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Marbach et al.

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(54) **ELECTRICAL CABLE INSULATOR ASSEMBLY**

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Related U.S. Application Data

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(51) **Int. Cl.**

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E21B 33/03	(2006.01)
H01R 13/52	(2006.01)
H01R 13/533	(2006.01)
H01R 13/621	(2006.01)
H01R 13/622	(2006.01)

(52) **U.S. Cl.**
CPC ***H01R 13/521*** (2013.01); ***E21B 33/03*** (2013.01); ***H01R 13/502*** (2013.01); ***H01R 13/5202*** (2013.01); ***H01R 13/621*** (2013.01); ***H01R 13/622*** (2013.01)

(58) **Field of Classification Search**
CPC .. H01R 13/42; H01R 13/502; H01R 13/5202; H01R 13/521; H01R 13/523; H01R 13/621; H01R 13/622
See application file for complete search history.

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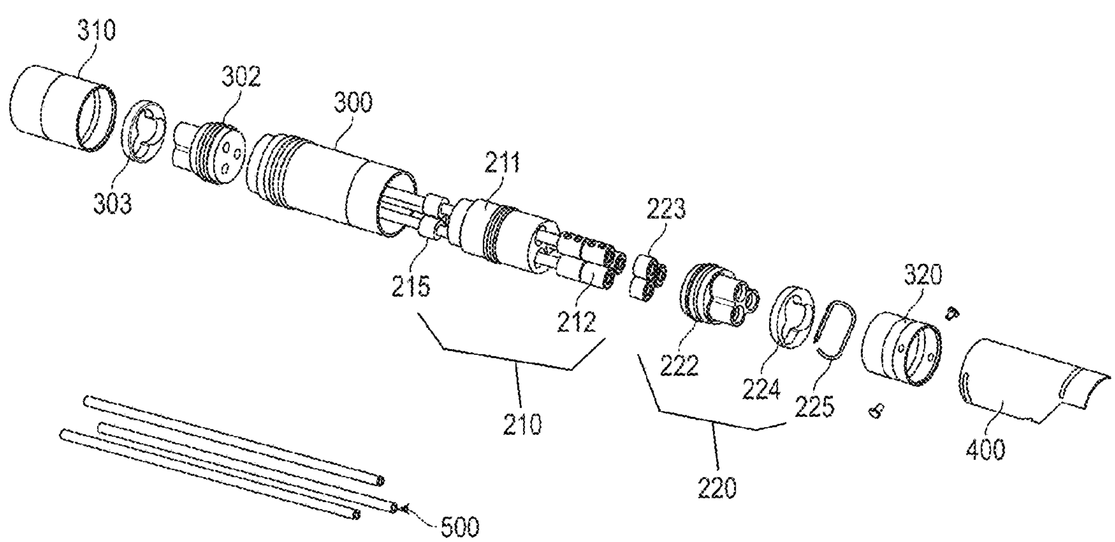
(57) **ABSTRACT**

An improved wellhead electrical connection assembly utilizing multiple sealing mechanisms to minimize pressure and fluid leakage without reliance on epoxies or other sealants. The assembly utilizes upper and lower sealing systems to provide protection at both ends of the electrical connection.

