(12) STANDARD PATENT (11) Application No. **AU 2019212363 B2**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Termination arrangement for an overhead electrical cable

(51) International Patent Classification(s)
B32B 15/04 (2006.01) ***H02G 1/04*** (2006.01)
B32B 27/04 (2006.01) ***H02G 7/02*** (2006.01)
H01B 5/10 (2006.01) ***H02G 7/04*** (2006.01)
H01B 7/17 (2006.01) ***H02G 7/05*** (2006.01)
H02G 1/02 (2006.01) ***H02G 15/18*** (2006.01)

(21) Application No: **2019212363** (22) Date of Filing: **2019.01.24**

(87) WIPO No: **WO19/147838**

(30) Priority Data

(31) Number	(32) Date	(33) Country
62/621,173	**2018.01.24**	**US**

(43) Publication Date: **2019.08.01**
(44) Accepted Journal Date: **2024.11.14**

(71) Applicant(s)
CTC Global Corporation

(72) Inventor(s)
BOSZE, Eric;WONG, Christopher;PILLING, Ian M.;WEBB, William;PILLING, Douglas A.

(74) Agent / Attorney
FPA Patent Attorneys Pty Ltd, Level 19, South Tower 80 Collins Street, Melbourne, VIC, 3000, AU

(56) Related Art
US 2012/0305312 A1
US 2006/0084327 A1

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
01 August 2019 (01.08.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/147838 A1

(51) International Patent Classification:

B32B 15/04 (2006.01)	*H02G 7/02* (2006.01)
B32B 27/04 (2006.01)	*H02G 7/04* (2006.01)
H01B 5/10 (2006.01)	*H02G 7/05* (2006.01)
H01B 7/17 (2006.01)	*H02G 1/02* (2006.01)
H02G 15/18 (2006.01)	*H02G 1/04* (2006.01)

(21) International Application Number:
PCT/US2019/014986

(22) International Filing Date:
24 January 2019 (24.01.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/621,173 24 January 2018 (24.01.2018) US

(71) Applicant: **CTC GLOBAL CORPORATION** [US/US]; 2026 McGaw Avenue, Irvine, California 92614 (US).

(72) Inventors: **BOSZE, Eric**; 2026 McGaw Avenue, Irvine, California 92614 (US). **WONG, Christopher**; 2026 McGaw Avenue, Irvine, California 92614 (US). **PILLING, Ian M.**; 2026 McGaw Avenue, Irvine, California 92614 (US). **WEBB, William**; 2026 McGaw Avenue, Irvine, California 92614 (US). **PILLING, Douglas A.**; 2026 McGaw Avenue, Irvine, California 92614 (US).

(74) Agent: **DOCKERY, David F.**; Marsh Fischmann & Breyfogle LLP, 8055 E. Tufts Avenue, Suite 450, Denver, Colorado 80237 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Declarations under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

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

(54) Title: TERMINATION ARRANGEMENT FOR AN OVERHEAD ELECTRICAL CABLE

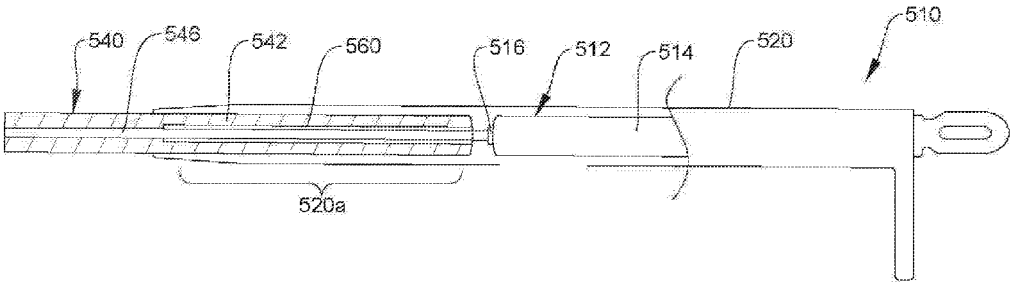


FIG. 5

(57) Abstract: A termination arrangement for securing an overhead electrical cable to a dead-end structure such as a dead-end tower. The termination arrangement includes a compression sheath that is configured to be disposed between a strength member and the conductive strands of the overhead electrical cable. The compression sheath mitigates damage to the strength member that may occur when an outer metallic sleeve is compressed around the conductive strands and the conductive strands are compressed against the strength member. The arrangement is particularly useful for securing overhead electrical cables having a composite strength member to a dead-end structure.

WO 2019/147838 A1

TERMINATION ARRANGEMENT FOR AN OVERHEAD ELECTRICAL CABLE

FIELD

[0001] This disclosure relates to the field of overhead electrical cables, and in particular relates to structures and methods for the termination of overhead electrical cables having a composite strength member, such as termination at a dead-end structure.

BACKGROUND

[0002] In the construction of an overhead electrical transmission and/or distribution line, the overhead electrical cable that transmits the electricity is strung upon support towers along the length of the line. The overhead electrical cable typically includes one or more conductive layers that each include of a plurality of individual conductive strands that are wrapped around and are supported by a strength member. The strength member is necessary because the conductive strands do not have sufficient mechanical properties (e.g., tensile strength) to be self-supporting when strung between the support towers. Traditionally, the conductive strands are fabricated from aluminum or an aluminum alloy and the strength member is fabricated from steel, specifically several independent steel elements that are combined (e.g., twisted together) to form the strength member, a configuration referred to as ACSR (aluminum conductor steel reinforced).

[0003] In recent years, the steel strength member has been replaced by advanced composite materials for some installations. The advanced composite materials include two or more distinct material phases, such as structural fibers in a binding matrix, that combine to enhance one or more properties of the strength member. Some of these composite materials offer significant benefits as compared to steel, including higher tensile strength, lower coefficient of thermal expansion, resistance to corrosion and the like.

[0004] One example of an overhead electrical cable having such a composite strength member is the ACCC® overhead electrical cable available from CTC Global Corporation

2019212363 22 Oct 2024

of Irvine, CA, USA. See, for example, U.S. Patent No. Pat. No. 7,368,162 by Hiel et al, which is incorporated herein by reference in its entirety. The ACCC® electrical cable includes a plurality of conductive aluminum strands surrounding a single-element (e.g., single rod) fiber-reinforced composite strength member. The composite strength member includes an inner core of continuous carbon fibers in a polymer (e.g., resin) binding matrix, surrounded by an outer layer of continuous glass fibers in the binding matrix.

[0005] When constructing electrical transmission and distribution lines, the electrical cable must be frequently terminated, such as for connection to another segment of electrical cable, for drop down to a power station, or for drop down to an underground cable. In these cases, the electrical cable is terminated and attached to a dead-end structure (e.g., a dead-end tower) using termination hardware. Often, the termination hardware requires crimping of an outer conductive metal sleeve onto the electrical cable using very high compressive forces to deform the metal outer sleeve.

[0006] Termination hardware for overhead electrical cables having a fiber-reinforced composite strength member typically relies on the electrical cable including fully annealed, trapezoidal-shaped aluminum conductive strands to uniformly distribute the compressive pressure required to deform the aluminum outer housing onto the composite strength member. However, not all overhead electrical cable installations can utilize this particular type of aluminum strand, for example where the overhead electrical cable will be subjected to severe ice-loading and/or other severe weather events.

