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Jackson

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(54) **ROBUST HIGH VOLTAGE CABLE ROUTING/MOUNTING COUPLING**

(71) Applicant: **Caterpillar Inc.**, Peoria, IL (US)

(72) Inventor: **Robert A. Jackson**, Edwards, IL (US)

(73) Assignee: **Caterpillar Inc.**, Peoria, IL (US)

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(51) **Int. Cl.**

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B60R 16/027	(2006.01)
B60R 16/03	(2006.01)
H01B 7/00	(2006.01)
H01B 7/02	(2006.01)
H01B 7/18	(2006.01)
H02G 3/04	(2006.01)

(52) **U.S. Cl.**

CPC ***B60R 16/0207*** (2013.01); ***B60R 16/0231*** (2013.01); ***B60R 16/027*** (2013.01); ***B60R 16/03*** (2013.01); ***H02G 3/0406*** (2013.01); *H01B 7/0009* (2013.01); *H01B 7/02* (2013.01); *H01B 7/1875* (2013.01)

(58) **Field of Classification Search**

CPC B60R 16/0207; B60R 16/0231; B60R 16/027; B60R 16/03; H02G 3/0406; H01B 7/0009; H01B 7/02; H01B 7/1875

See application file for complete search history.

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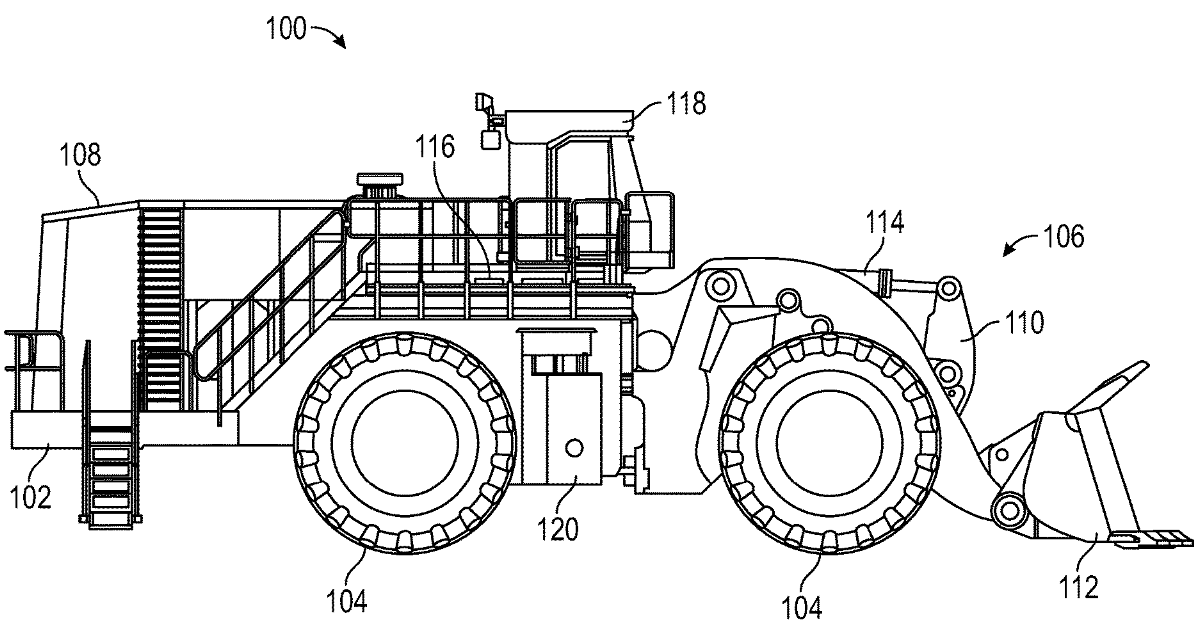
Primary Examiner — Carlos Amaya

(74) *Attorney, Agent, or Firm* — Schwegman Lundberg & Woessner, P.A.

(57) **ABSTRACT**

A cable assembly for a work machine, includes a cable and a collet. The cable includes an electrically conductive core, an insulating layer covering the core; an electrically conductive shield layer covering the insulating layer over a first length of the cable, and the insulating layer is exposed over a second length of the cable. The shield layer is folded back over a fold length, and the fold length includes two layers of the shield layer. The collet includes an inner sleeve and an outer sleeve extending over a portion of the inner sleeve at an end of the collet. The two shield layers of the fold length are arranged over the inner sleeve and under the outer sleeve, the insulating layer is arranged under the inner sleeve, and the second length of the cable extends through the inner sleeve.