8 Claims, 22 Drawing Sheets



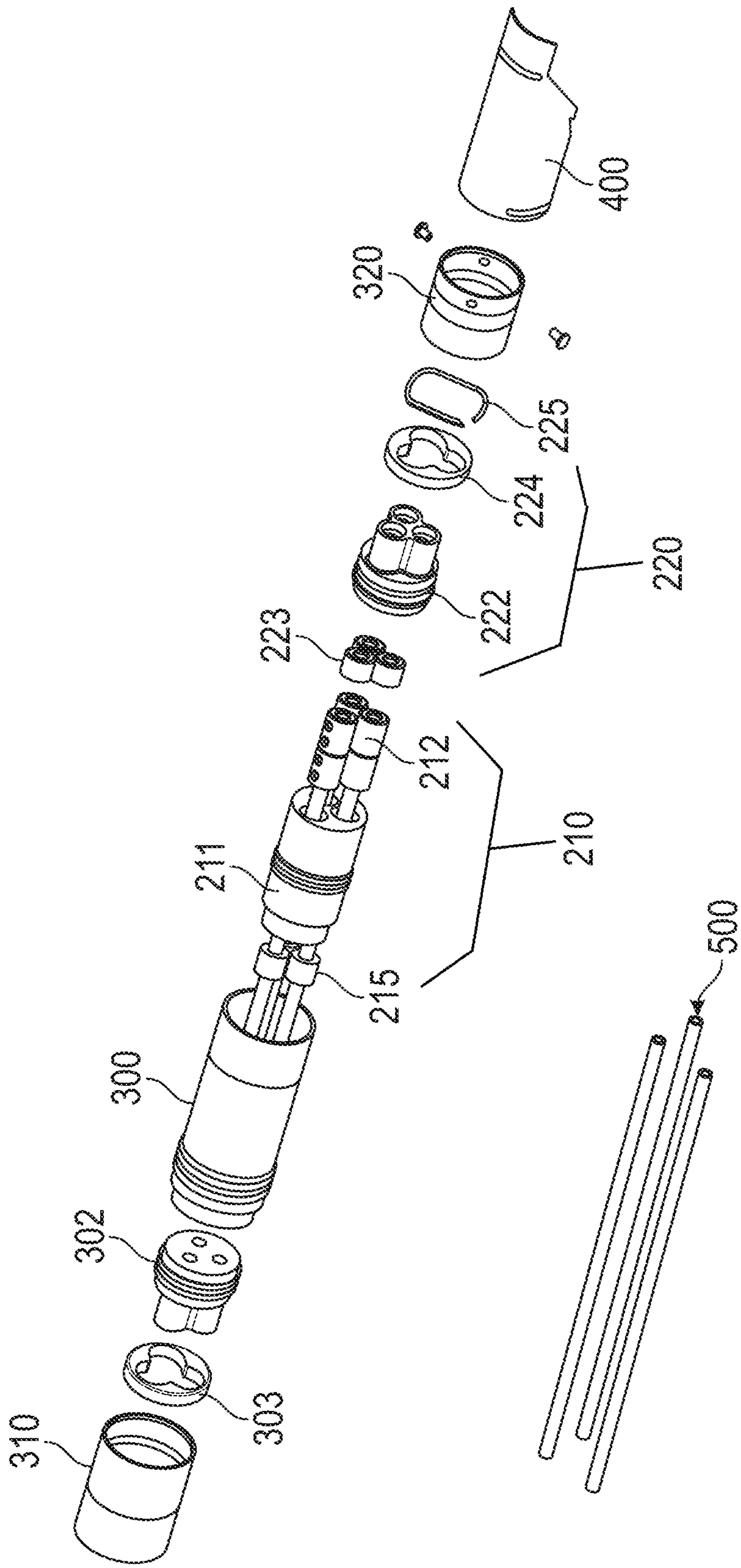


FIG. 1

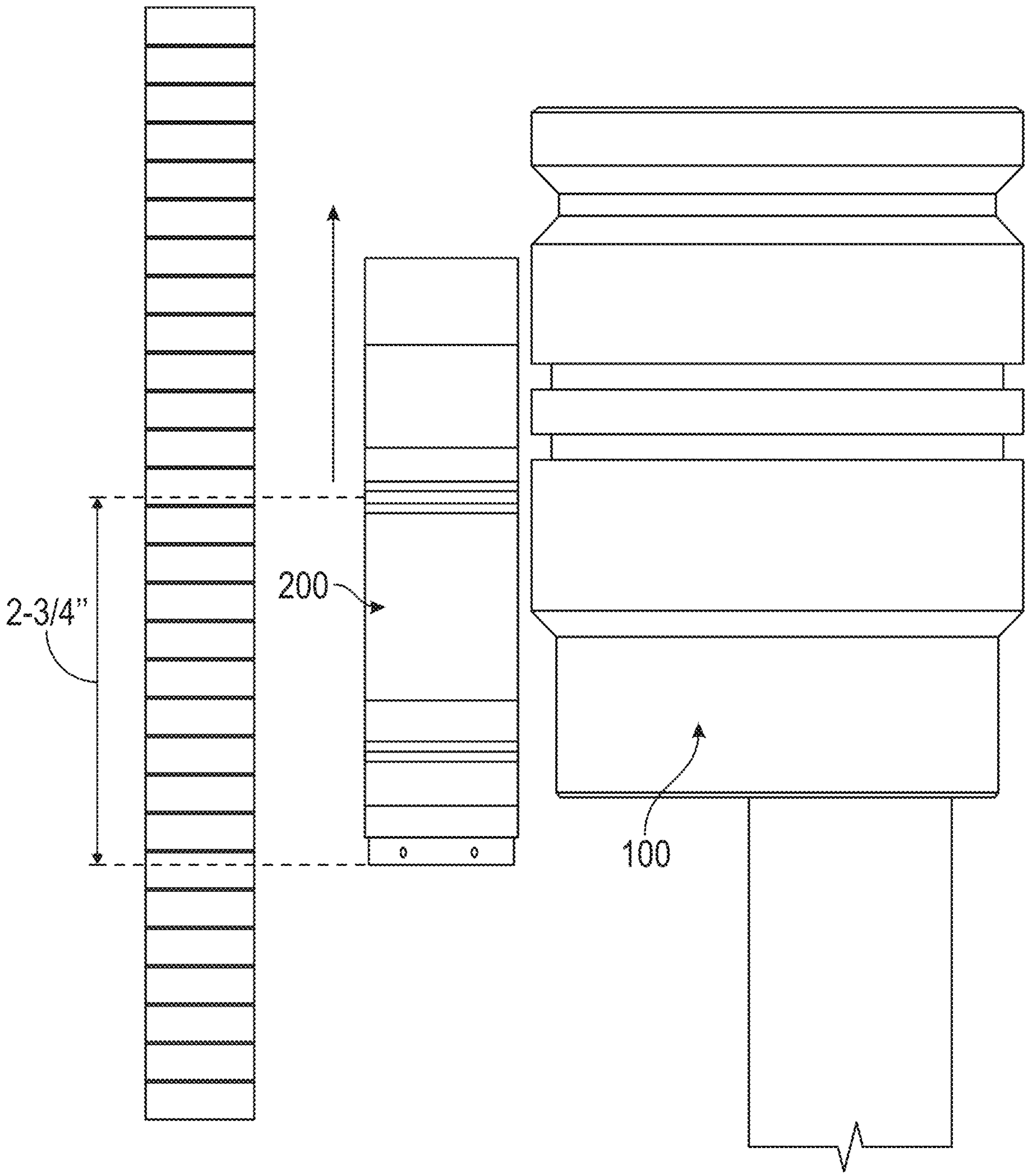


FIG.2

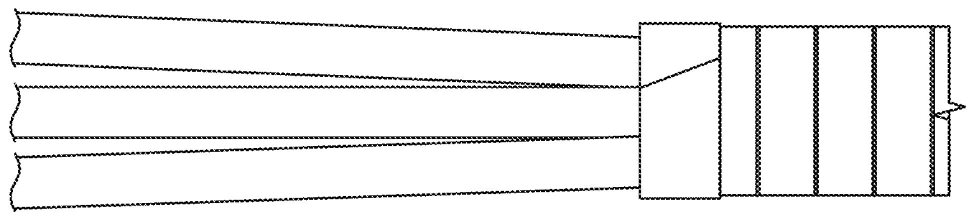


FIG. 3

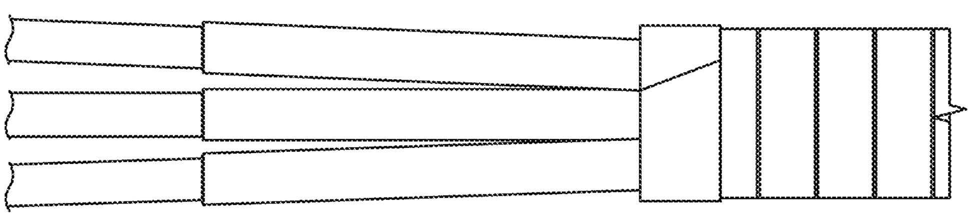


FIG. 4

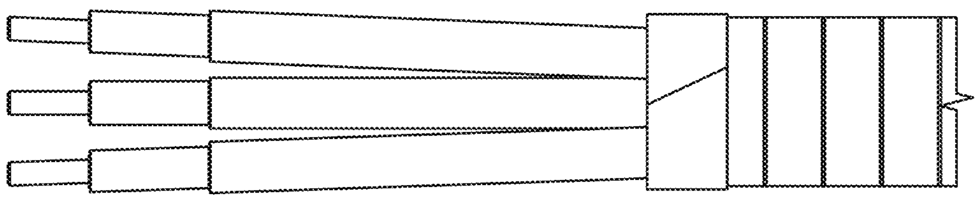


FIG. 5

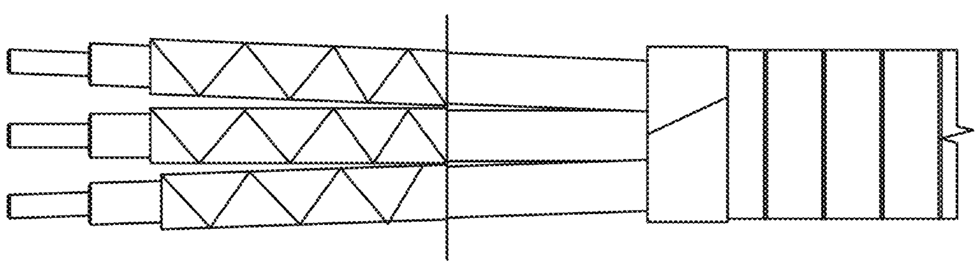


FIG. 6

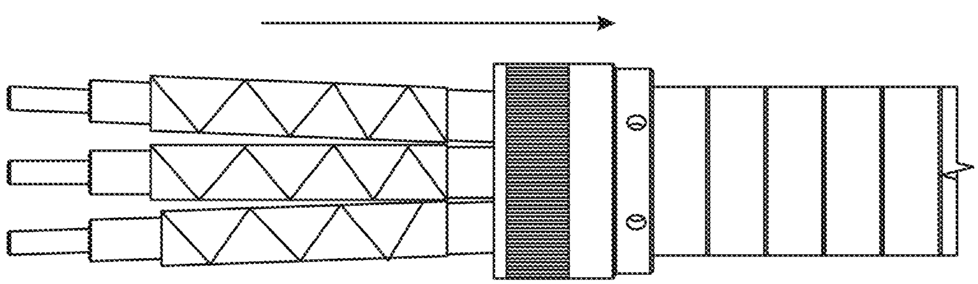


FIG. 7

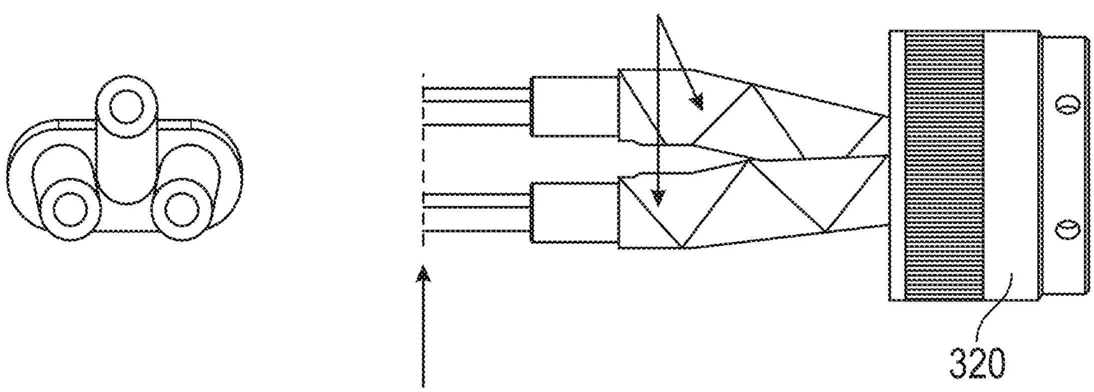


FIG. 8

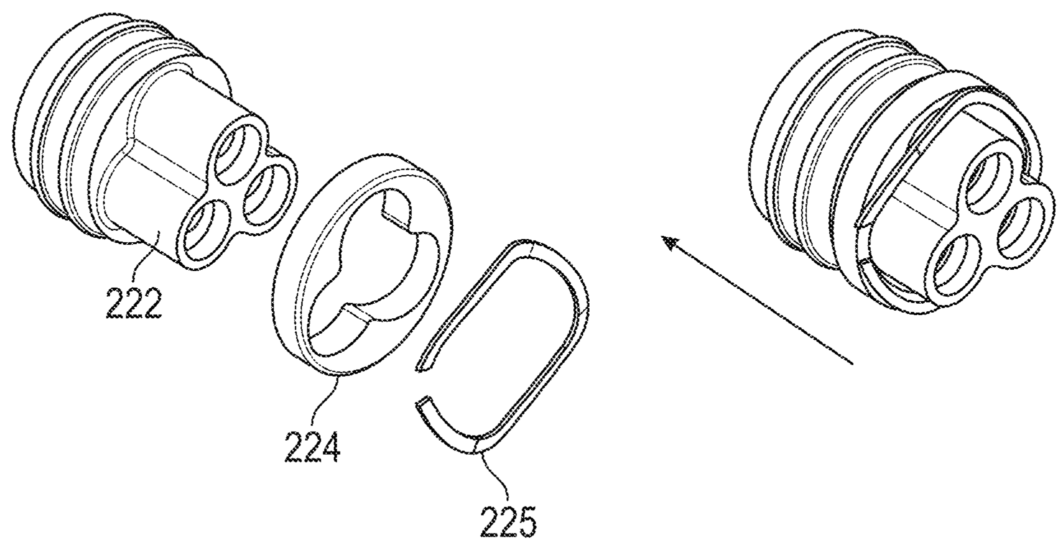


FIG. 9

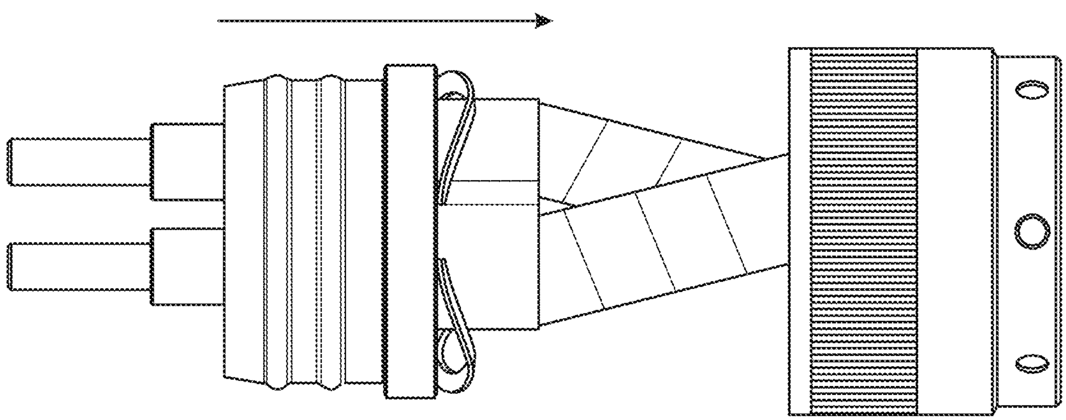


FIG. 10

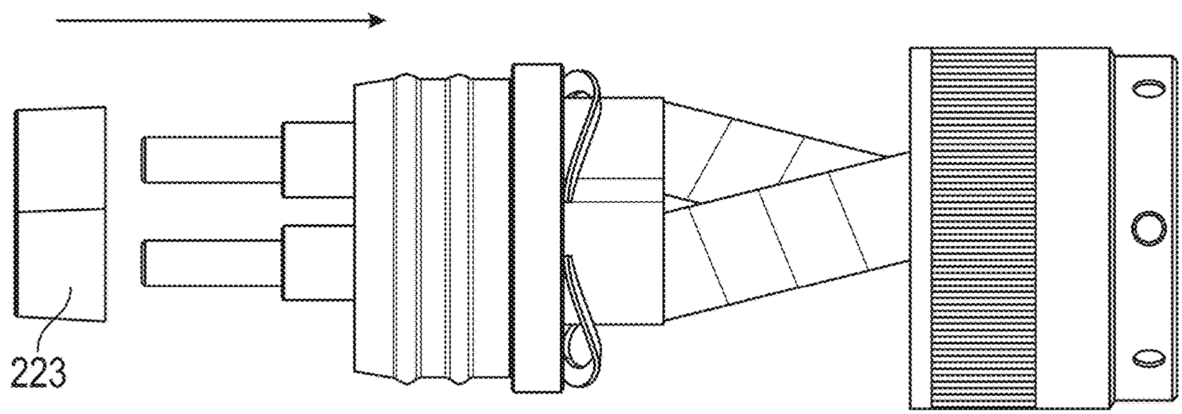


FIG. 11

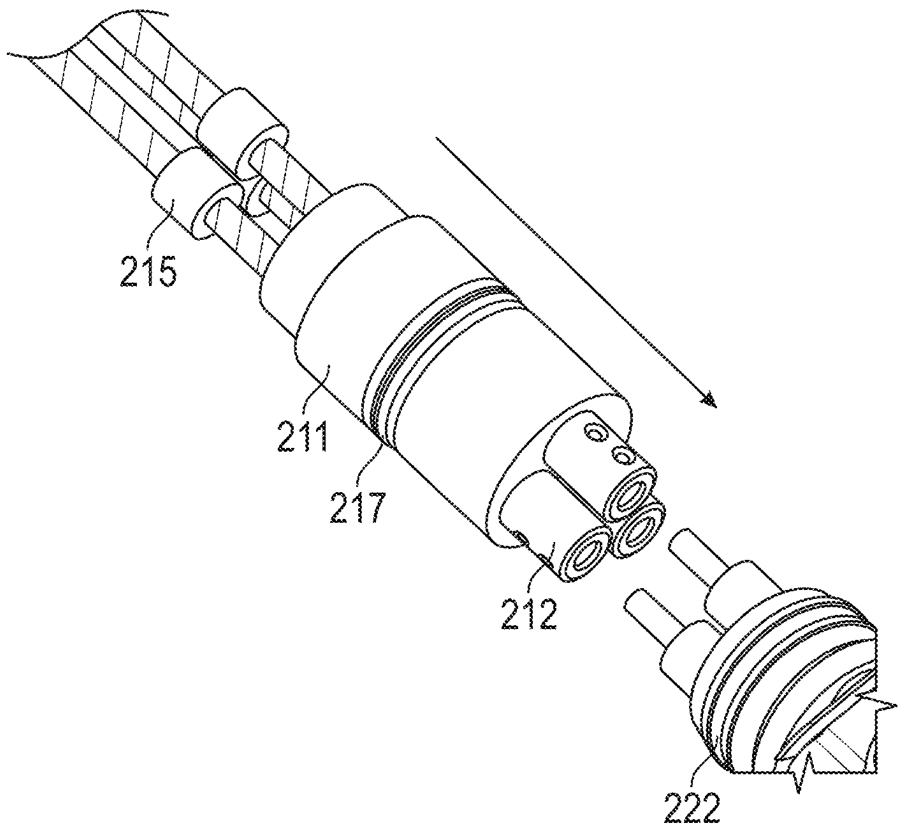


FIG. 12

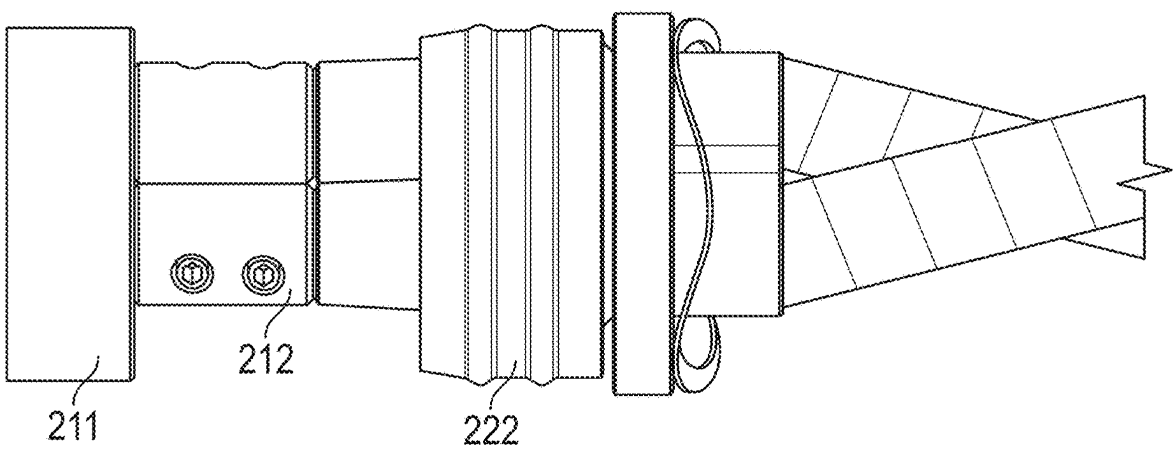


FIG. 13

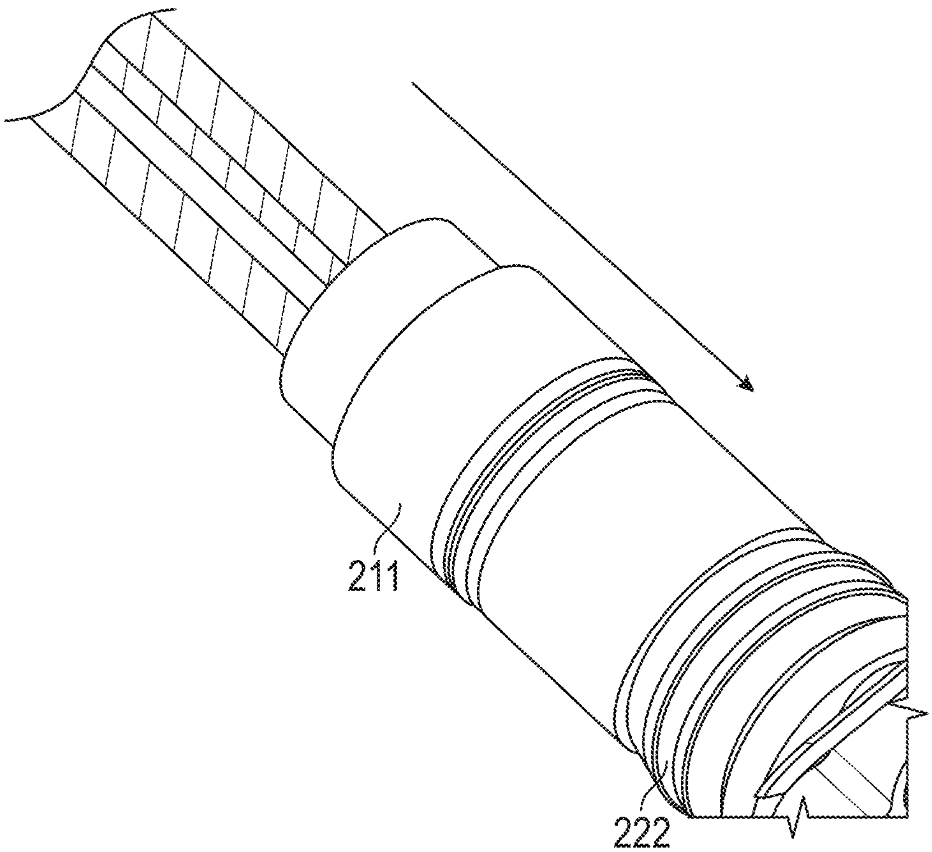


FIG. 14

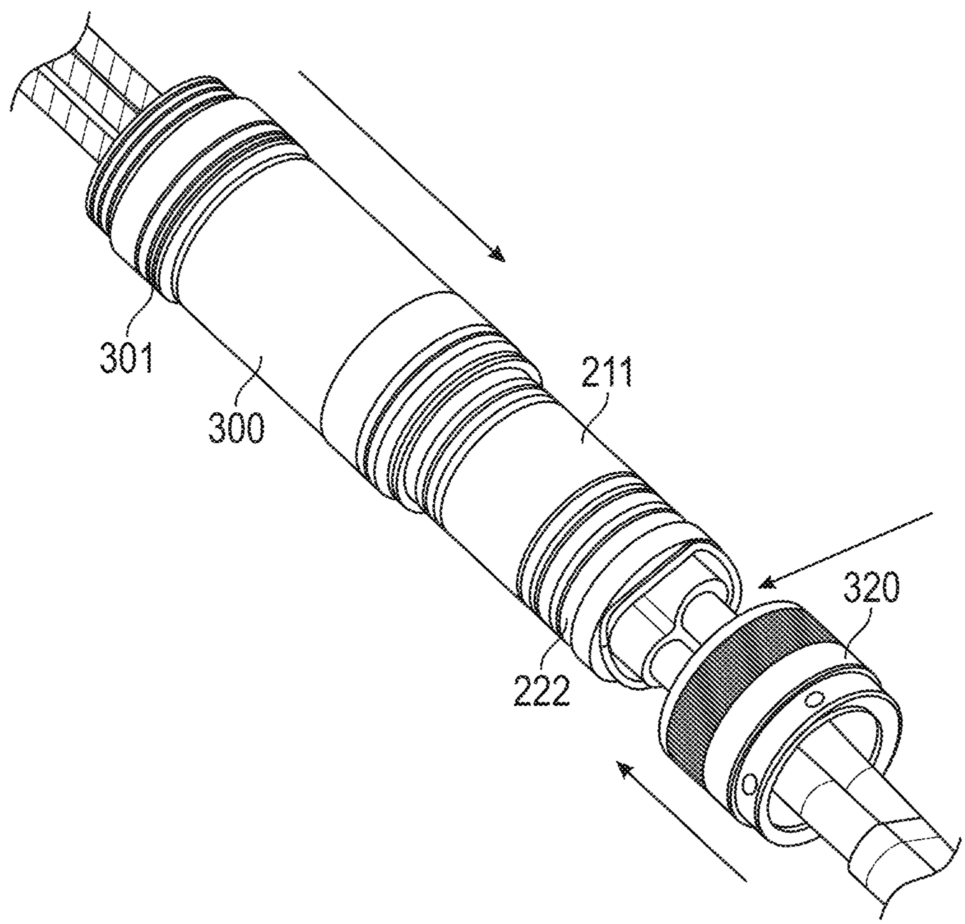


FIG. 15

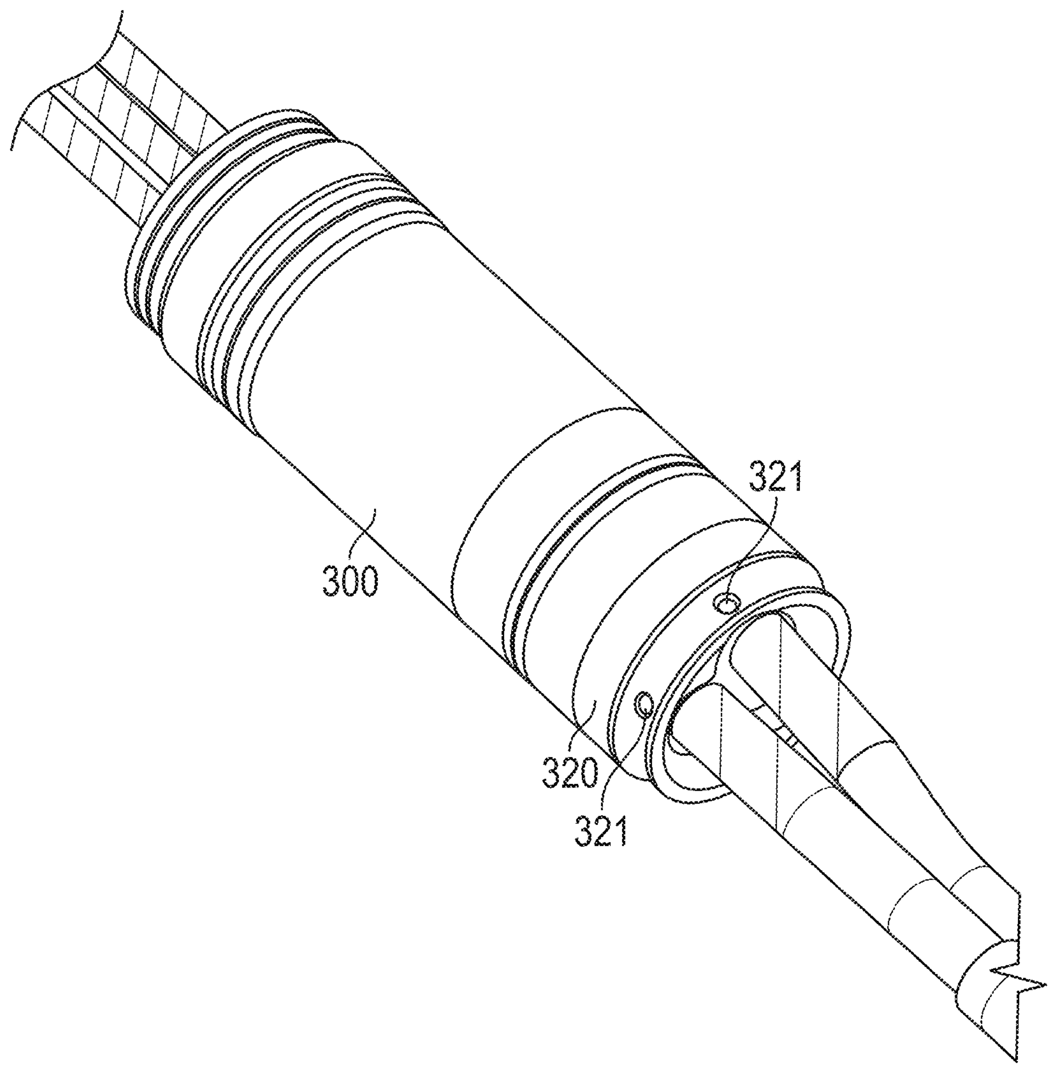


FIG. 16

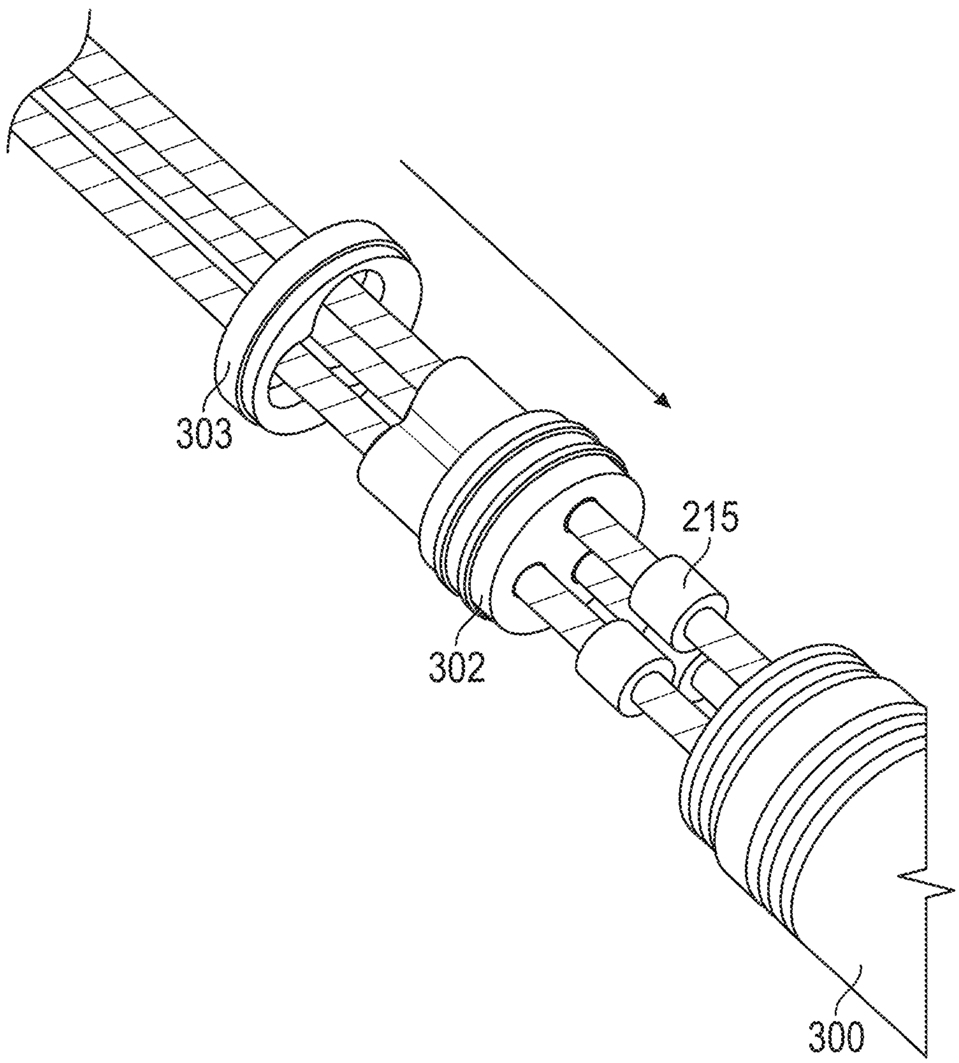


FIG. 17

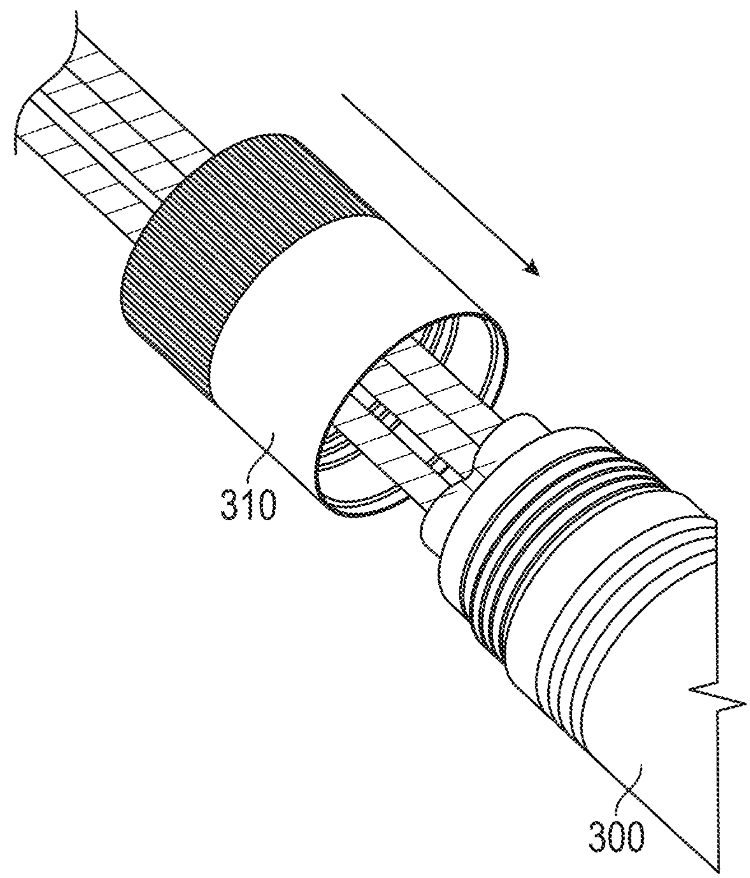


FIG. 18

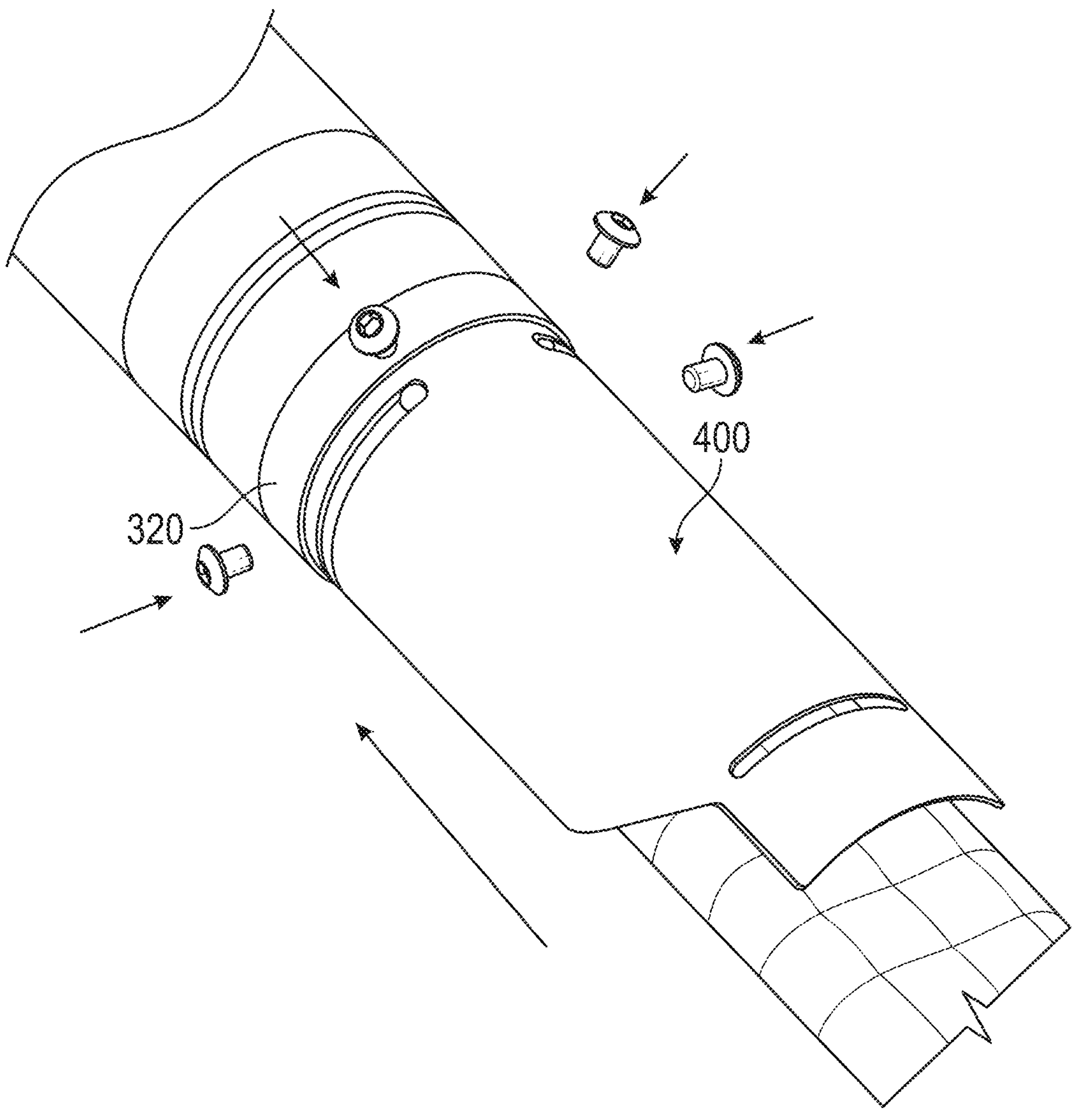


FIG. 19

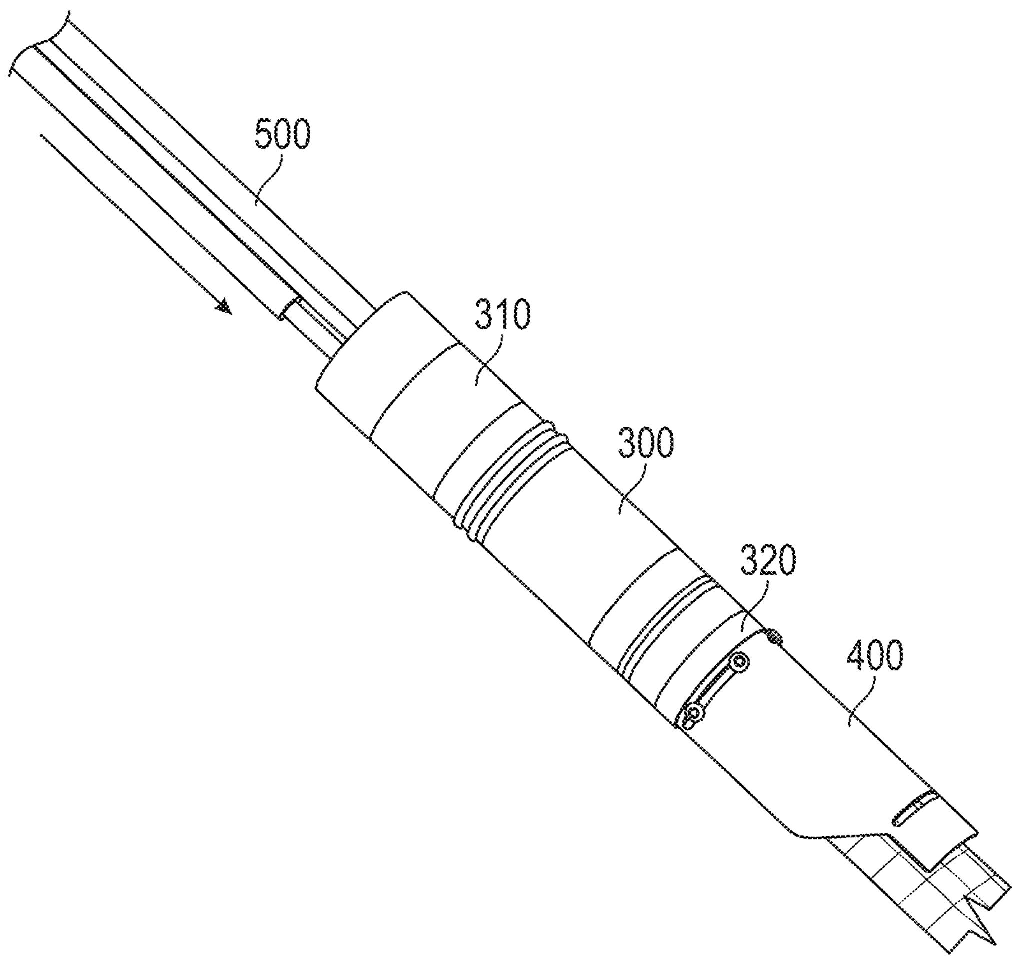


FIG. 20

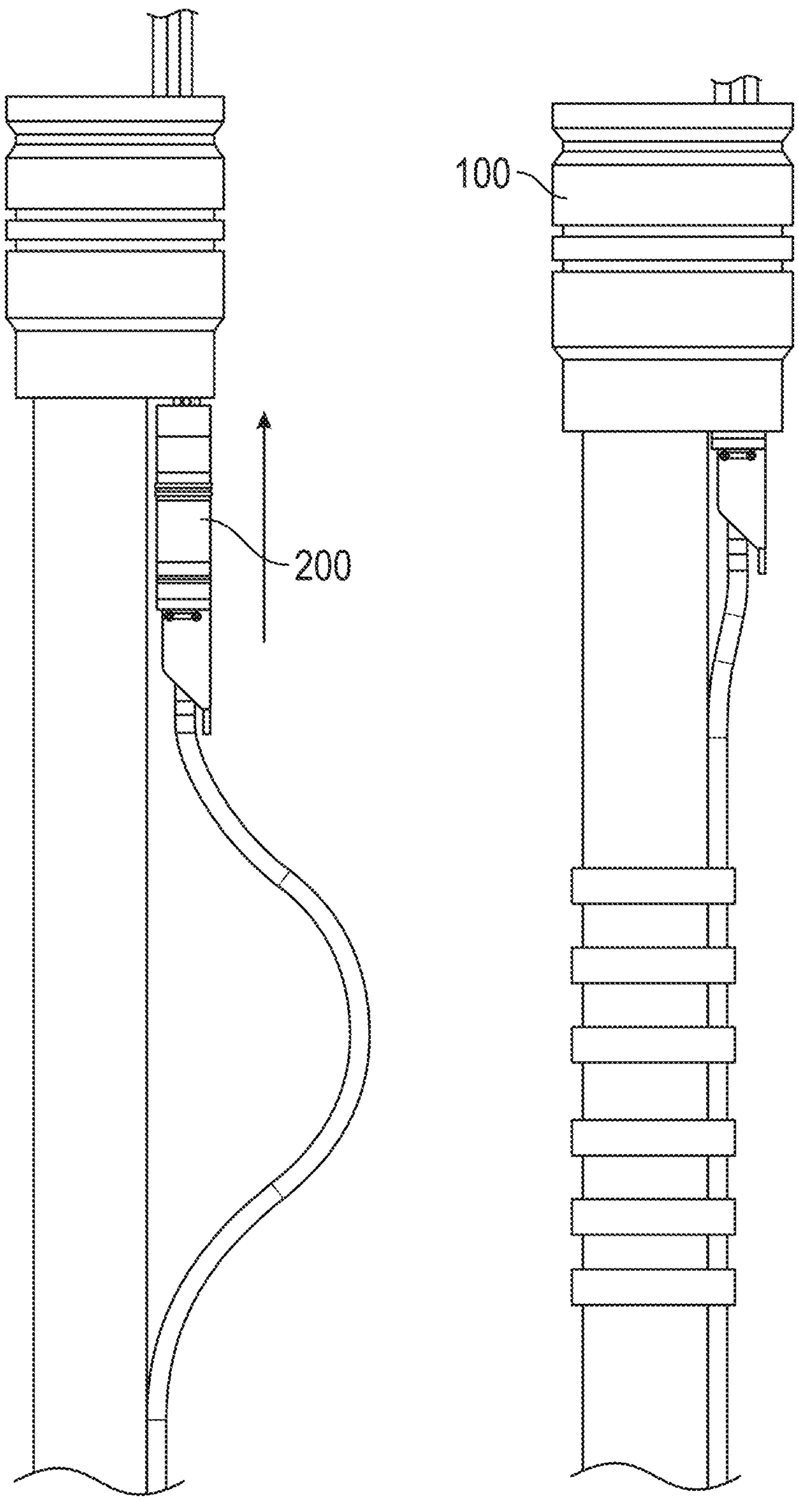


FIG. 21

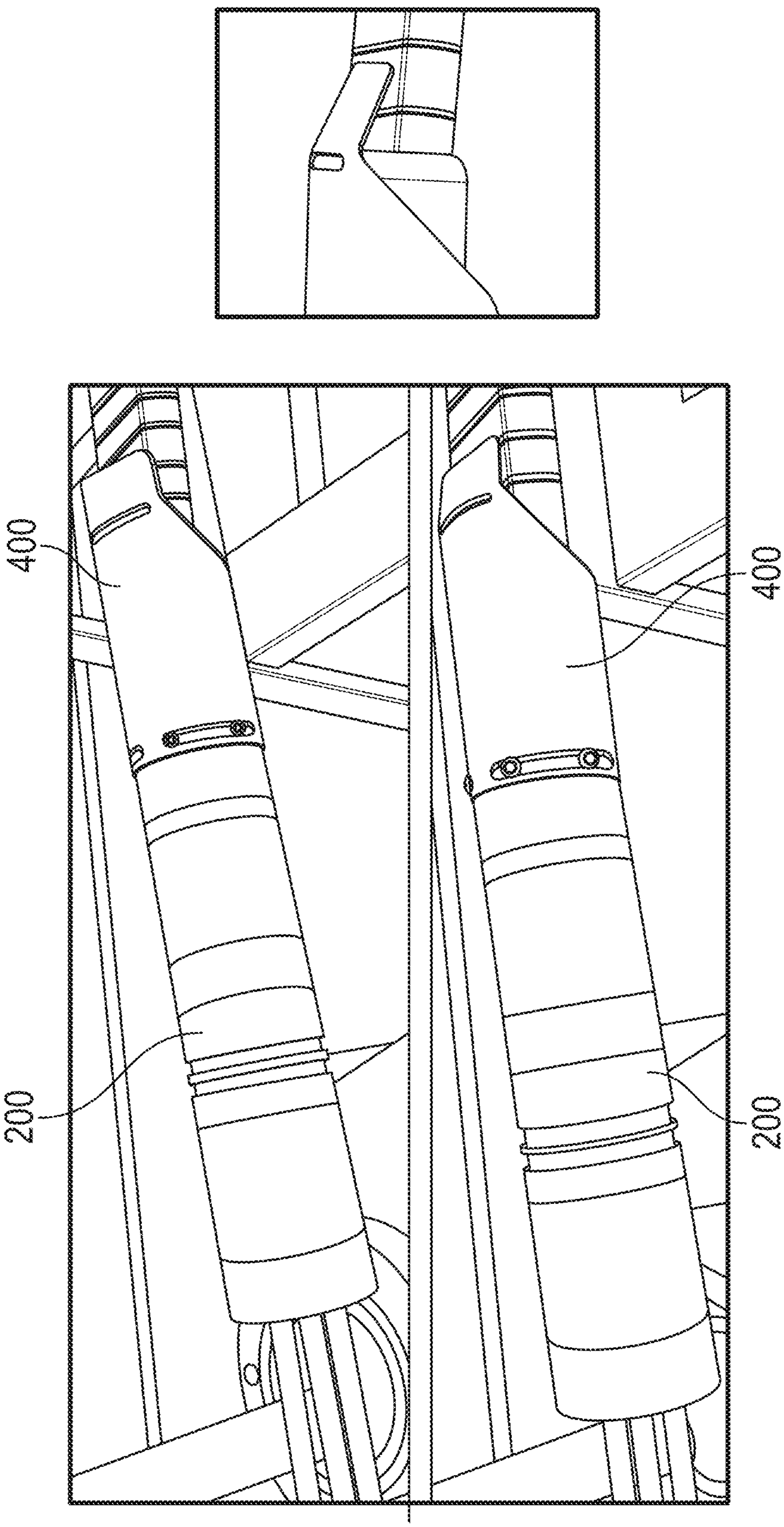


FIG. 22

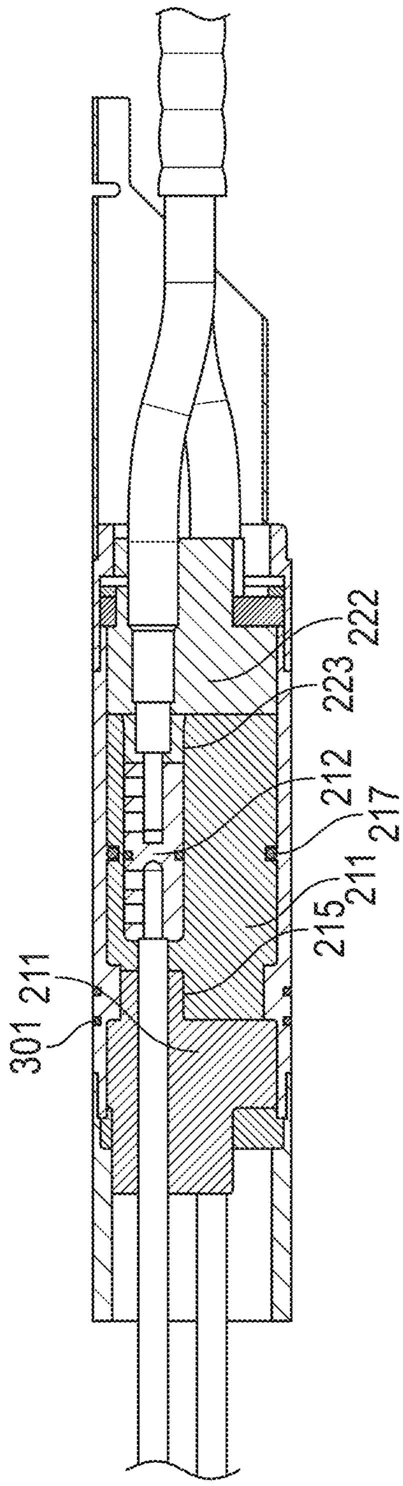


FIG. 23

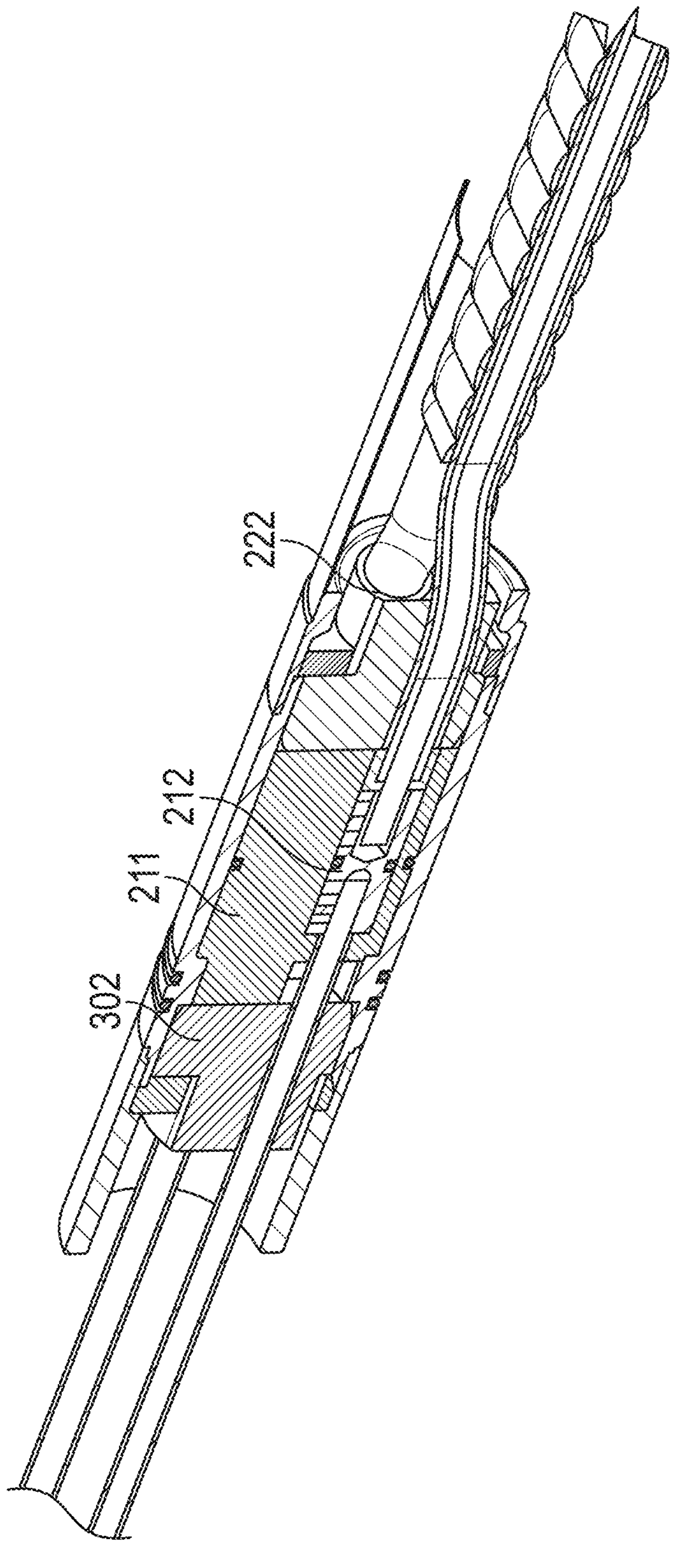


FIG. 24

ELECTRICAL CABLE INSULATOR ASSEMBLY

CITATION TO PRIOR APPLICATIONS

The present application is a continuation of and claims priority to U.S. Provisional Application No. 63/202,334, titled "Electrical Cable Insulator Assembly" and filed Jun. 7, 2021.

BACKGROUND AND SUMMARY

Wellhead penetrators are purposed to allow electrical power to be delivered down a well from a surface source. As a result, wellhead penetrators play an integral role in many wellhead operations. Penetrators incorporate sealing mechanisms to prevent well fluids and gases from escaping upward toward the surface as well as environmental fluids (such a rain) or well fluid seepage from escaping downward into the well. Accordingly, conventional