[0006A] Reference to any prior art in the specification is not an acknowledgement or suggestion that this prior art forms part of the common general knowledge in any jurisdiction or that this prior art could reasonably be expected to be combined with any other piece of prior art by a skilled person in the art.

SUMMARY

[0007] Disclosed herein is a termination arrangement that, when used to terminate and overhead electrical cable with aluminum alloy (e.g., harder than annealed) conductive strands, and/or with round or oval conductive strands, reduces localized pressure on the composite strength member during crimping operations. The termination arrangement

20192123363 22 Oct 2024

includes a compression sheath (e.g., a tube or sleeve) that is installed over the composite core in the area where the outer housing is compressed over the conductive strands. The compression sheath may remain between the strength member and the aluminum conductive strands for the life of the connection. The compression sheath may be characterized as having internal dimensions (e.g., an internal diameter) that very closely matches the composite strength member (e.g., the outer diameter of the composite strength member) that the compression sheath is protecting.

[0008] In one embodiment, a termination arrangement securing an overhead electrical cable to a dead-end structure is disclosed. The overhead electrical cable has a composite strength member and conductive strands surrounding the composite strength member. The termination arrangement includes a connector anchoring the termination arrangement to a dead-end structure, a gripping element secured by the connector and gripping the composite strength member at a proximal end of the overhead electrical cable, an outer metallic sleeve surrounding at least the gripping element and the proximal end of the overhead electrical cable, the outer metallic sleeve having a compressed portion disposed over the proximal end of the overhead electrical cable, and a compression sheath disposed over the composite strength member and under the conductive strands along at least the length of the conductive strands under the compressed portion. The compression sheath is a cylindrical aluminum tube that is structurally independent from the composite strength member and has a thickness of at least about 0.20 mm and not greater than about 2.6 mm.

[0009] The foregoing termination arrangement may be characterized as having further refinements and/or additional features, which may be implemented alone or in any combination. For example, in one refinement, the composite strength member may include reinforcing fibers disposed within a binding matrix, such as a metallic matrix or a polymer matrix. Examples of useful polymer matrix materials include thermoset resin polymers and a thermoplastic polymers. In another refinement, the reinforcing fibers fibers selected from the group consisting of carbon fibers, boron fibers, metal oxide ceramic fibers, glass fibers, carbide fibers, aramid fibers and basalt fibers. Carbon fibers may be particularly useful due to their high tensile strength and light weight.

20192123632 22 Oct 2024

[0010] In another refinement, the composite strength member may include a plurality of individual composite rods that are operatively combined to form the composite strength member. Alternatively, the composite strength member may include only a single composite rod. In another refinement, at least a portion of the conductive strands have a cross-sectional shape that is polygonal. In yet another refinement, at least a portion of the conductive strands have a cross-sectional shape that is non-polygonal, e.g., a cross-sectional shape that is substantially circular. In a further refinement, at least a portion of the conductive strands have a cross-sectional shape that is substantially circular, and those strands are in direct contact with the compression sheath. The conductive strands may be fabricated from materials such as copper and aluminum, and in one refinement the conductive strands are formed from hardened aluminum.

[0011] In another refinement, the compression sheath does not extend substantially beyond the compressed portion of a distal end of the termination arrangement. In another refinement, the compression sheath is a closed cylindrical tube. Alternatively, the compression sheath is a cylindrical tube having a slot along a length thereof to facilitate placement of the compression sheath over the composite strength member. In another refinement, the compression sheath is structurally independent from the composite strength member. As noted above, the compression sheath is a cylindrical aluminum tube. In one particular refinement, the compression sheath is fabricated from hardened aluminum.

[0012] In another refinement, the connector includes an eye bolt, e.g., for attaching to a dead-end structure. In another refinement, the termination arrangement includes a jumper plate, e.g., for making an electrical connection.

[0013] In another refinement, the gripping element includes a collet that is compressed to grip the composite strength member. The collet may be disposed within a collet housing, and the collet housing may be operatively attached to the connector.

[0014] In one refinement, the compression sheath includes a proximal portion and a distal portion, wherein the distal portion is disposed between the composite strength member and the conductive strands and the proximal portion surrounds a portion of the composite strength member that extends beyond the proximal end of the overhead

20192123363 22 Oct 2024

electrical cable. In a further refinement, the proximal portion of the compression sheath has a larger outer diameter than an outer diameter of the distal portion of the compression sheath. In yet a further refinement, the distal portion of the compression sheath is disposed within a cavity formed in the connector.

[0015] In another embodiment, a method for securing an overhead electrical cable to a dead-end structure is disclosed. The overhead electrical cable includes a composite strength member and conductive strands surrounding the composite strength member. The method includes sliding a compression sheath over the composite strength member and under the conductive strands at a proximal end of the overhead electrical cable, placing an outer metallic sleeve over at least the proximal end of the overhead electrical cable and the compression sheath, and compressing at least a portion of the outer metallic sleeve onto the conductive strands.

[0016] The foregoing method may be characterized as having further refinements and/or additional steps, which may be implemented alone or in any combination. For example, the compressing step may include the application of a pressure of at least about 15 tons to the outer metallic housing. In another refinement, the method includes the step of securing a proximal end of the composite strength member to a connector. In yet another refinement, the method includes anchoring the connector to a dead-end structure.

[0017] In another embodiment, a kit comprising components that are configured to be assembled into a termination arrangement for securing an overhead electrical cable to a dead-end structure is disclosed. The kit includes a connector configured to anchor the termination arrangement to a dead-end structure, a gripping element configured to be secured by the connector and to operatively grip the composite strength member at a proximal end of the overhead electrical cable, an outer metallic sleeve configured to surround at least the gripping element and the proximal end of the overhead electrical

2019212363 22 Oct 2024

cable, and a compression sheath configured to be disposed over the composite strength member and under the conductive strands along at least the length of the outer metallic housing.

[0017A] By way of clarification and for avoidance of doubt, as used herein and except where the context requires otherwise, the term "comprise" and variations of the term, such as "comprising", "comprises" and "comprised", are not intended to exclude further additions, components, integers or steps.

DESCRIPTION OF THE DRAWINGS

[0018] **FIG. 1** illustrates a schematic view of a termination arrangement for an overhead electrical cable having a composite strength member.

[0019] **FIG. 2** illustrates a perspective view of a termination arrangement that has been crimped onto an overhead electrical cable.

[0020] **FIG. 3** illustrates a perspective view of an overhead electrical cable having a composite strength member.

[0021] **FIGS. 4A** and **4B** illustrate a compression sheath according to an embodiment of the present disclosure.

[0022] **FIG. 5** illustrates a termination arrangement according to an embodiment of the present disclosure.

[0023] **FIGS. 6A and 6B** illustrate cross-sectional views of overhead electrical cables.

[0024] **FIG. 7** illustrates a cross-sectional view of a termination arrangement and a compression sleeve according to an embodiment of the present disclosure.

DESCRIPTION OF THE EMBODIMENTS

[0025] **FIG. 1** illustrates a termination arrangement (e.g., a dead-end) for use with an overhead electrical cable. The termination arrangement **110** illustrated in **FIG. 1** is also illustrated and described in PCT Publication No. WO 2005/041358 by Bryant and in U.S. Patent No. 8,022,301 by Bryant et al., each of which is incorporated herein by reference in its entirety.