11 Claims, 7 Drawing Sheets



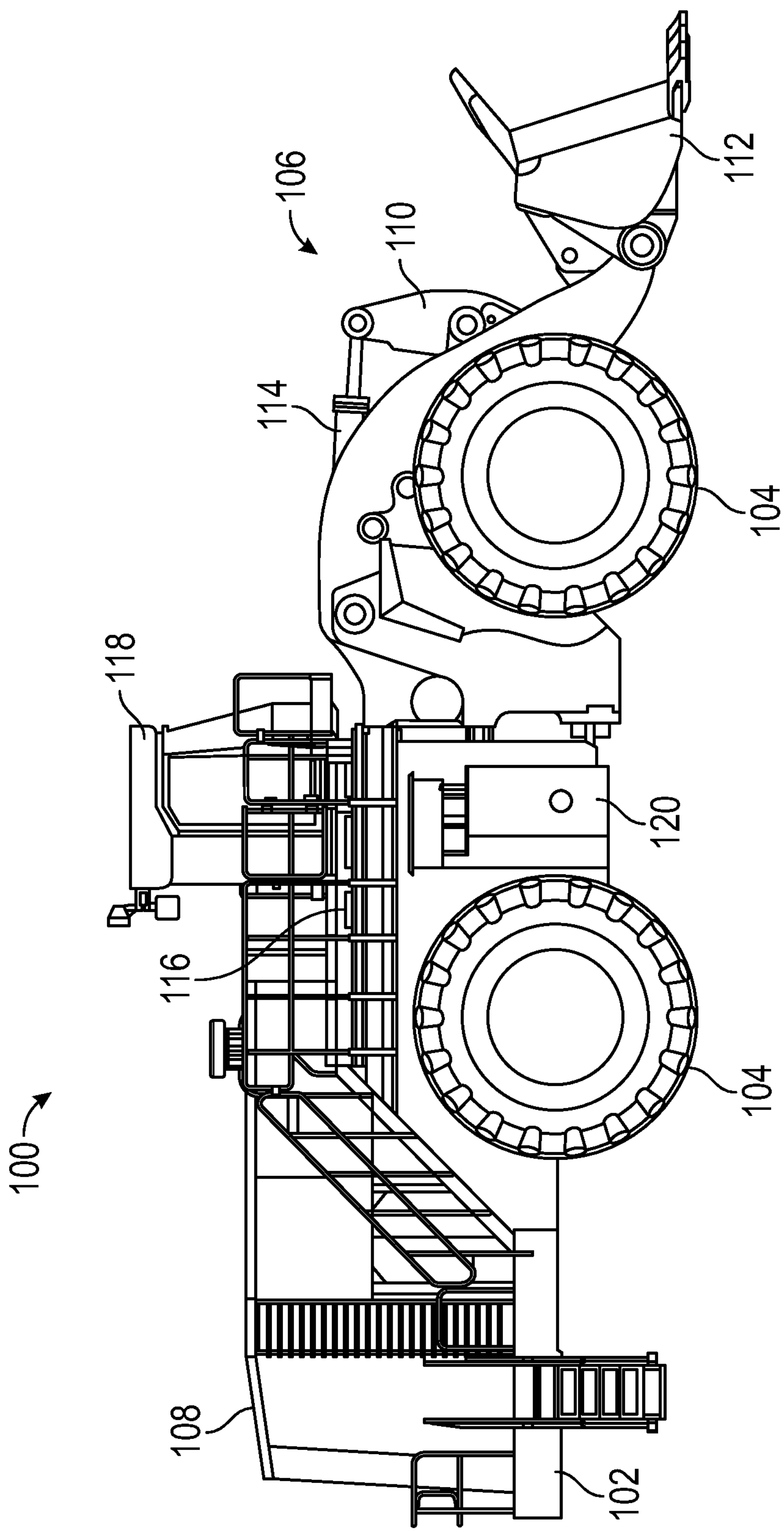


FIG. 1

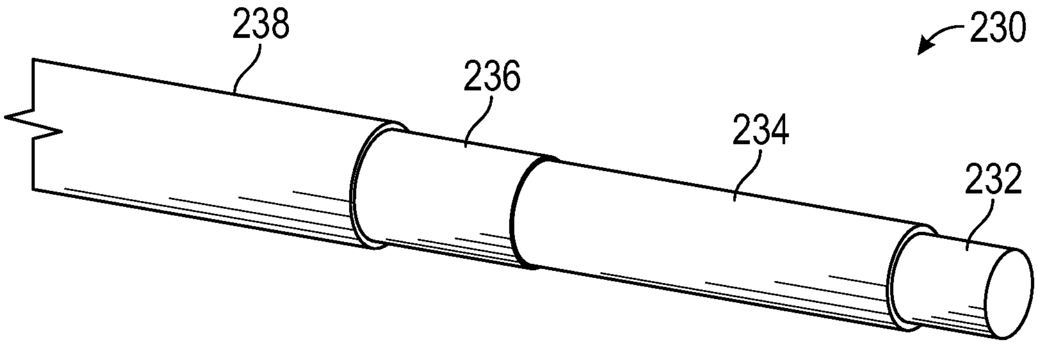


FIG. 2

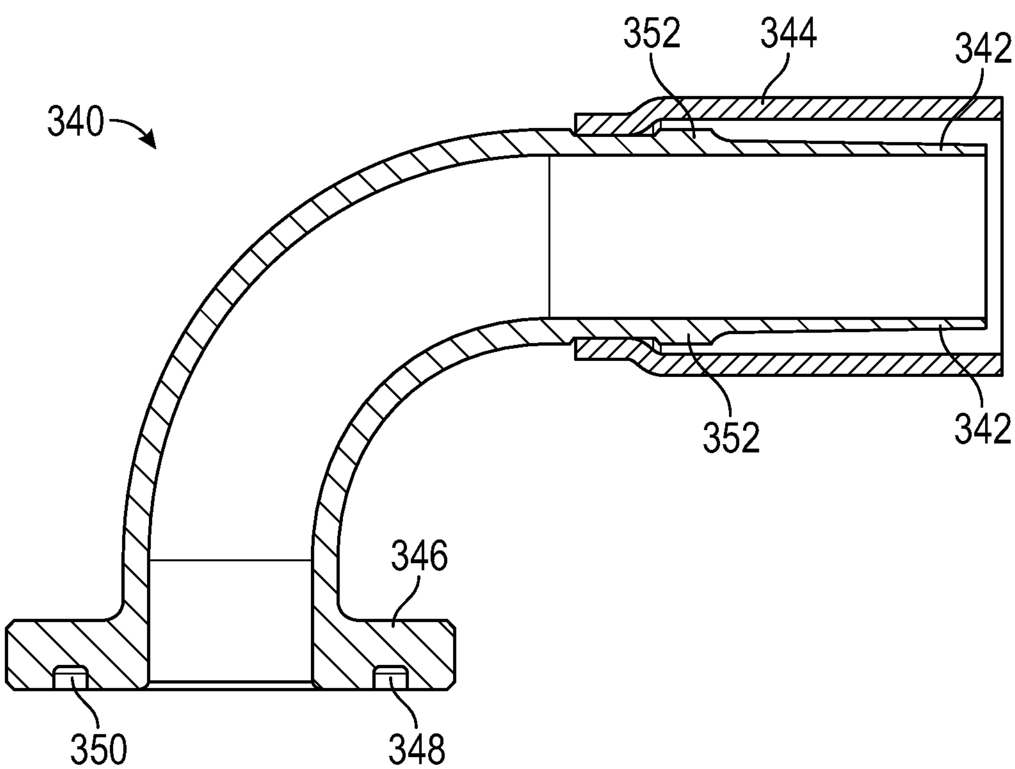
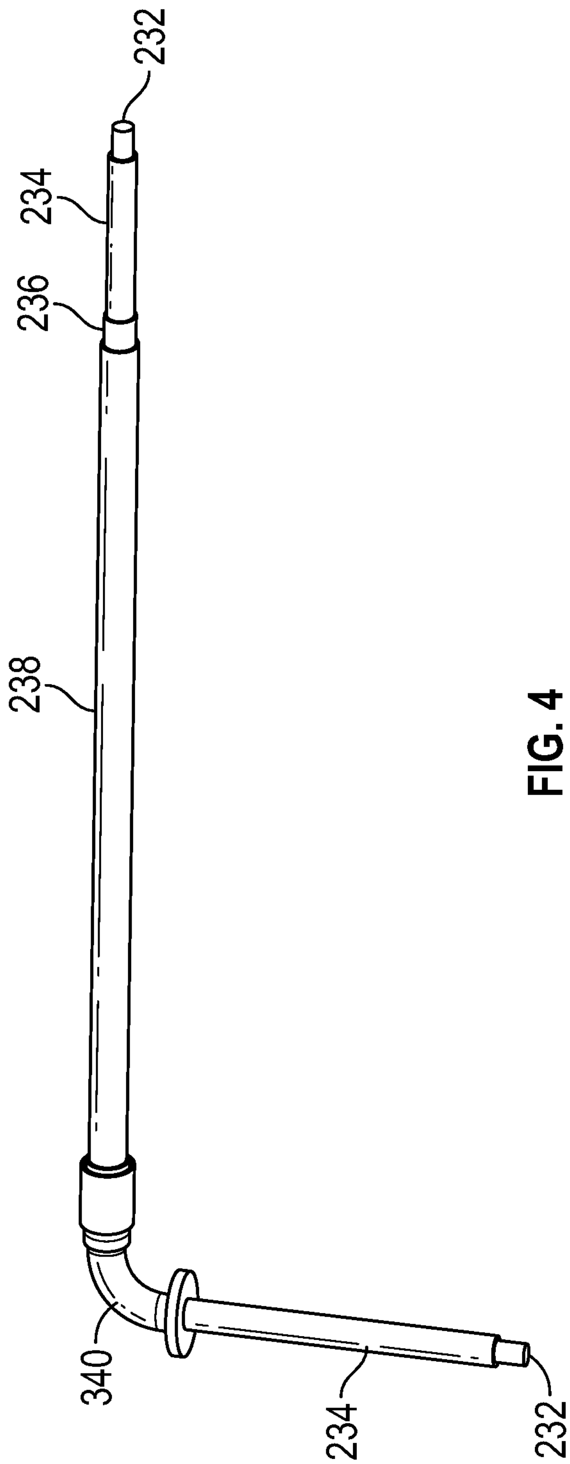
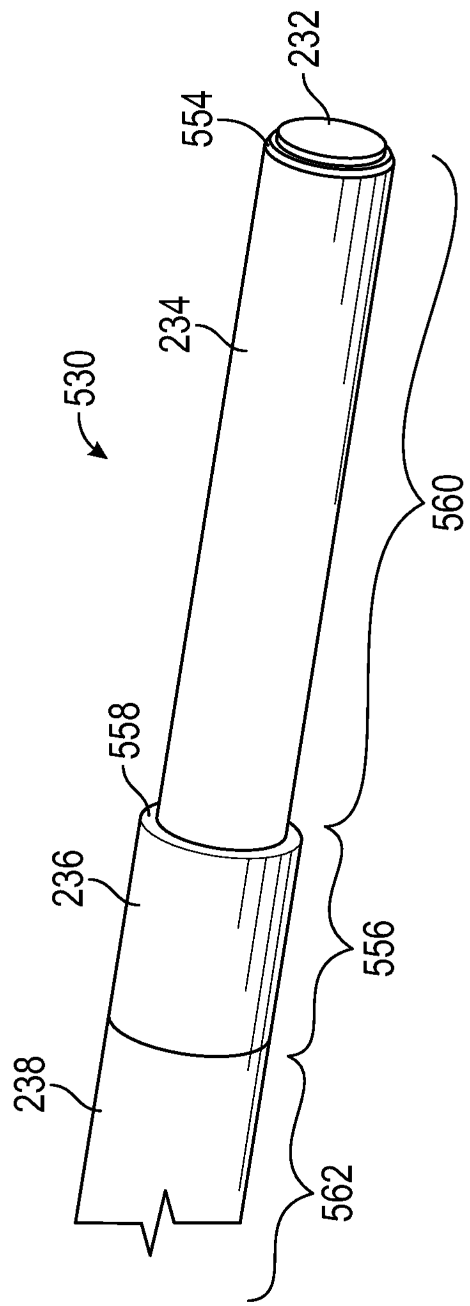


