
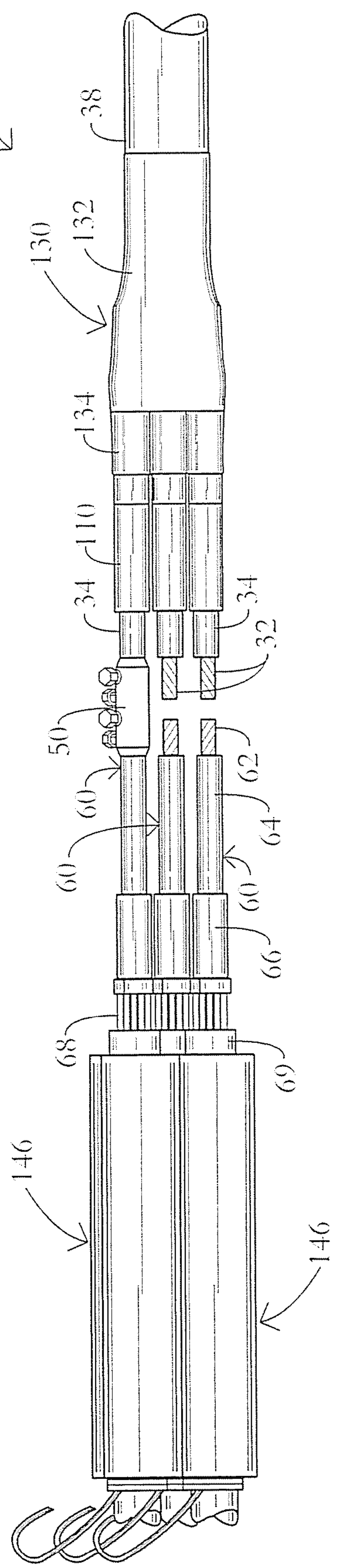

30
130
134
40
110
134
132
38
40
40
110
134
F
E

FIG. 12


30
38
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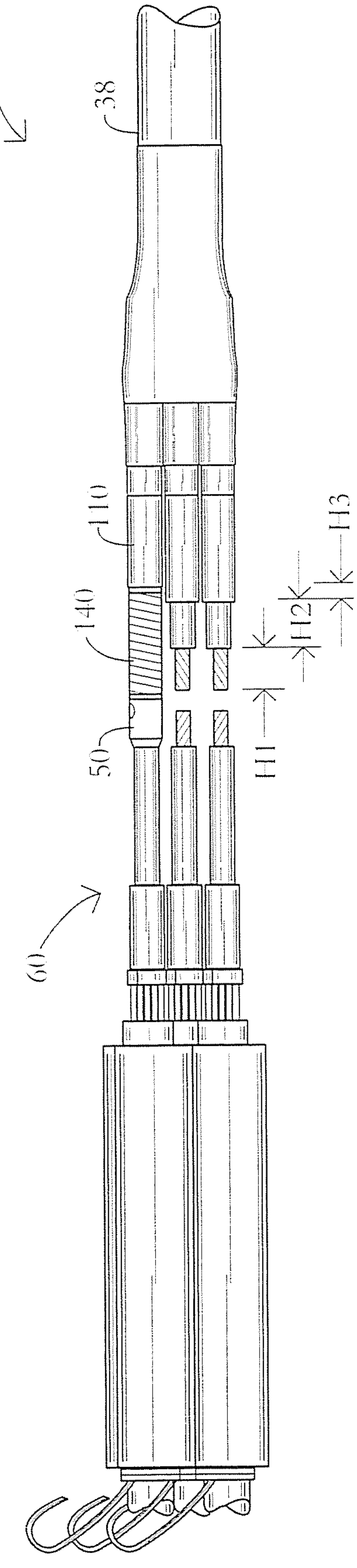
32
50
60
62
60
64
60
60
66
68
69
146
146

FIG. 13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38
110
140
H3
H2
H1
50
60

