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(54) **MULTIDIRECTIONAL ELECTRICAL CONNECTOR, PLUG AND SYSTEM**

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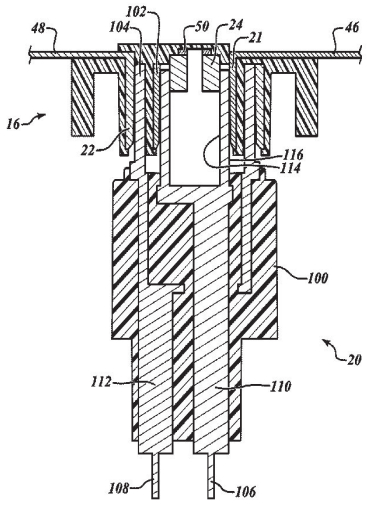
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(57) **ABSTRACT**

Multidirectional electrical connectors, electrical connector plugs and electrical connection systems for electrically connecting a portable energy storage device to an electrically powered device, such as an electric powered vehicle or a device for electrically charging the portable electrical energy storage device are described. The multidirectional feature of the electrical connectors, electrical connector plugs and electrical connections systems permits electrical connection between the electrical connectors and electrical connector plugs in a plurality of rotational orientations between a portable electrical energy storage device to which a connector or plug is electrically connected and an electrically powered device to which a corresponding plug or connector is electrically connected.

25 Claims, 27 Drawing Sheets



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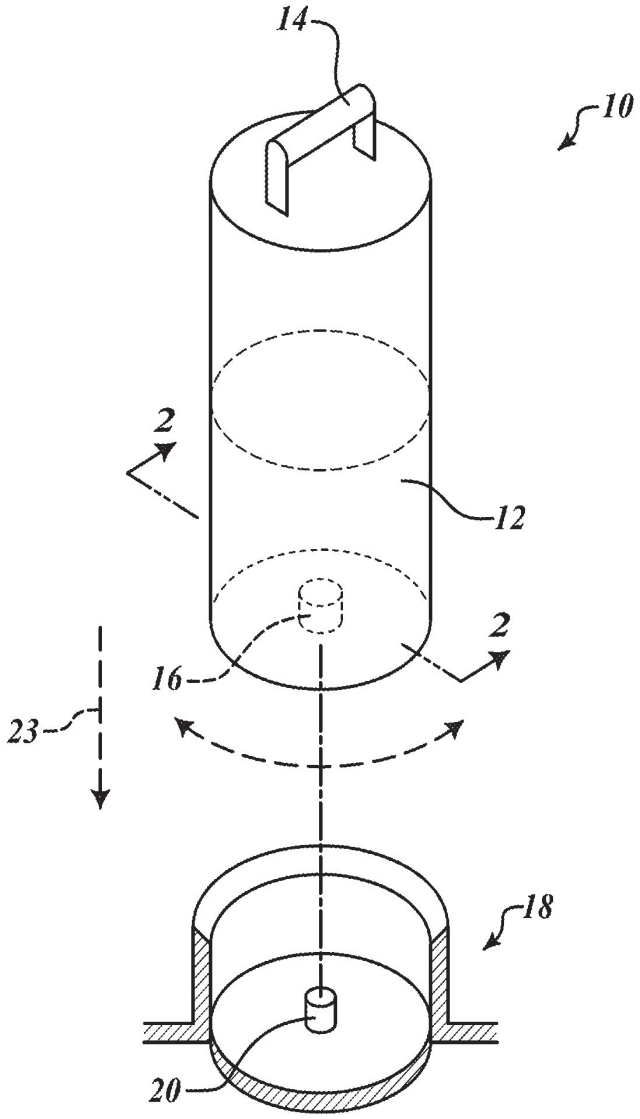


