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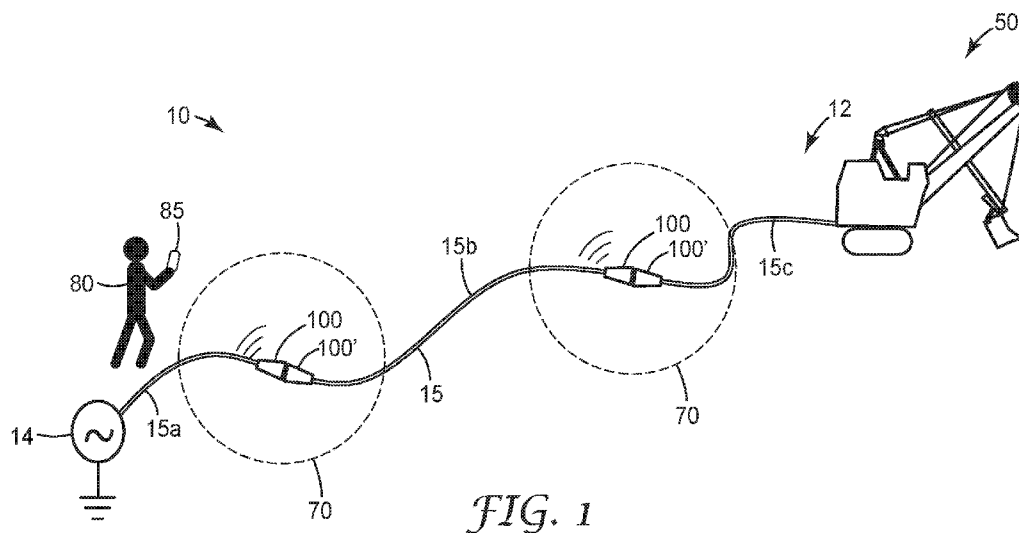
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(54) Title: TEMPERATURE MONITORING ELECTRICAL CABLE COUPLER



(57) Abstract: An electrical coupler device for making a cable joint and connecting a plurality of electrical conductors in a power cable is described. The electrical coupler device comprises a main body and a front portion mechanically coupled to the main body, the electrical coupler device configured to terminate the plurality of electrical conductors that are configured to carry electrical power, a temperature sensor disposed adjacent to each of the plurality of electrical conductors, wherein each temperature sensor monitors a service temperature for one of the plurality of conductors, and a communication module configured to send conductor temperature data to a remote device wirelessly.

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TEMPERATURE MONITORING ELECTRICAL CABLE COUPLER**BACKGROUND OF THE INVENTION****Field of the Invention**

The present invention is directed to electrical couplers, and more particularly, devices and methods for electrical couplers that include temperature monitoring of each conductor being connected by the electrical coupler.

Background

In various industrial environments and other environments where equipment is being operated, such as in mining operations, many devices can be employed that require electrical power to be provided to the device by a wired power connection. These wired connections often take the form of an electrical coupler system that is configured to interconnect two electrical cables where each electrical cable includes a plurality of individual insulated electrical conductors provided together in a protective outer sheath or that connects an electrical cable to a piece of equipment.

In many instances, individual pieces of this equipment need to be mobile or need to be reconfigured in their environment which means that the cables connecting the equipment to a power source need to be moveable or reconfigurable. For example, a piece of equipment, such as an electrical shovel, are employed in mining operations. The electrical shovels require electric power to operate and move from one location to another. The electrical shovels can be connected to a power source by an electrical link comprising a plurality of shorter cable segments that are interconnected by a coupler system. The coupler systems generally comprise two coupler devices that interconnect to make the electrical connection.

Due to harsh physical and environmental conditions (UV rays, snow, dust, humidity, rocks, geographic altitude, etc.) in mining operations, coupler systems or coupler devices are frequently damaged. When a coupler system or a coupler device fails, the power to the piece of electrical equipment to which it is connected is disrupted and the production of that piece of electrical equipment stops until the coupler system or device can be replaced.

Thus, there is a need to be able to monitor the operating condition of the electrical coupler system/coupler device in the field to avoid potential failures or timely react to a potential failure to minimize disruptions in operations.

SUMMARY

This disclosure is generally directed to devices, systems, and methods for monitoring the operating condition of an electrical coupler system or electrical coupler device for signs of potential failure, including monitoring the current, voltage and/or operating temperatures of the individual electrical conductors connected by said electrical coupler system or electrical coupler device, and transmitting the data to a data unit disposed at a safe operating distance from the electrical coupler system or electrical coupler device. The electrical coupler system comprises at least one electrical coupler device configured to allow connection and disconnection of an electrical cable(s) that includes a plurality of electrical conductors terminated within the electrical coupler device, wherein the electrical coupler device is connectable to another electrical coupler device disposed on another electrical cable, and/or to other electrical devices, such as power sources and devices, to be powered by electrical power provided through the electrical cables.

In a first embodiment, an electrical coupler device for making a cable joint and connecting a plurality of electrical conductors in a power cable is described. The electrical coupler device comprises a main body and a front portion mechanically coupled to the main body. The electrical coupler device is configured to terminate the plurality of electrical conductors that are configured to carry electrical power. The electrical coupler device further includes a temperature sensor disposed adjacent to each of the plurality of electrical conductors, wherein each temperature sensor monitors a service temperature for one of the plurality of conductors, and a communication module configured to send conductor temperature data to a remote device wirelessly. The electrical coupler can further include a terminal attached to the end of each of the plurality of electrical conductors and held in the front portion of the electrical coupler device.

In a second embodiment, a temperature monitoring system for monitoring the temperature of electrical conductors in a power cable is disclosed. The monitoring system comprises an electrical coupler device; the electrical coupler device attached to the power cable, the electrical coupler device comprising a main body and a front portion mechanically coupled to the main body. The electrical coupler device is configured to terminate the plurality of electrical conductors configured to carry electrical power. The electrical coupler can further includes a temperature sensor disposed adjacent to each of the plurality of electrical conductors, wherein each temperature sensor monitors a service temperature of one of the plurality of conductors; and a communication module configured to send conductor temperature data to a remote device wirelessly. The system also includes a remote device configured to receive the conductor

temperature data from the electrical coupler at a distance of between about 2 meters to about 10 meters. The remote device includes a display screen to show the temperature data of each conductor to a user. The electrical coupler device of the monitoring system can be connected to a piece of electrical equipment, a mating electrical coupler device or a power source.

5 In an exemplary aspect, the electrical coupler of the monitoring system further comprises a sensor module to position the temperature sensors adjacent to each of the plurality of electrical conductors. The sensor module has a base and a plurality of hollow legs extending from the base, wherein each of the plurality of hollow legs is configured to receive an end of one of the plurality of electrical conductors. The base of the sensor module comprises a recess to house
10 sensor electronics that are connected to the sensors associated with each of the electrical conductors, wherein the sensor electronics comprise a printed circuit board having a plurality of sensor connections, a data collection unit to collect the data relating to the in-service characteristic and the communications module to wirelessly transmit the data to a remote device. In some embodiments, the sensor electronics further comprise a geolocation module to tag the
15 location of the electrical coupler device.

In a third embodiment, an electrical coupler device is disclosed for connecting a plurality of electrical conductors in a power cable. The electrical coupler device comprises a main body and a front portion mechanically coupled to the main body, the electrical coupler device configured to the plurality of electrical conductors configured to carry electrical power; a sensor
20 module disposed adjacent to each of the plurality of electrical conductors, wherein each sensor monitors an in-service characteristic of one of the plurality of conductors; and a communication unit configured to send data relating to the in-service characteristic to a remote device wirelessly. The sensor module has a base having a recess to house sensor electronics and a plurality of hollow legs extending from the base, wherein each of the plurality of hollow legs is configured
25 to receive an end of one of the plurality of electrical conductors. The sensor electronics are connected to the sensors associated with each of the electrical conductors and comprise a printed circuit board having a plurality of sensor connections, a data collection unit to collect the data relating to the in-service characteristic and the communications module to wirelessly transmit the data to a remote device. In some embodiments, the sensor electronics further comprise a
30 geolocation module to tag the location of the electrical coupler device.

In a fourth embodiment, a method of evaluating a cable joint is presented. The method comprises measuring an in-service characteristic of each electrical conductor in a power cable; transmitting data related to the in-service characteristic to a remote device disposed between 2 m

and 10 m from the cable joint; displaying the data on a remote device; and comparing the in-service characteristic data from the plurality of electrical conductors to predict a fault in the joint.

The above summary of the present invention is not intended to describe each illustrated embodiment or every implementation of the present invention. The figures and the detailed
5 description that follows more particularly exemplify these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be further described with reference to the accompanying drawings, wherein:

Fig. 1 is a schematic diagram illustrating an exemplary temperature monitoring system
10 for monitoring the temperature of electrical conductors in a power cable in accordance with the present invention.

Figs. 2A-2C are three views of an exemplary electrical coupler device in accordance with the present invention.

Fig. 3 is an isometric view of the housing of the electrical coupler device of Figs. 2A-2C.

15 Figs. 4A-4E are five views of a sensor module that can be disposed in the electrical coupler device of Figs. 2A-2C.

Fig. 5 is a cross-sectional view of the electrical coupler device of Figs. 2A-2C that has been installed on the terminal end of a power cable.