FIG. 14

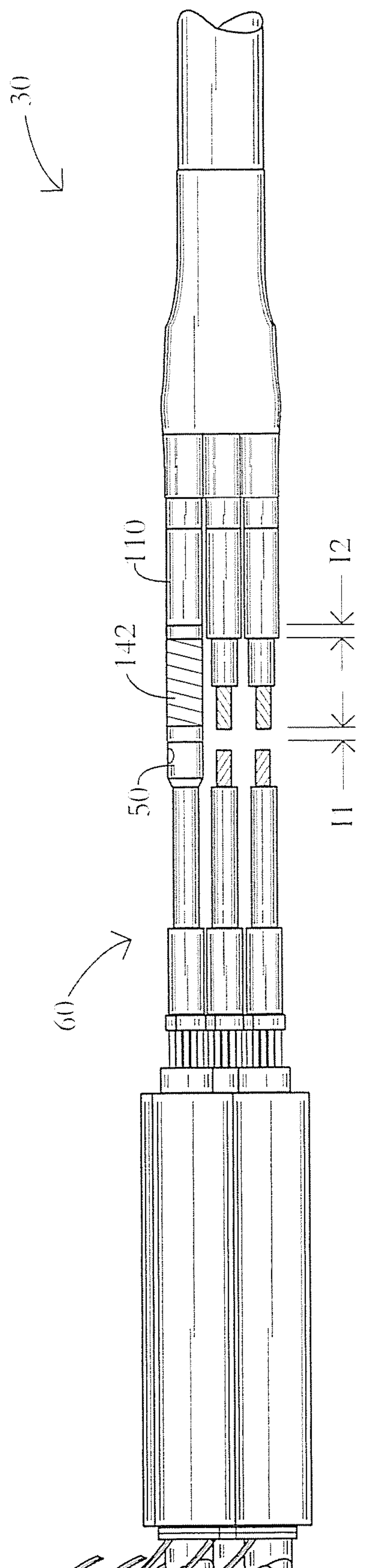


FIG. 15

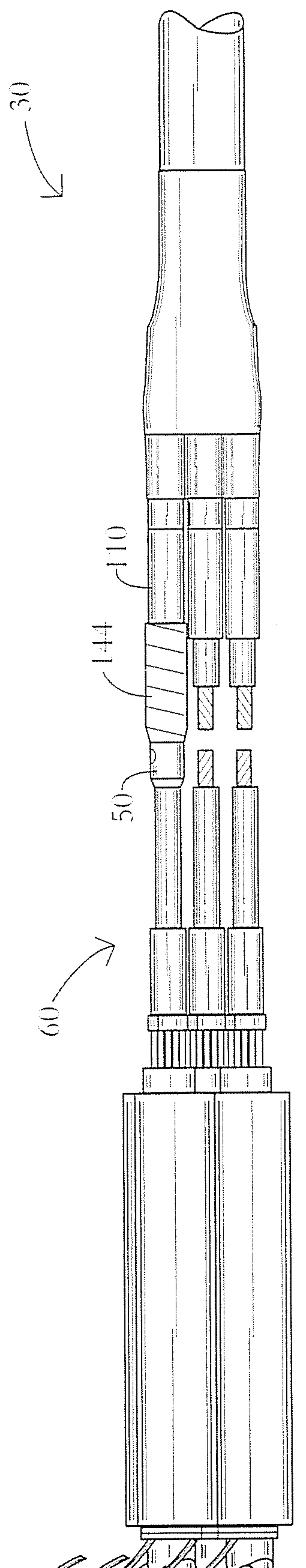


FIG. 16

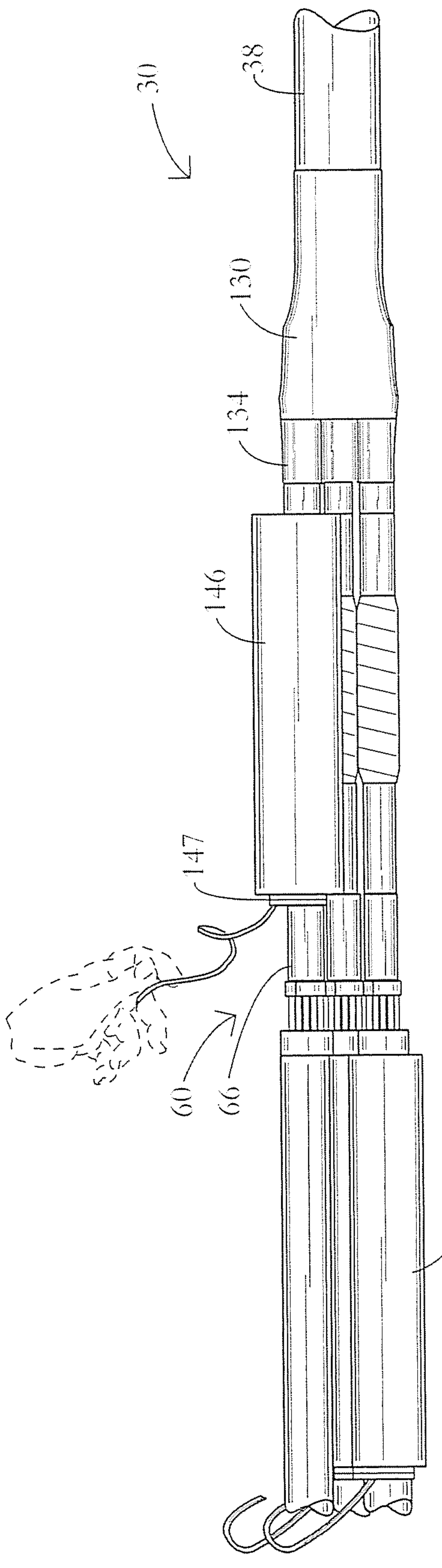


FIG. 17