FIG. 1

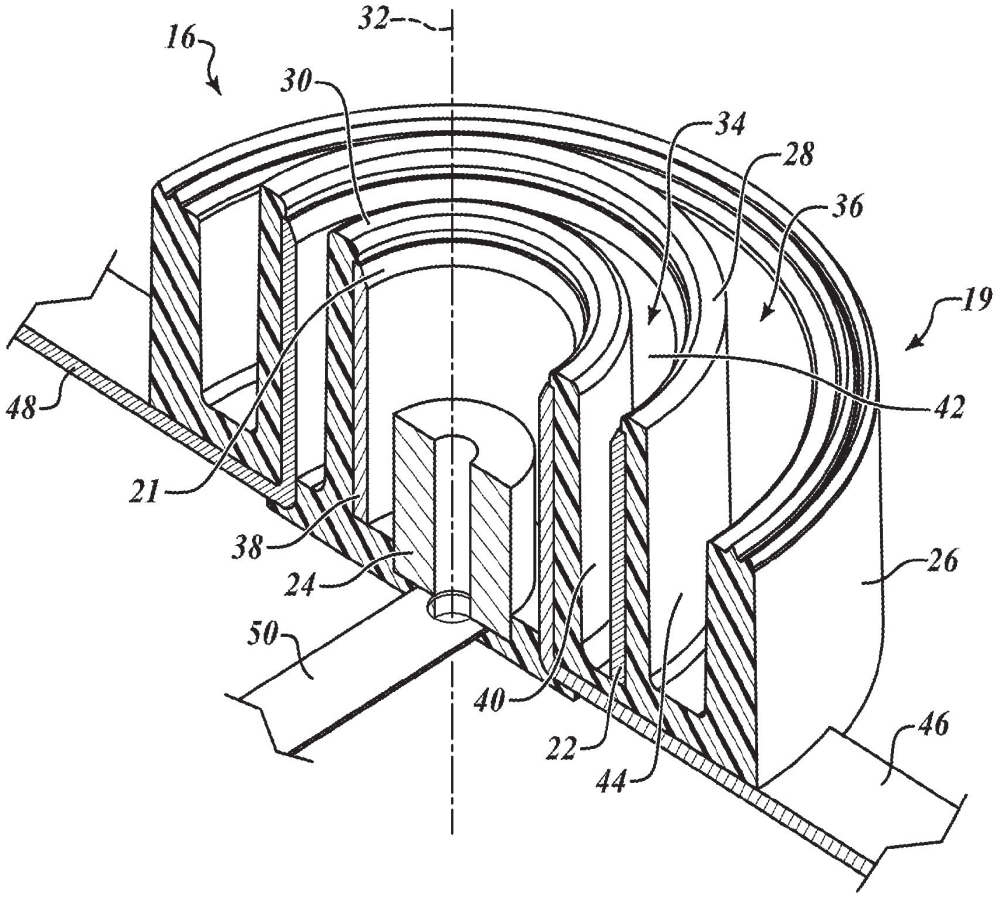


FIG.2

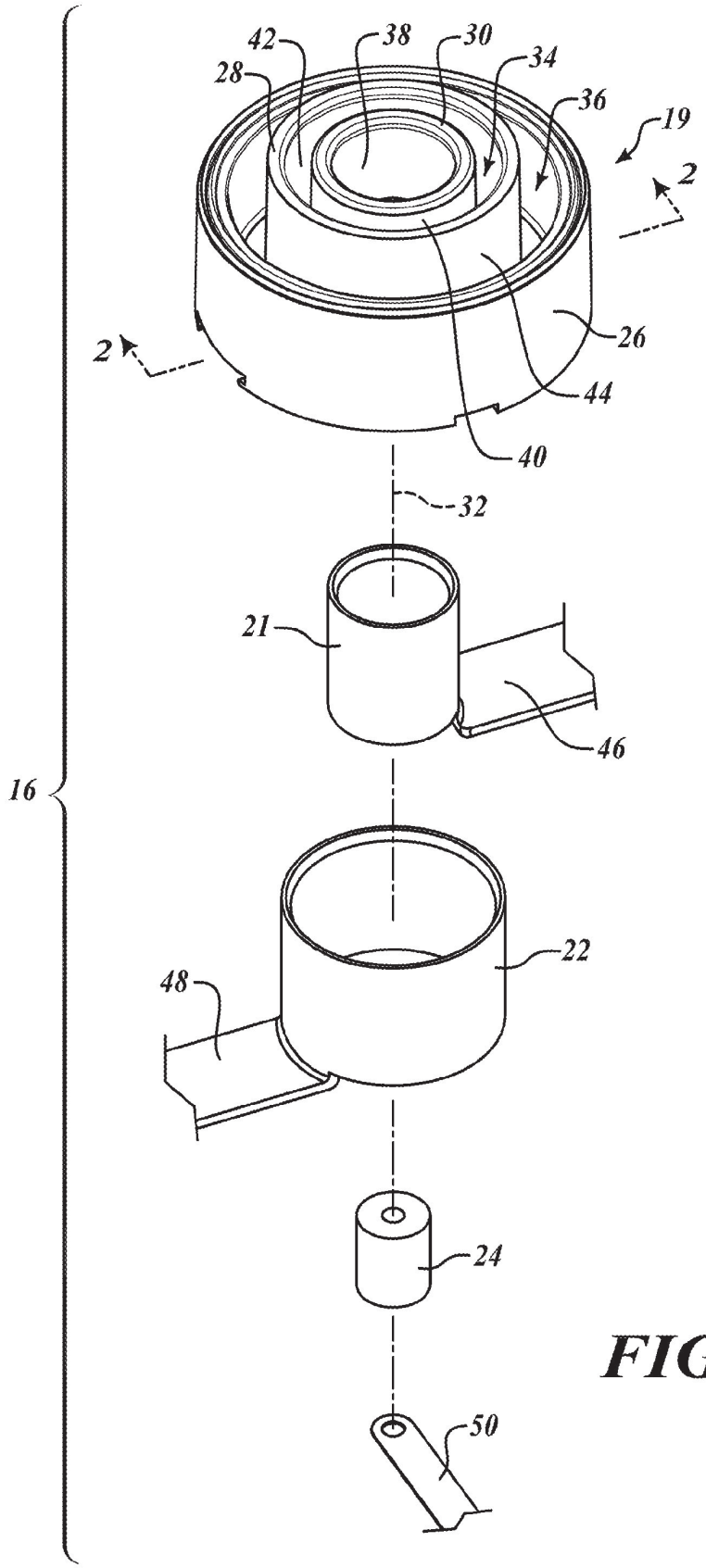


FIG.3

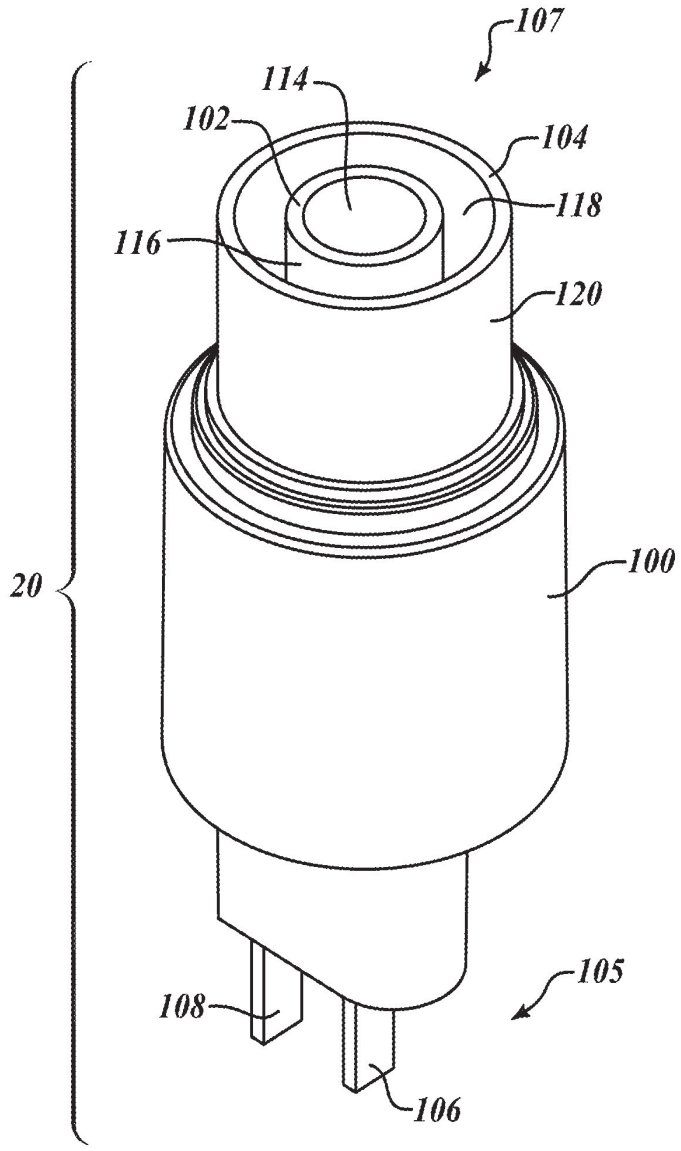


FIG.4

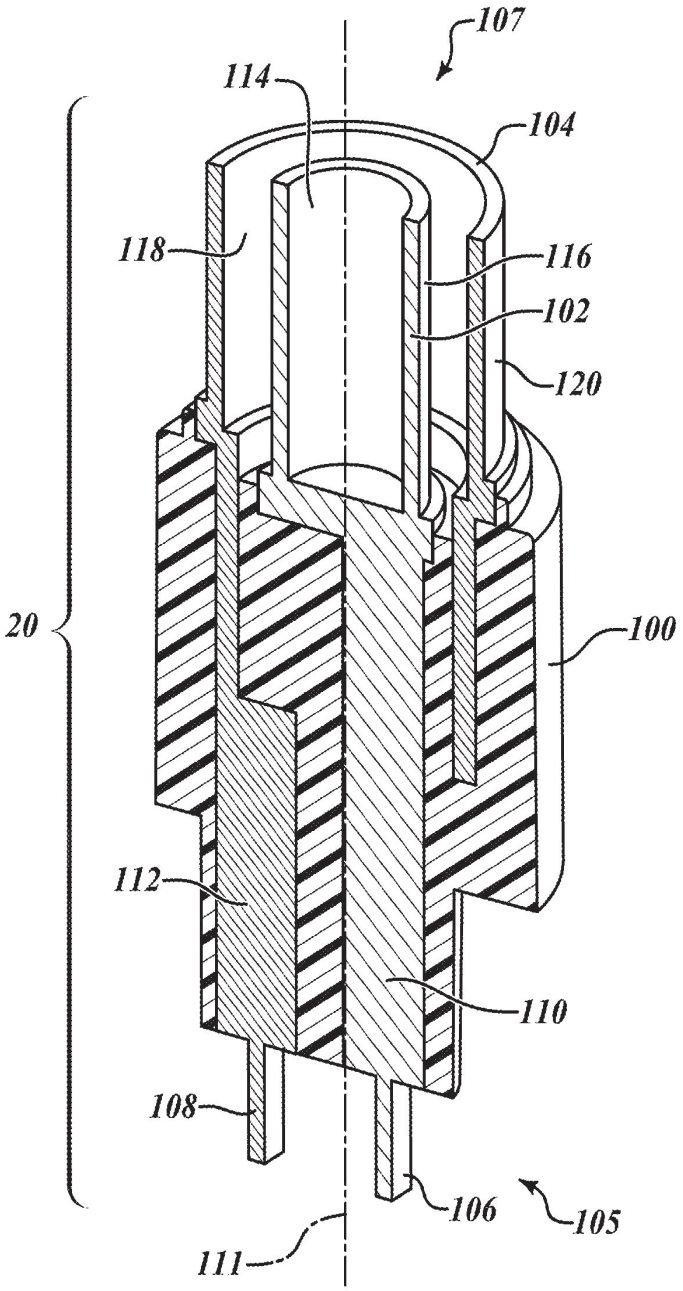


FIG.5

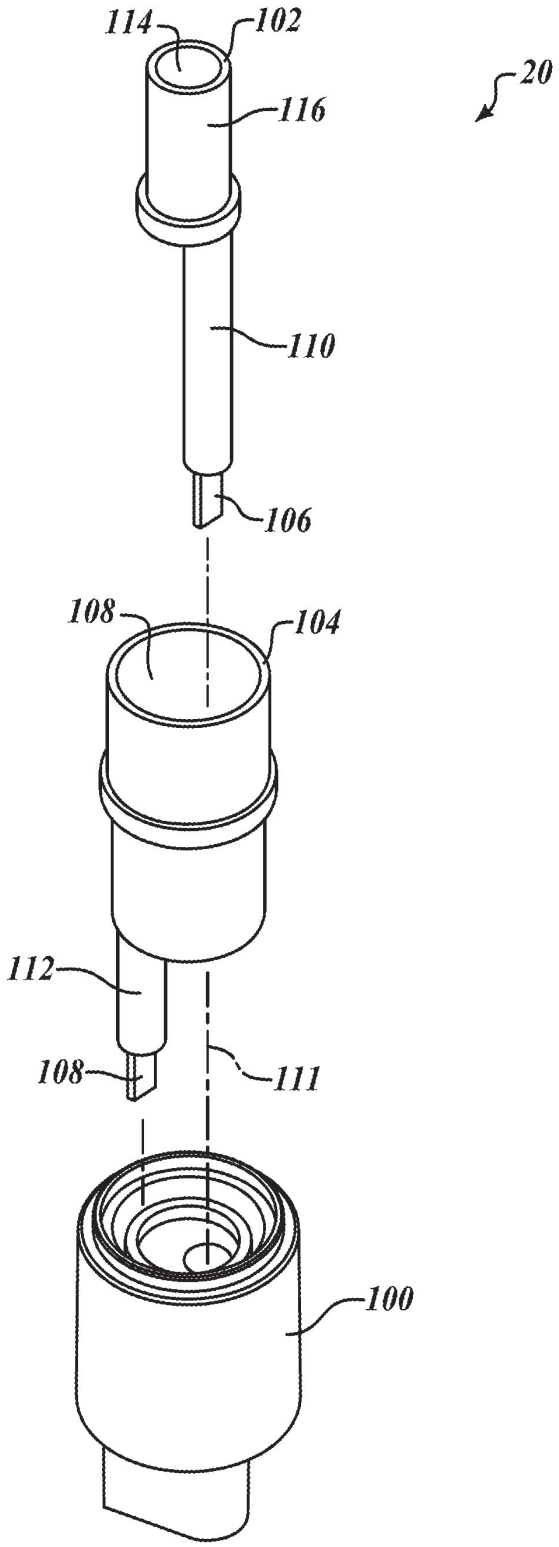


FIG. 6

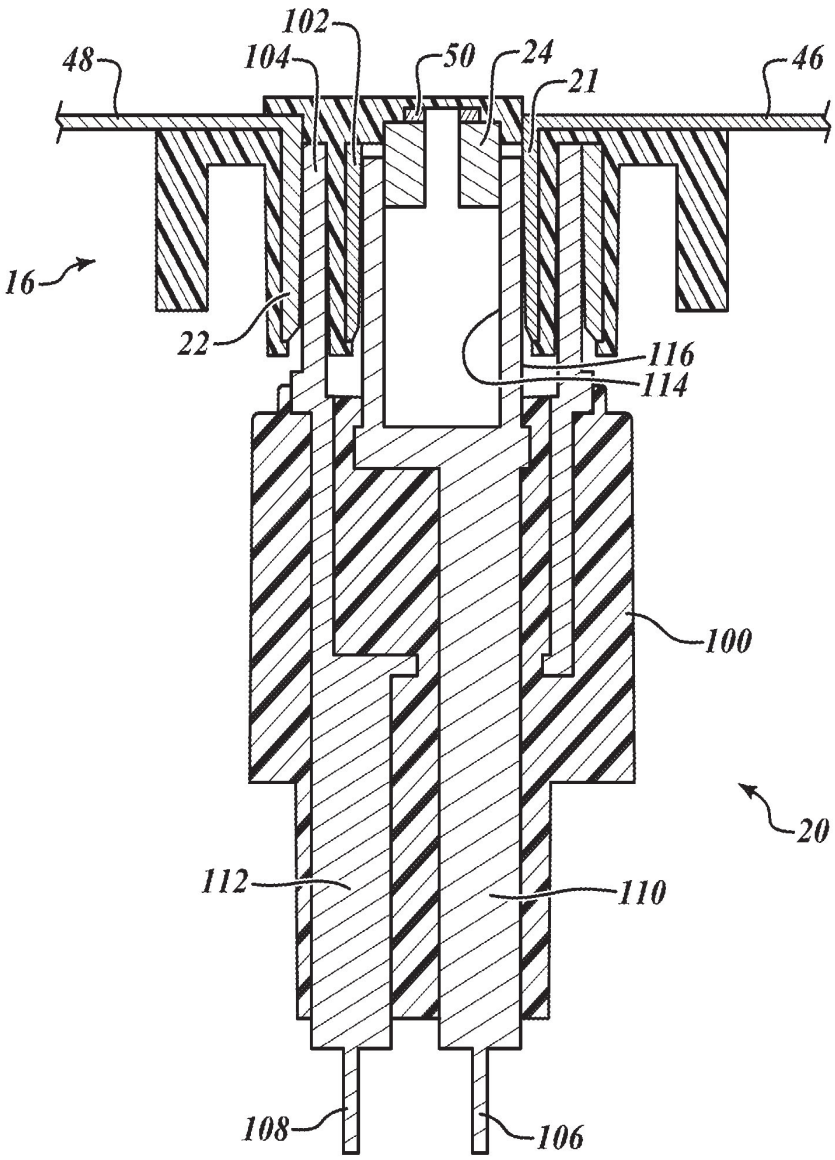


FIG. 7

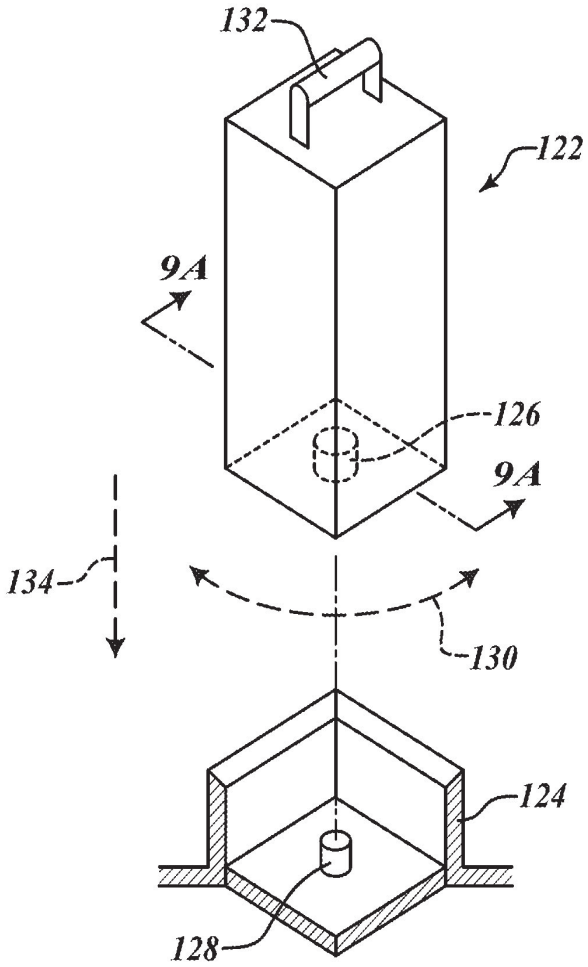


FIG.8

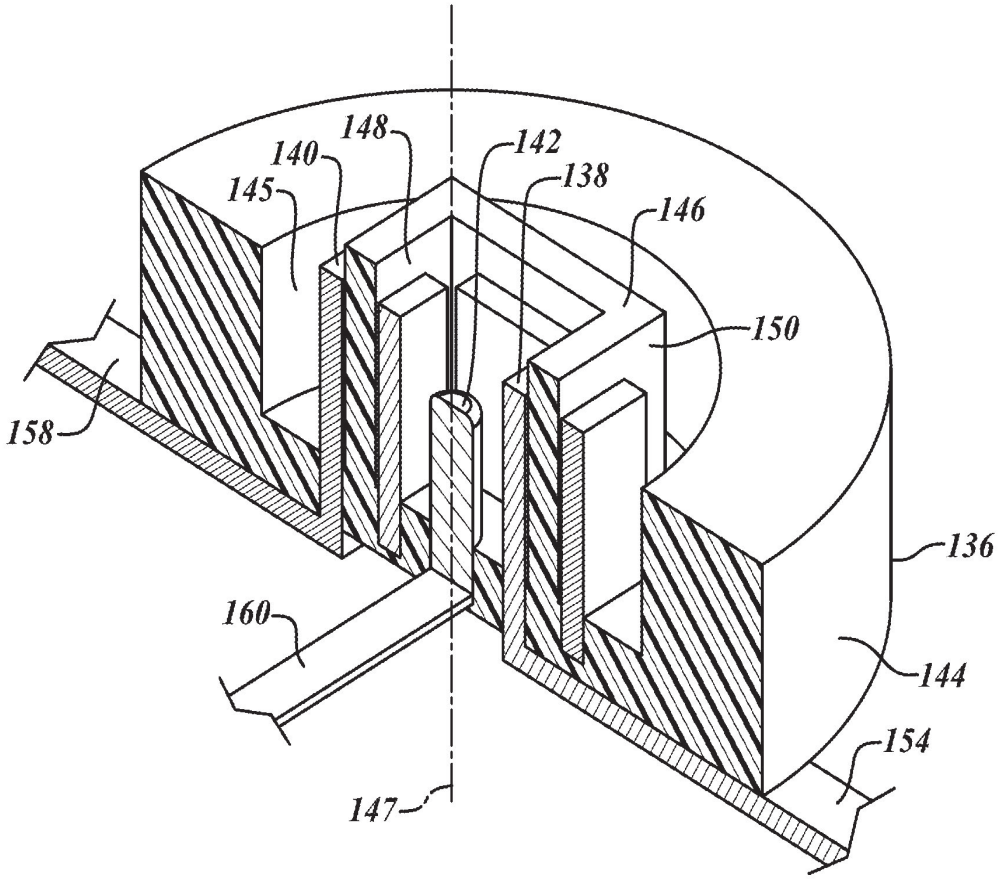


FIG.9A

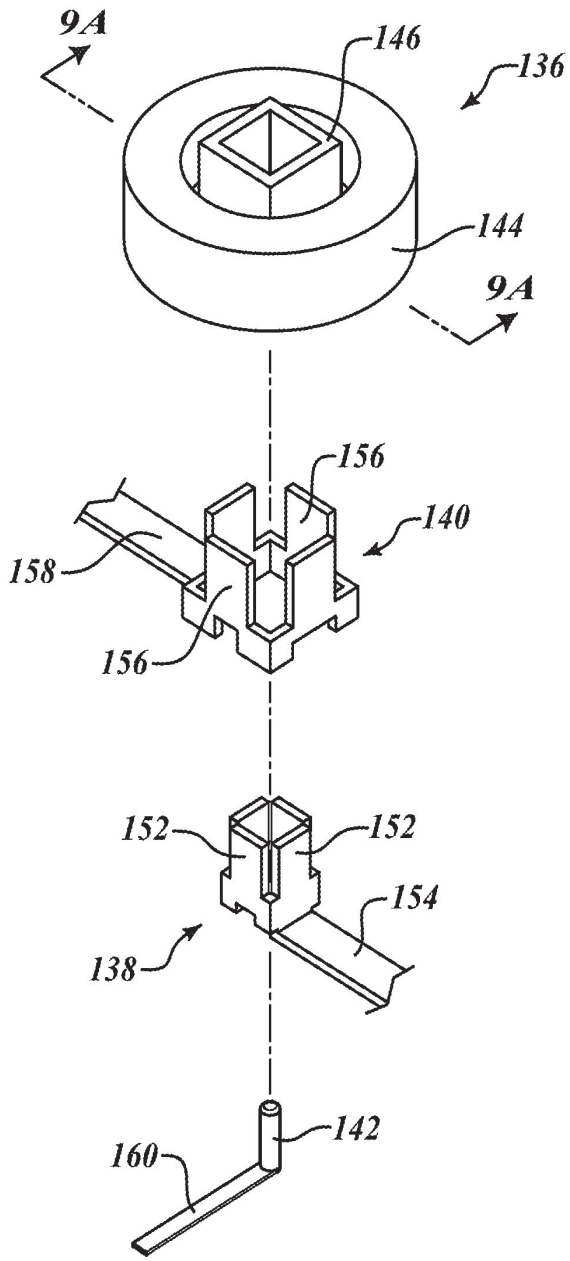


FIG.9B

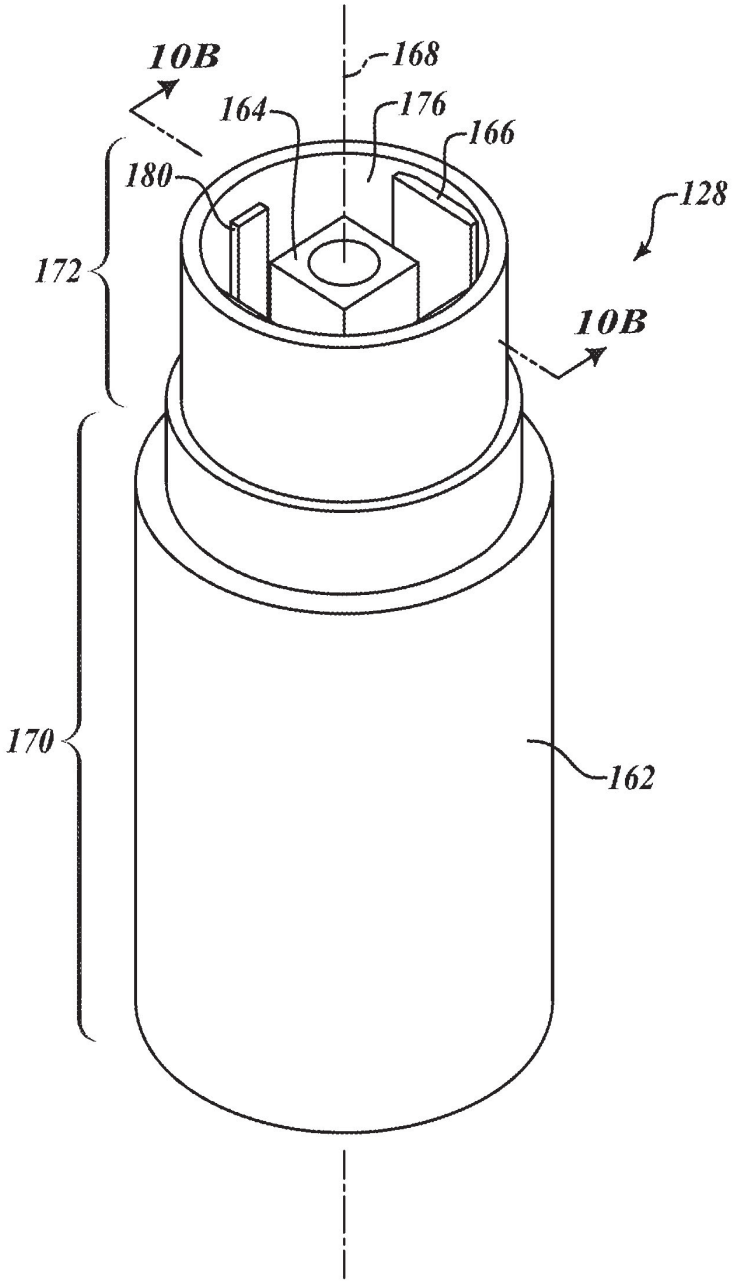


FIG.10A

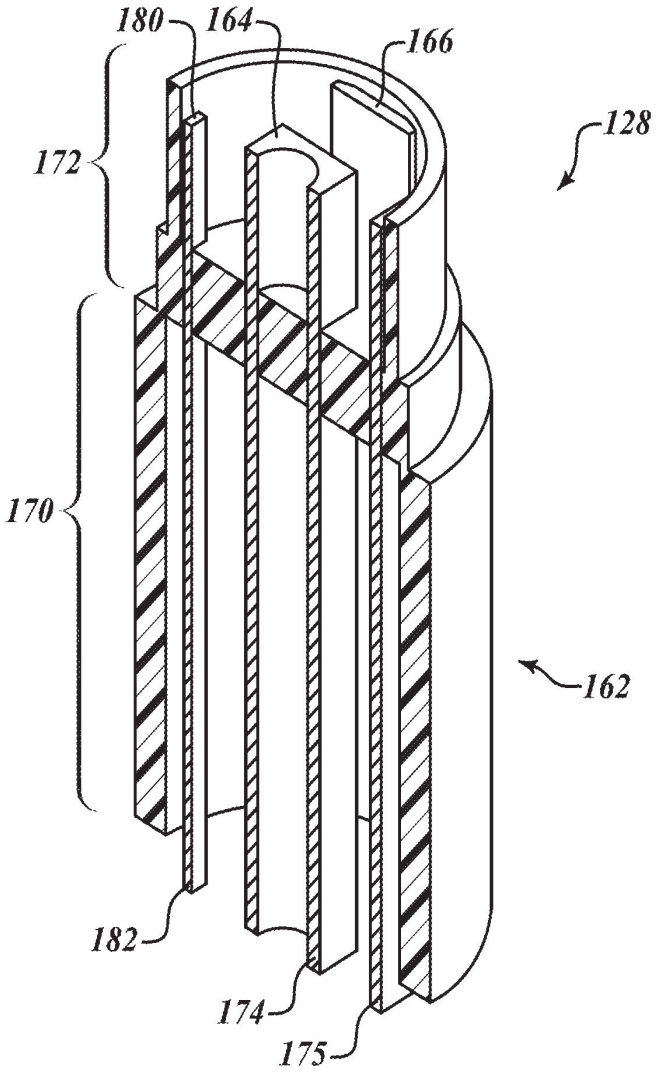


FIG.10B