[0026] Broadly characterized, the termination arrangement **110** illustrated in **FIG. 1** includes a gripping element **112**, an outer sleeve **120** and a connector **130** for anchoring the termination arrangement **110** to a dead-end structure (e.g., to a termination tower), not illustrated, e.g., using eyebolt **132**. Opposite the eyebolt **132**, the termination arrangement **110** is operatively connected to an overhead electrical cable **140** that includes an electrical conductor **142** that surrounds a composite strength member **144**.

[0027] The gripping element **112** tightly grips the composite strength member **144** to secure the overhead electrical cable **140** to the termination arrangement **110**. As illustrated in **FIG. 1**, the gripping element **112** includes a collet **116** having a lumen that surrounds and grips onto the strength member **144**. The collet **116** is disposed in a collet

housing **114**. As the electrical cable **140** is tensioned and pulls the strength member **144**, friction develops between the strength member **144** and the collet **116** (e.g., along the lumen), and the strength member **144** pulls the collet **116** further into the collet housing **114**. The conical shape of the collet **116** and the funnel shape of the collet housing **114** create increased compression on the strength member **144**, ensuring that the strength member **144** does not slip out of the collet **116**.

[0028] An outer sleeve **120** surrounds the gripping element **112**, and surrounds the threaded portion **134** and on intermediate portion **136** of the connector **130**. The outer sleeve **120** includes a conductive body **128** to facilitate electrical conduction between the electrical conductor **142** and a jumper plate **126.** For example, the conductive body **128** may be fabricated from aluminum**.** As illustrated in **FIG. 1**, the jumper plate **126** is welded onto the conductive body **128**. In use, the jumper plate **126** is configured to attach to a connection plate **150** to facilitate electrical conduction between the electrical cable **140** and another conductor, e.g., another electrical cable (not illustrated) that is operatively connected to the connection plate **150**.

[0029] The connector **130** includes an eyebolt **132** at a proximal end of the connector **130** and a threaded portion **134** disposed at a distal end of the connector **130**. The threaded portion **134** is configured to operatively mate with a threaded portion **118** of the collet housing **114** to facilitate movement of the connector **130** toward the collet **116**, pushing the collet **116** into the collet housing **114**, when the connector is rotated, e.g., rotated clockwise. This strengthens the grip of the collet **116** onto the strength member **144**, further securing the overhead electrical cable **140** to the termination arrangement **110**. The eyebolt **132** is configured to be attached to a dead-end structure to secure the termination arrangement **110** and hence the electrical cable **140**, to the dead-end structure, e.g., to a termination tower.

[0030] In some situations, it is desirable or necessary to further secure the overhead electrical cable **140** to the termination structure **110**. For example, it may be desirable to crimp the outer sleeve **120** onto the connector **130**, particularly onto the intermediate portion **136** of the connector. Crimping involves the application of extreme pressure to the sleeve **120** using a press and die to mechanically deform and compress the sleeve

120 onto the connector **130**. Further, the sleeve **120** may also be crimped onto the overhead electrical cable **140** at the distal end of the termination structure **110**. Such crimping of the outer sleeve **120** ensures that the housing **120** will not move relative to the overhead electrical cable **140** after installation. The termination structure **110** may also include a metallic (e.g., aluminum) inner filler sleeve **122** to enhance the electrical and mechanical contact between the outer sleeve **120** and the electrical cable **140** when the sleeve **120** is crimped onto the electrical cable **140**. The use of a soft (e.g., annealed) aluminum for the electrical conductor **142** (e.g., conductive strands), and the use of trapezoidal conductive strands, prevents damage to the composite strength member **144** when the outer sleeve **120** is crimped onto the electrical cable **140**.

[0031] **FIG. 2** illustrates a perspective view of a termination arrangement that has been crimped onto an overhead electrical cable. As is described above with respect to **FIG. 1**, the termination arrangement **210** includes a connector having an eye bolt **232** that extends outwardly from a proximal end of an outer metallic sleeve **220**. A jumper plate **226** is welded to the proximal end of the conductive body **228** for electrical connection to, e.g., a connection plate (see **FIG. 1**). As illustrated in **FIG. 2**, the outer sleeve **220** is crimped over two regions, namely proximal crimped region **220b** and distal crimped region **220a**. The proximal crimped region **220b** is situated over an intermediate portion of the connector (see **FIG. 1**), and the distal crimped region **220a** is situated over a portion of the overhead electrical cable **240**. The extreme compressive forces placed around the outer sleeve **220** during the crimping operation are transferred to the underlying components, i.e., to the connector under the crimped region **220b** and to the overhead electrical cable **240** under the crimped region **220a**.

[0032] Thus, the conductive strands and other components of the termination arrangement, e.g., the outer sleeve, are fabricated from aluminum. As used herein, and unless otherwise specified, when the term “aluminum” is used on its own, it refers generally to pure aluminum or aluminum alloys (e.g., comprising at least about 50 wt.% aluminum), as well as all types of aluminum that have been heat treated (e.g., annealed), work hardened, extruded or otherwise processed in a manner that results in a desirable property in the final component. As used herein, the term “soft aluminum” refers to a substantially pure (e.g., unalloyed) form of aluminum, which may be annealed. Examples

of soft aluminum include the Aluminum Association “1xxx” series (e.g., greater than 99% aluminum) that have been annealed, such as the AA1350-O aluminum, which is a fully annealed aluminum. Further, the terms "hardened aluminum" or “hard aluminum” refer to aluminum that that has a tensile strength of at least about 100 MPa, such as at least about 120 MPa, such as at least about 150 MPa, or even at least about 200 MPa. Hardened aluminum may have a tensile strength up to about 380 MPa, for example. As noted above, when the conductive strands surrounding the composite strength member are fabricated from a soft aluminum, the strand will deform and absorb some of the compressive force, thereby reducing the stresses on the underlying composite strength member. The use of trapezoidal-shaped (i.e., trapezoidal cross-section) conductive stands, which have a high surface area in direct contact with the strength member, can also reduce the stress that is placed on the composite strength member. As a result, there is very low probability that the crimping operation will damage the underlying composite strength member.

[0033] **FIG. 3** illustrates a cross-section of an overhead electrical cable **340**. The cable **340** includes an electrical conductor **342** for the conduction of electricity. The electrical conductor includes of two layers of conductive strands **342a** and **342b** that are wrapped (e.g., stranded) around a central strength member **344**. The strength member **344** is formed from a single rod of a fiber-reinforced composite material having an inner carbon fiber core **344a** and an outer layer **344b** of an insulative material such as glass fibers.

[0034] The conductive strands **342a/342b** have a substantially trapezoidal cross-section with top and bottom surfaces that may be slightly curved (e.g., arcuate) to form the substantially cylindrical conductor structure with few gaps between adjacent strands **342a/342b** and between the strands **342a** and the strength member **344**. The conductive strands **342a/342b** are selected to have a high conductivity and are fabricated from AA-1350-O aluminum having a high conductivity (e.g., about 61% IACS).

[0035] In some installations, however, the overhead electrical cable includes a conductor formed from conductive strands that have a shape (e.g., the cross-section) that creates stress points along a length of the composite strength member when the outer sleeve is compressed onto the conductive strands. For example, conductive stands

having a circular cross-section may produce stress points due to the relatively small contact area of the strands with the underlying composite strength member. Under such circumstances, the strength member may be susceptible to damage (e.g., fracture) when the conductive strands are compressed onto the strength member at high pressure.

[0036] The conductive strands may also be formed from hard aluminum, such as when the line is installed in a region the experiences heavy ice-loading of the electrical cable. For example, the conductive strands may include, but are not limited to, conductive strands of Al-Zr alloys or AA1350-H10 aluminum, which is a strain-hardened aluminum.