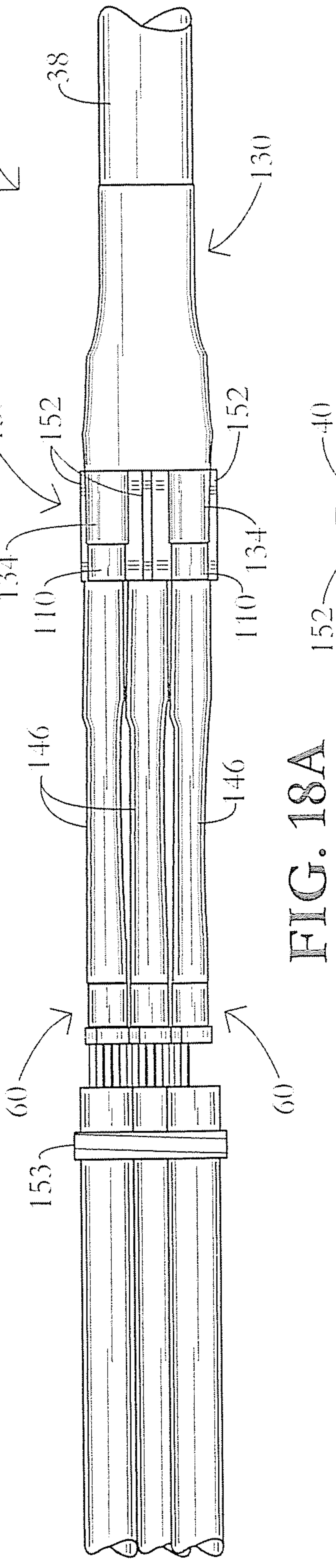


FIG. 18A

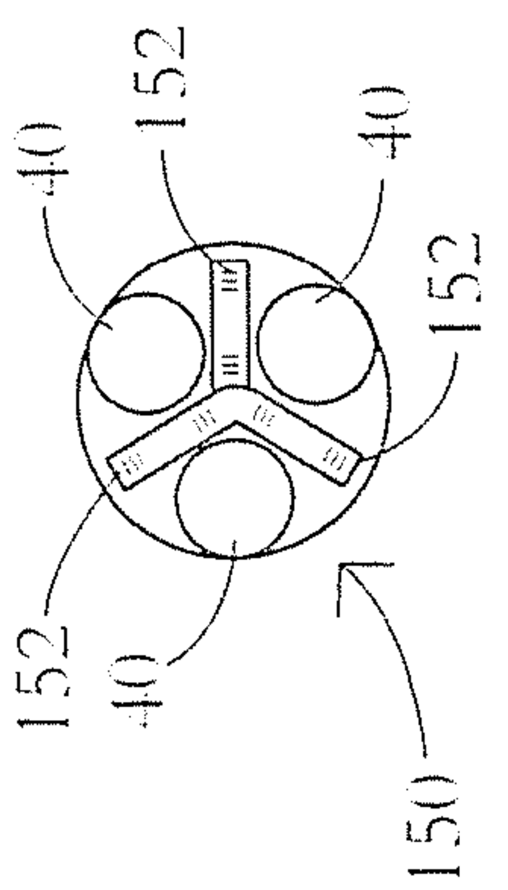


FIG. 18B

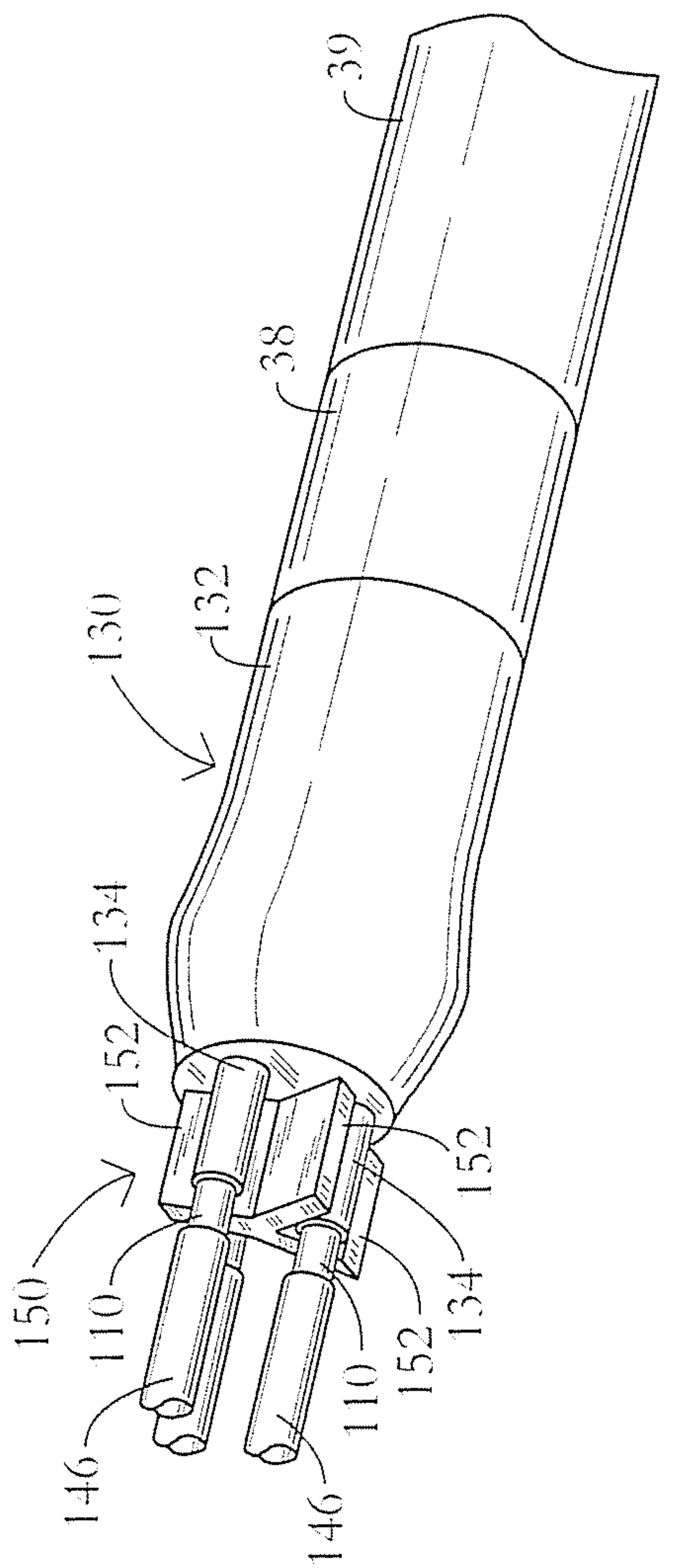


FIG. 18C