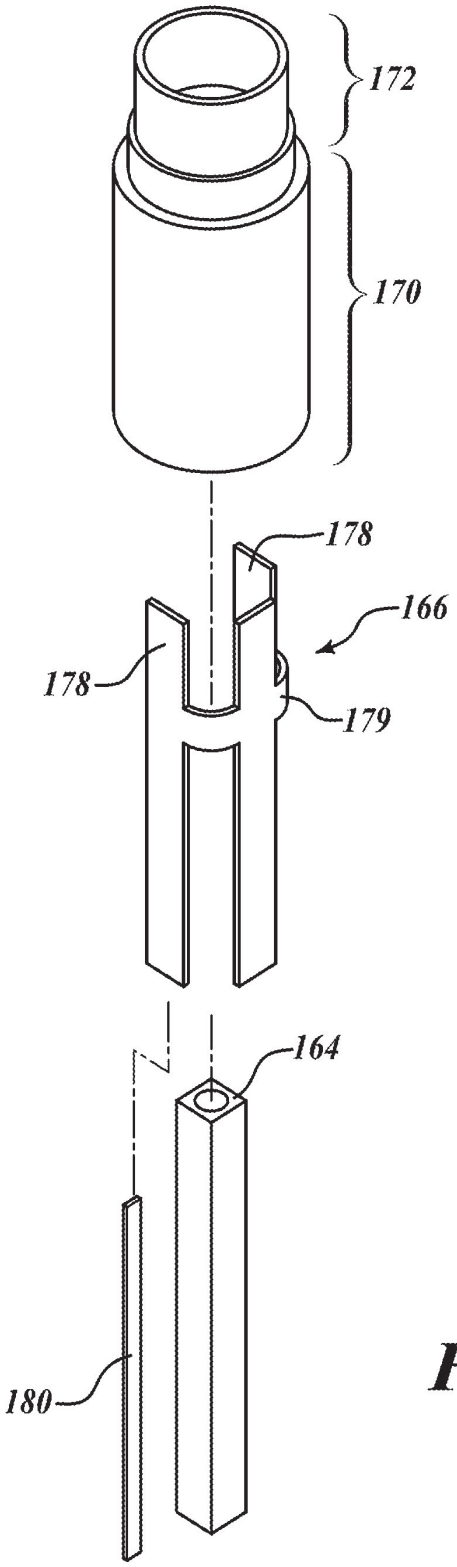


FIG.10C

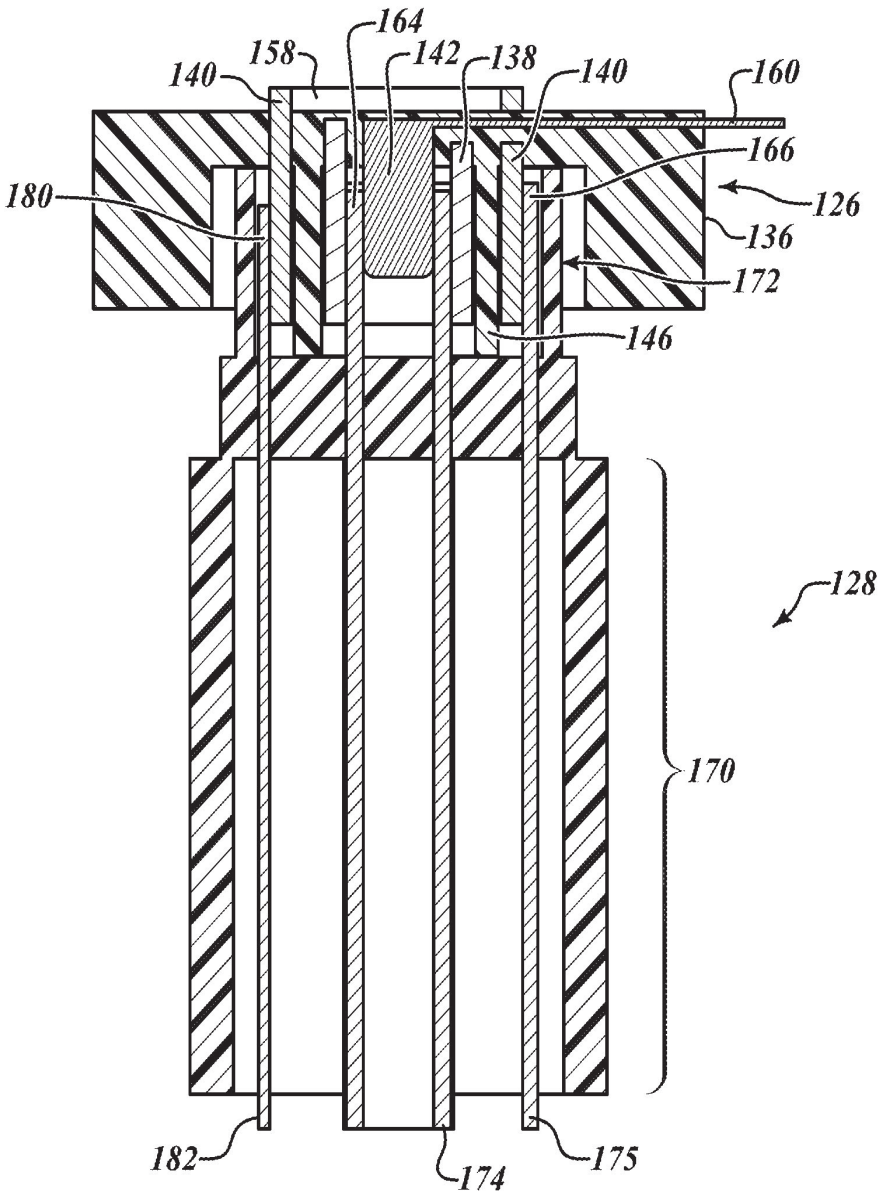

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FIG.11

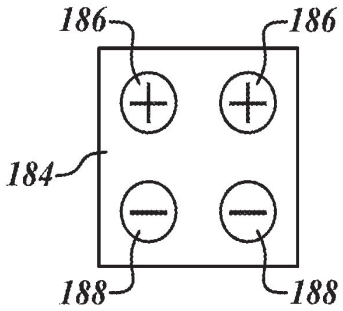


FIG.12A

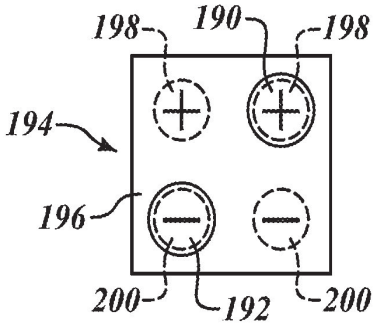


FIG.12B

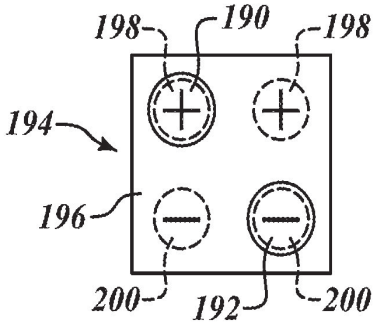


FIG.12C

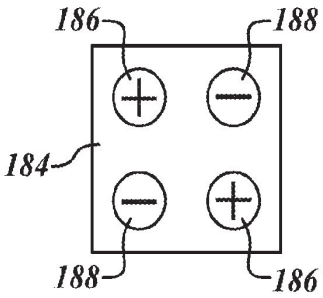


FIG.13A

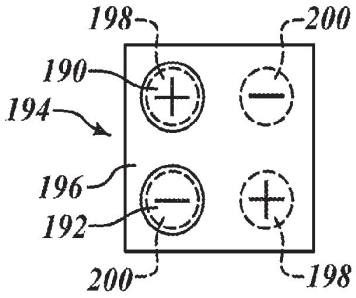


FIG.13B

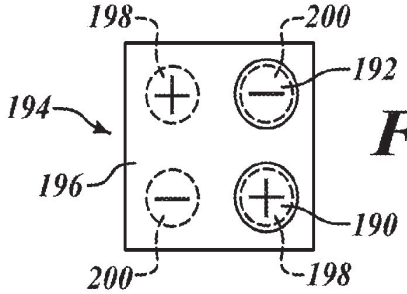


FIG.13C

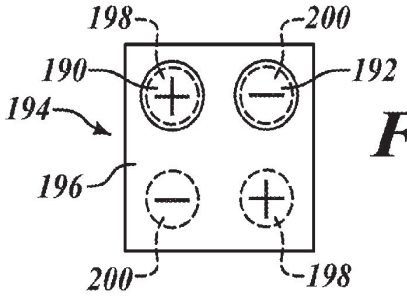


FIG.13D

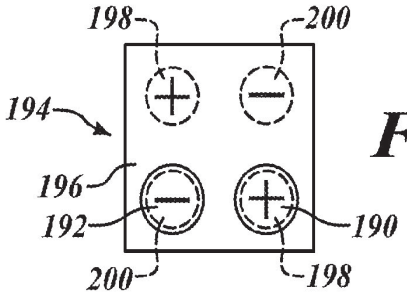


FIG.13E

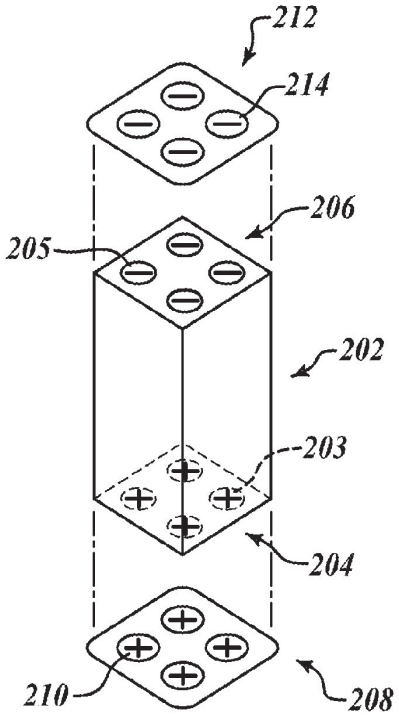