While the invention is amenable to various modifications and alternative forms, specifics
20 thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE EMBODIMENTS

25 In the following Detailed Description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention can be practiced. In this regard, directional terminology, such as “top,” “bottom,” “front,” “back,” “forward,” etc., is used with reference to the orientation of the Figure(s) being described. Because components of embodiments of the present invention can be
30 positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is in no way limiting. It is to be understood that other embodiments can be utilized and that structural or logical changes can be made without departing from the scope of

the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

This disclosure is generally directed to devices, systems, and methods for monitoring the operating condition of an electrical coupler system or electrical coupler device for signs of potential failure, including monitoring the current, voltage and/or operating temperatures of the individual electrical conductors connected by said electrical coupler system or electrical coupler device, and transmitting the data to a data unit disposed at a safe operating distance from the electrical coupler system or electrical coupler device.

Electrical resistance at the joint can be highly dependent on temperature. For this reason, in some aspects of the invention temperature monitoring is employed to watch for early indications of a future joint failure. Additional property data (current, voltage, etc.) can also be monitored to provide additional indications of potential joint failure. Due to safety considerations, maintenance personnel must maintain a minimum safe distance from live electrical couplers. For this reason, the property data is conveyed to a remote device (e.g. positioned between about 2 meters to about 10 meters away from the joint) where it can be viewed by the maintenance worker. The remote device can optionally include global positioning capability to mark the location of the joint, if needed.

The electrical coupler system comprises at least one electrical coupler device configured to allow connection and disconnection an electrical cable(s) that include a plurality of electrical conductors terminated within the electrical coupler device, wherein the electrical coupler device is connectable to another electrical coupler device disposed on another electrical cable, and/or to other electrical devices such as power sources and devices to be powered by electrical power provided through the electrical cables.

The electrical coupler device, or more simply the electrical coupler, is configured to be mounted on the end of a power cable, for example a medium voltage power cable that can carry at least one kilovolt of electrical power. The electrical coupler is configured to be used with power cables having a plurality of electrical conductors, for example a medium voltage (4 to 36 kV) three-phase electrical power cable. The electrical coupler device comprises a set of electrical terminals which are connected to the conductors in the power cable to which the coupler device is attached and a temperature sensor disposed adjacent to each conductor in the cable.

The electrical coupler can be configured to be received by or otherwise engage with a second or mating electrical coupler having a corresponding set of electrical terminals configured so that when the electrical coupler and the second electrical coupler are physically coupled

together, the terminals within each electrical coupler provide an electrical connection between the terminals of the electrical coupler and the second electrical coupler. A second set of electrical conductors can be physically and electrically coupled to the corresponding terminals in the second electrical coupler. The ability to couple and uncouple (disconnect) the electrical
5 coupler to and from the second electrical coupler provides a mechanism to electrically connect and disconnect the electrical conductors received in each of the electrical couplers to and from one another, for example to and from other electrical conductors in different cables, or for example to a power source or to a device to be powered by electrical power provided through the electrical conductors provided to the electrical coupler.

10 Fig. 1 is a simplified schematic diagram illustrating an example electrical coupler system 10 in accordance with the devices and techniques described in this disclosure. System 10 is illustrative of an example of an electrical distribution system 12 in a mining environment including the electrical couplers 100, 100' described in this disclosure, and any equivalents thereof. However, the electrical couplers, and any equivalents thereof, as described in this
15 disclosure are not limited to use in an electrical distribution system 12 or for use in the mining environment, can be utilized in any electrical system that utilizes electrical couplers for connection and disconnection of one or more electrical conductors according to the examples of electrical couplers described herein.

Electrical power source 14 provides power to an electrically powered piece of equipment, such as loader 50, by a distribution line (i.e. electrical cable 15) of distribution system 12. The
20 electrical power provided by power source 14 is not limited to any particular configuration of electrical power, may include any configuration of electrical power that is required to provide the electrical power needed for proper operation of the electrically powered devices included in or intended to operate in the mining environment. A configuration of electrical power as used
25 herein refers to any arrangement of electrical power with respect to the voltage, maximum current, waveform, frequency, and/or number of and the arrangement of any different phases by which the electrical power is provided to the electrical conductors being connected through and disconnected by the electrical couplers described herein, and any equivalents thereof. For electrical power configurations providing an alternating current form of electrical power, voltage
30 can be expressed as a peak voltage, a peak-to-peak voltage, or an average voltage, such as root-mean-square (RMS) voltage.

In some examples, the electrical power provided by power source 14 can be a commercially available electrical power having a voltage, several phases, a frequency, and/or an electrical configuration that is a same electrical configuration as provided by a commercial or

governmental electrical utility provider. In some examples, the electrical power provided by power source 14 may include an electrical power configuration that is generated on-site, for example using an electrical generator that operates from another power source, such as another electrical power source, a chemical/fuel source, a wind or hydroelectrically generated power source, or some other source of energy. In some examples, the electrical power provided by power source 14 includes a configuration of electrical power that is transformed from one electrical power source, such as a commercial or governmentally provided electrical power source, to a different electrical power configuration with respect to voltage, number of phases, frequency, and/or an alternating current (AC) versus a direct current (DC) electrical power configuration.

In some examples, power source 14 provides a direct current (DC) electrical power supply to the electrical distribution system 12. Power source 14 may in some examples provide an alternating current (AC) electrical power supply to the electrical distribution system 12. In examples of power source 14 providing AC electrical power, the electrical configuration of the AC electrical power is not limited to any particular number of phases or phase configurations. In some examples, the AC electrical power can be a single-phase configuration. In other examples, the AC electrical power can be provided in a multi-phase electrical configuration, including a two-phase or a three-phase electrical configuration. For example, the electrical power provided by power source 14 may including a three-phase grounded or ungrounded delta configuration. In some examples, the electrical power provided by power source 14 may include a three-phase “Y” configuration that can be ungrounded or can be center-grounded.

The voltage level provided by power source 14 is not limited to any particular voltage or range of voltages. Voltages provided by power source 14 can be in a range of 5,000 to 36,000 V peak volts. A voltage provided by power source 14 may include three-phase electrical power having a root-mean-square (RMS) voltage of 15,000 VAC. In addition, the range of current levels that power source 14 is configured to provide is not limited to any particular range or maximum current levels. In some examples, power source 14 is configured to provide currents in the range of 250 to 800 amperes (A).

As previously mentioned, electrical power source 14 provides power to an electrically powered piece of equipment, such as loader 50 by a distribution line (e.g. electrical cable 15) of distribution system 12. Loader 50 is an example of a piece of electrically powered equipment provided in mining environment as part of system 10. Other pieces of electrical equipment can be disposed in the distribution system between the power source and the loader, such as one or more portable breaker skids or substations (not shown). The portability of the electrical

equipment and the electrical distribution system itself allows for flexibility in locating and relocating the electrical equipment as needed by the loader 42 and/or any other devices that are supplied power from the power source. In contrast to more permanent devices and distribution systems which can make use of wire troughs and/or rigid electrical conduits to protect the distribution systems, electrical connections used to electrically couple the power source and any additional electrical equipment to loader 50 in the portable distribution systems described herein cannot be easily protected.

To facilitate the portability and flexibility of the electrical distribution system, each the distribution line can include a plurality of cable segments 15a, 15b, 15c connected together by an electrical coupler system comprising a pair of mateable electrical coupler devices 100, 100'. The electrical coupler devices are provided at one or more locations along or at the end(s) of these electrical cable segments, to allow for connecting and disconnecting the electrical cable segments to and from these devices, and/or to and from other electrical cable segments. As shown in Fig. 1, electrical distribution line includes a plurality of electrical coupler devices 100, 100'.

Because these electrical couplers operate in harsh environments, the electrical couplers are typically positioned so that they are laying on open ground in a mining environment. The electrical couplers can be damaged in a way that exposes a portion of an electrical conductor and/or an electrical terminal of the electrical coupler to unintended access through the damaged portion of the coupler.

Safety considerations dictate that maintenance personnel must maintain a minimum safe distance from live electrical couplers. This excluded space 70 is represented by the dashed ring disposed around each coupler device pair in Fig. 1. For this reason, any property data obtained by sensor module 150, shown in Figs. 2C and 4A-4E, in electrical coupler 100, 100' is conveyed to a remote device that positioned between about 2 meters to about 10 meters away from the cable joint where it can be safely viewed by the maintenance worker 80 on a remote device 85. In some embodiments, the remote device can optionally include global positioning capability to mark the location of the joint, if needed.

The ability to monitor the coupler devices for indications of future failure without the need to touch or otherwise manipulate the electrical coupler provides a safety feature that may help avoid an accident and/or help prevent injuries to a user who is using the electrical coupler, who can be operating in the area of the electrical coupler, and/or when performing maintenance procedures on the electrical coupler. These and other benefits of the electrical couplers equipped to monitor their operating condition within the electrical coupler will be further described by the

additional figures and the associated description of these figures as provided coupling device. The electrical couplers included in system 10 can be configured to provide an electrical connection between electrical conductors in a first electrical cable and other electrical conductors within different electrical cables, or between electrical conductors within an electrical cable and a device, such as the substations, the breaker skids, and the equipment illustrated and described with respect to system 10. Each coupler device is configured to receive, secure and/or terminate one or more of the electrical conductors within the coupler device. The electrical coupler devices of the present invention can be constructed to provide adequate structure and have electrical rating properties to connect, to carry, and to disconnect the electrical power intended to be carried by the electrical conductors being connected and disconnected by the electrical coupler. One or more of these electrical couplers may also incorporate sensors, electrical circuits, communication units and/or one or more indication devices configured to provide information on the operating condition of the electrical connection.