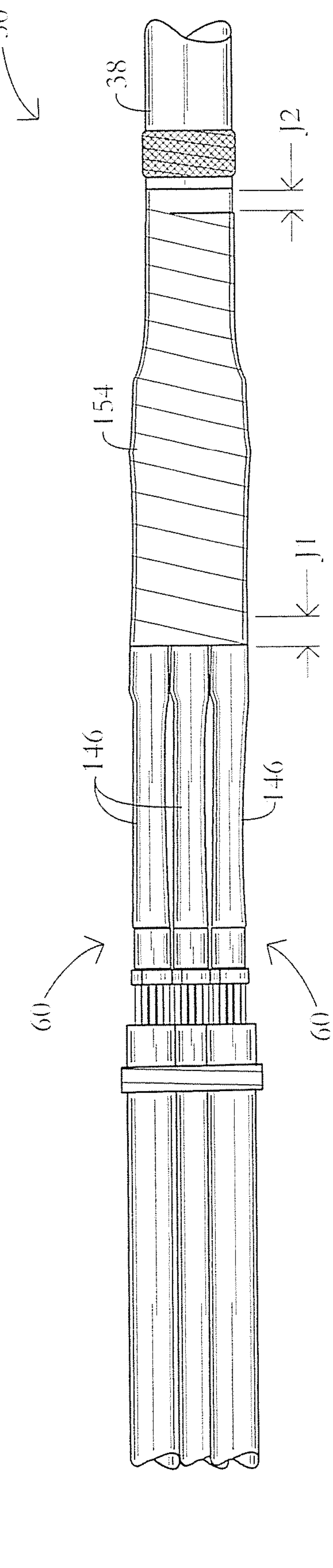


FIG. 19A

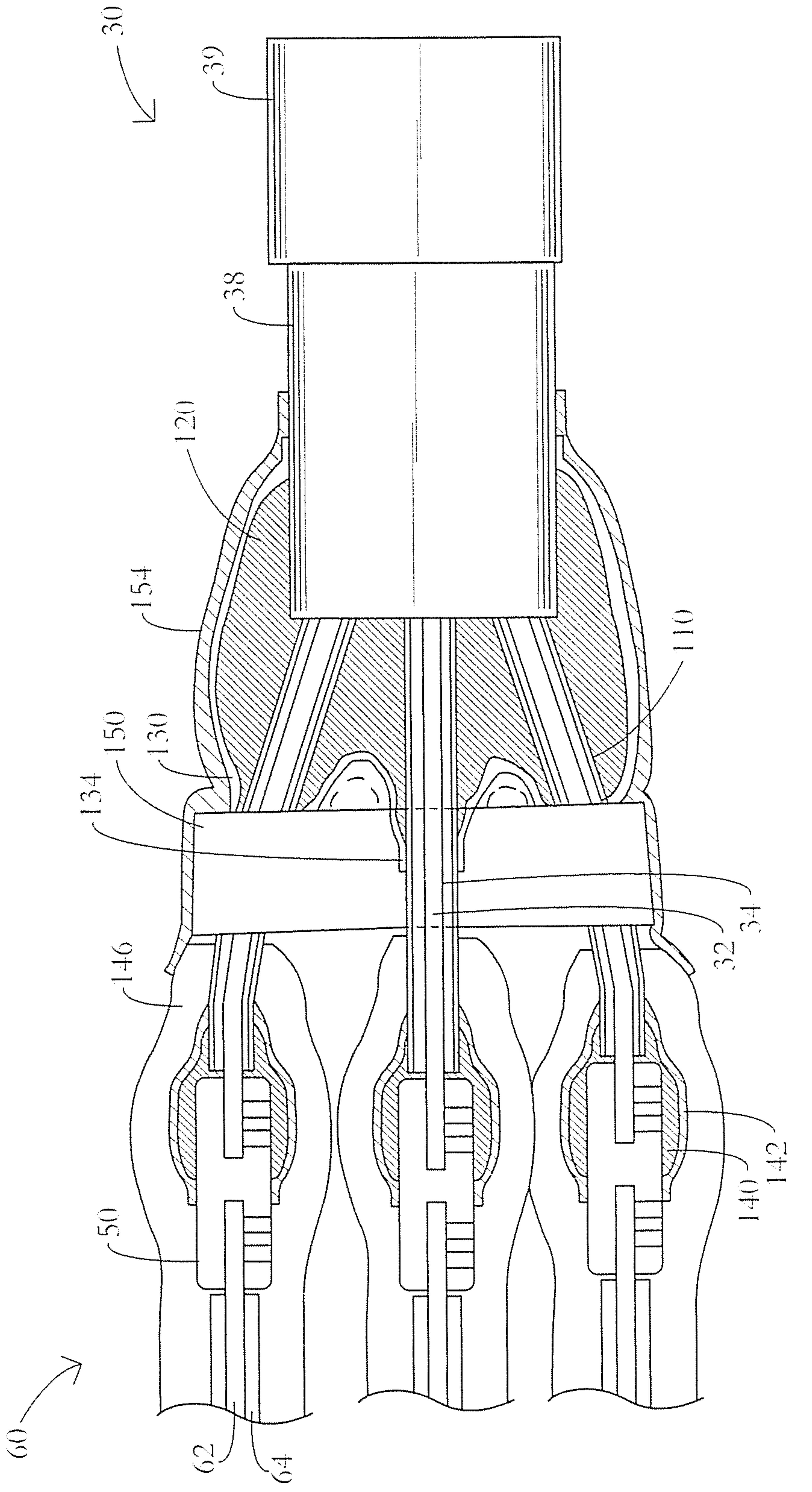


FIG. 19B

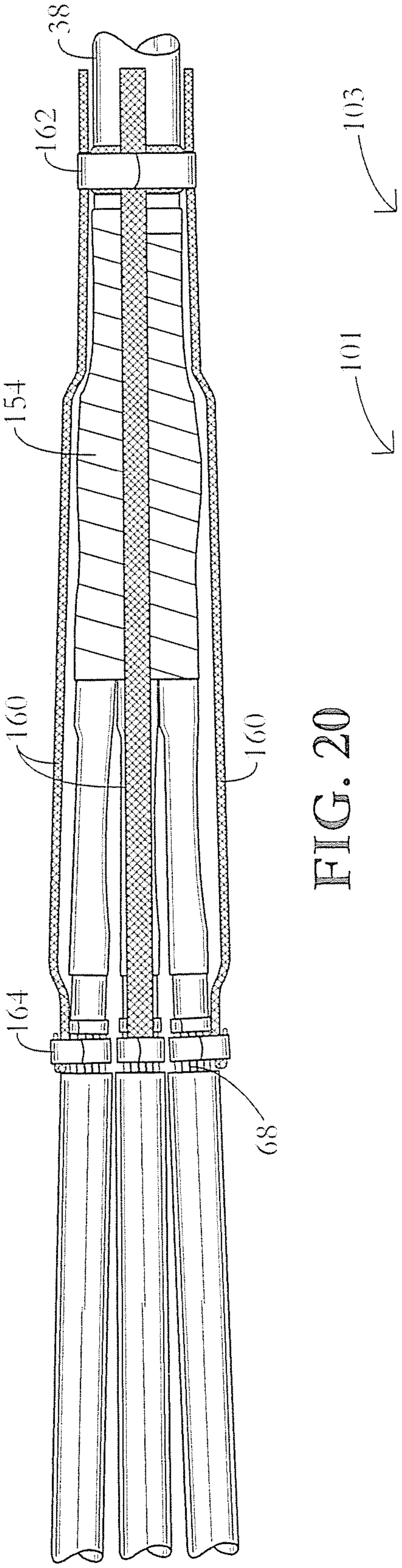


FIG. 20

FIG. 21

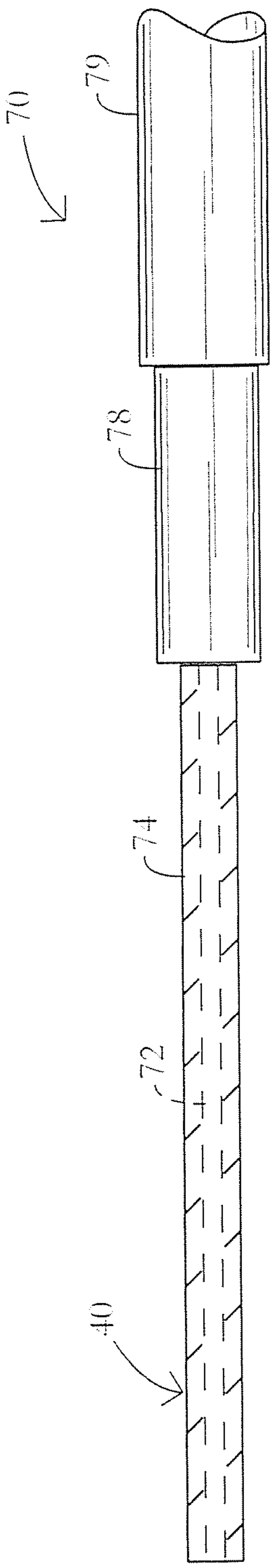