FIG.14A

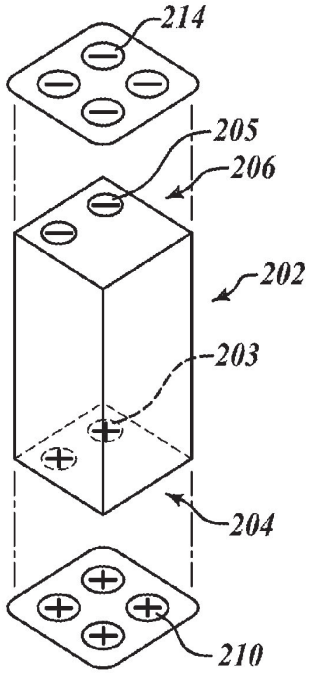


FIG.14B

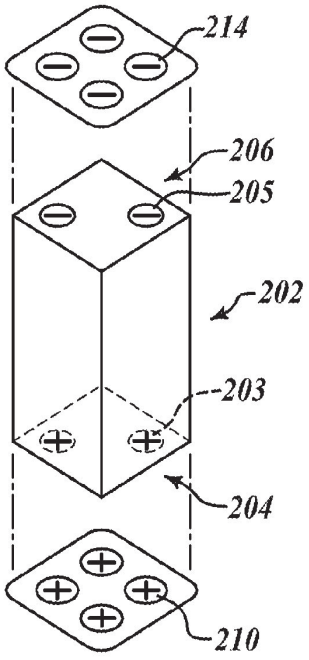


FIG.14C

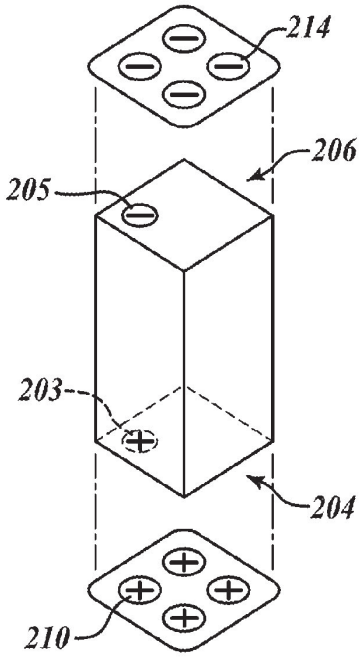


FIG.14D

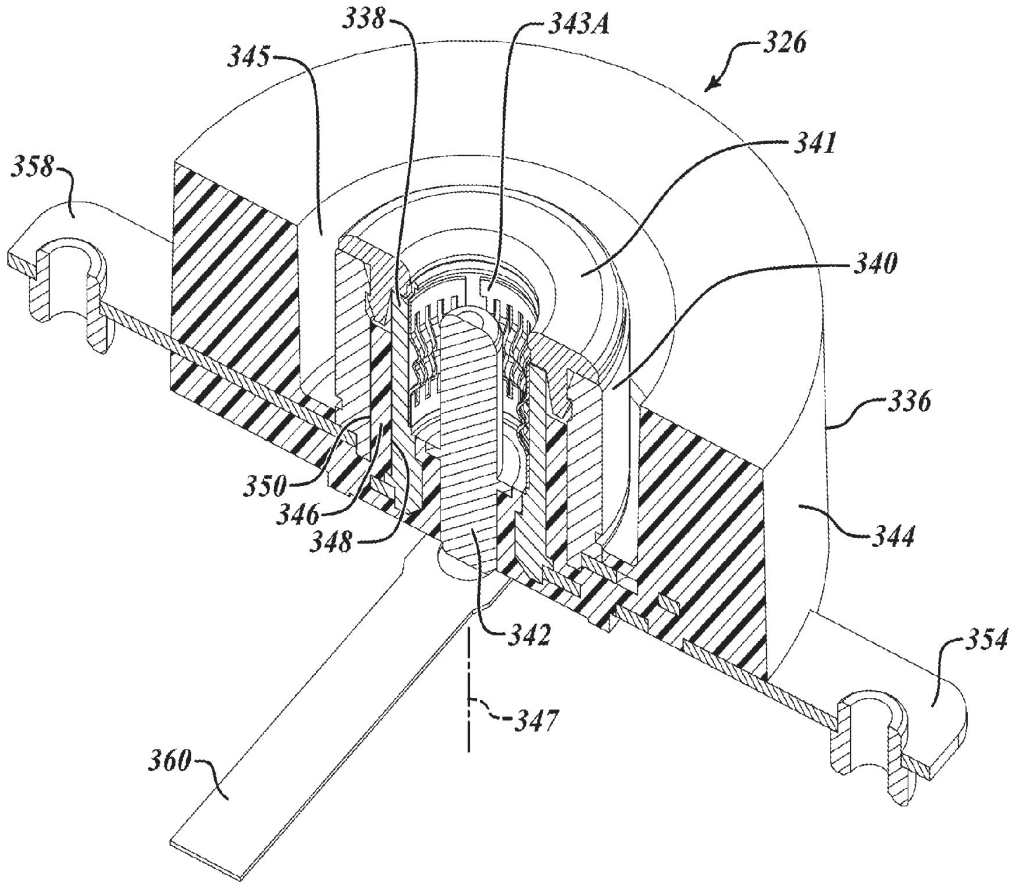


FIG. 15

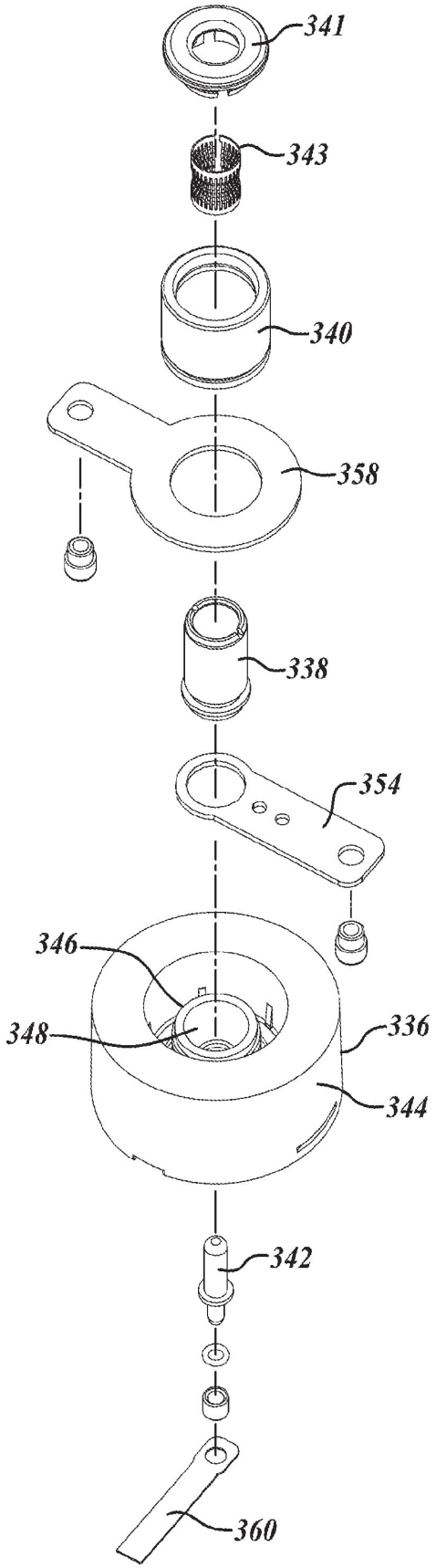


FIG. 16

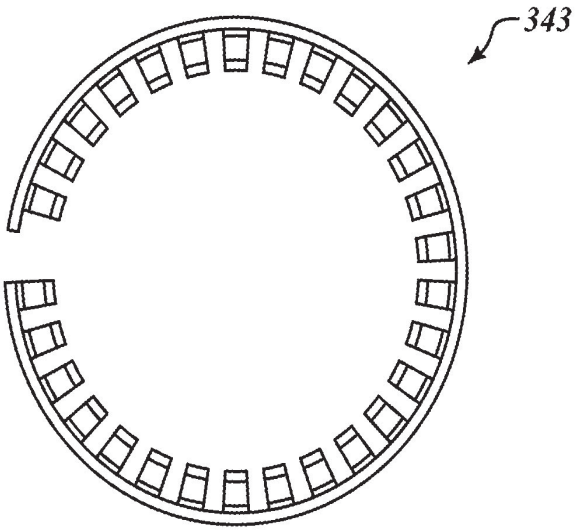


FIG.17

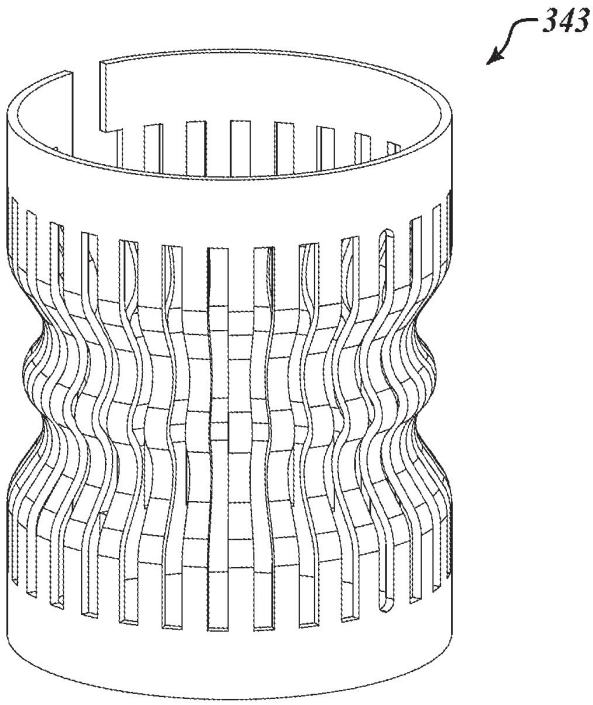


FIG.18

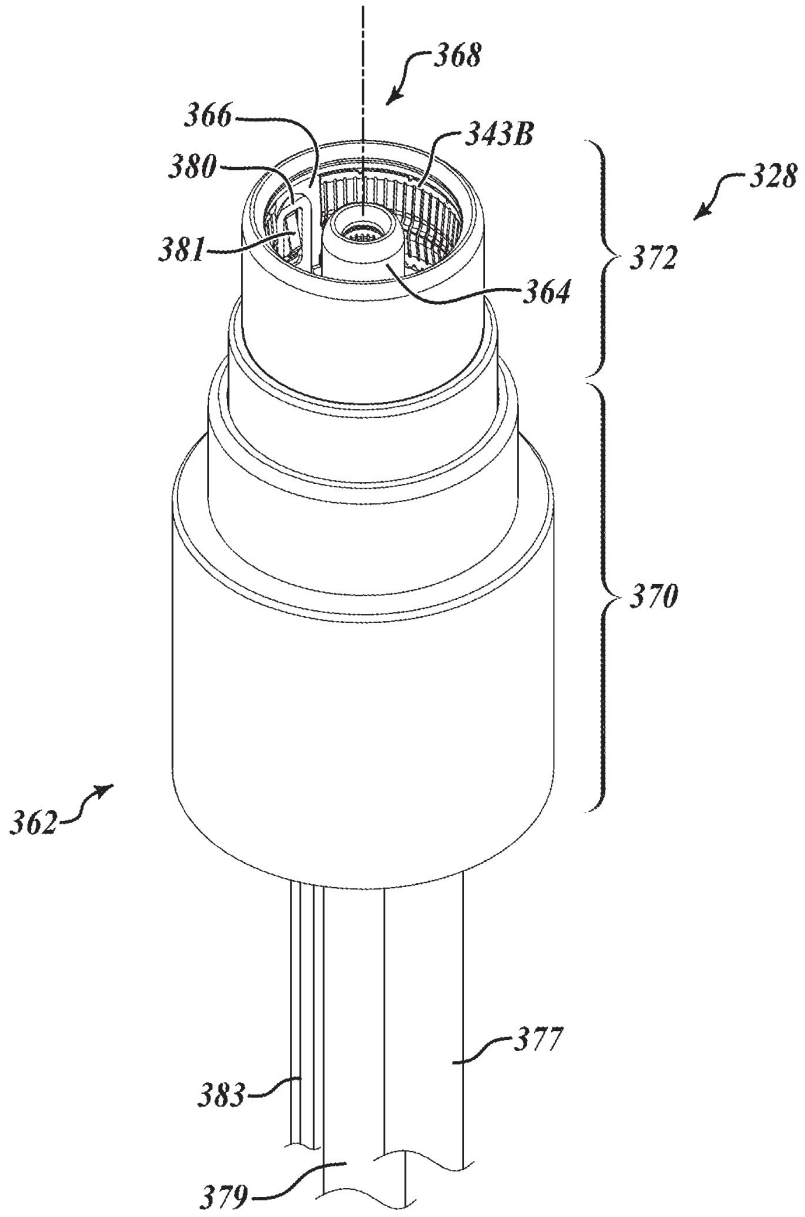


FIG.19A

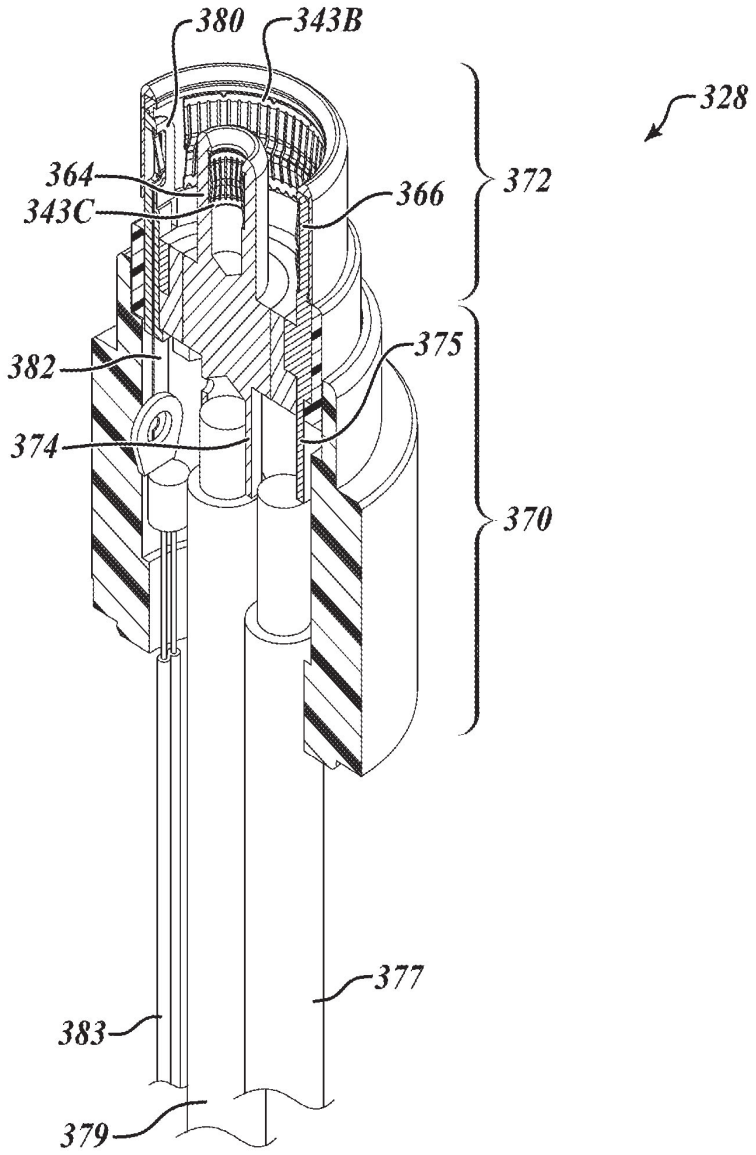


FIG.19B

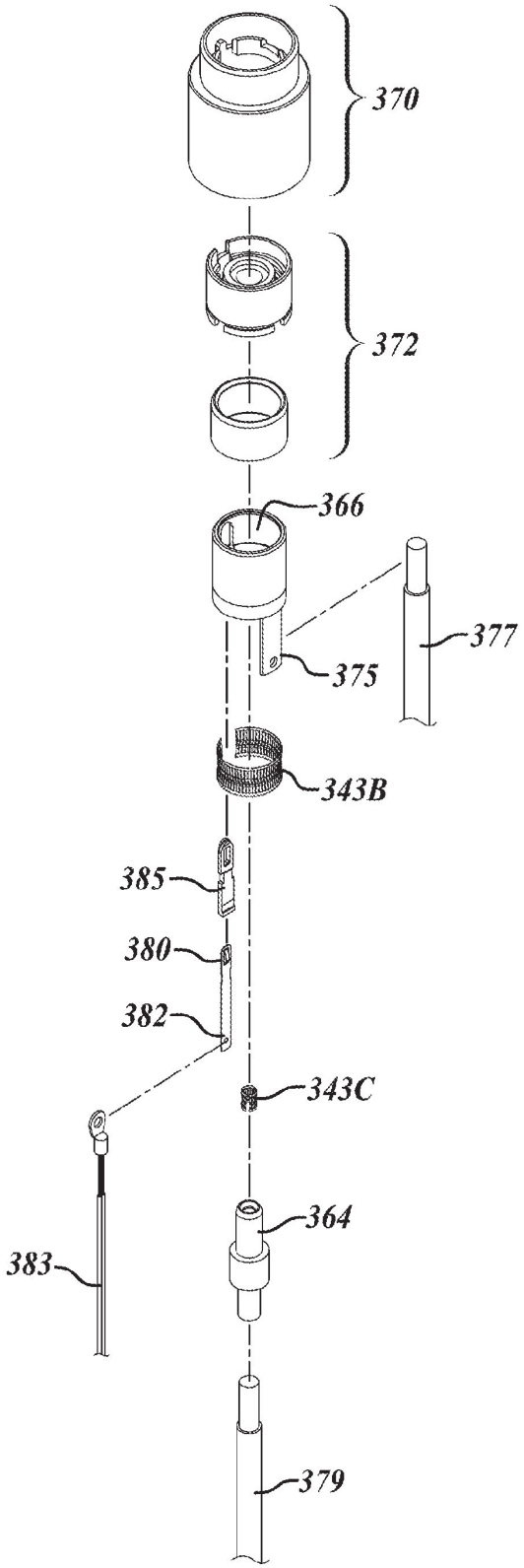


FIG.19C

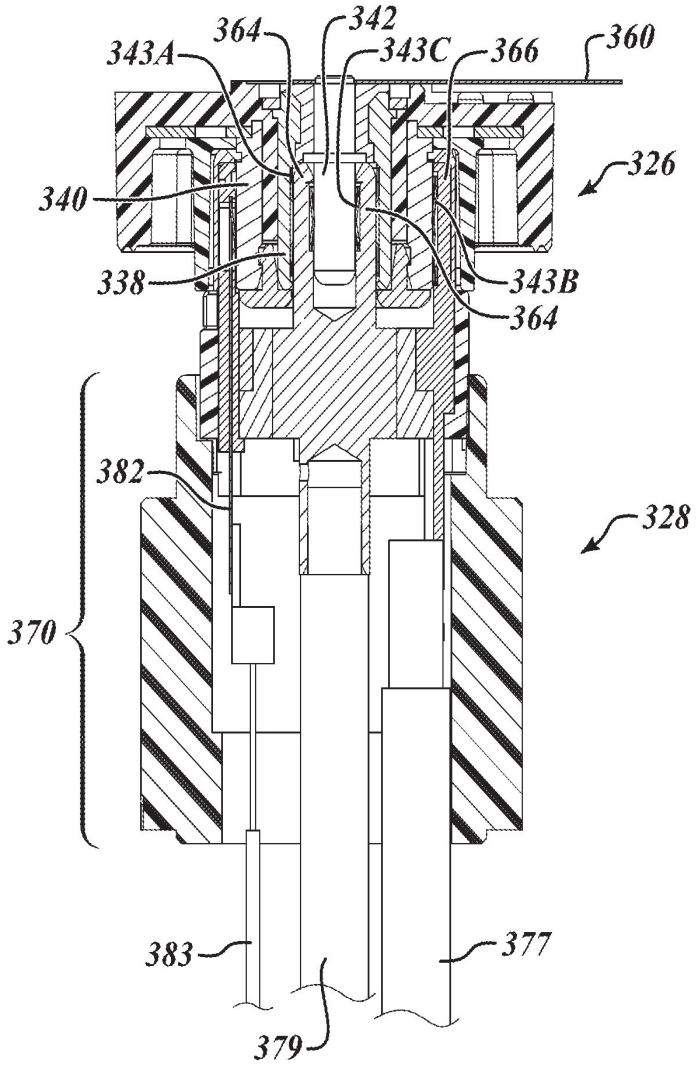