wellhead penetrators attempt to incorporate various sealing elements to achieve these ends and maintain a viable electrical connection. Conventional penetrators often rely on epoxies or other packed or injected sealants. However, consistent with other wellhead components and structures, a wellhead penetrator can sometimes become exposed to the high-pressure environment that arises within a producing well. These conventional approaches are not suitable for reliable and consistent results (particularly for preventing fluid or gas ingress) in high pressure environments.

A penetrator assembly in accordance with the present disclosure creates an improved sealed connection between a surface-originating power cable and an electric submersible pump ("ESP") (or other similar technology) cable by providing a gas-blocking seal at pressures up to 5,000 psi from below and above the penetrator using materials well-suited for hydrocarbon environments resulting in a greater run-life relative to conventional epoxy seals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts an exploded view of a penetrator assembly in accordance with various embodiments of the present disclosure.

FIG. **2** depicts a side view of a conventional tubing hanger and a penetrator assembly in accordance with various embodiments of the present disclosure.

FIG. **3** depicts a side view of an ESP cable prepared in accordance with various embodiments of the present disclosure.

FIG. **4** depicts a side view of an ESP cable prepared in accordance with various embodiments of the present disclosure.

FIG. **5** depicts a side view of an ESP cable prepared in accordance with various embodiments of the present disclosure.

FIG. **6** depicts a side view of an ESP cable prepared in accordance with various embodiments of the present disclosure.

FIG. **7** depicts a side view of a lower penetrator cap and an ESP cable prepared in accordance with various embodiments of the present disclosure.