In an exemplary, non-limiting aspect, electrical coupler devices 100, 100', described below, can be directed to electrical coupler devices arranged to terminate electrical conductors intended to carry medium voltage three-phase AC electrical power. The term "medium voltage" may include peak voltages (relative to a reference voltage) in a range of 4 to 36 kV. The term "three-phase" refers to any arrangement of AC electrical power having a frequency and that includes three separate phases of electrical potential provided on three separate electrical conductors, and arranged in a phase relationship to one another, such as in a "delta" or a "Y" configuration. The separate electrical conductors intended to carry the three-phase AC electrical power can be referred to as the electrical power conductors or more simply conductors throughout this disclosure, and represent the electrical conductors, which can be provided for example in an electrical cable, and that can be terminated at each end by an electrical coupler device, such as electrical coupler device 100 or a mating coupler device which can be mated with electrical coupler device 100 to form a cable joint between adjacent cable segments 15a, 15b, 15c in the distribution line (i.e. cable 15).

In addition to the power electrical conductors, an electrical conductor coupled to a reference voltage for the three-phase AC electrical power may also be included in the electrical cable, which can be referred to as a "common" conductor or "ground" and may also be terminated by one of the terminals provided within each of the electrical coupler device. In addition, an electrical cable that is terminated by the exemplary electrical coupler devices, described throughout this disclosure, may include one or more additional electrical conductors intended to carry other voltage potentials, such as a low voltage DC electrical power.

The electrical coupler device of the present invention is configured to accommodate an electrical power cable having a plurality of electrical conductors provided within an outer sheath or jacket. Electrical coupler device 100 will be describe with reference to Figs. 2A-2C and Fig. 5. Fig. 2A is a side view of electrical coupler device 100 that has been installed on one of the
5 ends of cable segment 15a. Fig. 2B is an end view of electrical coupler device 100 and Fig. 2C is an exploded view of the electrical coupler device. Fig. 5 is a sectioned view of electrical coupler device 100 installed on an end of cable and electrical cable 15.

Each of the electrical conductors 17 of electrical cable 15 may also include an insulating layer 17a that insulates and protects the individual metallic conductors 17b provided within the
10 outer sheath of the electrical cable. The number of electrical conductors is not limited to two electrical conductors, or to a particular number of electrical conductors, and may include a number of electrical conductors required to provide one or more particular type(s) of electrical power, including electrical power provided as direct current (DC), alternating current (AC), and
15 with one or multiple phases of AC electrical power. In an exemplary aspect, an electrical cable used in mining applications is a mining cable type SHD-GC comprising 6 conductors. In this cable, there are three power conductors with insulation layer for medium voltage, 1 insulating conductor for 600V maximum that serves as a pilot wire for protection and two additional
conductors without insulation for ground protection.

Electrical coupler device 100 comprises a main body 110, a front portion 130
20 mechanically coupled to the main body, wherein the electrical coupler device configured to terminate a plurality of electrical conductors 17 that carry electrical power, and a sensor module 150 disposed at least partially within the main body. Sensor module 150 is configured to position a sensor adjacent to each of the plurality of electrical conductors to measure an in-
service characteristic of one of the plurality of conductors. Sensor module 150 can also include
25 a communication unit configured to send data about the in-service characteristic to a remote device wirelessly. In an exemplary aspect, the sensor module is configured to position a temperature sensor adjacent to each of the plurality of electrical conductors, so that each
temperatures sensor will monitor a service temperature for one of the plurality of conductors
terminated by the electrical coupler device and communicate that temperature data wirelessly to
30 a remote device, such as remote device 85 shown in Fig. 1.

Main body 110 can be in the form of a housing or a shroud that extends from the rear flange 112 to a front flange 111 of the main body 110 and encloses a hollow cavity or space 113 within the main body 110, and increases in its cross-sectional dimension relative to a longitudinal axis 199 electrical coupler device 100 as the tapered housing extends from the rear

flange 112 to the front flange 111 (Fig. 3). The overall shape of the electrical coupler device 100 can have a substantially circular cross-section, at least with respect to the outmost surfaces of the electrical coupler, in a dimension perpendicular to the longitudinal axis 199. However, the shape of the electrical coupler device 100 is intended to be illustrative example of an electrical coupler device, and cross-sectional shapes, such as square, rectangular, and elliptical shapes may exist.

A cable clamp 125 is coupled to rear flange 112 of the main body 110. The cable clamp includes a collar 126 having a passage 126a disposed therethrough to accommodate the end of the cable to be terminated in electrical coupler device 100. At least one window 126b is formed in the sidewall of collar 126. A clamping element 127 can be secured over the window by mechanical fasteners such that it clamps onto the outer jacket or sheath of the cable passing through the collar. Collar 126 also include an attachment ring 126c to secure the collar to the rear flange 112 of main body 110 by mechanical means, such as bolts 192.

Cable clamp 125 can include a plurality of ridged or teeth (not shown) formed in the passage and on the inner surface of clamping element 127 to further grip the outer sheath of an electrical cable held by the clamp in order to strain relieve to the cable when a portion of cable outside the electrical coupler device 100 is pulled on or bent in a direction away from the electrical coupler.

Front portion 130 of electrical coupler device 100 includes positioning member 131, a sensor module and a set of terminals 140 configured to provide electrical connection of each individual power electrical conductor with other terminals in a mating coupler (not shown). Positioning member 131 is generally cup shaped and comprises openings 132 that can accept and position insulators 170 in the proper position for interconnection of the electrical coupler device with a mating coupler or a receptacle on a piece of electrical equipment or a power supply. In an exemplary aspect, insulators 170 can be ceramic insulators.

Terminals 140 are configured to be positioned between sensor module 150 and the insulators 170 and can extend partially into or through the sensor module and/or the insulators. Each terminal can be electrically and physically coupled to one of the power electrical conductors provided in an electrical cable. Some embodiments of electrical coupler device 100 can also include a ground terminal 142 to provide continuity of an electrical conductor that is coupled to a reference voltage through the cable joint comprising the electrical coupler device.

Referring to Figs. 2C and 4A-4E, sensor module 150 comprises a base 151 and a plurality of hollow legs 161 extending from the base that form the terminal housings for the electrical coupler device 100. In an exemplary aspect, the number of hollow legs corresponds to the number of power electrical conductors disposed in the cable being terminated. In the

exemplary aspect shown in the figures, the sensor module includes three hollow legs 161a, 161b, 161c disposed in a tripod configuration which can be used when terminating a medium voltage three-phase electrical power cable. Each hollow leg is configured to fit into a bore 172 of an insulator 170. The insulators are held in openings 132 of the positioning member 131 to ensure alignment of the terminals with a mating coupler as shown in Fig. 5.

Each hollow leg 161 has a conduit portion 162 surrounded by a side wall 163 through which the electrical conductor passes. When the terminal is attached to the end of one of the plurality of power electrical conductors, an end portion of that electrical conductor is disposed in the conduit portion of one of the hollow legs. Each hollow leg also includes a closed bottom bore 164 formed in a side wall of the hollow leg to accommodate a sensor 180 that monitors an in-service characteristic of a conductor disposed in the conduit portion of the sensor module.

The base of the sensor module includes a recess to house sensor electronics that are connected to the sensors 180 disposed in bores 164. The sensor electronics 185 can comprise a printed circuit board 186 having a plurality of sensor connections 187, a data collection unit 188 and a communications module 189 to wirelessly transmit data relating to the in-service characteristic being monitored to a remote device. In some embodiments, the sensors can also include a geolocation module (not shown) to tag the location of the electrical coupler device such as a GY-NEO6MV2 GPS Module available from Arduino (Somerville, MA) and a u-blox 6 based NEO-6 series of GPS module available from u-blox (Reston, VA). In some embodiments, the geolocation module can be integrated into the communication unit.

In an exemplary embodiment, the communications unit can be a BLUETOOTH[®] module that can send the in-service characteristic data to a remote device, such as Bluetooth compatible smartphones, tablets or laptop computers. (BLUETOOTH[®] is a registered trademark of Bluetooth Special Interest Group (Bluetooth SIG) of Kirkland, WA). The remote device can be provided with a mobile application that allows the reception of the information sent from the sensor electronics to the screen of the remote device allowing the in-service characteristics to be measured and displayed in real time.

In an exemplary embodiment, sensors 180 can be temperature sensors that measure the in-service temperature of the electrical conductors. Exemplary temperature sensors can be a DS18B20 digital temperature sensor such as is available from Dallas Semiconductors (Dallas, TX).

In alternative embodiments, the sensors can be a current sensor, a voltage sensor, a phase detector, etc.

In an exemplary embodiment, the sensor module is configured to hold a temperature sensor adjacent to each electrical conductor and an additional sensor type can be disposed within the electrical coupler device to monitor a second in-service characteristic of the cable joint. The additional sensor type used to monitor the second in-service characteristic of the cable joint can
5 comprise at least one of a current sensor, a voltage sensor, a phase detector, etc.