[0037] According to the present disclosure, a compression sheath is included between the conductive strands and the composite strength member, at least along the portion of the overhead electrical cable that is subject to compression. The compression sheath is configured to absorb (e.g., to dissipate) at least a portion of the compressive stresses that would otherwise be placed on the composite strength member. **FIG. 4A** illustrates a perspective view of a compression sheath according to an embodiment of the present disclosure, and **FIG. 4B** illustrates a cross-section of the compression sheath of **FIG. 4A**. The compression sheath **460** is configured (e.g., shaped and sized) to slide over a composite strength member, for example a single-element composite strength member having a circular cross-section, and under the conductive strands.

[0038] In this regard, the inner diameter (**ID**) of the compression sheath **460** is sized to substantially match the outer diameter of the strength member, e.g., so that there is substantially no gap between the inner circumference of the compression sheath **460** and the outer circumference of the composite strength member. For example, the inner diameter of the compression sheath for use with a single-element composite strength member may be at least about 1 mm, such as at least about 2 mm, such as at least about 2.5 mm. Typically, the inner diameter of the compression sheath for use with a single-element composite strength member will typically not be greater than about 25 mm, such as not greater than about 20 mm, or even not greater than about 15 mm.

[0039] However, compression sheaths having other inner diameters are contemplated depending on the outer diameter and configuration of the composite strength member. For example, the composite strength member may be composed of a plurality of individual

elements (e.g., individual rods) that are operatively combined (e.g., helically twisted together) to form the strength member. Such a multi-element configuration will typically have an effective outer diameter that is larger than the diameter of a single-element composite strength member. Examples of such multi-element composite strength members include, but are not limited to: the multi-element aluminum matrix composite strength member illustrated in U.S. Patent No. 6,245,425 by McCullough et al.; the multi-element carbon fiber strength member illustrated in U.S. Patent No. 6,015,953 by Tosaka et al.; and the multi-element carbon fiber strength member illustrated in U.S. Patent No. 9,685,257 by Daniel et al. Each of these U.S. patents is incorporated herein by reference in its entirety. Such multi-element composite strength members may necessitate the use of a compression sheath having a relatively large inner diameter as compared to a compression sheath used with a single-element composite strength member.

[0040] The thickness (***t***) of the compression sheath should be sufficient to protect the underlying composite strength member from fracturing under the compressive forces of the crimping operation. However, if the thickness is too large, it may be difficult to place (e.g., to slide) the sheath between the composite strength member and the conductive strands during the termination process. In one characterization, the sheath has a thickness of at least about 0.20 mm, such as at least about 0.5 mm, such as at least about 1.0 mm. In another characterization, the sheath has a thickness of not greater than about 2.6 mm, such as not greater than about 2.0 mm.

[0041] The compression sheath **460** may be fabricated from a variety of materials. In one characterization, the compression sheath **460** is fabricated from a metallic material. In one particular characterization, the compression sheath may be fabricated from aluminum. The use of hardened aluminum is particularly advantageous for the compression sheath because it allows the aluminum sheath to maintain its shape while being installed in between the composite core strand and the conductive strands wrapped around the composite core. Hardened aluminum is also readily extrudable.

[0042] In one particular characterization, the compression sheath is fabricated from an Aluminum Association Series 6*xxx* alloy ("AA6*xxx* alloy"), which typically has a tensile strength of at least about 150 MPa and not greater than about 380 MPa. AA6xxx alloys

include silicon and magnesium as alloying elements to form magnesium silicide with the alloy. Other useful aluminum alloys include Al-Zr alloys such as AA7*xxx* alloys. Other useful metals for the compression sleeve may include copper and steel. Non-metallic materials may also be useful, such as high performance plastics (e.g., polymers) including, but not limited to, PEEK (polyetheretherketone), PEK (polyehterketone) and PES (poly(ethersulfone)). Such plastics may be reinforced with fibers such as carbon fibers, glass fibers, aramid fibers, fluorocarbon fibers (e.g., PTFE fibers) and the like to enhance the mechanical properties of the plastic.

[0043] As illustrated in **FIGS. 4A-4B**, the compression sleeve **460** may include a longitudinally-extending slot **462**. The longitudinally extending slot **462** may facilitate the placement of the compression sleeve **460** over the composite strength member during assembly of the termination arrangement. Although illustrated as a longitudinally-extending slot **462**, the compression sleeve **460** may also include a non-linear slot, such as a slot that is in the shape of a spiral around the outer circumference of the sleeve **460**. Other sheath configurations may include knurls around the outside of the surface of the sheath, and/or a taper on one or both ends. These configurations may facilitate the separation of the conductive strands from the composite strength member and allow the sheath to more easily be inserted between the composite strength member and the conductive strands wrapped around the composite strength member. Further, the sheath may be configured in two or more parts that can come together to form a substantially continuous cylinder around the composite strength member when installed between the strength member and the conductive strands wrapped around the strength member.

[0044] In another configuration, the compression sheath may include a closed cylindrical tube, e.g., a cylindrical tube that is open at both ends and does not include a slot or other separation along the wall of the sheath.

[0045] The length of the compression sheath **460** is selected such that the compression sheath **460** surrounds the composite strength member at least along the length of composite strength member that is subjected to the compressive forces during the crimping process. In one characterization, the compression sheath **460** has a length of at least about 150 mm, such as at least about 450 mm. However, the compression

sheath **460** should not extend substantially beyond the length of composite strength member that is under compression, e.g., should not extend toward the connector beyond the conductive strands. In one characterization, the compression sheath **460** has a length of not greater than about 915 mm, such as not greater than about 650 mm.

[0046] **FIG. 5** illustrates a partial cross-section of a termination arrangement according to the present disclosure, e.g., for securing an overhead electrical cable to a dead-end structure. The overhead electrical cable **540** includes a composite strength member **546** and conductive strands **542** surrounding the composite strength member **546**. The termination arrangement **510** includes a gripping element secured by the connector and gripping the composite strength member **546** at a proximal end of the overhead electrical cable **540**. As illustrated in **FIG. 5**, the gripping element **512** includes a collet **516** and a collet housing **514**, where the collet **516** extends slightly beyond the housing **514** and grips the composite strength member **546**. The outer metallic sleeve **520** surrounds the gripping element **512** and the proximal end of the overhead electrical cable **540**. A compressed portion **520a** of the outer metallic sleeve **520** is disposed over (e.g., around) the proximal end of the overhead electrical cable **540**. The compression sheath **560** is disposed between the composite strength member **546** and the conductive strands **542** along at least the length of the compressed portion **520a**.