FIG. **8** depicts views of a lower penetrator cap and an ESP cable prepared in accordance with various embodiments of the present disclosure.

FIG. **9** depicts a perspective view of lower penetrator sealing elements in accordance with various embodiments of the present disclosure.

FIG. **10** depicts a side view of the installation of lower penetrator sealing elements in accordance with various embodiments of the present disclosure.

FIG. **11** depicts a side view of the installation of lower penetrator sealing elements in accordance with various embodiments of the present disclosure.

FIG. **12** depicts a perspective view of an upper body and lower sealing elements in accordance with various embodiments of the present invention.

FIG. **13** depicts a side view of conductor receivers and lower sealing elements in accordance with various embodiments of the present disclosure.

FIG. **14** depicts a perspective view of an upper body and lower sealing elements in accordance with various embodiments of the present invention.

FIG. **15** depicts a perspective view of a partially assembled penetrator assembly in accordance with various embodiments of the present disclosure.

FIG. **16** depicts a perspective view of a penetrator housing element and lower penetrator cap in accordance with various embodiments of the present disclosure.

FIG. **17** depicts a perspective view of upper sealing elements in accordance with various embodiments of the present disclosure.

FIG. **18** depicts a perspective view of a partially assembled penetrator assembly in accordance with various embodiments of the present disclosure.

FIG. **19** depicts a perspective view of a lower penetrator cap and a cable protector in accordance with various embodiments of the present disclosure.

FIG. **20** depicts a side view of a penetrator assembly in accordance with various embodiments of the present disclosure.

FIG. **21** depicts a side view of a penetrator assembly installation in accordance with various embodiments of the present disclosure.