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FIG.20

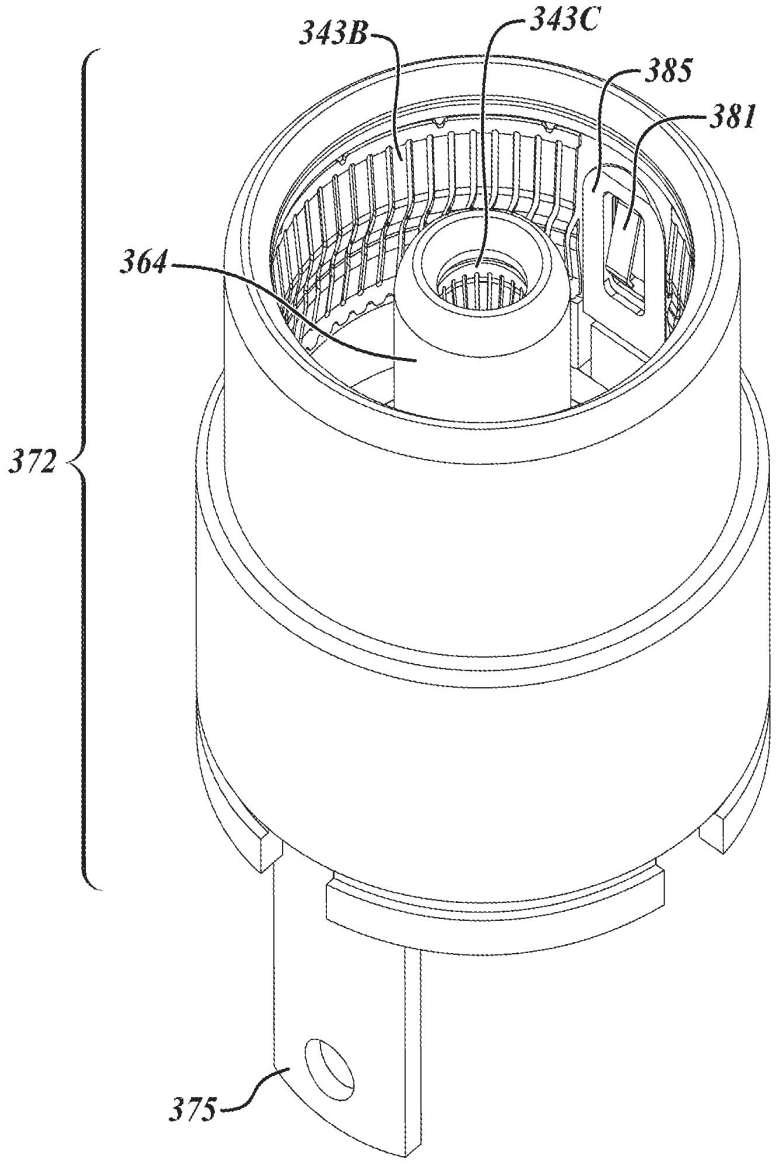


FIG.21

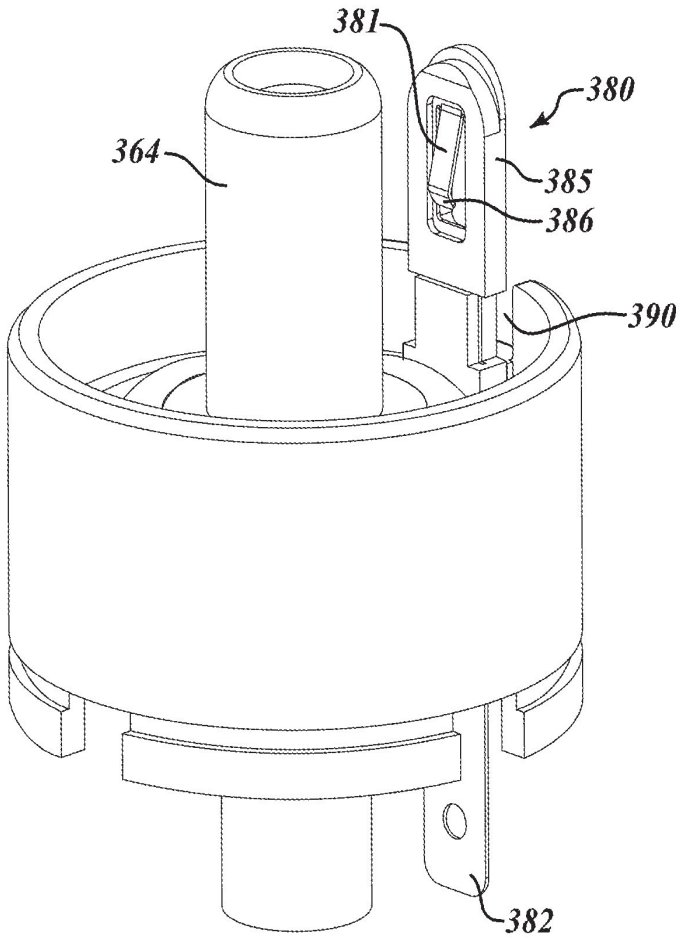


FIG.22

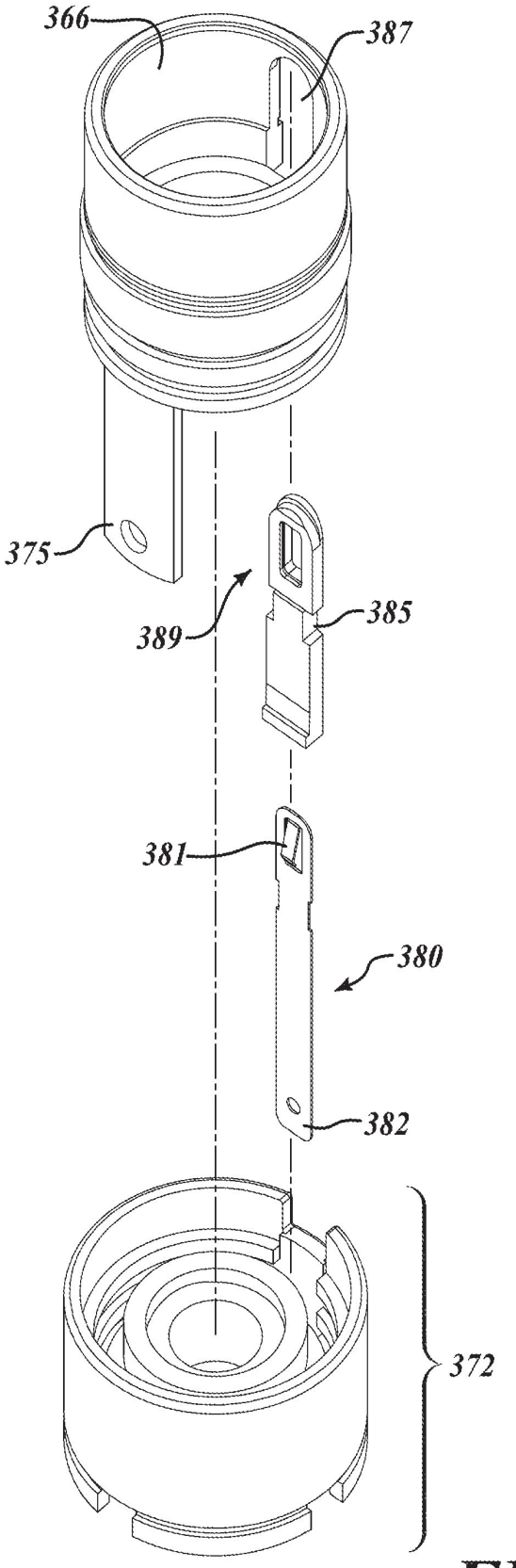


FIG.23

MULTIDIRECTIONAL ELECTRICAL CONNECTOR, PLUG AND SYSTEM

BACKGROUND

1. Technical Field

The embodiments described herein relate to portable electrical energy storage devices, such as those used to power electric powered devices such as vehicles and consumer electronics, and connectors for making an electrical connection between such portable electrical energy storage devices and devices to be powered by or used to charge such portable electrical energy storage devices.

2. Description of the Related Art

Batteries such as lithium-ion batteries are known for storing more energy into smaller, lighter units. Lithium-ion batteries have found wide application in powering portable electronic devices such as cell phones, tablets, laptops, power tools and other high-current equipment. The low weight and high energy density also makes lithium-ion batteries attractive for use in hybrid electric vehicles and fully electric-powered vehicles.