[0047] The termination arrangement **510** is particularly suited for use with an overhead electrical cable **540** that includes a composite strength member **546**. Examples of overhead electrical cables for which the termination arrangement **510** is particularly useful include, but are not limited to, those having a strength member comprising reinforcing fibers bound in a matrix, such as a polymeric matrix or a metallic matrix. The reinforcing fibers may be substantially continuous reinforcing fibers that extend along the length of the composite strength member, and/or may include short reinforcing fibers (e.g., fiber whiskers or chopped fibers) that are dispersed through the matrix. The fibers may be selected from a wide range of materials, including but not limited to, carbon, glass, boron, metal oxides, metal carbides, high-strength polymers such as aramid fibers or fluoropolymer fibers, basalt fibers and the like. The matrix material may include, for example, a plastic (e.g., polymer) such as a thermoplastic polymer or a thermoset polymer. The matrix may also be a metallic matrix, such as an aluminum matrix. One

example of an aluminum matrix composite strength member is illustrated in U.S. Patent No. 6,245,425 by McCullough et al., which is incorporated herein by reference in its entirety. One example of a polymer matrix fiber-reinforced strength member is the strength member used in the ACCC® overhead electrical cable that is manufactured by CTC Global Corporation of Irvine, CA, USA. Such an overhead electrical cable is illustrated, for example, in U.S. Pat. No. 7,368,162 by Hiel et al, which is incorporated herein by reference in its entirety. Although illustrated in **FIG. 5** as a single-element strength member **546** (e.g., a single rod), the strength member may include a plurality of individual composite elements that are combined (e.g., helically twisted together) to form the strength member, as is discussed above.

[0048] The conductive strands **542** may have a polygonal or a non-polygonal cross-section. In one characterization, the conductive strands **542** have a non-polygonal cross-section, e.g., that creates stress points along the length of the composite strength member **546** that is being compressed. In one characterization, the conductive strands include strands having a circular cross-section section that are in direct contact with the composite strength member **546**. Strands having a circular cross-section concentrate the applied force along the line of contact between the circular strand and the composite strength member, which may lead to fracture of the composite strength member **546** even under relatively moderate compressive loads. The conductive strands may be fabricated from conductive metallic materials, including but not limited to, aluminum and copper. One particular characterization, the conductive strands include hardened aluminum, e.g., non-annealed, aluminum conductive strands such as Al-Zr conductive strands or AA1350-H19 conductive strands.

[0049] **FIGS. 6A** and **6B** illustrate schematic cross-sections of an end of an overhead electrical cable without a compression sheath (**FIG. 6A**) and with a compression sheath (**FIG. 6B**). As illustrated in **FIG. 6A**, the overhead cable **640A** comprises a composite strength member **646A** that includes carbon fibers in a polymeric matrix. A plurality of conductive strands **642A** having a circular cross-section are helically wrapped around the strength member **646A**. It can be seen in **FIG. 6A** that the circular conductive strands **642A** have a relatively small portion that is in direct contact with the underlying strength member **646A**. Thus, when the conductive strands **642A** are compressed onto the

strength member **646A** during a crimping operation, stresses are concentrated under the portion of conductive strand **642A** contacting the strength member **646A**.

[0050] **FIG. 6B** illustrates the use of a compression sleeve during the termination process according to an embodiment of the present disclosure. Similar to **FIG. 6A**, the overhead cable **640B** comprises a composite strength member **646B** that includes carbon fibers in a polymeric matrix. A plurality of conductive strands **642B** having a circular cross-section are helically wrapped around the strength member **646B**. In the embodiment of **FIG. 6B**, a compression sheath **624B** is placed between the conductive strands **642B** and the composite strength member **646B**. The compression sheath **624B** is a closed cylindrical tube that is placed over (e.g., slid onto) the composite strength member **646B** before the crimping operation. As a result, when the conductive strands **642B** are compressed onto the strength member **646B** during the crimping operation, the compression sheath **624B** absorbs and distributes the compressive forces around the entire circumference of the strength member **646B**, thereby reducing the chance of a fracture in the strength member **646B**.

[0051] **FIG. 7** illustrates another embodiment of a termination arrangement according to the present disclosure. The embodiment of a termination arrangement illustrated in **FIG. 7** is a modification of the termination arrangement disclosed in U.S. Patent No. 7,348,489 by Chadbourne, which is incorporated herein by reference in its entirety.

[0052] As illustrated in **FIG. 7**, the termination arrangement **710** includes a connector **730** having an eye bolt **732**, e.g., for anchoring the termination arrangement **710** to a dead-end structure. A distal portion **724a** of the compression sheath **724** is disposed between the composite strength member **746** and the conductive stands **742** along a distal portion **720a** of the outer metallic housing. The compression sheath **724** includes a proximal portion **724b** that has an outer diameter that is larger than the outer diameter of the distal portion **724a**. The proximal portion **724b** is disposed between the interior of the connector **730** and a portion of the composite strength member **746** that extends beyond the conductive strands **742**. In this manner, the outer metallic housing **720** may be crimped along substantially its entire length, e.g., along portions **720a** and **720b**, while

the composite strength member **746** remains protected along the entire length that is subject to the compressive stresses.

[0053] It will be appreciated from the foregoing that the present disclosure is also directed to a method for securing an overhead electrical cable to a dead-end structure. Broadly characterized, the overhead electrical cable includes a composite strength member and conductive strands surrounding the composite strength member. The method includes placing a compression sheath between the composite strength member and the conductive strands at a proximal end of the overhead electrical cable, placing an outer metallic sleeve over at least the proximal end of the overhead electrical cable and the compression sheath, and compressing at least a portion of the outer metallic sleeve onto the conductive strands.

[0054] The method may be implemented using the termination arrangement disclosed above. The step of compressing the outer sleeve onto the conductive strands may utilize a pressure of at least about 15 tons to deform and compress the outer sleeve.

[0055] It will also be appreciate from the foregoing that the present disclosure is also directed to a kit, e.g., an assembly of components that are configured to be assembled into a termination arrangement for securing an overhead electrical cable to a dead-end structure is disclosed. The kit may include a connector configured to anchor the termination arrangement to a dead-end structure, a gripping element configured to be secured by the connector and to operatively grip the composite strength member at a proximal end of the overhead electrical cable, an outer metallic sleeve configured to surround at least the gripping element and the proximal end of the overhead electrical cable, and a compression sheath configured to be disposed between the composite strength member and the conductive strands along at least the length of the outer metallic housing.

[0056] While various embodiments of a termination arrangement and a method for securing an overhead electrical cable to a dead-end structure have been described in detail, it is apparent that modifications and adaptations of those embodiments will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present disclosure.

2019212363 22 Oct 2024

CLAIMS

1. A termination arrangement securing an overhead electrical cable to a dead-end structure, the overhead electrical cable having a composite strength member and conductive strands surrounding the composite strength member, the termination arrangement comprising:

a connector anchoring the termination arrangement to a dead-end structure;

a gripping element secured by the connector and gripping the composite strength member at a proximal end of the overhead electrical cable;

an outer metallic sleeve surrounding at least the gripping element and the proximal end of the overhead electrical cable, the outer metallic sleeve having a compressed portion disposed over the proximal end of the overhead electrical cable; and

a compression sheath disposed over the composite strength member and under the conductive strands along at least the length of the conductive strands under the compressed portion, wherein the compression sheath is a cylindrical aluminum tube that is structurally independent from the composite strength member and has a thickness of at least about 0.20 mm and not greater than about 2.6 mm.

2. The termination arrangement recited in Claim 1, wherein the composite strength member comprises reinforcing fibers disposed within a binding matrix.

3. The termination arrangement recited in Claim 2, wherein the binding matrix is a metallic matrix.

4. The termination arrangement recited in Claim 2, wherein the binding matrix is a polymeric matrix.

5. The termination arrangement recited in any one of Claims 1 to 4, wherein the reinforcing fibers comprise carbon fibers.

2019212363 22 Oct 2024

6. The termination arrangement recited in any one of Claims 1 to 5, wherein the composite strength member comprises a plurality of individual composite rods that are operatively combined to form the composite strength member.