FIG. 22

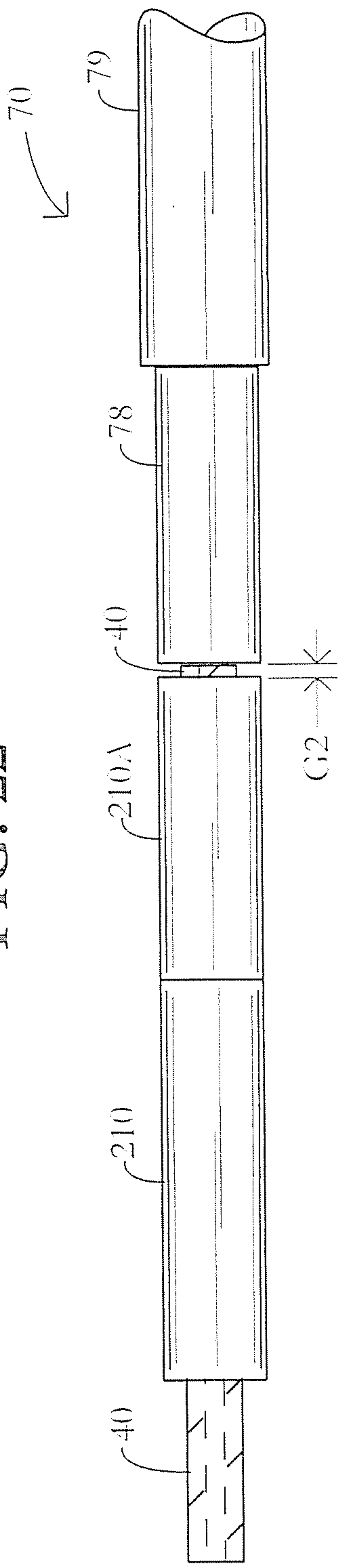


FIG. 23

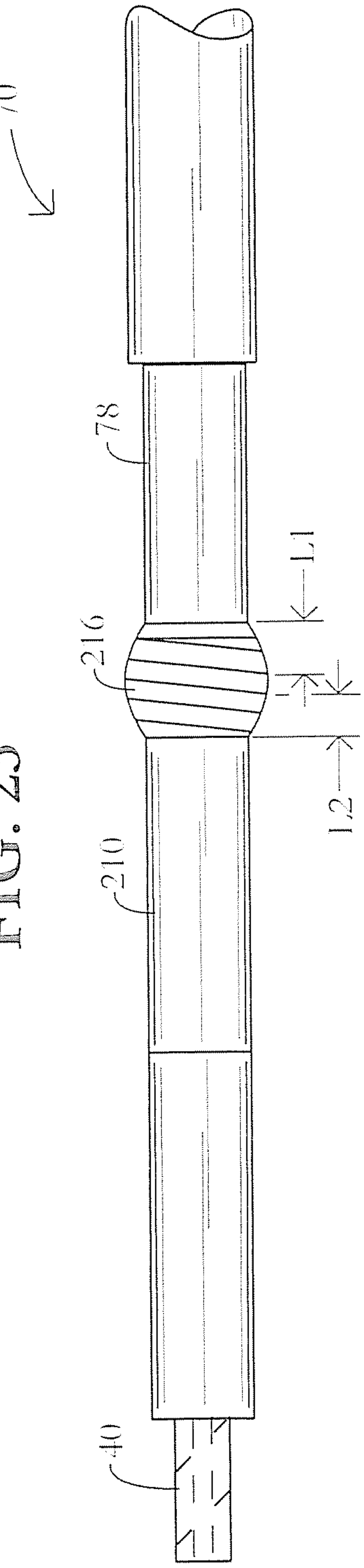


FIG. 24

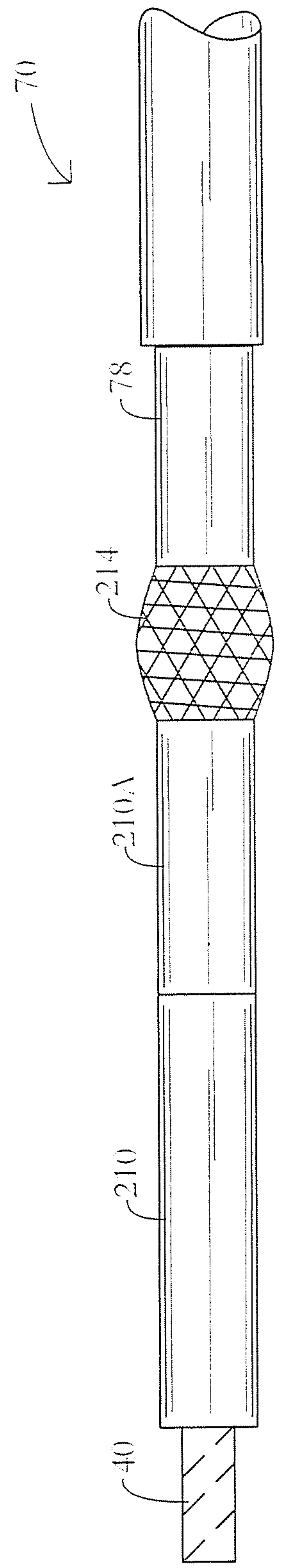