FIG. **22** depicts a side view of a penetrator assembly including a cable protector in accordance with various embodiments of the present disclosure.

FIG. **23** depicts a cutaway side view of a penetrator assembly in accordance with various embodiments of the present disclosure.

FIG. **24** depicts a cutaway perspective view of a penetrator assembly in accordance with various embodiments of the present disclosure.

DETAILED DESCRIPTION

This description, with references to the figures, presents non-limiting examples of embodiments of the present disclosure.

Embodiments of this disclosure relate generally to an improved wellhead electrical connection assembly that may be used, for example, in oil and gas operations. Some embodiments of such an improved wellhead electrical connection assembly include a penetrator assembly.

As shown in FIG. **2**, several approaches according to embodiments of this disclosure (and even conventional approaches often) utilize a tubing hanger **100** having a penetrator assembly disposed therein. These penetrator assembles are used to facilitate a connection between an external power source and downhole apparatus, such as ESPs. Tubing hangers are often configured to receive a penetrator assembly in a designated volume **110** such as a feed-thru pocket in the tubing hanger.

In certain embodiments of the present disclosure, as illustrated in FIGS. **1**, **23**, and **24**, a penetrator assembly **200** may have an upper assembly **210** and a lower assembly **220**. Upper assembly **210** may include an upper body **211** and at least one conductor receiver **212**. Upper body **211** may be substantially formed of polyetheretherketone (PEEK) or other suitable insulating material. Upper body **211** may be configured with a first upper groove on an upper body exterior face to receive a first outer sealing element **217**. First outer sealing element **217** may