7. The termination arrangement recited in any of Claims 1 to 5, wherein the composite strength member consists essentially of a single composite rod.

8. The termination arrangement recited in any one of Claims 1 to 7, wherein at least a portion of the conductive strands have a cross-sectional shape that is polygonal.

9. The termination arrangement recited in any of Claims 1 to 8, wherein at least a portion of the conductive strands have a cross-sectional shape that is non-polygonal.

10. The termination arrangement recited in Claim 9, wherein the conductive strands that have a non-polygonal cross-sectional shape have a cross-sectional shape that is substantially circular, wherein at least a portion of the conductive strands having a cross-sectional shape that is substantially circular are in direct contact with the compression sheath.

11. The termination arrangement recited in any one of Claims 1 to 10, wherein the conductive strands comprise aluminum strands.

12. The termination arrangement recited in Claim 11, wherein the conductive strands comprise hardened aluminum strands.

13. The termination arrangement recited in any of Claims 1 to 12, wherein the compression sheath does not extend substantially beyond the compressed portion of a distal end of the termination arrangement.

14. The termination arrangement recited in any of Claims 1 to 13, wherein the cylindrical aluminum tube is a closed cylindrical tube.

15. The termination arrangement recited in any of Claims 1 to 13, wherein the cylindrical aluminum tube comprises a slot along a length thereof to facilitate placement of the cylindrical aluminum tube over the composite strength member.

2019212363 22 Oct 2024

16. The termination arrangement recited in any one of Claims 1 to 15, wherein the compression sheath is fabricated from hardened aluminum.

17. The termination arrangement recited in any of Claims 1 to 16, wherein the connector comprises an eye bolt.

18. The termination arrangement recited in any of Claims 1 to 17, wherein the termination arrangement further comprises a jumper plate.

19. The termination arrangement recited in any of Claims 1 to 18, wherein the gripping element comprises a collet that is compressed to grip the composite strength member.

20. The termination arrangement recited in Claim 19, wherein the collet is disposed within a collet housing.

21. The termination arrangement recited in Claim 20, wherein the collet housing is operatively attached to the connector.

22. The termination arrangement recited in any of Claims 1 to 21, wherein the compression sheath comprises a proximal portion and a distal portion, wherein the distal portion is disposed between the composite strength member and the conductive strands and the proximal portion surrounds a portion of the composite strength member that extends beyond the proximal end of the overhead electrical cable.

23. The termination arrangement recited in Claim 22, wherein the proximal portion of the compression sheath has a larger outer diameter than an outer diameter of the distal portion of the compression sheath.

24. The termination arrangement recited in Claim 23, wherein the distal portion of the compression sheath is disposed within a cavity formed in the connector.

25. A method for securing an overhead electrical cable to a dead-end structure, the overhead electrical cable having a composite strength member and conductive strands surrounding the composite strength member, the method comprising:

sliding a compression sheath over the composite strength member and under the conductive strands at a proximal end of the overhead electrical cable;

2019212363 22 Oct 2024

placing an outer metallic sleeve over at least the proximal end of the overhead electrical cable and the compression sheath; and

compressing at least a portion of the outer metallic sleeve onto the conductive strands.

26. The method recited in Claim 25, wherein the compressing step comprises applying a pressure of at least about 15 tons to the outer metallic sleeve.

27. The method recited in Claim 25 or Claim 26, further comprising the step of securing a proximal end of the composite strength member to a connector.

28. The method recited in Claim 27, further comprising the step of anchoring the connector to a dead-end structure.

29. The method recited in Claim 27 or Claim 28, wherein the outer metallic housing and the connector are part of the termination arrangement recited in any one of Claims 1 to 23.

30. A kit comprising components that are configured to be assembled into a termination arrangement for securing an overhead electrical cable to a dead-end structure, the overhead electrical cable having a composite strength member and conductive strands surrounding the composite strength member, the kit comprising:

a connector configured to anchor the termination arrangement to a dead-end structure;

a gripping element configured to be secured by the connector and to operatively grip the composite strength member at a proximal end of the overhead electrical cable;

an outer metallic sleeve configured to surround at least the gripping element and the proximal end of the overhead electrical cable; and

a compression sheath configured to be disposed over the composite strength member and under the conductive strands along at least the length of the outer metallic housing.