FIG. 3



232
234
236
238
340
234
232

FIG. 4



232
554
234
530
560
558
236
556
238
562

FIG. 5

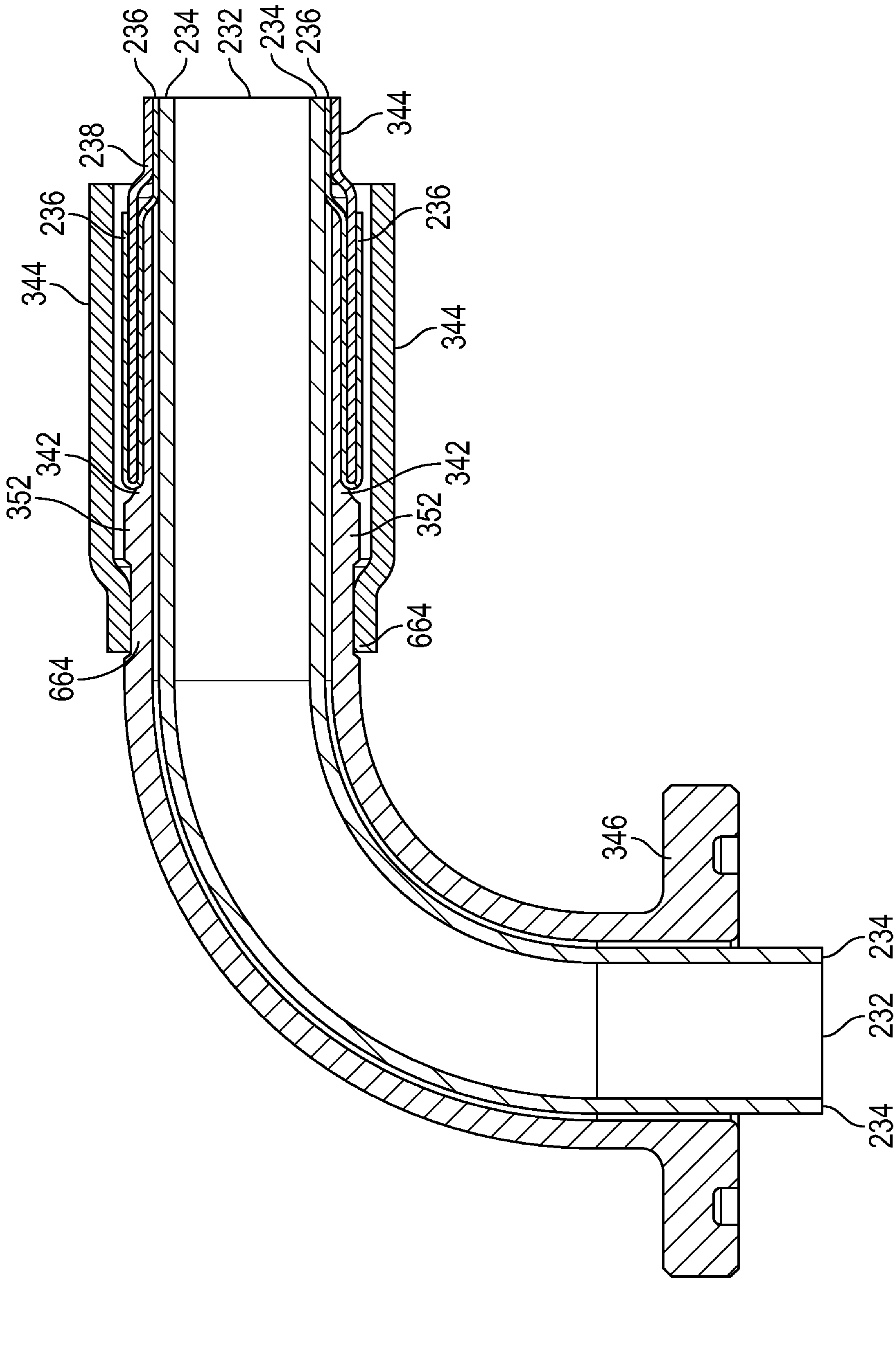

236
234
232
234
236
238
344
236
236
344
344
342
352
342
352
664
664
346
234
232
234