Current measurement can be made by placing a Rogowsky coil put around of the electrical conductors. The Rogowsky coil can be connected to the sensor electronics in the sensor module. Voltage can be measured using a capacitive voltage divider that is connected to the sensor electronics in the sensor module or a voltage indicator detector. In the voltage sensor,
10 the Voltage is reduced through a multi-step capacitive divider, where the output voltage, V_{out} , is proportional to input voltage, V_{in} , ($4.200 V_{rms}$) and is processed by the sensor electronics. An exemplary voltage indicator detector is described in PCT Publication No. WO 2019/003073, which is herein incorporated by reference.

To facilitate assembly into the electrical coupler, the sensor module 150 can be formed of
15 an inner part 150a and an outer part 150b. The inner part comprises a portion of the base containing the recess 152 for the sensor electronics and inner sidewall portions 163a of the hollow legs 161. The outer part comprises a circumferential receiving portion configured to receive the inner part when it is inserted into the outer part. The inner sidewall portions 163a and outer sidewall portions 163b form the hollow legs 161 when the inner part is inserted into the
20 outer part as shown in Figs. 4A and 4B. The inner part can be secured to the outer part by mechanical fasteners, an interference fit, an adhesive or by welding.

In some embodiments, a cover 158 can be secured over recess 152 of the sensor module to protect the sensor electronics disposed therein. Where additional protection of the sensor electronics is desired, the sensor electronics can be submerged in a potting material. Exemplary
25 potting materials can include a conventional urethane based potting material, epoxy based potting material or other potting material commonly used in the electronics industry.

As mentioned previously, the sensor electronics 185 disposed in the sensor module may contain a wireless communication unit configured to transmit the in-service characteristic data to a remote device disposed at a safe distance (such as is indicated by the dashed ring in Fig. 1)
30 from the mining coupler device. In particular, the remote device is configured to receive the in-service characteristic data, such as conductor temperature data. The remote device comprises a receiver for receiving the data and a display screen to show the data to a user, such as a maintenance worker. In an exemplary aspect, the remote device is configured to receive the

conductor temperature data at a range of between, for example, about 2 meters to about 10 meters from the electrical coupling device 100.

Monitoring the in-service characteristics at a cable joint can assist in anticipating future events which could cause fault resulting in a shutdown of power to a piece of electrical equipment. This in turn can cause an undesirable decrease in productivity. Faults can be caused by a catastrophic failure at a point along the distribution line due to wear and tear on an element in the distribution line or age. Monitoring at least one in-service characteristic of the distribution line can help maintenance workers anticipate future faults.

In an exemplary embodiment, an electrical coupler device can comprise a plurality of temperature sensors to monitor the service temperature of each electrical conductor to determine if fault conditions are occurring. Each temperature sensor is disposed adjacent to one of the plurality of electrical conductors in the power cable. If the service temperatures of the electrical conductors are close to one another, then no fault is determined. If one of the service temperature in one of the electrical cables varies from the service temperature in the remaining electrical conductors, then a fault can be anticipated. Being able to anticipate a failure rather than reacting to a fault that has already happened allows the maintenance team to get necessary repair materials and resources in place prior to failure, thus minimizing any down time of the electrical equipment connected to the distribution line. The maximum working temperature of typical electrical cables may be around 90°C.

The materials used to form the front portion 130, the main body 110, and the cable clamp 125 are not limited to any particular material or materials. In some examples of electrical coupler device 100, one or more of the front portion 130, the main body 110, and/or the cable clamp 125 are formed, in whole or in part, of a metal or metallic material, such as cast aluminum. In some examples of electrical coupler device 100, one or more of the front portion 130, the main body 110, and/or the cable clamp 125 are formed, in whole or in part, of plastic or resin material, such as polyurethane or epoxy. The coupling of the front portion 130, the main body 110, and/or the cable clamp 125 together to form the electrical coupler device 100 as shown in Fig. 2A is not limited to use of any particular devices or fastening techniques. In some examples, one or more parts of the electrical coupler device 100 including the front portion 130, the main body 110, and the cable clamp 125 can be coupled using fasteners, such as threaded machine screws or by using nuts and bolt type fasteners. In some examples, one or more parts of the electrical coupler device 100 including the front portion 130, the main body 110, and the cable clamp 125 can be coupled together using an adhesive, such as an epoxy cement, or for

example, by some form of coupling using a welding technique suitable to bond together the types of material used to form the parts of the electrical coupler that are to be joined together.

Various modifications, equivalent processes, as well as numerous structures to which the present invention can be applicable will be readily apparent to those of skill in the art to which

5 the present invention is directed upon review of the present specification.

What is Claimed is:

1. An electrical coupler device for making a cable joint and connecting a plurality of electrical conductors in a power cable, the electrical coupler device comprising:

5 a main body and a front portion mechanically coupled to the main body, the electrical coupler device configured to terminate the plurality of electrical conductors that are configured to carry electrical power;

10 a temperature sensor disposed adjacent to each of the plurality of electrical conductors, wherein each temperature sensor monitors a service temperature for one of the plurality of conductors, further comprising a sensor module to position the temperature sensors adjacent to each of the plurality of electrical conductors; and

a communication module configured to send conductor temperature data to a remote device wirelessly.

2. The device of claim 1, further comprising a terminal attached to the end of each of the plurality of electrical conductors and held in the front portion of the electrical coupler device.

15 3. The device of claim 1, wherein the sensor module comprises a base and a plurality of hollow legs extending from the base, wherein one of the plurality of electrical conductors extends at least partially into each of the plurality of hollow legs.

20 4. The device of claim 3, wherein each of the plurality of hollow legs further comprises a sidewall having a closed bottom bore formed longitudinally in the side wall to accommodate the sensor that monitors an in-service characteristic of the electrical conductor disposed in the conduit portion of the sensor module.

5. The device of claim 3, wherein the base of the sensor module comprises a recess to house sensor electronics that are connected to the sensor associated with each of the electrical conductors.

25 6. The device of claim 5, wherein the sensor electronics comprise a printed circuit board having a plurality of sensor connections, a data collection unit to collect the data relating to the in-service characteristic and the communications module to wirelessly transmit the data to a remote device.

7. The device of either claims 5 and 6, wherein the sensor electronics further comprise a geolocation module to tag the location of the electrical coupler device.

8. The device of any of the preceding claims, further comprising an additional sensor type to monitor a second in-service characteristic of the cable joint.

5 9. A temperature monitoring system for monitoring the temperature of electrical conductors in a power cable, the monitoring system comprising:

an electrical coupler device of claim 1, further comprising a sensor module to position the temperature sensors adjacent to each of the plurality of electrical conductors; and

10 a remote device configured to receive the conductor temperature data, the remote device comprising a display screen to display the temperature data of each conductor to a user, wherein the remote device is configured to receive the conductor temperature data at a range of between about 2 meters to about 10 meters.

15 10. The system of claim 9, wherein the sensor module comprises a base and a plurality of hollow legs extending from the base, wherein one of the plurality of electrical conductors extends at least partially into each of the plurality of hollow legs.

11. The system of claim 10, wherein each of the plurality of hollow legs further comprises a sidewall having a closed bottom bore formed longitudinally in the side wall to accommodate the sensor that monitors an in-service characteristic of the electrical conductor disposed in the conduit portion of the sensor module.

20 12. The system of claim 10, wherein the base of the sensor module comprises a recess to house sensor electronics that are connected to the sensor associated with each of the electrical conductors, wherein the sensor electronics comprise a printed circuit board having a plurality of sensor connections, a data collection unit to collect the data relating to the in-service characteristic and the communications module to wirelessly transmit the data to a remote device.

25 13. The system of claim 12, wherein the sensor electronics further comprise a geolocation module to tag the location of the electrical coupler device.

14. The system of any of claims 9-13, further comprising an additional sensor type to monitor a second in-service characteristic of the cable joint.

14. A electrical coupler device for connecting a plurality of electrical conductors in an power cable, the electrical coupler device comprising:

a main body and a front portion mechanically coupled to the main body, the electrical coupler device configured to terminate the plurality of electrical conductors configured to carry electrical power;

a sensor module disposed within the main body wherein the sensor module is configured to position a sensor adjacent to each of the plurality of electrical conductors such that the sensor monitors an in-service characteristic of one of the plurality of conductors; and

a communication module configured to send data relating to the in-service characteristic to a remote device wirelessly.

15. The device of claim 14, wherein the sensor module comprises a base and a plurality of hollow legs extending from the base, wherein one of the plurality of electrical conductors extends at least partially into each of the plurality of hollow legs, wherein each of the plurality of hollow legs has a conduit portion surrounded by a side wall and is configured to hold a terminal attached to the one of the plurality of electrical conductors disposed within the conduit portion.

16. The device of claim 15, wherein each of the plurality of hollow legs further comprises a closed bottom bore formed longitudinally into the side wall of the hollow leg to accommodate the sensor that monitors an in-service characteristic of the electrical conductor disposed in the conduit portion of the sensor module, wherein the sensor disposed in each of the closed bottom bores is a temperature sensor.

17. The device of any of claims 15 and 16, wherein the base of the sensor module comprises a recess to house sensor electronics that are connected to the sensors disposed in the sensor module, wherein the sensor electronics comprise a printed circuit board having a plurality of sensor connections, a data collection unit to collect the data relating to the in-service characteristic and the communications module to wirelessly transmit the data to a remote device.