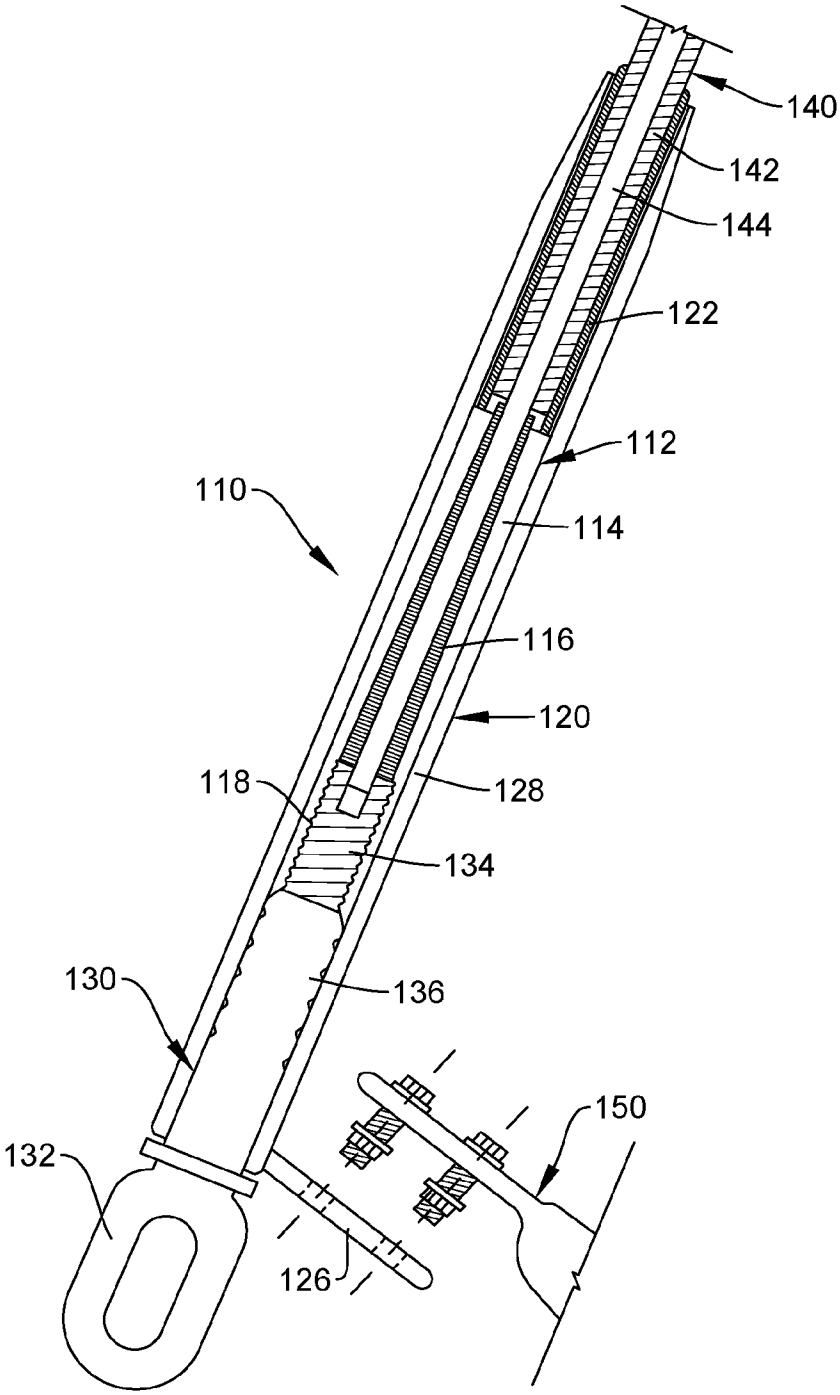

140
142
144
122
112
110
114
116
120
118
128
134
130
136
150
132
126

FIG. 1

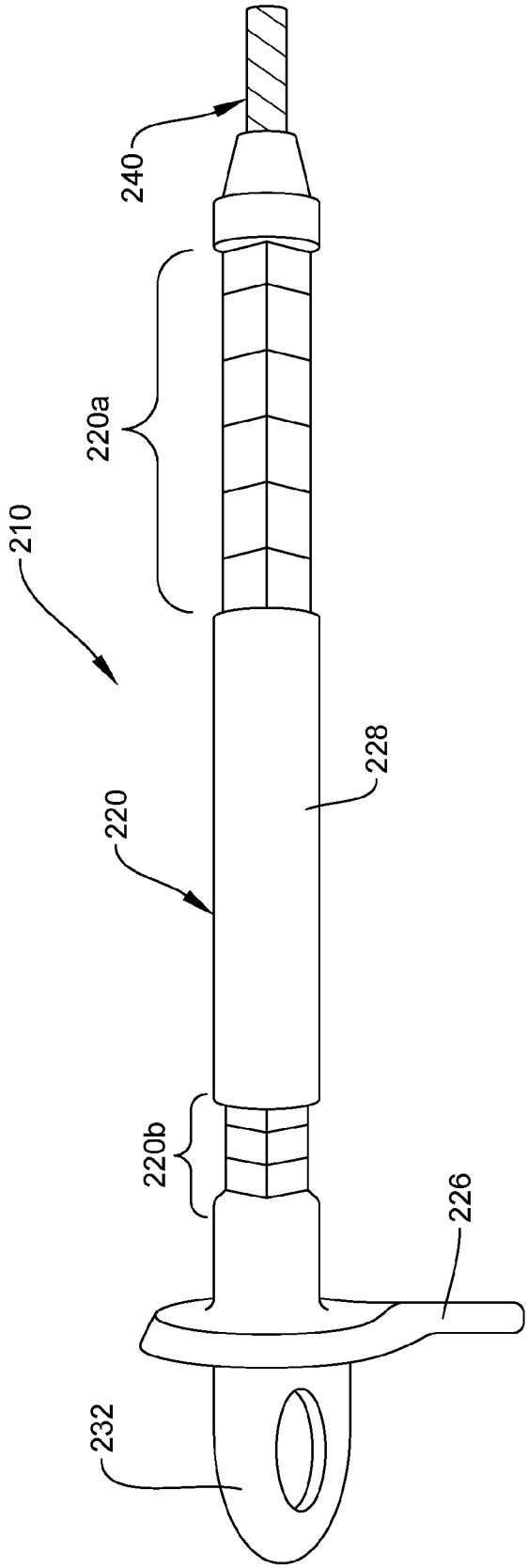


FIG. 2

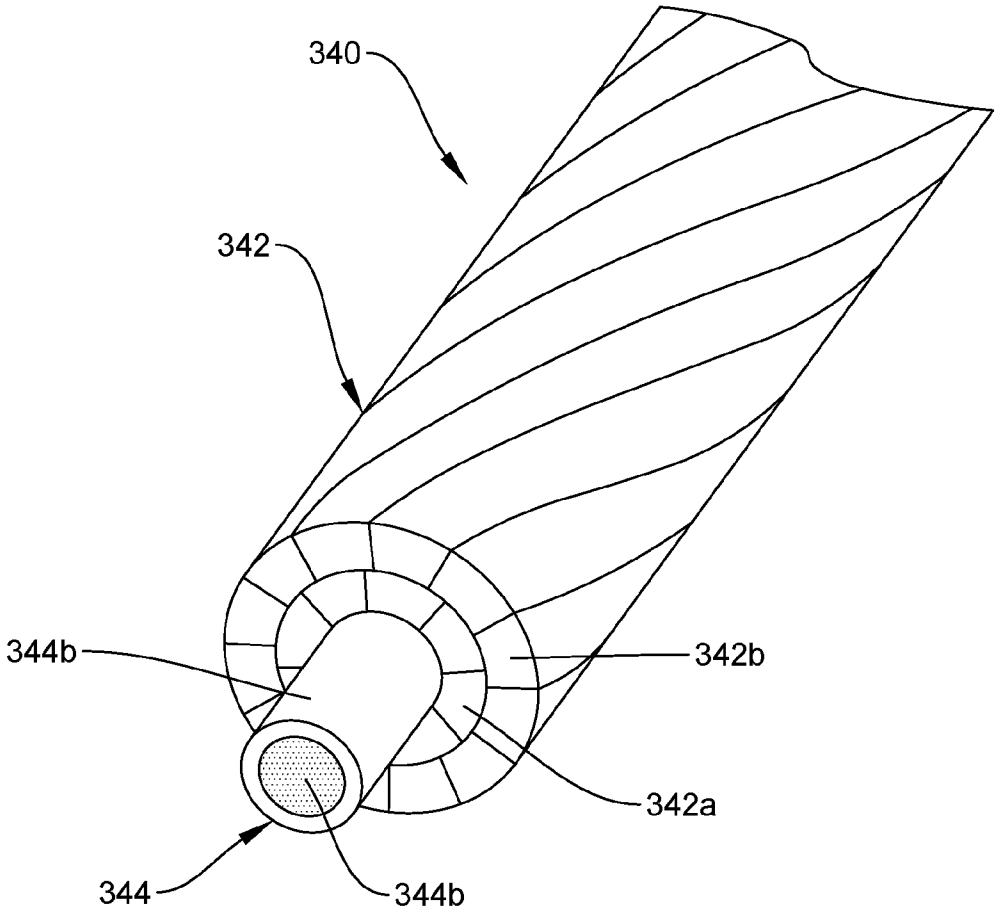


FIG. 3

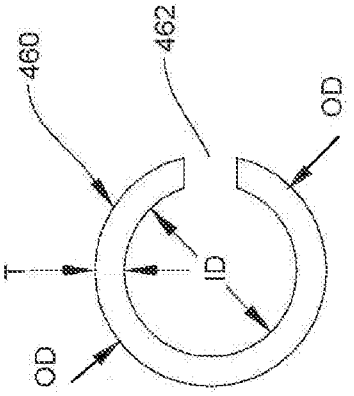