FIG. 25

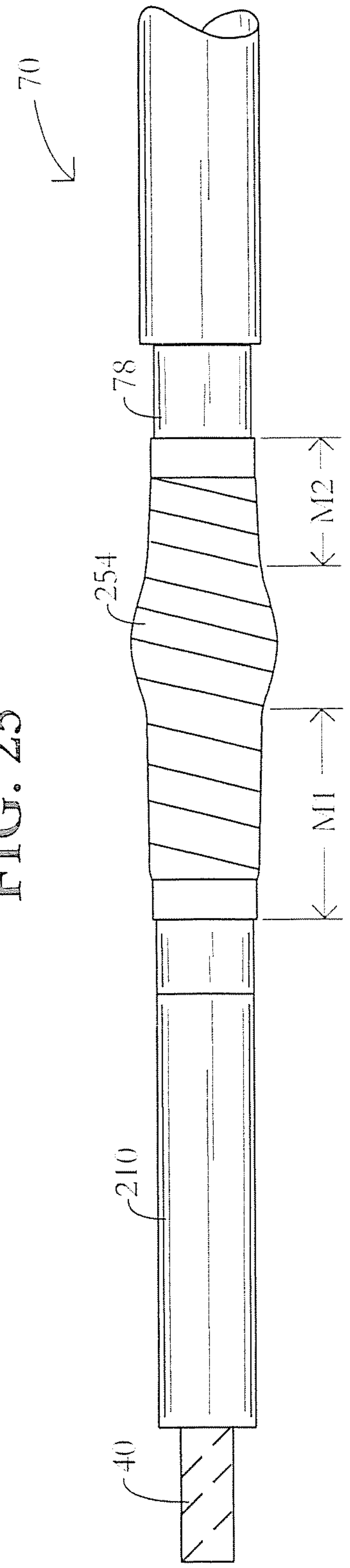


FIG. 26

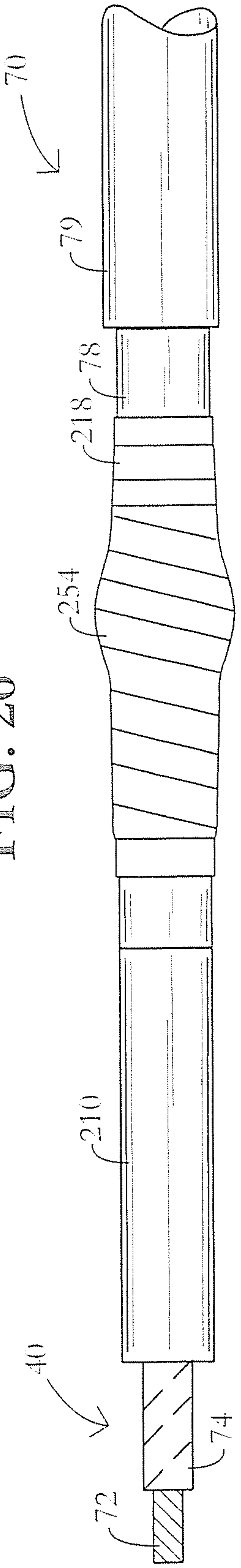


FIG. 27

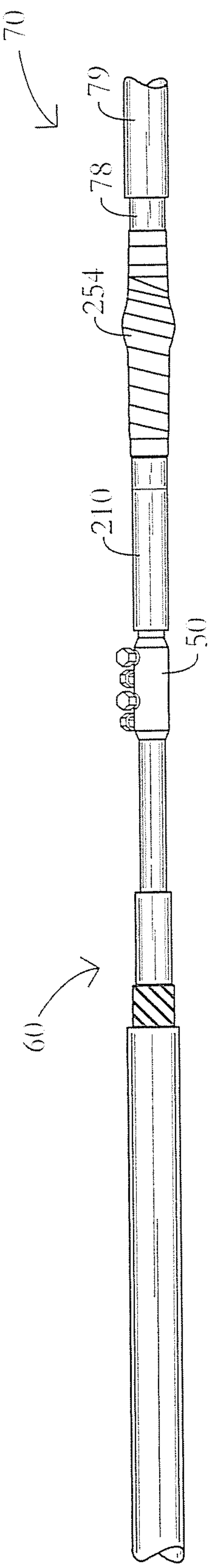


FIG. 28