be an elastomeric O-ring. First outer sealing element **217** is configured to minimize any potential fluid flow beyond its position on the exterior surface of upper body **211**. Each of the at least one conductor receiver **212** may include a conductor retention element **213**. Each of the at least one conductor receiver **212** may be a copper lug. Each of the at least one conductor receiver **212** may be configured with a first female end and a second female end positioned opposite one another wherein the first and second female end are each configured to receive a conductor. Conductor retention element **213** may be at least one set screw which may be tightened to securely retain any conductor that is received within the conductor receiver **212**. Upper assembly **210** may be configured to receive at least one external power cable **214**. At least one nose sealing element **215** may also be included in upper assembly **210**. Lower assembly **220** may include a primary lower sealing element **222**, at least one secondary lower sealing element **223**, and a follower **224**. Lower assembly **220** is configured to be installed on at least one ESP cable **400**. Each conductor of each of at least one ESP cable **400** may be passed through primary lower sealing element **222**. Each conductor of each of at least one ESP cable **400** may pass through one of said at least one secondary lower sealing element **223**. Lower assembly **220** may further include a spring element **225**. Spring element **225** may be a wave spring.

Prior to installation into lower assembly **220** each conductor of the at least one ESP cable **400** may be configured for insertion into lower assembly **220**. As depicted in FIGS. **3-6**, an exemplary ESP cable may include layers including armor. Any exterior armor may be carefully cut and secured in place by wrapping the cut site two times with high-modulus tape. Any conductors to be inserted into lower assembly **220** may be spread apart from each other with any tape and/or braid removed. The cable and conductors should be examined for damage. At this stage, the cable length may also be confirmed to ensure proper dimensions relative the production tubing. Any lead sheath or other barrier may be stripped back from each conductor while avoiding any cutting or damaging of the primary insulation. Any burrs on the lead may be removed or smoothed. Cable and conductor damage should again be checked for. Any insulation on each conductor may be stripped back. The ends of each conductor may be penciled or tapered before the insulation is abraded. Each conductors should be thoroughly cleaned before installation. For additional conductor protection, high-modulus tape may be used to wrap each conductor, for example, from between any remaining insulation to a point on any remaining lead sheath or other barrier. The tape be applied with 50% overlap and half-stretch starting from the point on the any remaining barrier to a point on the any remaining insulation and back to the point on the remaining barrier. Any excess tape should be carefully cut and removed.

Depicted in FIGS. **7** and **8**, as the conductors are passed through lower penetrator cap **320**, each conductor leg may be bent in a substantially triangular pattern such that the conductors may be fitted into primary lower sealing element **222**. As shown in FIG. **8**, the lower conductor legs are bent slightly downward relative the upper conductor leg while the upper conductor leg is bent slightly upward relative the lower conductor legs. Care should be taken to avoid stressing or cracking any remaining lead sheath or other barrier. Additionally, the conductor legs should be substantially equally bent. This may be confirmed by examining any lead cuts, insulation cuts, and/or conductor ends of the conductor legs to verify that the respective sections of each conductor leg are substantially even with each other.