In some applications, a plurality of individual lithium-ion batteries are packaged together to form a battery pack. Such battery packs include electrical components that make electrical connection between the plurality of individual lithium-ion batteries and primary negative and positive electrical terminals of the battery pack. The negative and positive electrical terminals of the battery pack can be connected to corresponding negative and positive electrical terminals of a device to provide electric power to the device. In applications such as computers or mobile phones, the electric connection to the electrical terminals of the battery pack often can only be achieved when the battery pack is inserted into the battery compartment in one position. In other positions, the battery pack either cannot be received into the battery compartment and/or the terminals of the battery pack do not make electrical connection to the terminals of the device. Similarly, chargers for such types of battery packs often include compartments for receiving the battery pack to be charged. The battery compartment of these chargers is often a replica of the compartment contained in the device to be powered by the battery pack. As with the devices, if the battery pack is not oriented properly in the battery compartment of the battery charger, the battery pack may be not be accepted into the compartment and/or the electrical terminals of the battery pack may not make electrical connection with the electrical terminals of the charger. In other instances, when the battery pack is received into the battery compartment of the charger or device in an improper orientation, the electrical terminals of the battery pack may make contact with the electrical terminals of the charger or the device; however, such contact may not meet the design parameters set for the electrical connection between the battery pack and the charger and/or device. For example, the area of contact between the electrical terminals of the battery pack and the electrical terminals of the device or charger when the battery pack is not in its proper orientation may be less than the area of contact between the electrical terminals of the battery pack and the electrical terminals of the device or charger when the battery pack is in its proper orientation. This reduced area of contact when the battery pack is not in its proper orientation can result in the temperature of the electrical terminals rising to undesired and potentially unsafe levels.

Insertion of a battery pack in an improper orientation within a device to be electrically powered by the battery pack or within a device for charging the battery pack may occur due to the user's lack of understanding the proper orientation or due to carelessness on the part of the user. With the proliferation of electric powered devices, such as electric powered tools, appliances, personal portable communication devices, laptop and tablet computers, personal media devices, vehicles and the like, there is interest in battery pack and battery pack electrical connection designs that minimize the likelihood of installing a battery pack in an orientation within a device to be powered by the battery pack or within a device for charging the battery pack such that the electrical power does not flow between the two or does flow, but creates unsafe conditions. Avoiding improper orientation avoids the risk of creating potentially unsafe conditions and promotes proper discharge and charging of the battery pack, as well as avoiding damage to the terminals of the battery pack and/or terminals of the electrically powered device or charging device.

Connectors capable of electrically connecting a source of electrical energy to a device to be powered by electrical energy from the source of electrical energy without regard to the rotational orientation of the connector are known. For example, connectors historically referred to as 12V cigarette lighter socket, utilize a round female connector and a round male connector. An electrical connection can be made between the two, regardless of the rotational orientation the male connector is inserted in the female connector. Such types of connectors are designed for 12V systems and typically have recommended maximum operating currents on the order of 5 to 10 amps, well below current levels required for modern day high current draw devices, e.g., electric powered tools, electric powered appliances and electric powered vehicles, which draw current at levels one or two orders of magnitude greater than current levels 12V cigarette lighter electrical connectors are rated.

Even when a battery pack is installed/inserted in a proper orientation, the electrical connection between electrical terminals of the battery pack and electrical terminals of a device to be powered by the battery pack or a device for charging the battery pack may not operate as designed. For example, unwanted conductive or nonconductive materials could become lodged between the terminals of the battery pack and the terminals of the device or charger. Portions of the terminals could become damaged or could be broken off. Such conditions can result in unsafe conditions and degraded performance. Thus, even in situations where the battery pack is installed/inserted in its proper orientation, there is interest in effective ways to confirm the electrical connection between the electrical terminals of the battery pack and the electrical terminals of the electrically powered device or the device for charging the battery is as designed.

BRIEF SUMMARY

Zero tail pipe emissions alternatives to combustion engines would greatly benefit the air quality of, and hence health of, large populations.

While the zero tail pipe emissions benefit of all-electric vehicles are appreciated, adoption of all-electric vehicles by large populations has been slow. One of the reasons appears to be the cost, particularly the cost of secondary batteries. Another one of the reasons appears to be the limited driving range available on a single charge of a battery, and the relatively long time (e.g., multiple hours) necessary to recharge a secondary battery when depleted. Yet another reason appears to be the complicated nature of replacing secondary batteries in all-electric vehicles.

The approaches described herein may address some of the issues which have limited adoption of zero tailpipe emission

technology, particularly in densely crowded cities, and in populations with limited financial resources.

For example, subject matter described herein relates to connectors for electrically connecting portable electrical energy storage devices, e.g., batteries or battery packs, to a device to be powered by the portable electrical energy storage device or a device for charging the portable electrical energy storage device. The connectors can make an electrical connection between the portable electrical energy storage device and a device to be powered by the portable electrical energy storage device or a device for charging the portable electrical energy storage device in more than one spatial (e.g., rotational) orientation. Electrical connectors for portable electrical energy storage devices of the type described herein are able to make the above-described electrical connections in a plurality of spatial orientations (e.g., a first position, a second position rotated from the first position, a third position rotated from the first and second position, and other rotational positions). The described connectors provide safe electrical connection between a portable electrical energy storage device and an electric device having extended time period electrical current that demands one, two or even more orders of magnitude greater than extended time period current ratings for conventional electrical connectors, such as 12V cigarette lighter style electrical connectors which typically have extended time period current ratings from about 5 to 10 amps and momentary peak ratings of about 15 to 20 amps. Conventional electrical connectors like cigarette lighter style electrical connectors include a positive pin in the form of a spring and point contact which are not designed to safely handle currents much greater than 20 amps or applications involving high levels of vibration. Connectors of the type described herein provide an advantage in that robust and safe electrical connections can be made in a plurality of the spatial orientations of the connector on the portable electrical energy storage device relative to the connector on the electrically powered device or the device for charging the portable electrical energy storage device.

Because a portable electrical energy storage device connector in accordance with embodiments described herein can mate with a connector of the electrically powered device or the device for charging the portable electrical storage device in a plurality of specific spatial orientations in which the portable electrical energy storage device is installed or received by the electrically powered device or the device for charging the portable electrical energy storage device, users of portable electrical energy storage devices utilizing electrical connectors of the type described herein will be confident that a robust and safe electrical connection can be made to an electrically powered device or a device for charging the portable electrical energy storage device. The user will be less concerned with and less likely to install the portable electrical energy storage device incorrectly and therefore utilization of the portable electrical energy storage devices will be safer and occur more rapidly and be more widespread.

Electrical connectors of the type described herein include a connector for making electrical connection between a portable electrical energy storage device electrically connected to the connector or an electric powered device electrically connected to the connector and a plug electrically connected to an electric powered device or a portable electrical energy storage device that is not electrically connected to the connector. The connectors include an electrically nonconductive connector base having a connector central axis; an electrical contact housing including an outer sidewall extending in a direction parallel to the connector central axis and an inner sidewall extending in a direction parallel to the connector central axis, the inner sidewall located closer to the connector central axis than the outer sidewall, the electrical contact housing centered on the connector central axis; a first terminal including at least two electrically conductive contact pads located adjacent the inner sidewall of the electrical contact housing; and a second terminal including at least one electrically conductive contact pad located adjacent the outer sidewall of the electrical contact housing.

The connectors may further comprise a connection test terminal located closer to the connector central axis than the first terminal and configured to be electrically connected to the first terminal when the connector is electrically connected to the plug.

The connection test terminal may include a high impedance material.

The connectors may be configured to mate with the plug in two or more orientations and make an electrical connection to the plug in each of the two or more orientations, the two or more orientations corresponding to different positions of the connector relative to the plug, each different position of the connector relative to the plug corresponding to different rotational positions of the connector relative to the connector central axis.

The two or more orientations may be three or more orientations, four or more orientations, or five or more orientations.

The electric powered device may be a traction electric motor for a vehicle.

The outer sidewall and the inner sidewall of the connector may be concentric.

The at least two electrically conductive contact pads of the first terminal and the at least one electrically conductive pad of the second terminal may be concentric.

The at least two electrically conductive contact pads may include at least three electrically conductive contact pads.

The at least one electrically conductive contact pad of the second terminal may include two or more contact pads.

A periphery of the electrical contact housing may lie in a plane perpendicular to the connector central axis and the periphery may define a quadrilateral with opposing angles that are equal. Adjacent sides of the quadrilateral may be equal in length.

The outer sidewall of the electrical contact housing may include four outer sidewalls with each outer sidewall arranged perpendicular to adjacent outer sidewalls and extending parallel to the connector central axis. The inner sidewall of the electrical contact housing may include four inner sidewalls with each inner sidewall arranged perpendicular to adjacent inner sidewalls and extending parallel to the connector central axis. The four inner sidewalls may be located closer to a connector base axis than the four outer sidewalls.

The at least two electrically conductive contact pads of the first terminal may include four electrically conductive contact pads, and one electrically conductive contact pad of the first terminal may be located adjacent each of the four inner sidewalls of the electrical contact housing.

The at least one electrically conductive contact pad of the second terminal may include four electrically conductive contact pads, and one electrically conductive contact pad of the second terminal may be located adjacent each of the four outer sidewalls of the electrical contact housing.

An electrical plug for making electrical connection between an electric powered device electrically connected to the plug or a portable electrical energy storage device electrically connected to the plug and a connector electrically connected to an electric powered device or a portable electrical energy storage device that is not electrically connected to

the plug may include an electrically nonconductive plug housing including a plug end, a terminal end and a plug housing central axis, the plug end located at an end of the nonconductive plug housing that is opposite an end of the nonconductive plug housing where the terminal end is located; a first terminal located at the plug end and including at least two electrically conductive contact pads, each contact pad of the first terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis; and a second terminal located at the plug end and including at least two electrically conductive contact pads, each contact pad of the second terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis, the first terminal of the plug located closer to the plug housing central axis than the second terminal of the plug, each contact pad of the first terminal separated from the contact pads of the second terminal by an electrically nonconductive medium.

The plug may further include a connection test terminal located at the plug end further from the plug housing central axis than the contact pads of the first plug terminal, the connection test terminal configured to be electrically connected to the connector when the connector mates with the plug.

The plug may be configured to mate with the connector when the connector is in one of two or more orientations and the plug is configured to make an electrical connection to the connector in each of the two or more orientations with each of the connector's two or more orientations corresponding to a different position of the connector relative to the plug with each different position of the connector relative to the plug achieved by rotating the connector around the plug housing central axis.

The two or more orientations may be three or more orientations, four or more orientations, or five or more orientations.

The electric powered device may be a traction electric motor.

The at least two contact pads of the first terminal and the contact pads of the second terminal may be concentric.

The at least two contact pads of the first terminal may be are three contact pads or may be four contact pads.

The at least two contact pads of the second terminal may be three contact pads.

A system for electrically connecting a portable electrical energy storage device to an electrically powered device may include a connector that may include an electrically nonconductive connector base including a connector central axis; an electrical contact housing that may include an outer sidewall extending in a direction parallel to the connector central axis and an inner sidewall extending in a direction parallel to the connector central axis, the inner sidewall located closer to the connector central axis than the outer sidewall and the electrical contact housing centered on the connector central axis; a first connector terminal that may include at least one electrically conductive contact surface located adjacent the inner sidewall of the electrical contact housing; and a second connector terminal that may include at least one electrically conductive contact surface located adjacent the outer sidewall of the electrical contact housing.

The system may further include a plug including an electrically nonconductive plug housing including a plug end, a terminal end and a plug housing central axis, the plug end may be located at an end of the nonconductive plug housing that is opposite an end of the nonconductive plug housing where the terminal end is located; a first plug terminal may be located at the plug end and include at least two electrically conductive contact pads with each contact pad of the first plug terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis; and a second plug terminal may be located at the plug end and include at least two electrically conductive contact pads, each contact pad of the second plug terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis, the first plug terminal located closer to the plug housing central axis than the second plug terminal and each contact pad of the first plug terminal separated from the contact pads of the second plug terminal by an electrically nonconductive medium.

The connector of the system may further include a connection test terminal located at the plug end closer to the connector central axis than contact pads of the first plug terminal and configured to be electrically connected to the second connector terminal when the connector is mated with the plug.

The connector may be configured to mate with the plug in two or more orientations and make an electrical connection to the plug in each of the two or more orientations, each of the two or more orientations corresponding to a different position of the connector relative to the plug, each different position achieved by rotating the connector around the connector central axis.

The outer sidewall of the electrical contact housing and the inner sidewall of the electrical contact housing may be concentric.

The at least one electrically conductive contact surface of the first connector terminal and the at least one electrically conductive contact surface of the second connector terminal may be concentric.

The connector of the system may further include a connection test terminal located closer to the connector central axis than the first connector terminal and configured to be electrically connected to the first plug terminal when the connector is mated with the plug.