18. A method of evaluating an in-service characteristic of a cable joint, comprising:
measuring the in-service characteristic of each electrical conductor in a power cable;
transmitting data related to the in-service characteristic to a remote device disposed at a distance of between 2 m and 10 m from the cable joint;
displaying the data on a display on the remote device; and

comparing the in-service characteristic data from the plurality of electrical conductors to predict a future fault in the cable joint.

19. The method of claim 18, further comprising submitting a work order to repair or replace a cable joint when the future fault is predicted.

5 20. The method of either of claims 18 and 19, wherein the in-service characteristic data being monitored is the temperature of the electrical conductors.

21. The method of claim 20, wherein the future fault is indicated by a first service temperature in one of the plurality of electrical conductors that is significantly different than the service temperatures in the remaining electrical conductors.

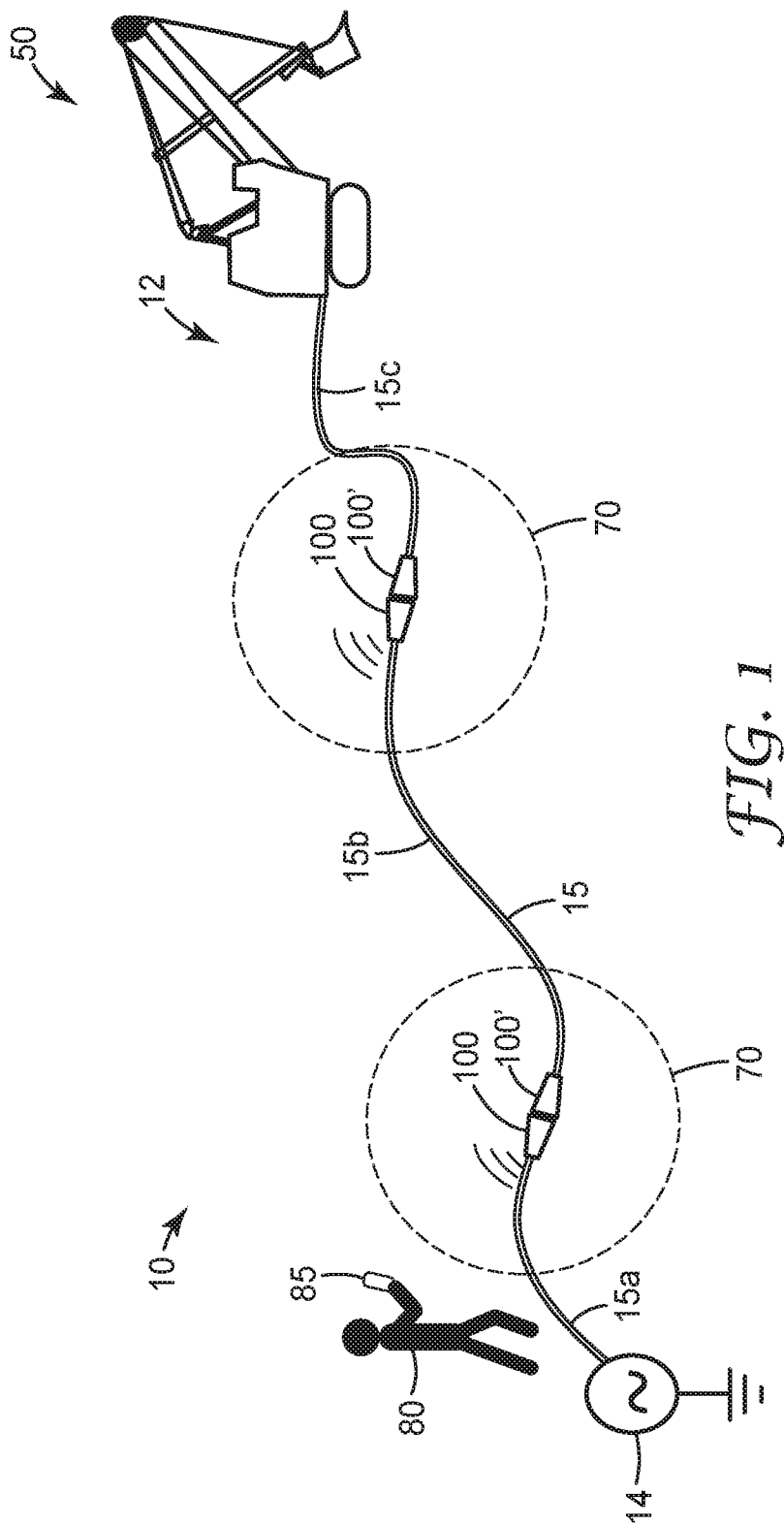


FIG. 1

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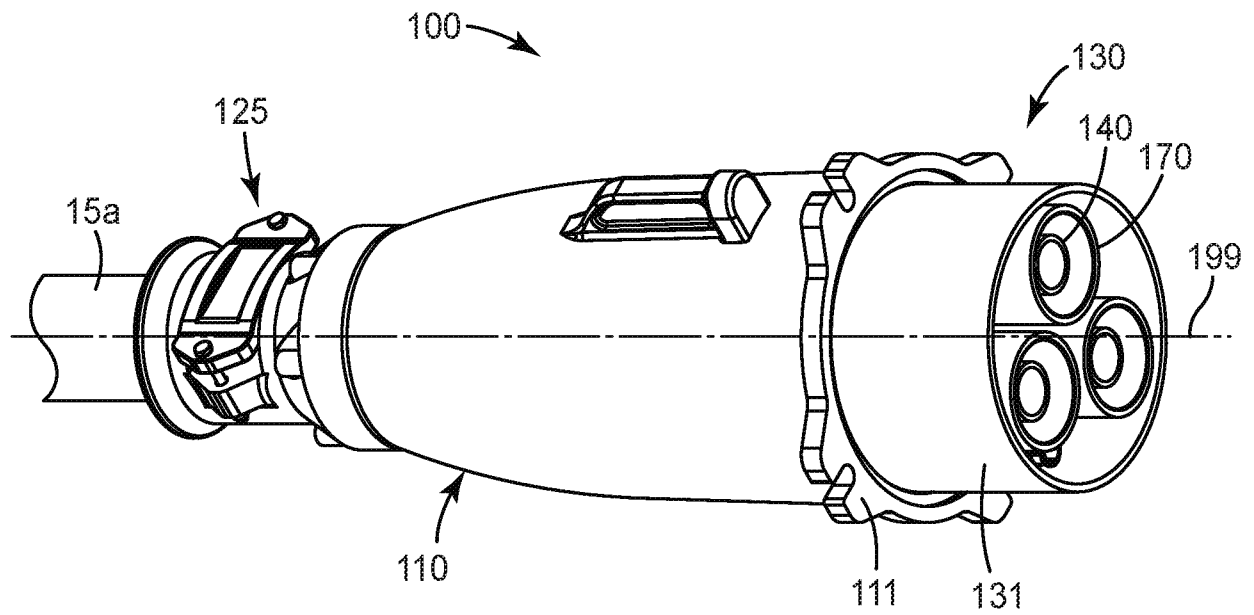