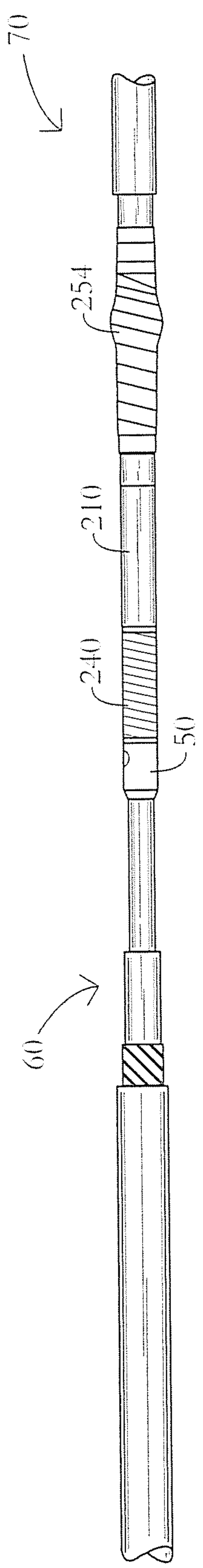


FIG. 29

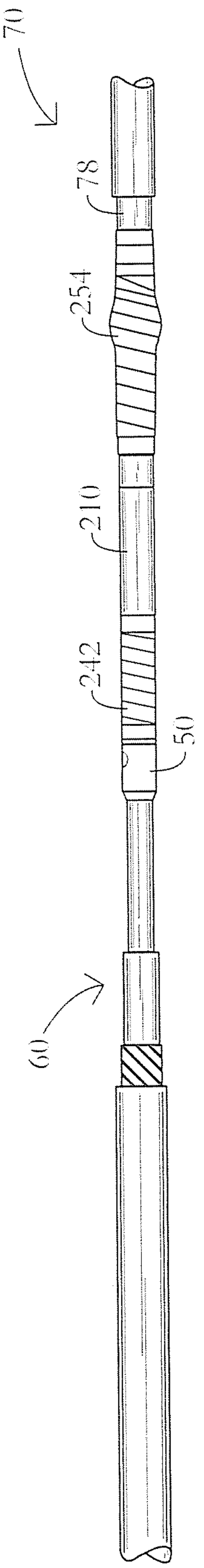


FIG. 30A

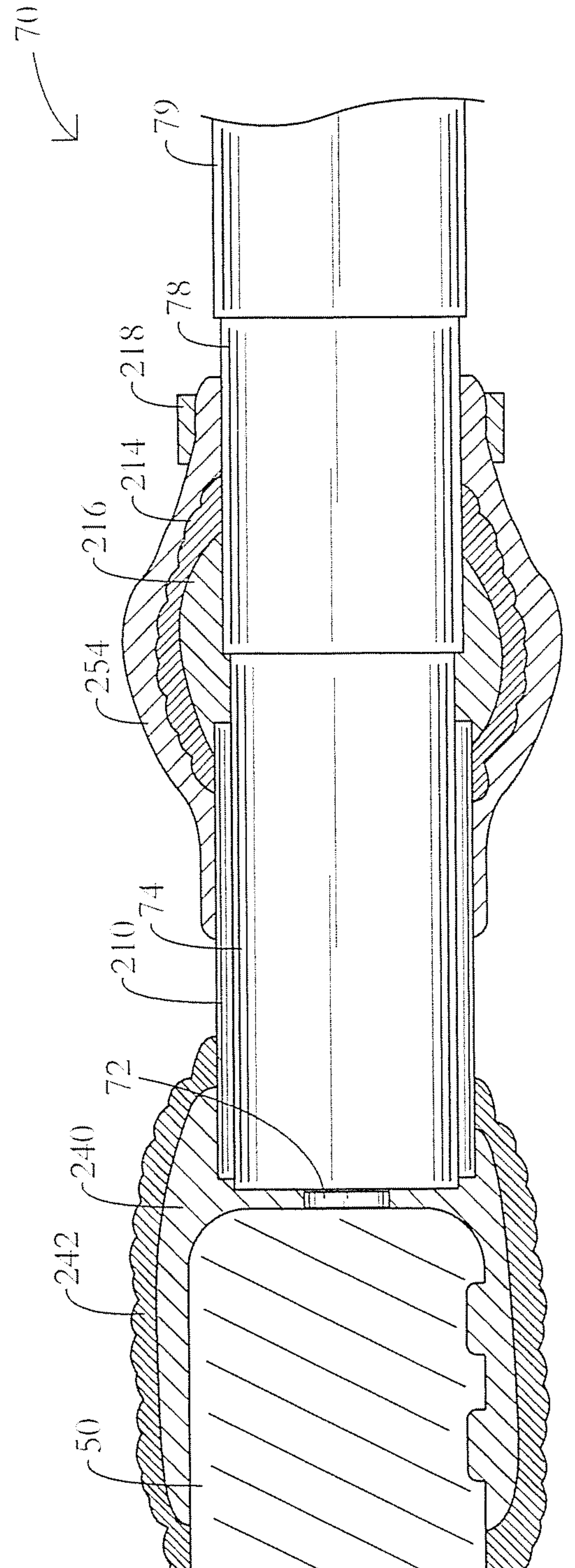


FIG. 30B

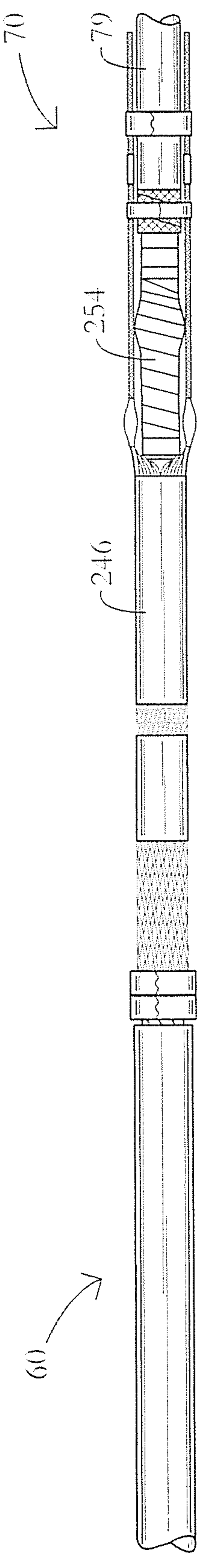