During an exemplary use, upper assembly **210** may be installed on three external power cables **214**. First outer sealing element **217** is disposed on the exterior surface of upper body **211**. Each external power cable **214** will be inserted through a nose sealing element **215** and into upper body **211** through to respective first female ends of each lug **212** as seen in FIG. **24**. All three conductors from cables running from an ESP will be inserted through spring element **225**, follower **224**, and primary lower sealing element **222** as shown in FIGS. **9** and **10**. Primary lower sealing element **222** is configured with a receptable for each of the three conductors. Each conductor may then be passed through a respective secondary lower sealing element **223** as shown in FIG. **11**. To facilitate installation, an amount of dielectric grease may be applied on any remaining insulation and high-modulus tape for each conductor leg/phase. Each secondary lower sealing element **223** may come to rest against the face of any remaining exposed insulation of each respective conductor leg.

To combine upper assembly **210** and lower assembly **220**, each conductor of the three ESP cables is inserted into a respective second female end of each lug **212** which are exposed beyond a lower face **218** of upper body **211**. Each lug **212** has two set screws to secure the inserted conductor from an ESP cable as shown in FIG. **12**. Each set of the two set screws may be tightened to secure each conductor. An amount of dielectric grease may be applied to primary lower sealing element **222** and each secondary lower sealing element **223**. Once the conductors have been inserted into the lugs, a witness mark may be made on the high-modulus tape just behind primary lower sealing element **222** as seen in FIG. **13**. The witness mark may serve as a guide for proper connector assembly. There should be no gap between the mark and the back of the cable seal. If a gap exists, components have moved from their proper location. The assemblies should be repositioned in such a scenario. While the base of primary lower sealing element **222** near spring element **225** is held, the upper assembly **210** may be slid toward lower assembly **220**. This action will cause lugs **212** to be pushed upward and into upper body **211** as depicted in FIG. **14**. In some embodiments, each conductor receiver **212** may have an outer receiver sealing element (such as an elastomeric O-ring) to provide further sealing when at least partially contained in said upper body **211**. The witness mark(s) should be reviewed to ensure proper component position has been maintained.

In further embodiments, as depicted in FIGS. **15-18**, penetrator assembly **200** may further include a penetrator housing element **300**, an upper penetrator cap **310**, and a lower penetrator cap **320**. Penetrator housing element **300** may be configured with one or more outer grooves to receive at least one second outer sealing element **301**. Penetrator housing element **300** may also be configured to at least partially contain upper assembly **210** and lower assembly **220**. Penetrator housing element **300** may be configured with an upper threaded portion **304** and a lower threaded portion **305**. These threaded portions may be used to facilitate threaded engagement with upper penetrator cap **310** and lower penetrator cap **320**. Additionally, these threaded portions may be positioned on the external surface of penetrator housing element **300**. Upper penetrator cap **310** may be configured with first threaded portion **311**. First threaded portion **311** may be positioned on the internal surface of a first end of upper penetrator cap **310** and be configured for engagement with upper threaded portion **304** of penetrator housing element **300**. Lower penetrator cap **320** may be configured with a lower cap threaded portion **321** configured for engagement with lower threaded portion **305** of penetrator housing element **300**. As shown in FIG. **17**, penetrator assembly **200** may also include a primary upper sealing element **302** and upper sealing follower **303**. Conductors from external power cable **214** may be passed through upper penetrator cap **310** before passing through upper sealing follower **303** and upper sealing element **302**. Each conductor of an external power cable may be inserted into a corresponding aperture of upper sealing element **302**.

Returning to the exemplary use scenario set out above, the additional components of an embodiment of the present disclosure can be incorporated as follows. A penetrator housing element **300**, which the external power cables may have been passed through before passing through upper assembly **210** and having two installed secondary outer sealing elements, may then be slid down and onto upper assembly **210**. This can be achieved by holding primary lower sealing element **222** and sliding penetrator housing element **300** over upper assembly **210**. An amount of dielectric grease may be applied to first outer sealing element **217** and primary lower sealing element **222** to facilitate the sliding of penetrator housing element **300**. Penetrator housing element **300** should continue to slide down until it substantially contains both upper assembly **210** and lower assembly **220**. As depicted in FIG. **15**, primary lower sealing element **222** may have ridges on its exterior surface. When installed over lower assembly **220**, there should be minimal distance, if any, between the interior surface of penetrator housing element **300** and these ridges. The witness mark(s) should again be examined to confirm proper component positions have been maintained. Lower penetrator cap **320**, which the ESP cables may have been passed through before passing through lower assembly **220**, may then be threaded onto lower threaded portion **305** of penetrator housing element **300**. In some embodiments, lower penetrator cap **320** may be initially positioned on the ESP cable such that it seats on any remaining armor or drifts slight past the leading edge of any remaining armor prior to being secured to penetrator housing element **300**.

Lower penetrator cap **320** may include at least one retention aperture **321** as shown in FIG. **16**. Once lower penetrator cap **320** is secured to penetrator housing element **300**, the penetrator assembly may be rotated such that two apertures are visible when viewing a central conductor leg from above. The witness mark should again be examined to confirm proper component positions have been maintained.

Shown in FIG. **17**, upper sealing element **302** and upper sealing follower **303**, which may also have had the external power cables passed through before including the penetrator housing element **300** and upper assembly **210**, may then be installed into penetrator housing element **300**. Upper sealing element **302** resembles primary lower sealing element **222** in structure but is oriented in the opposite direction. Each nose sealing element **215** may be slid into upper body **211** until they are flush with an upper face **216** of upper body **211**. Dielectric grease may be applied to the outer surfaces of each nose sealing element **215** to facilitate their insertion into upper body **211**.

Upper sealing element **302** may then be slid down along the external power cables and into penetrator housing element **300** until it is flush against the upper face **216** of upper body **211**. In such a position, the outer ridges depicted on upper sealing element **302** should be contained within penetrator housing element **300** with minimal, if any distance, between the interior surface of penetrator housing element **300** and the ridges. Upper sealing element **302** may be lightly lubricated to facilitate the insertion into penetrator housing element **300**. Upper sealing follower **303** is then slid downward and into penetrator housing element **300**. Upper sealing following **303** may be configured with a shoulder such that, when installed into penetrator housing element **300**, it is not fully inserted into penetrator housing element **300** but is rather supported by an upper annular surface of penetrator housing **300** while leaving upper threaded portion **304** unobscured and capable of engagement with upper penetrator cap **310**. Depicted in FIG. **18**, upper penetrator cap **310**, which may have had the external power cables passed through before passing them through upper sealing element **302** and upper sealing follower **303**, is then slid down the external power cables and threaded onto penetrator housing element **300** via upper threaded portion **304** and first threaded portion **311** as shown. In some embodiments, upper penetrator cap **310** may have one or more knurled sections to allow use of channel-lock pliers to tighten it when threaded onto penetrator housing element **300**.

In further embodiments, penetrator assembly **200** may further comprise a lower cable protector **400** as shown in FIG. **19**. Lower cable protector **400** may be slide over the ESP cable until it fits over lower penetrator cap **320**. The gap or shaped section at the lower end of lower cable protector **400** may be rotated such that the exposed portion is facing toward the tubing string. Lower cable protector **400** may include one or more connection slots that may be aligned with the at least one retention aperture **321** of lower penetrator cap **320**, When aligned, one or more screws (or other similar retention elements) may be used to secure lower cable protector **400** to lower penetrator cap **320**. Lower cable protector **400** may also include a tabbed segment that may be bent by hand as shown in FIG. **22** to facilitate entry of the cable into the wellhead.

In some embodiments, one or more protective cable sleeves **500** may be slid over each external power cable **214** until they are seated against upper sealing element **302** as depicted in FIG. **20**. Once penetrator assembly **200** is assembled, it can then be installed into the bottom of the feed-thru port within tubing hanger **100** until it shoulders out on an internal edge of tubing hanger **100** as depicted in FIG. **21**. To facilitate this installation any secondary outer sealing elements **301** may be lubricated with dielectric grease. The installation may begin with passing wires upward through the tubing hanger and pushing penetrator assembly **200** until it is firmly seated in the feed-thru pocket. Four cable bands may be installed below lower cable protector **400** to secure the ESP cable.

The invention claimed is:

1. A wellhead electrical connector assembly comprising:

a substantially cylindrical outer housing body, said outer housing body being configured to substantially contain a first retention assembly and a second retention assembly,

wherein said first retention assembly comprises:

a substantially cylindrical inner housing body:

a primary upper sealing element disposed at a first end of said inner housing body, said primary upper sealing element being configured to receive said at least one of a first set of conductors;

at least one conductor receptacle partially disposed in a second end of said inner housing body, said at least one conductor receptacle being configured to engage with said at least one of a first set of conductors, said at least one conductor receptacle being further configured to engage with at least one of a second set of conductors;

wherein said second retention assembly comprises:

a primary lower sealing element configured to receive said at least one of a second set of conductors; and

an upper assembly cap configured to engage with a first end of said outer housing body.

2. The wellhead electrical connector assembly of claim **1** wherein said outer housing body has a first threaded outer housing section, wherein said upper assembly cap has a first threaded inner cap section, said first threaded outer housing section and said first threaded inner cap are configured for threaded engagement with one another.

3. The wellhead electrical connector assembly of claim **1** further comprising a lower assembly cap configured to engage with a second end of said outer housing body.

4. The wellhead electrical connector assembly of claim **1** further comprising at least one outer upper body sealing ring disposed around an outer surface of said inner housing body.

5. The wellhead electrical connector assembly of claim **4** wherein each of said at least one conductor receptacle is configured with an outer receptacle sealing ring disposed around an outer surface of said at least one conductor receptacle.

6. The wellhead electrical connector assembly of claim **1** wherein said at least one conductor receptacle comprises one or more conductor retention elements adapted for reversible engagement between said at least one conductor receptacle and said at least one of a second set of conductors.

7. The wellhead electrical connector assembly of claim **6** wherein said at least one conductor receptacle is at least one lug.

8. The wellhead electrical connector assembly of claim **7** wherein said one or more conductor retention elements is at least one set screw.

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