FIG. 2A

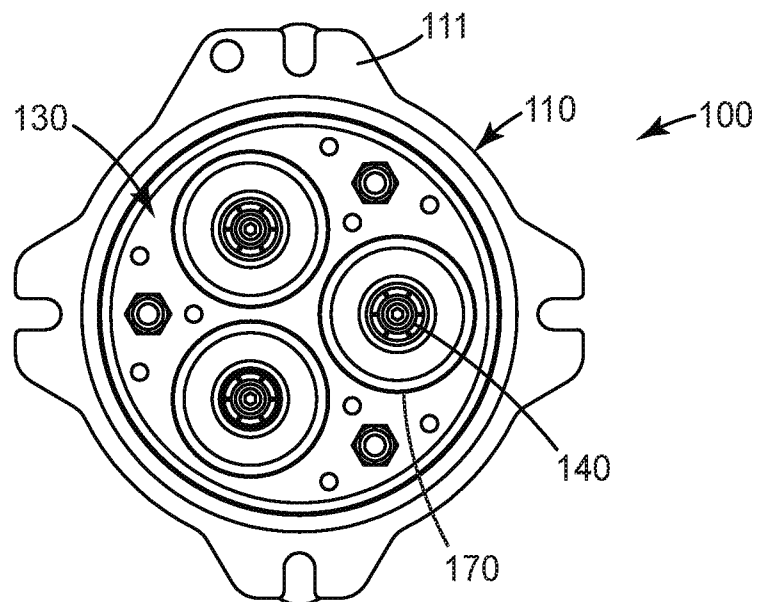


FIG. 2B

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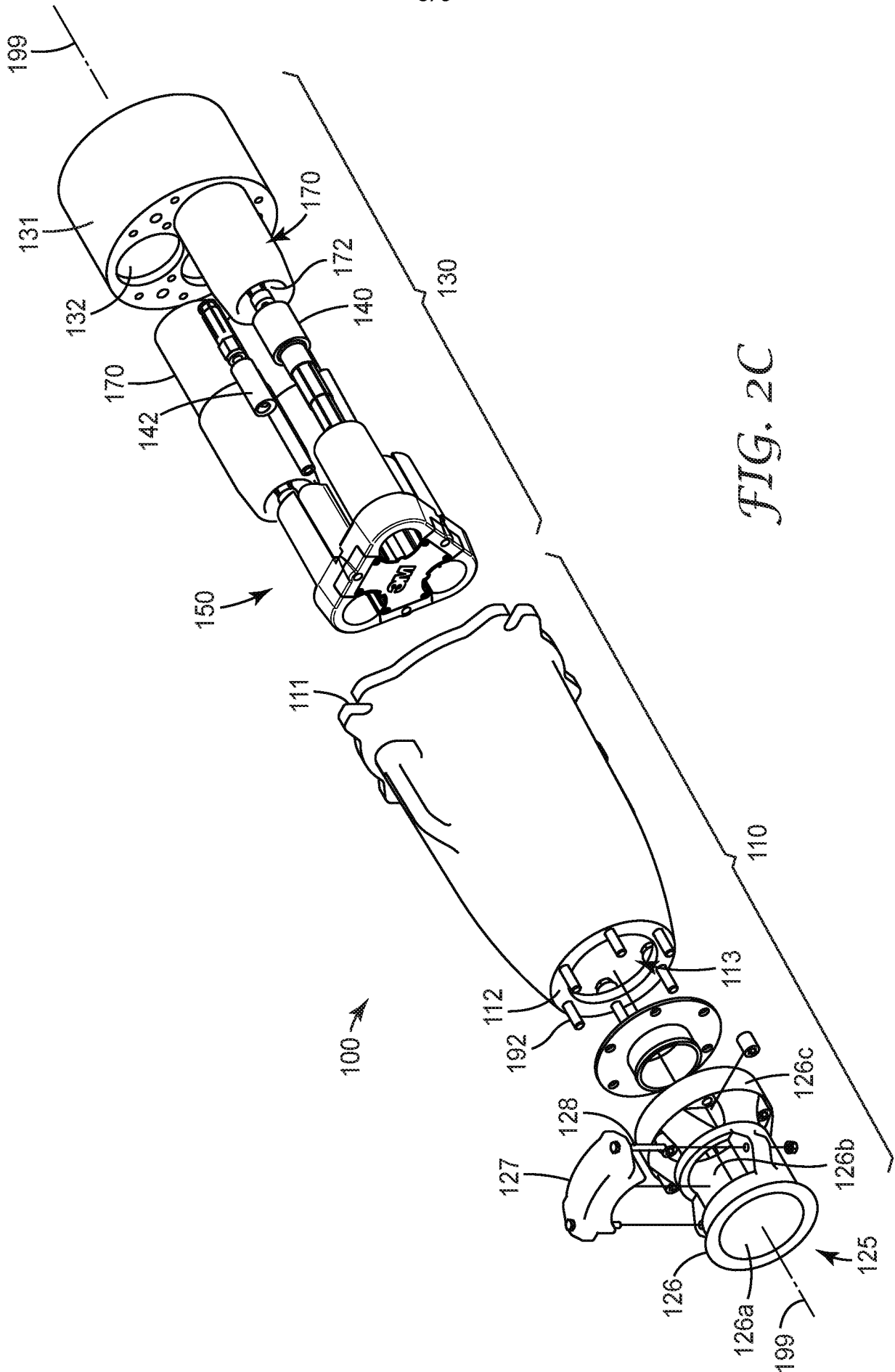


FIG. 2C

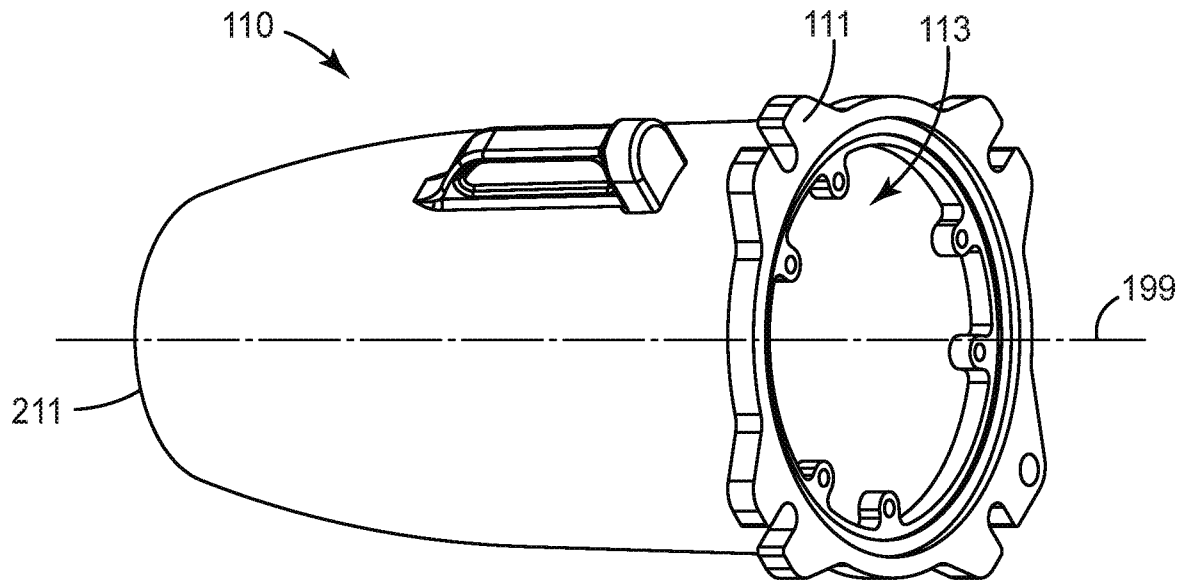
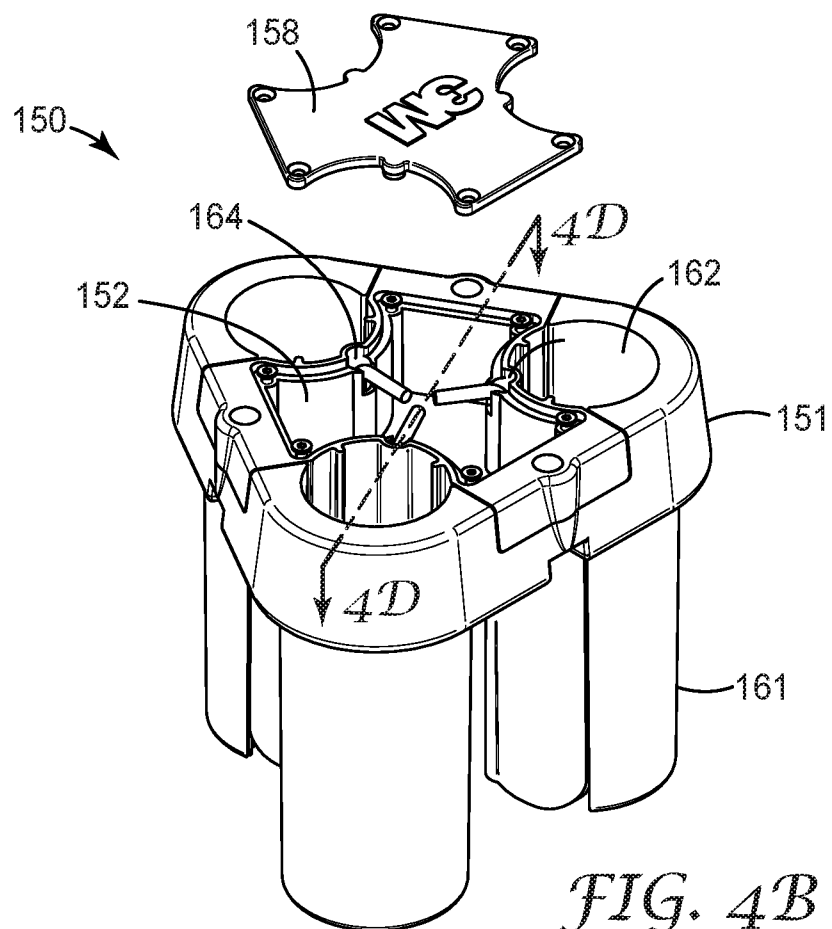
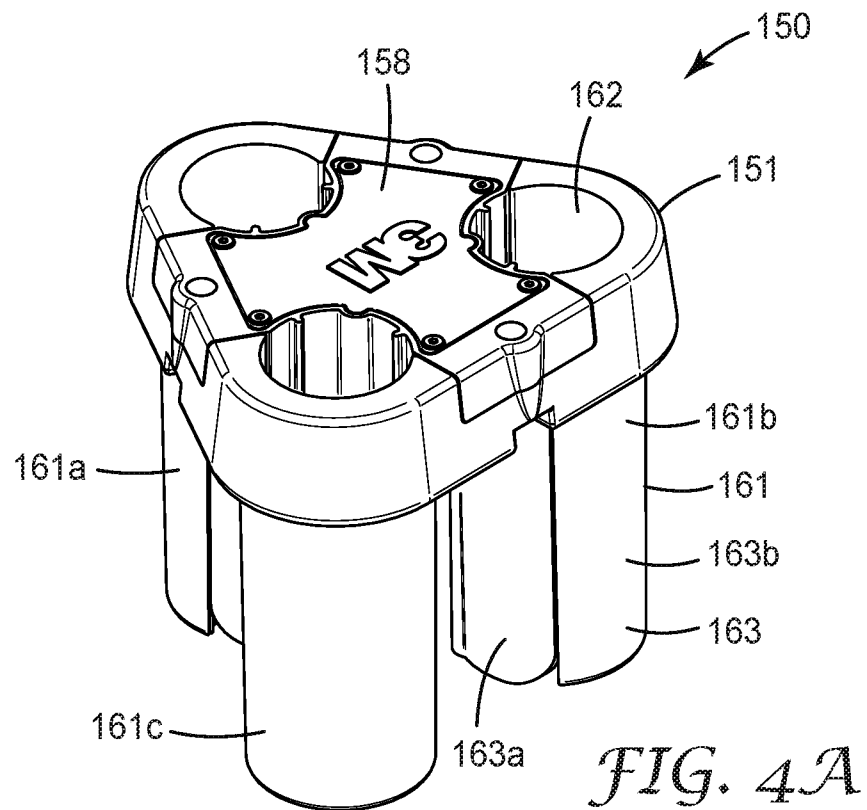