FIG. 6

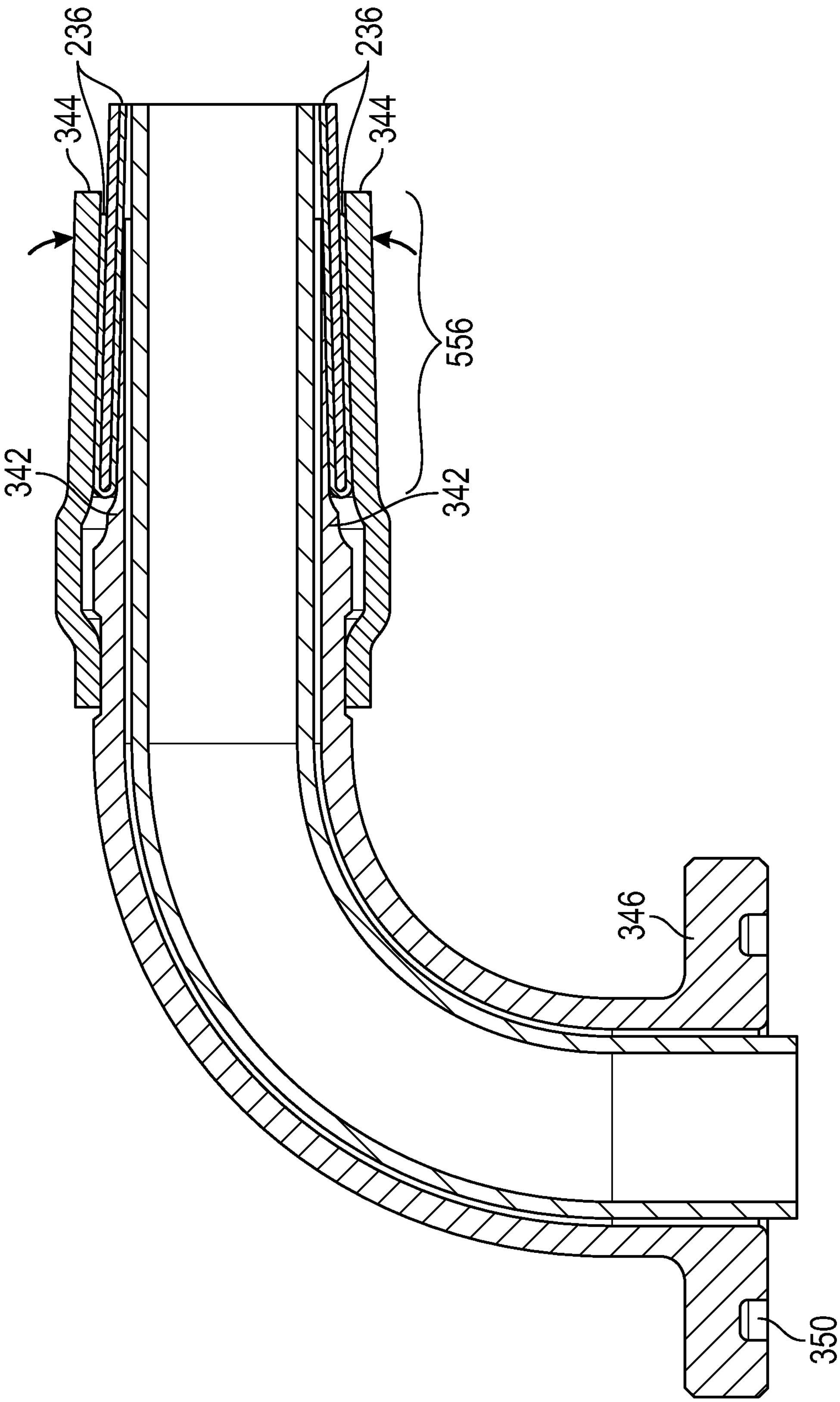


FIG. 7

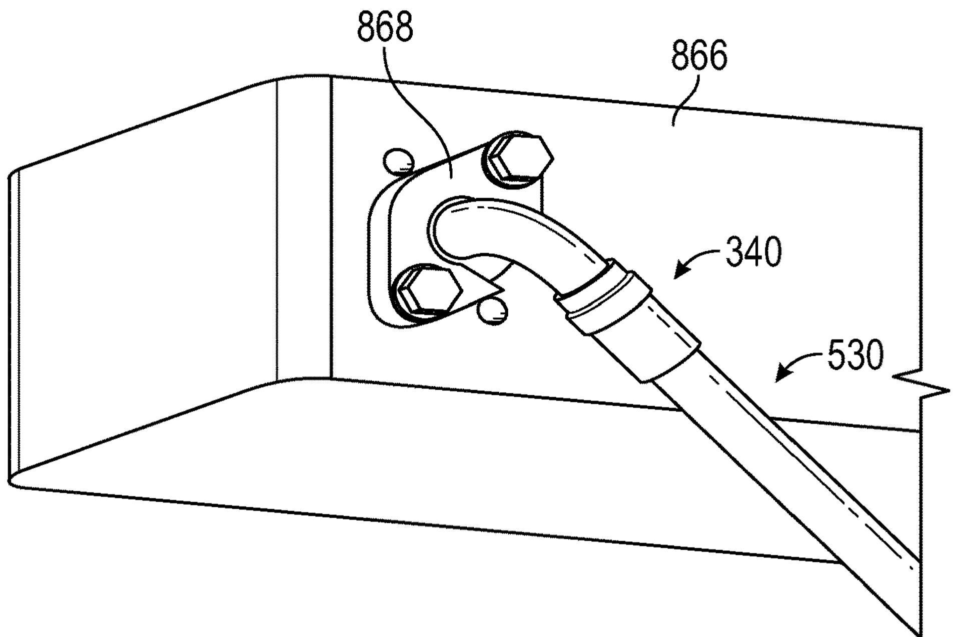


FIG. 8

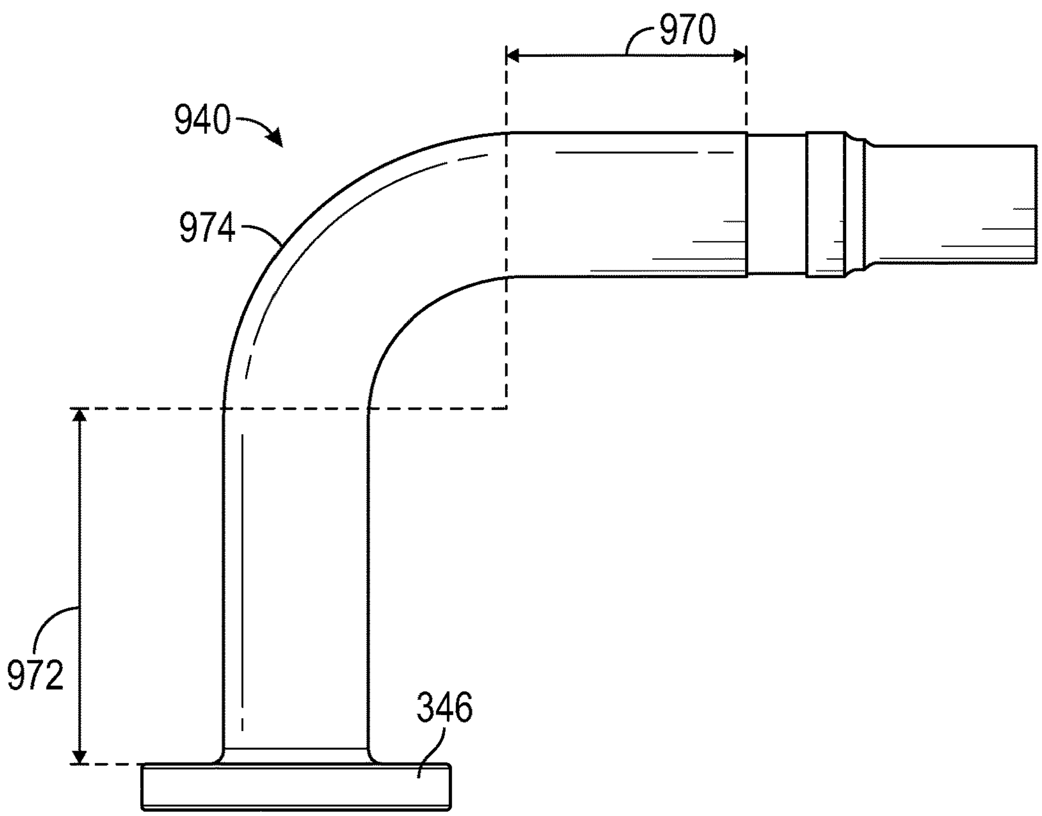


FIG. 9

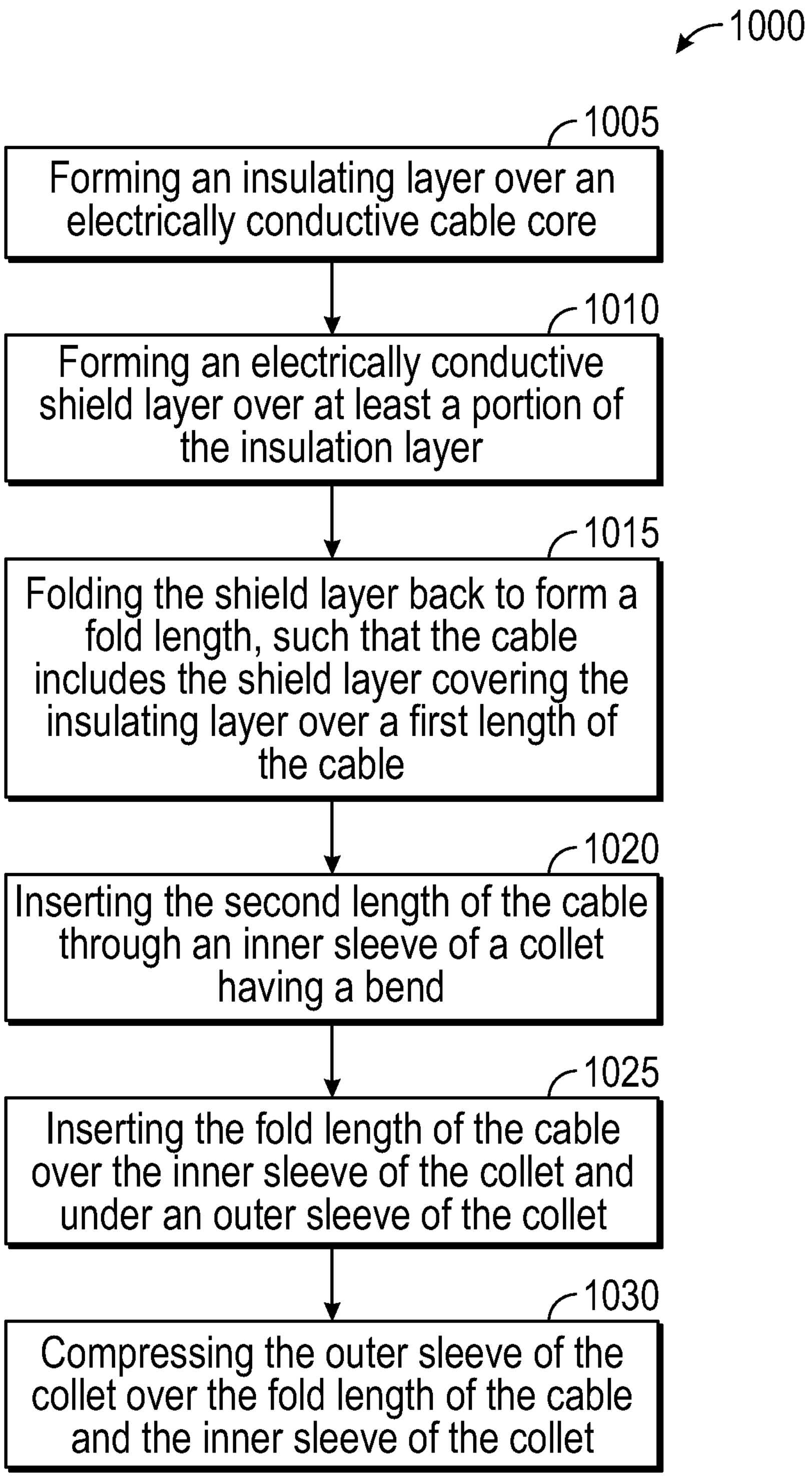

1000
1005
Forming an insulating layer over an electrically conductive cable core
1010
Forming an electrically conductive shield layer over at least a portion of the insulation layer
1015
Folding the shield layer back to form a fold length, such that the cable includes the shield layer covering the insulating layer over a first length of the cable
1020
Inserting the second length of the cable through an inner sleeve of a collet having a bend
1025
Inserting the fold length of the cable over the inner sleeve of the collet and under an outer sleeve of the collet
1030
Compressing the outer sleeve of the collet over the fold length of the cable and the inner sleeve of the collet