FIG. 4B

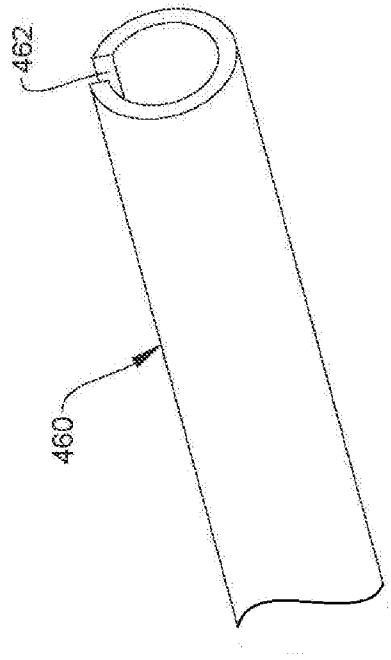


FIG. 4A

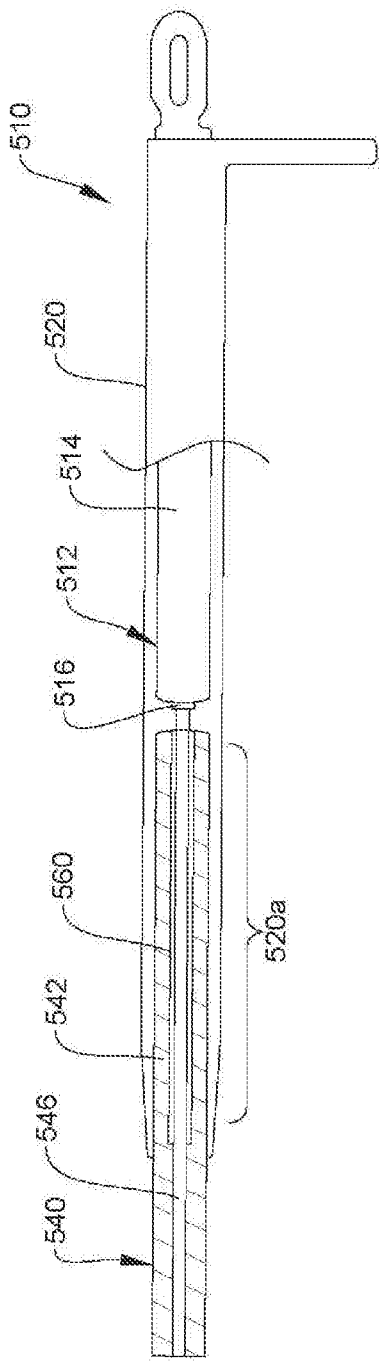


FIG. 5

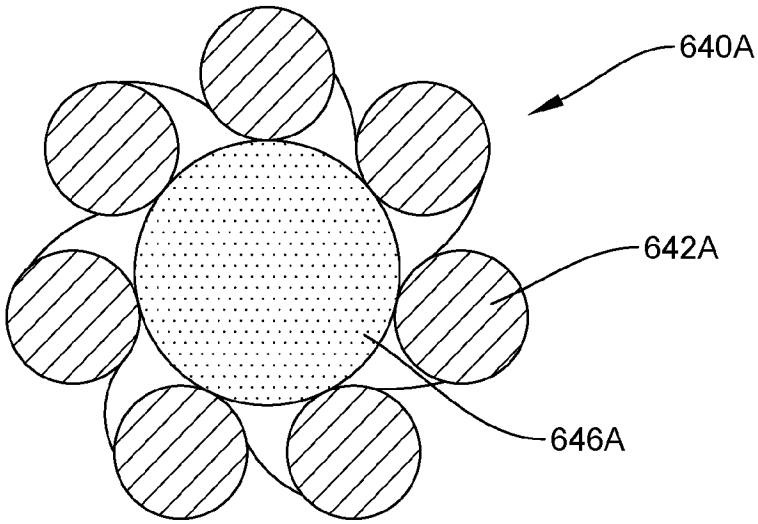


FIG. 6A

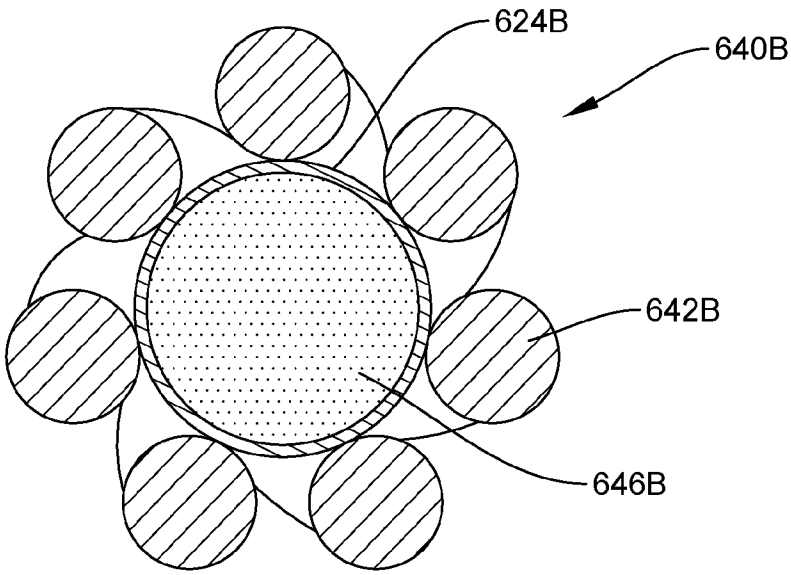


FIG. 6B

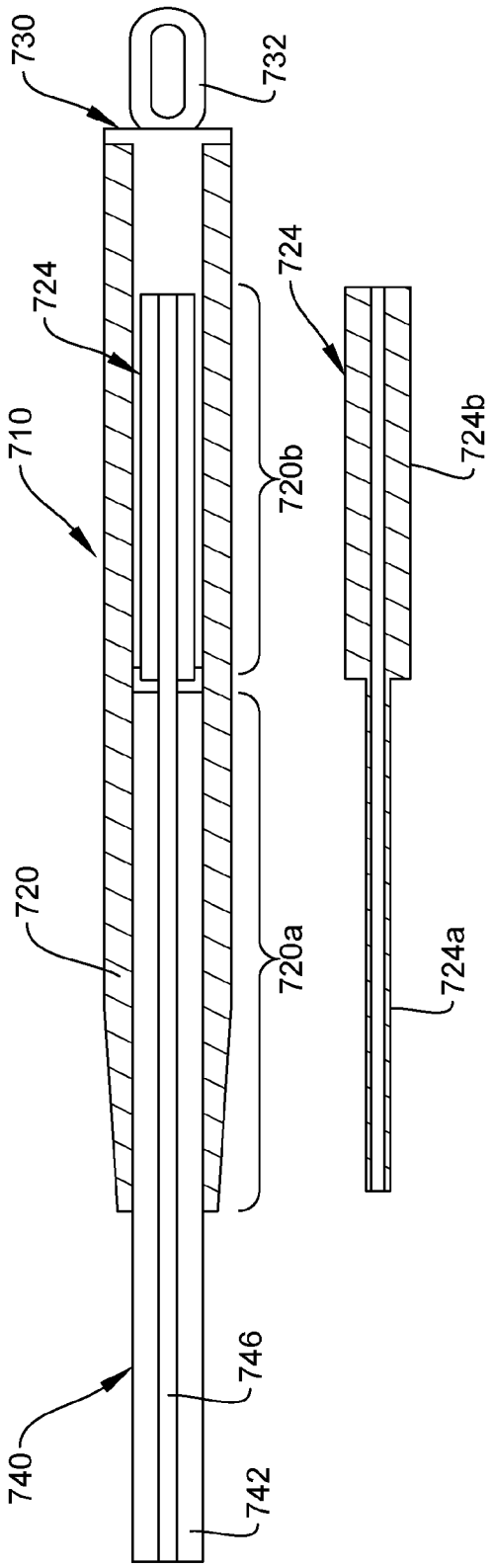


FIG. 7