FIG. 3



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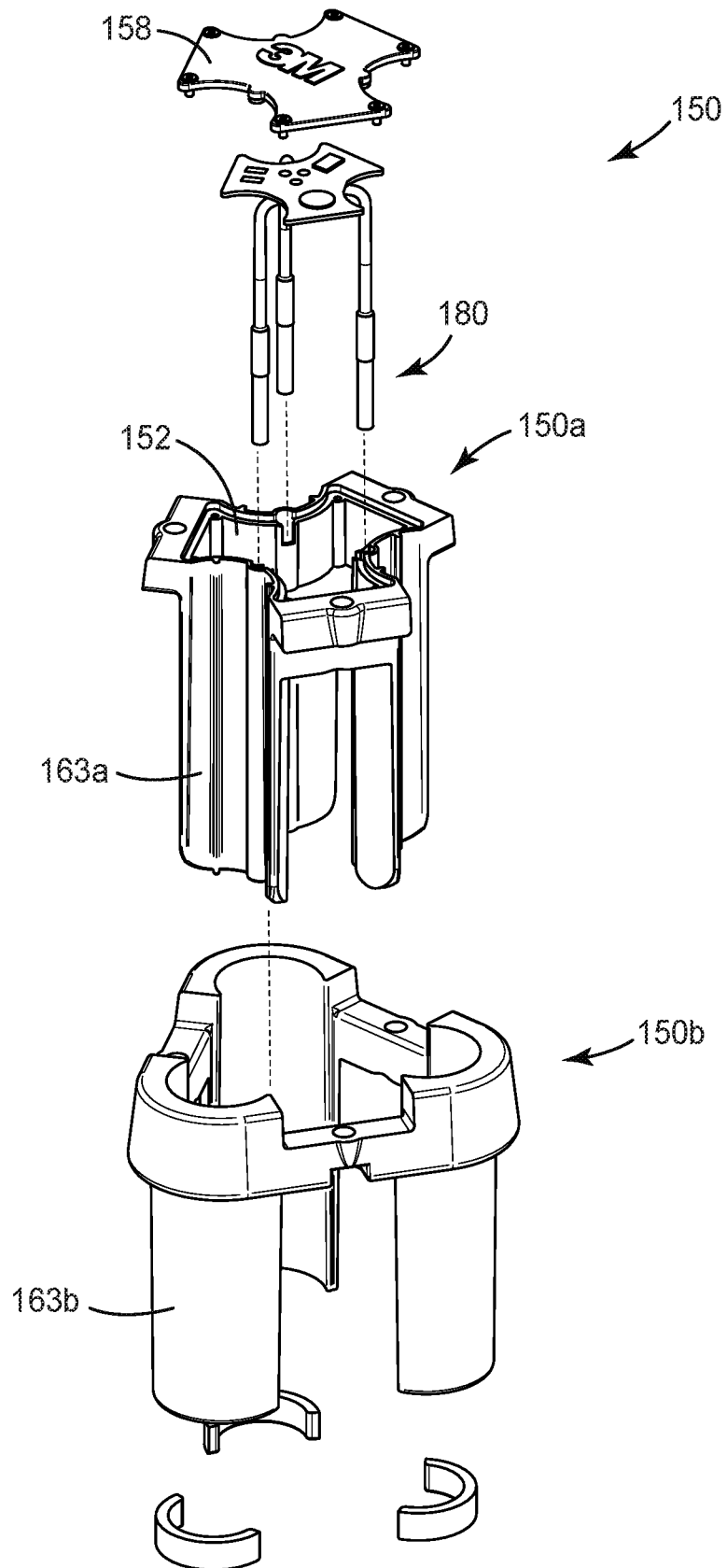