FIG. 31

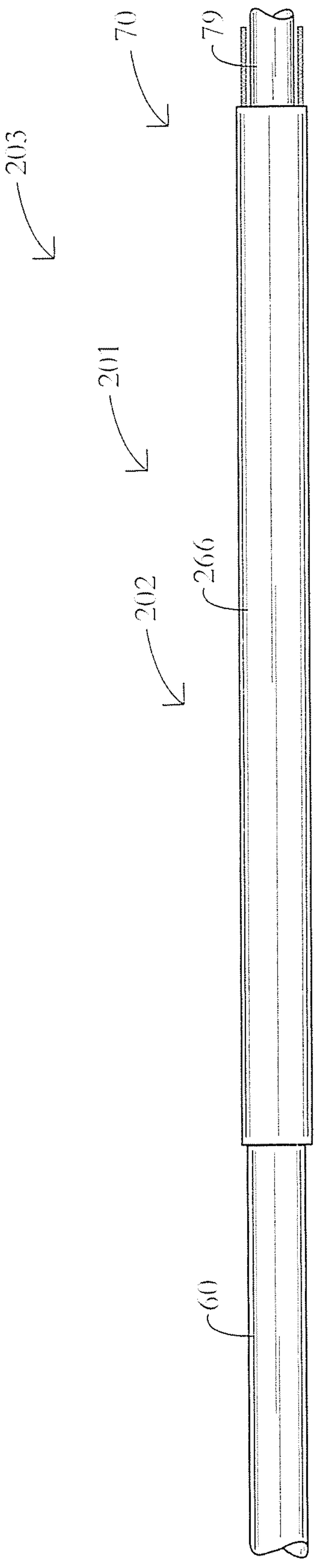
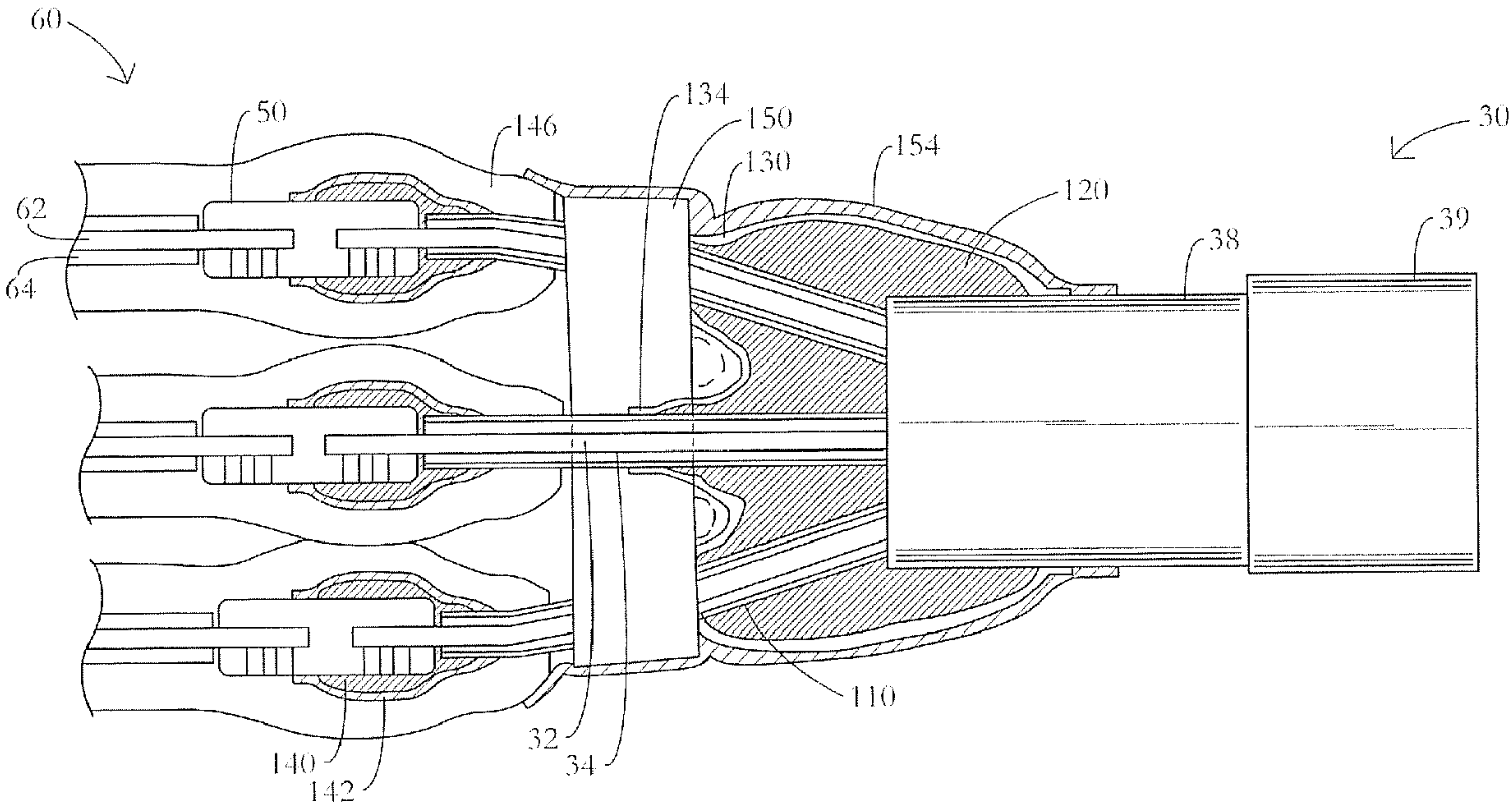


FIG. 32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