FIG. 10

ROBUST HIGH VOLTAGE CABLE ROUTING/MOUNTING COUPLING

TECHNICAL FIELD

This document relates to electric powered work machines and in particular to techniques of routing the electric power to different compartments of the work machines.

BACKGROUND

Powering a large moving work machine (e.g., a wheel loader) with an electric motor requires a large mobile electric energy source that can provide current of hundreds of Amperes (Amps) at hundreds of volts. This large mobile energy source can include multiple large capacity battery cells connected in parallel as battery strings that provide the sustained energy power needed by a large electric-powered moving work machine. High-capacity cables route the electric power between various compartments of the work machine. The physical requirements of cables that handle high-capacity electric power make it difficult to efficiently route electric power around the work machine.

SUMMARY OF THE INVENTION

Electric powered large moving work machines use large capacity energy sources that source high voltage electrical energy to the work machines. Work machines can be exposed to environmental conditions (e.g., vibration, water, temperature, etc.) that require robust cabling. The thickness and stiffness of robust high-capacity cables can make it difficult to conform the cables (e.g., by bending) to the space or compartment in which it is intended to be used.

A cable assembly for a work machine includes a cable and a collet. The cable includes an electrically conductive core, an insulating layer covering the core; an electrically conductive shield layer covering the insulating layer over a first length of the cable, and the insulating layer is exposed over a second length of the cable. The shield layer is folded back over a fold length, and the fold length includes two layers of the shield layer. The collet includes an inner sleeve and an outer sleeve extending over a portion of the inner sleeve at an end of the collet. The shield layers of the fold length of the shield layer are arranged over the inner sleeve and under the outer sleeve, the insulating layer is arranged under the inner sleeve, and the second length of the cable extends through the inner sleeve.

An example method of making a cable assembly for a work machine includes forming an insulating layer over an electrically conductive cable core; forming an electrically conductive shield layer over at least a portion of the insulating layer; folding the shield layer back to form a fold length such that the cable includes the shield layer covering the insulating layer over a first length of the cable, the insulating layer exposed over a second length of the cable, and two shield layers covering the insulating layer over the fold length of the cable; inserting the second length of the cable through an inner sleeve of a collet having a bend; inserting the shield layers of the fold length of the cable over the inner sleeve of the collet and under an outer sleeve of the collet; and compressing the outer sleeve of the collet over the fold length of the cable and the inner sleeve of the collet.

An example collet for a cable of a work machine includes an inner sleeve and an outer sleeve. The inner sleeve has a tube shape with a bend. The inner sleeve includes a first sleeve portion at an end of the collet and including a constant inner diameter and an outer diameter that increases from an end of the inner sleeve, and a second sleeve portion including a constant outer diameter. The outer sleeve extends over the first sleeve portion of the inner sleeve.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevation view depicting an example work machine in accordance with this disclosure.

FIG. **2** is an illustration of a cable to carry high voltage electrical energy on a work machine in accordance with this disclosure.

FIG. **3** is an illustration of a cross section view of an example of a cable routing coupling in accordance with this disclosure.

FIG. **4** is an illustration of an example of a high voltage cable inserted into a collet in accordance with this disclosure.

FIG. **5** is an illustration of a cable prepared for insertion into a collet in accordance with this disclosure.

FIGS. **6** and **7** are illustrations of a cross section view of a cable inserted into a collet in accordance with this disclosure.

FIG. **8** is an illustration of an example of a collet and cable attached to a compartment of a work machine in accordance with this disclosure.

FIG. **9** is an illustration of another example of a collet in accordance with this disclosure.

FIG. **10** is a flow diagram of an example of a method of making a cable assembly for a work machine in accordance with this disclosure.

DETAILED DESCRIPTION

Examples according to this disclosure are directed to methods and devices for routing high voltage electrical energy between compartments of a work machine. Techniques to provide efficient and robust cable routing on a work machine are described.

FIG. **1** depicts an example machine **100** in accordance with this disclosure. In FIG. **1**, machine **100** includes frame **102**, wheels **104**, implement **106**, and a speed control system implemented in one or more on-board electronic devices like, for example, an electronic control unit or ECU. Example machine **100** is a wheel loader. In other examples, however, the machine may be other types of machines related to various industries, including, as examples, construction, agriculture, forestry, transportation, material handling, waste management, and so on. Accordingly, although a number of examples are described with reference to a wheel loader machine, examples according to this disclosure are also applicable to other types of machines including graders, scrapers, dozers, excavators, compactors, material haulers like dump trucks, along with other example machine types.

Machine **100** includes frame **102** mounted on four wheels **104**, although, in other examples, the machine could have more than four wheels. Frame **102** is configured to support and/or mount one or more components of machine **100**. For example, machine **100** includes enclosure **108** coupled to frame **102**. Enclosure **108** can house, among other components, an electric motor to propel the machine over various terrain via wheels **104**. In some examples, multiple electric motors are included in multiple enclosures at multiple locations of the machine **100**.

Machine **100** includes implement **106** coupled to the frame **102** through linkage assembly **110**, which is configured to be actuated to articulate bucket **112** of implement **106**. Bucket **112** of implement **106** may be configured to transfer material such as, soil or debris, from one location to another. Linkage assembly **110** can include one or more cylinders **114** configured to be actuated hydraulically or pneumatically, for example, to articulate bucket **112**. For example, linkage assembly **110** can be actuated by cylinders **114** to raise and lower and/or rotate bucket **112** relative to frame **102** of machine **100**.