FIG. 4C

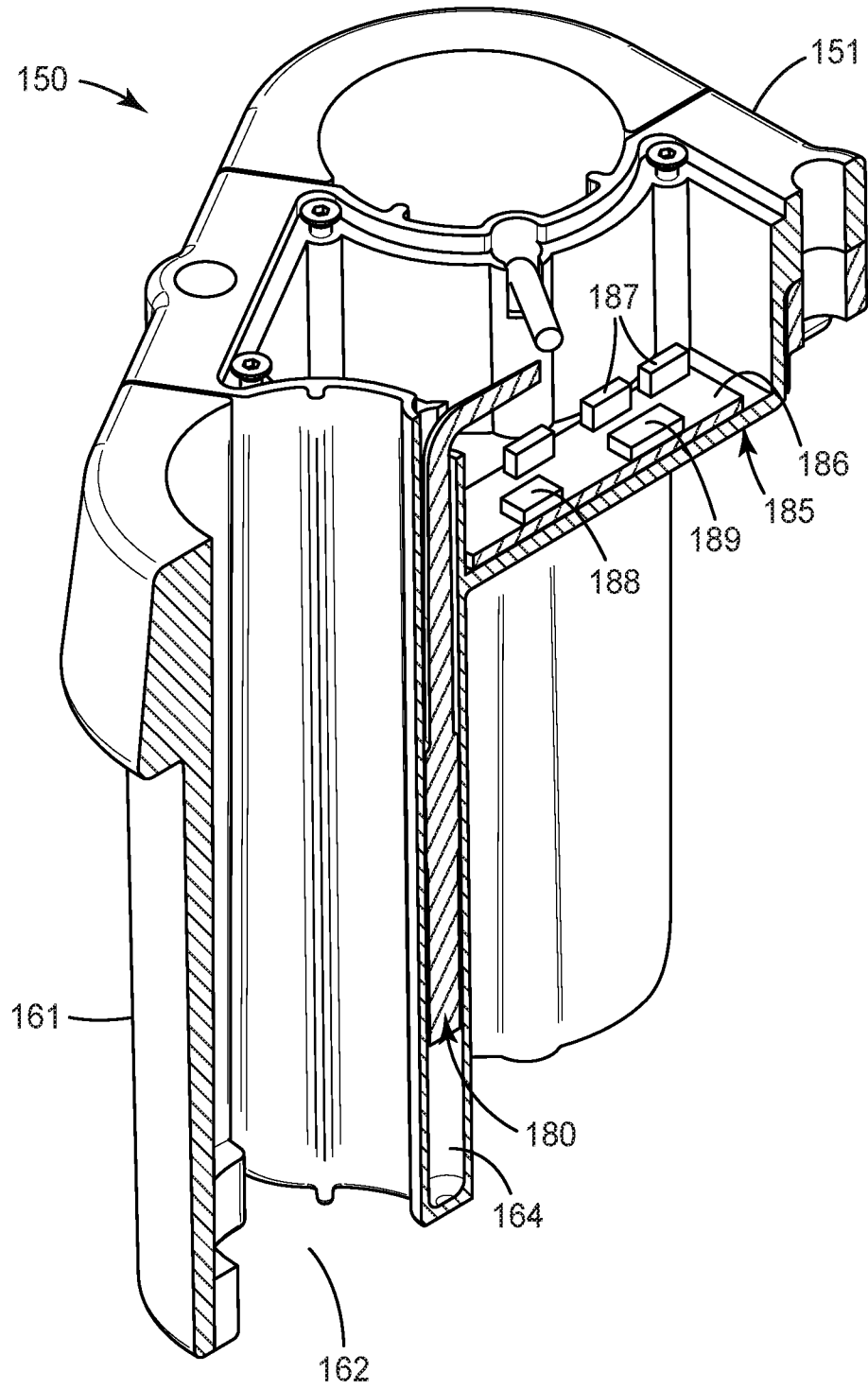


FIG. 4D

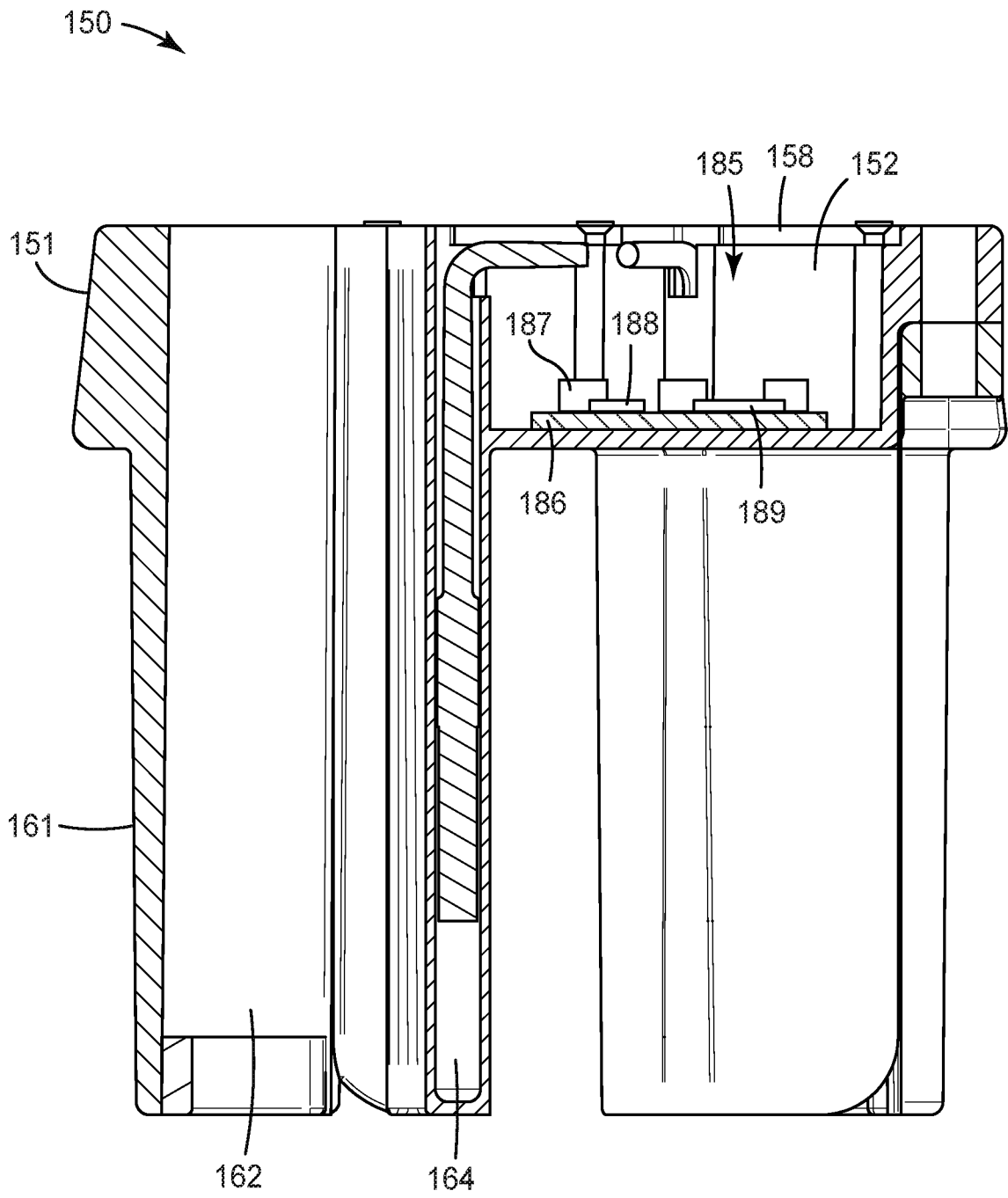


FIG. 4E

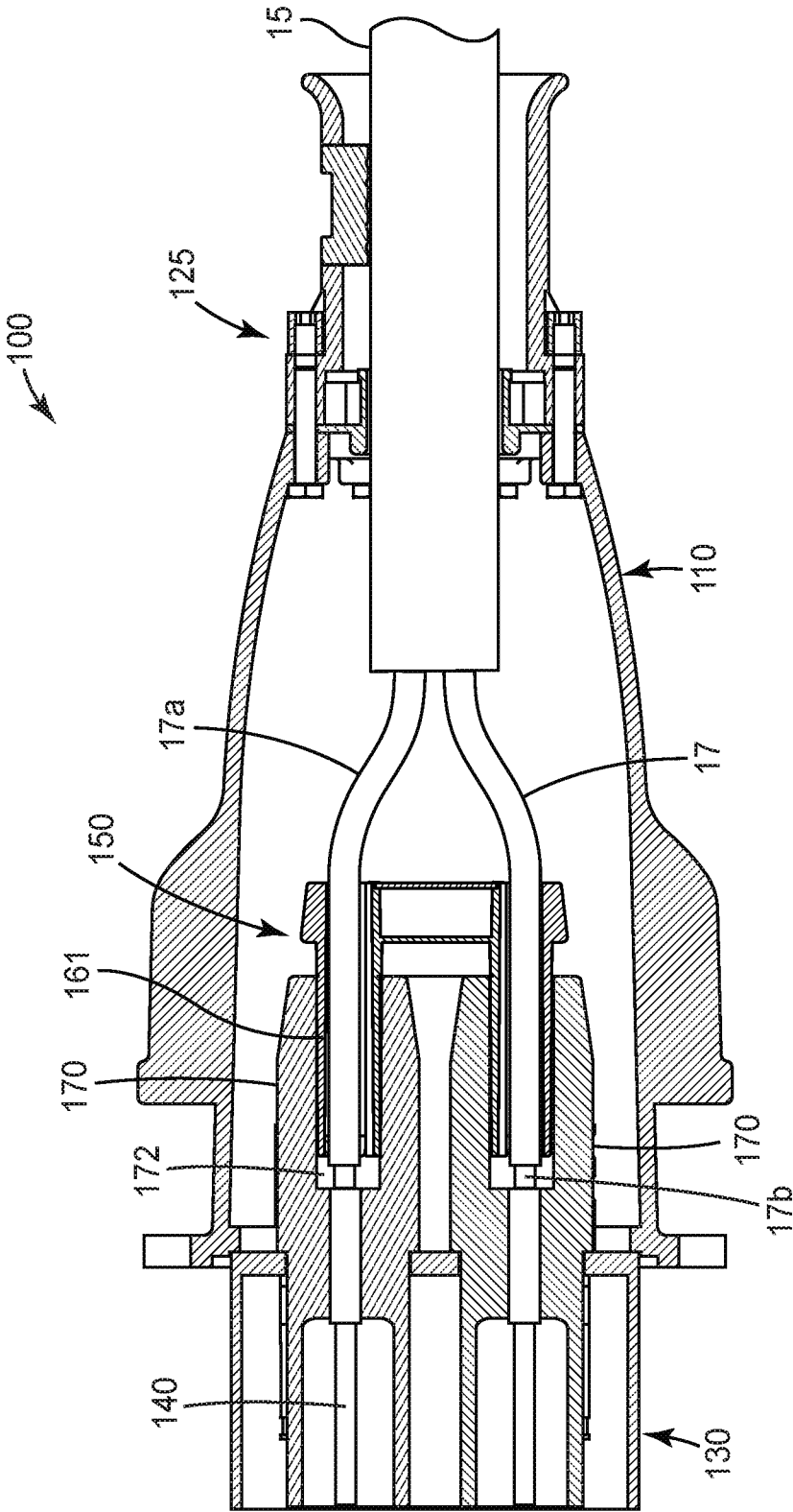


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2019/056030

A. CLASSIFICATION OF SUBJECT MATTER

H01R 24/00 (2011.01) H01R 13/66 (2006.01) G01K 1/02 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: PATENW (EPODOC, WPIAP, TXTE), Google, Google Patents with classification marks (H01R 13/426; H01R 13/66; H01R 13/665; H01R 13/6658; H01R 13/6683; H01R 13/6691; H01R 24/00; H01R 24/86; G01K 1/02; G01K 1/022; G01K 1/024) and keywords (electrical; cable; coupler; temperature; sensor; fault; housing; location; adjacent; data; difference; prediction) and similar terms.

Applicant/inventor name searched in Google Patents, ESPACENET, AUPAT and Internal databases provided by IP Australia.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

☒ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"D" document cited by the applicant in the international application	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
18 November 2019

Date of mailing of the international search report
18 November 2019

Name and mailing address of the ISA/AU

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INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/IB2019/056030
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2018/0219316 A1 (YAZAKI CORPORATION) 02 August 2018 Figures 1-4, 6, 8, 13, 15; Paragraphs [0036], [0038]-[0039]	1-17
Y	US 2012/0268290 A1 (HUANG, Q et al.) 25 October 2012 Paragraphs [0047], [0049]	1-17
X	US 9751413 B2 (LSIS CO., LTD) 05 September 2017 Abstract; Col. 4 Lines 27-29; Column 9 Lines 5-10; Column 18 Lines 38-46	18-21
A	US 2018/0048090 A1 (YAZAKI CORPORATION) 15 February 2018 Figures 1-6B; Abstract; Paragraphs [0006]-[0014]	1-17
A	US 2016/0322914 A1 (RODRIGUEZ RIOS, B. et al.) 03 November 2016 Figures 4-6; Paragraphs [0097], [0120]-[0121]	1-17
A	WO 2013/096354 A1 (3M Innovative Properties Company et al.) 27 June 2013 Page 8	18-21

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Supplemental Box**Continuation of: Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-17 are directed to "an electrical coupler device for making a cable joint and connecting a plurality of electrical conductors in a power cable". The feature of "a main body, a front portion mechanically coupled to the main body, a temperature sensor, and a communication module" is specific to this group of claims.
- Claims 18-21 are directed to "a method of evaluating an in-service characteristic of a cable joint". The feature of "measuring the in-service characteristic, transmitting data related to the in-service characteristic, displaying the data, and comparing the in-service characteristic data" is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori*.

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/IB2019/056030	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.
Form PCT/ISA/210 (Family Annex)(July 2019)

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/IB2019/056030	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
		JP 6467383 B2	13 Feb 2019
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2019)			

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/IB2019/056030	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/IB2019/056030	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
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		US 9960530 B2	01 May 2018
		WO 2013096424 A1	27 Jun 2013
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2019)			