Platform **116** is coupled to frame **102** and provides access to various locations on machine **100** for operational and/or maintenance purposes. Machine **100** also includes an operator cabin **118**, which can be open or enclosed and may be accessed via platform **116**. Operator cabin **118** may include one or more control devices (not shown) such as, a joystick, a steering wheel, pedals, levers, buttons, switches, among other examples. The control devices are configured to enable the operator to control machine **100** and/or the implement **106**. Operator cabin **118** may also include an operator interface such as, a display device, a sound source, a light source, or a combination thereof.

Machine **100** can be used in a variety of industrial, construction, commercial or other applications. Machine **100** can be operated by an operator in operator cabin **118**. The operator can, for example, drive machine **100** to and from various locations on a work site and can also pick up and deposit loads of material using bucket **112** of implement **106**. As an example, machine **100** can be used to excavate a portion of a work site by actuating cylinders **114** to articulate bucket **112** via linkage **110** to dig into and remove dirt, rock, sand, etc. from a portion of the work site and deposit this load in another location. Machine **100** can include a battery compartment connected to frame **102** and including a battery system **120**. Battery system **120** is electrically coupled to the one or more electric motors of the machine **100**.

The battery system **120** can include multiple large capacity battery cells (e.g., 750 Volt, 80 Amp-hour, or 60 kilowatt-hours) to provide a high-capacity electrical energy source. The battery cells **224** may be included in one battery pack or multiple battery packs connected in parallel in the battery system. In some examples, the battery system includes fuel cells that provide a high-capacity electrical energy source. The machine **100** may include multiple battery systems.

A battery system **120** may be used to provide a high voltage (e.g., 600V-1500V) direct current (DC) electrical energy source. The output of the battery system may be provided to a converter or inverter to produce a high voltage alternating current (AC) electrical energy source. The energy source or sources provide electrical power to electrical motors, pumps, etc., of the machine **100**.

Routing the electric energy to the several compartments of the machine **100** that require electric power is challenging. The electric cables that carry high voltage electrical energy need a large diameter (e.g., 10 millimeters (10 mm) or greater). In some examples, the cables are wire gauge 0 or a greater diameter than wire gauge 0. Also, the cabling needs to be robust to safely transfer electrical energy while exposed to vibration, large temperature changes, and even submersion in water. The thick electrical cables that meet these requirements are stiff and have large bend diameters, making it difficult to route high-capacity cables efficiently in the machine **100**.

FIG. **2** is an illustration of a cable **230** to carry high voltage electrical energy on a work machine such as the example machine **100** in FIG. **1**. The cable **230** includes an electrically conductive core. The core **232** can include metal such as copper or aluminum. The core **232** may be a solid core wire or may be comprised of braided wire. The core **232** may have a diameter of 10 mm or greater, but different cables of the work machine may have different diameters based on the amount of electrical energy carried by the cable.

The core **232** is covered by a primary insulating layer **234** that electrically insulates the core **232**. A shield layer **236** covers the insulating layer. The shield layer **236** may include braided stainless steel. The shield layer **236** can be grounded (e.g., to chassis ground of the work machine) to reduce electromagnetic emissions. The shield layer **236** is covered by a protective layer **238** (e.g., a protective braiding) that is abrasion resistant.

FIG. **3** is an illustration of a cross section view of an example of a cable routing coupling that makes it easier to route large capacity cables in a work machine. The cable routing coupling includes a collet **340** having an inner sleeve **342** that has the shape of a tube with a bend in it. The collet **340** also includes an outer sleeve **344** that covers a portion of the inner sleeve **342** on one end of the collet **340**. The other end of the collet **340** also has a mounting collar **346**. The mounting collar can include a circular groove **348** for holding a seal **350** (e.g., an O-ring gasket seal).

The inner sleeve **342** has a ridge **352** that rings the outside of the inner sleeve **342**. The cross section of FIG. **3** shows that the inner sleeve **342** has a constant inside diameter, and also shows that the outside diameter of the inner sleeve **342** gradually increases from the end of the inner sleeve **342** to the ridge **352** of the inner sleeve **342**, which changes the thickness of the inner sleeve. In the cross section, the change in thickness appears as a wedge with a slowly increasing slope. A cable (e.g., the example cable **230** of FIG. **2**) is inserted through the collet **340** and extends beyond both ends of the collet **340**.

FIG. **4** is an illustration of an example of the high voltage cable **230** of FIG. **2** inserted into the collet **340** of FIG. **3**. The collet **340** includes a bend that provides a bend to the thick cable **230**. In the example of FIG. **4**, the collet has a 90-degree bend and the angle between the two lengths of the cable extending from the collet **340** is 90 degrees. The collet may have a sharper bend to provide a sharper acute angle between the two extending lengths of the cable (e.g., 15, 30, 45, 60, or 75 degree angle), or a less sharp obtuse angle between the two lengths of the cable (e.g., 105, 120 degree angle). In certain examples, the collet is straight and does not include an angle.

It can be seen in FIG. **4**, that the cable core **232**, the insulating layer **234**, the shield layer **236**, and protective layer **238** are present on one length of the cable extending from the collet **340**, and only the insulating layer **234** and the cable core **232** are present on the other length of the cable extending from the collet. The length of the cable with only the insulating layer **234** and the cable core **232** is routed inside the machine compartment requiring the electrical energy, and the length of the cable with the protective layer **238** and shield layer **236** is routed outside and between machine compartments. The collet **340** also provides a robust and water-tight connection that prevents the cable **230** from becoming loose.

FIG. **5** is an illustration of a cable **530** (e.g., the cable **230** of FIG. **2**) prepped for insertion into the collet **340** of FIG. **3**. The inside diameter of the inner sleeve **342** of the collet **340** may be 0.1 mm to 0.2 mm greater than the outside diameter of the insulating layer **234**. A beveled edge **554** may be added to the insulating layer **234** to make insertion of the cable easier. A portion of the shield layer **236** is folded back over part of the protective layer **238** to a fold length **556**. The fold length **556** starts from the folded end **558** and is covered with two layers of the shield layer **236** with a protective layer **238** between the two shield layers. The inserted length **560** does not include a shield layer **256** or a protective layer **238**. The length **562** of the cable behind the fold length includes one shield layer **236** under the protective layer **238**.

FIG. **6** is an illustration of a cross section view of the cable **530** of FIG. **5** inserted into the collet **340** of FIG. **3** to form a cable assembly for a work machine. The length of the cable with only a cable core **232** and insulating layer **234** passes through the collet **340** and extends the beyond the mounting collar **346** of the collet **340**. The fold end of the folded shield layer **236** passes over the inner sleeve **342** and under the outer sleeve **344** up to the ridge **352** that provides a stop for the folded shield layer. At the end of the inner sleeve, the thinness of the inner sleeve **342** allows the inner sleeve to pass under the folded shield layer and protective layer, and the gradually increasing thickness helps in separating the folded shield layer and protective layer from the insulating layer **234** as the cable is inserted.

The outer sleeve **344** is crimped onto the inner sleeve of the collet **340** at one end of the outer sleeve **344**. The inner sleeve may include a notched ring **664** to receive the crimped end of the outer sleeve **344**. The folded shield layer and protective layer slide into the space between the inner sleeve **342** and the outer sleeve **344** as the cable is inserted. The fold length of the cable is positioned within the outer sleeve **344**. When the cable is positioned, the outer sleeve **344** is compressed (e.g., by crimping) onto the fold length of the cable and the inner sleeve **342**. Prior to the compressing, the cable may be rotatable about the center axis of the cable (e.g., 360 degrees rotatable) to assist with positioning of the thick cable.

FIG. **7** is an illustration of a cross section view of a cable assembly. The outer sleeve **344** is shown compressed onto the inner sleeve **342** and the onto the fold length **556** of the cable. The inner surface of the inner sleeve **342** may include one or more barbs or teeth helping to create a watertight seal when the outer sleeve **344** is compressed onto the inner sleeve **342** and cable. The cable shield layer **236** contacts the collet, and the metal collet provides a ground path between the shield layer **236** and the electrical components attached to the other end of the cable. A flange (not shown) is placed over the collar **346** and bolted to the compartment housing. The seal **350** provides a watertight seal at the compartment end of the collet.

FIG. **8** is an illustration of the collet **340** and cable **530** attached to a compartment **866** holding the electrical components that may either source the electrical energy (e.g., a battery system **120**) carried by the cable or use the electrical energy (i.e., an electrical load) carried by the cable **530**. The mating housing face may be machined flat and then drilled and tapped with a four-bolt pattern. A flange **868** that is placed over the mounting collar is held in place with two bolts. Depending on the desired orientation of the coupling and cable, one set of holes will be used and the other not used. The arrangement provides unobstructed access to the bolts and avoids having one bolt buried under the collet **340** where it is more difficult to tightened.

FIG. **9** is an illustration of another example of a collet **940**. The collet **940** includes a first straight section **970**, a second straight section **972**, and a collet bend **974** between the two sections. The example collet **940** in FIG. **9** shows that the two sections may have different lengths. Also, the bend angle between the two sections can vary to change the angle of the collet bend **974**. The dimension of the collet bend **974** can vary with respect to the overall dimension of the collet, and the dimension of the mounting collar **346** can vary with respect to the dimension of the collet bend **974**.

INDUSTRIAL APPLICABILITY

FIG. **10** is a flow diagram of an example of a method **1000** of making a cable assembly for a work machine (e.g., the cable assembly example in FIG. **7**). At block **1005**, an insulating layer is formed over an electrically conductive cable core. The cable core is sized to carry high voltage electric energy that can be either DC or AC. The cable may have a diameter of 10 mm or greater. The cable may be either solid wire or a braided wire.

At block **1010**, an electrically conductive shield layer is formed over at least a portion of the insulating layer. The shield layer may include braided stainless steel. At block **1015**, the shield layer is folded back to form a fold length having a double shield layer. The cable includes the shield layer covering the insulating layer over a first length of the cable, and the insulating layer exposed over a second length of the cable. The folded length is located between the other two lengths and includes two shield layers covering the insulating layer over the fold length of the cable. In some examples, a protective layer is formed over the shield layer. The protective layer may include a protective braiding that is resistant to abrasion. The shield layer may be folded back over the protective layer so that the fold length of the cable includes a portion of the protective layer between the two layers of the shield layer.

At block **1020**, the second length of the cable that does not include the shield layer is inserted through an inner sleeve of a collet having a bend. A bevel may be added to the insulating layer. The bend may be a 90-degree bend or a sharper bend than 90 degrees. The bend may also be a bend less sharp than 90-degrees. Different bends allow for efficient routing of thick cables around different geometries of the work machine.

At block **1025**, the fold length of the cable is inserted into the collet such that the insulating layer is under the inner sleeve of the collet, and the folded shield layer is over the inner sleeve of the collet and under the outer sleeve of the collet. The fold length is inserted until the fold end of the fold length reaches a stop of the collet. The stop may be a ridge formed on the outside surface of the inner sleeve of the collet. At block **1030**, the outer sleeve is compressed (e.g., by crimping) over the fold length of the cable and the inner sleeve of the collet.

The method **1000** provides a cable assembly with a watertight seal that can be used on both the source end of the cable and the load end of the cable. Sharp bend angles are possible which allows for clearing different geometries of the work machine with the cables and installing the cables in a low-profile arrangement that reduces wear on the cables when the work machine is in use.

The above detailed description is intended to be illustrative, and not restrictive. The scope of the disclosure should, therefore, be determined with references to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A cable assembly for a work machine, the cable assembly comprising:

a cable including:

an electrically conductive core;

an insulating layer covering the core;

an electrically conductive shield layer covering the insulating layer over a first length of the cable and the insulating layer is exposed over a second length of the cable, wherein the shield layer is folded back over a fold length, and the fold length is covered with two layers of the shield layer;

a collet including an inner sleeve and an outer sleeve extending over a portion of the inner sleeve at an end of the collet, wherein the shield layers of the fold length are arranged over the inner sleeve and under the outer sleeve, the insulating layer is arranged under the inner sleeve, and the second length of the cable extends through the inner sleeve.

2. The cable assembly of claim **1**, wherein the cable includes a protective layer over the shield layer, and a portion of the protective layer is between the two shield layers of the fold length.

3. The cable assembly of claim **1**, wherein the inner sleeve includes a bend.

4. The cable assembly of claim **1**, wherein the inner sleeve includes a bend that is at least a ninety-degree bend or sharper bend.

5. The cable assembly of claim **1**, wherein the inner sleeve includes a stop having a stop edge, and the fold length extends under the outer sleeve to the stop edge.

6. The cable assembly of claim **5**, wherein the inner sleeve has a constant inner diameter and an outer diameter that increases from the end of the collet to the stop edge.

7. The cable assembly of claim **5**, wherein the stop includes a ridge positioned between the stop and another end of the collet, wherein the ridge rings the inner sleeve and an end of the outer sleeve is crimped over the ridge of the inner sleeve.

8. The cable assembly of claim **1**, wherein the outer sleeve of the collet is compressed onto the fold length and the inner sleeve.

9. The cable assembly of claim **1**, wherein the collet includes a mounting collar at another end of the collet and the second length of the cable extends beyond the mounting collar of the collet.

10. The cable assembly of claim **1**, wherein the core of the cable has a diameter greater than or equal to ten millimeters (10 mm).

11. The cable assembly of claim **1**, wherein the shield layer of the cable includes braided metal.

* * * * *