The plug of the system may be configured to mate with the connector when the connector is in one of two or more orientations and the plug is configured to make an electrical connection to the connector in each of the two or more orientations. Each of the connector's two or more orientations corresponds to a different position of the connector relative to the plug, each different position of the connector relative to the plug achieved by rotating the connector around the plug housing central axis.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

In the drawings, identical reference numbers identify similar elements. The sizes and relative positions of elements in the drawings are not necessarily drawn to scale. For example, the shapes of various elements and angles are not drawn to scale, and some of these elements are arbitrarily enlarged and positioned to improve drawing legibility. Further, the particular shapes of the elements as drawn are not intended to convey any information regarding the actual shape of the particular elements, and they have been solely selected for ease of recognition in the drawings.

FIG. **1** is a schematic view illustrating receipt of a portable electrical energy storage device including an electrical connector in accordance with embodiments described herein by an electrically powered device including an electrical connector plug in accordance with embodiments described herein;

FIG. **2** is a cross-section view along line **2-2** in FIG. **3** of an electrical connector base according to one non-limiting illustrated embodiment of the subject matter described herein;

FIG. **3** is an exploded view of the connector base illustrated in FIG. **2**;

FIG. **4** is a perspective view of an electrical connector plug in accordance with one non-limiting illustrated embodiment of the subject matter described herein;

FIG. **5** is a cross-section view of the electrical connector plug illustrated in FIG. **4** taken along line **5**-**5**;

FIG. **6** is an exploded view of the electrical connector plug illustrated in FIG. **4**;

FIG. **7** is a cross-section of the electrical connector base illustrated in FIG. **2** and the electrical connector plug illustrated in FIG. **4** in a mated configuration;

FIG. **8** is a schematic view illustrating receipt of a portable electrical energy storage device including an electrical connector base in accordance with embodiments described herein by an electrically powered device including an electrical connector plug in accordance with additional embodiments described herein;

FIG. **9**A is a cross-section view of an electrical connector base according to another non-limiting illustrated embodiment of the subject matter described herein taken along line **9**A-**9**A in FIG. **9**B;

FIG. **9**B is an exploded view of the electrical connector base illustrated in FIG. **9**A;

FIG. **10**A is a perspective view of an electrical connector plug in accordance with one non-limiting illustrated embodiment of the subject matter described herein;

FIG. **10**B is a cross-section view of the electrical connector plug illustrated in FIG. **10**A taken along line **10**B-**10**B in FIG. **10**A;

FIG. **10**C is an exploded view of the electrical connector plug illustrated in FIG. **10**A;

FIG. **11** is a cross-section of the electrical connector base illustrated in FIG. **10**A and the electrical connector plug illustrated in FIG. **8** in a mated configuration;

FIGS. **12**A-**12**C are schematic illustrations of non-limiting illustrated embodiments of electrical connection terminals located on a portable electrical energy storage device and electrical connection terminals located on a device to be powered by the portable electrical energy storage device or a device for charging such portable electrical energy storage device;

FIGS. **13**A-**13**E are schematic illustrations of further non-limiting illustrated embodiments of electrical connection terminals located on a portable electrical energy storage device and electrical connection terminals located on a device to be powered by such portable electrical energy storage device or a device for charging such portable electrical energy storage device;

FIGS. **14**A-**14**D are schematic illustrations of additional non-limiting illustrated embodiments of electrical terminals located on a portable electrical energy storage device and electrical connection terminals located on a device to be powered by such portable electrical energy storage device or a device for charging such portable electrical energy storage device;

FIG. **15** is a cross-section view of an electrical connector base according to another non-limiting illustrated embodiment of the subject matter described herein taken along line **15**A-**15**A in FIG. **16**;

FIG. **16** is an exploded view of the electrical connector base illustrated in FIG. **15**;

FIG. **17** is a top view of a crown spring connector according to a non-limiting embodiment of the subject matter described herein;

FIG. **18** is a perspective view of the crown spring connector of FIG. **17**;

FIG. **19**A is a perspective view of an electrical connector plug in accordance with another non-limiting illustrated embodiment of the subject matter described herein;

FIG. **19**B is a cross-section view of the electrical connector plug illustrated in FIG. **19**A taken along line **19**B-**19**B in FIG. **19**A;

FIG. **19**C is an exploded view of the electrical connector plug illustrated in FIG. **19**A;

FIG. **20** is a cross-section of the electrical connector base illustrated in FIG. **19**A and the electrical connector plug illustrated in FIG. **15** in a mated configuration;

FIG. **21** is an enlarged view of a portion of the electrical connector plug illustrated in FIG. **19**A;

FIG. **22** is an enlarged view of a portion of the electrical connector plug illustrated in FIGS. **19**A and **21** with a portion removed to better illustrate features of the illustrated embodiment; and

FIG. **23** is an exploded view of a portion of the electrical connector plug illustrated in FIG. **22**.

DETAILED DESCRIPTION

It will be appreciated that, although specific embodiments of the present disclosure are described herein for purposes of illustration, various modifications may be made without departing from the spirit and scope of the present disclosure. Accordingly, the present disclosure is not limited except as by the appended claims.

In the following description, certain specific details are set forth in order to provide a thorough understanding of various disclosed embodiments. However, one skilled in the relevant art will recognize that embodiments may be practiced without one or more of these specific details, or with other methods, components, materials, etc. In other instances, well-known structures associated with portable electrical energy storage devices, batteries, super- or ultra-capacitors, electrical terminals, devices to be powered by portable electrical energy storage devices, devices for charging portable electrical energy storage devices and electrical connectors for electrically connecting portable electrical energy storage devices and devices to be powered by such portable electrical energy storage devices or devices for charging such portable electrical energy storage devices have not been shown or described in detail to avoid unnecessarily obscuring descriptions of the embodiments.

Unless the context requires otherwise, throughout the specification and claims that follow, the word "comprise" and variations thereof, such as "comprises" and "comprising" are to be construed in an open, inclusive sense, that is, as "including, but not limited to."

Reference throughout the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearance of the phrases in "one embodiment" or in "an embodiment" in various places throughout the specification are not necessarily all referring to the same aspect. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more aspects of the present disclosure.

The use of ordinals such as first, second and third does not necessarily imply a ranked sense of order, but rather may only distinguish between multiple instances of an act or structure.

In the figures, identical reference numbers identify similar features or elements. The sizes and relative positions of the features in the figures are not necessarily drawn to scale.

Reference to portable electrical power storage device or portable electrical energy storage device means any device capable of storing electrical power and releasing stored electrical power including but not limited to batteries and super or ultra-capacitors. Reference to batteries means a chemical storage cell or cells, for instance rechargeable or secondary battery cells including but not limited to nickel cadmium alloy or lithium ion battery cells. Chemistries besides nickel cadmium alloy or lithium ion are also included in the reference to batteries or chemical storage cells.

Reference throughout the specification to an electric powered device includes devices that can be powered by a portable electrical energy storage device and devices that are electrically powered from a source other than a portable electrical energy storage device, e.g., a device for electrically charging a portable electrical energy storage device.

Referring to FIG. **1**, a portable electrical energy storage device in the form of a battery pack **10** includes a battery pack housing **12**. Though not illustrated, contained within battery pack housing **12** are one or more individual portable electrical energy storage devices. These individual portable electrical energy storage devices can be arranged in different configurations, including single or multiple layers, with each layer including one or more individual electrical energy storage devices. In the illustrated exemplary embodiment of FIG. **1**, battery pack **10** has a cylindrical shape. A cross-section of the battery pack **10** along line **2-2** has a round cross-section in the illustrated embodiment. As will become apparent based on descriptions that follow, battery packs of the type described herein are not limited to battery packs that are cylindrical and have a round cross-section; battery packs having different shapes and cross-sections are included in the embodiments described herein. Battery packs having polygonal, e.g., square or rectangular, cross-sections are examples of different shaped battery packs that are included within the description of battery packs of the type described herein.

At one end, battery pack **10** includes a handle **14** attached to the top of battery pack **10** for grasping battery pack **10**. At an end of battery pack **10** opposite the end containing handle **14**, battery pack **10** includes a multidirectional electrical connector **16** shown in phantom lines. Multidirectional electrical connector **16** is represented schematically and is not limited to the shape illustrated in phantom lines, and can have a shape different than that shown in phantom lines in FIG. **1**.

In the embodiment illustrated in FIG. **1**, battery pack **10** is configured to cooperate with a battery pack receptacle **18** which includes an electrical connector plug **20**. Electrical connector plug **20** is represented schematically in FIG. **1** and is not limited to the shape illustrated in phantom lines and can have a shape different than that shown in FIG. **1**. Receptacle **18** is sized and configured to receive battery pack **10** when the battery pack **10** is moved in the direction of arrow **23** in FIG. **1**. An advantage of the electrical connector **16** and the electrical connector plug **20** is their ability to electrically connect to each other regardless of the rotational position of battery pack **10** relative to battery receptacle **18** when the battery receptacle **18** receives battery pack **10**. The ability to achieve an electrical connection between electrical connector **16** and electrical connector plug **20** regardless of the rotational orientation of the battery pack **10** relative to battery pack receptacle **18** reduces the likelihood that an ineffective electrical connection between electrical connector **16** and electrical connector plug **20** results due to insertion of a battery pack **10** into battery pack receptacle **18** in an improper orientation. Thus, in accordance with embodiments described herein, electrical connector **16** and electrical connector plug **20** provide a multidirectional electrical connection system which can make an electrical connection in a plurality of rotational orientations without compromising the quality and safety of the electrical connection due to insertion of a battery pack **10** into battery pack receptacle **18** in an improper orientation.

Specific embodiments are described herein with reference to connectors for electrically connecting portable electrical energy storage device(s) to an electrical system of electrically powered vehicles and devices for charging portable electrical energy storage devices; however, the present disclosure and the reference to connectors for electrically connecting a portable electrical energy storage device to an electrical system of electrically powered vehicles and devices for charging the portable electrical energy storage devices is not limited to electrical systems for electrically powered vehicles or devices for charging portable electrical energy storage devices. Connectors of the type described herein are also useful for electrically connecting portable electrical energy storage devices to electrical systems of electrically powered devices other than electrically powered vehicles and devices for charging the portable electrical energy storage devices. Connectors of the type described herein for use in providing an electrical connection between a portable electrical energy storage device and an electrical system of an electrically powered vehicle are capable of safely carrying electrical currents levels sufficient to drive a traction electric motor of the vehicle. For example, electric connectors of the type described herein safely carry electric current ranging from about 30 amps or more. In certain embodiments the electrical connectors can safely carry about 50 amps or more, about 75 amps or more, about 100 amps or more, about 200 amps or more, about 300 amps or more, about 400 amps or more, about 500 amps or more. In some embodiments the electrical connector can safely carry about 1000 amps or more.

Details of one embodiment of the present disclosure are described below with reference to FIGS. **2** and **3**. FIGS. **2** and **3** illustrate one exemplary embodiment of an electrical connector **16** electrically connected to a portable electrical energy storage device or to a device to be powered by the portable electrical energy storage device. Connector **16** in the illustrated exemplary embodiment includes an electrically nonconductive connector base **19**, a first terminal **21**, a second terminal **22**, and an electrical connection test terminal **24**. In order to avoid obscuring aspects of the subject matter described herein, details of how first terminal **21** and second terminal **22** are electrically connected to the portable electrical energy storage device or an electrically powered device are omitted.

Electrically nonconductive connector base **19** includes a conductor base outer wall **26**. In the illustrated exemplary embodiment of FIGS. **2** and **3**, electrically nonconductive connector base **19** is circular in shape when viewed along a longitudinal axis **32**. The electrically nonconductive connector base **19** including conductor base outer wall **26** is formed from a nonconductive material, such as plastic. Conventional techniques such as extrusion or injection molding can be used to form nonconductive connector base **19** and conductor base outer wall **26**. Connector base **19** further includes an electrical terminal outer wall **28** and an electrical terminal inner wall **30**. Electrical terminal outer wall **28** and electrical terminal inner wall **30** are also formed of an electrically nonconductive material. In the illustrated embodiment of FIGS. **2** and **3**, electrical terminal outer wall **28** and electrical terminal inner wall **30** are integral with conductor base outer wall **26**. Thus, in the illustrated embodiment, electrically nonconductive connector base **19** is an integral element; however, electrically nonconductive connector base **19** need not be an integral element, for example, conductor base outer wall **26**, electrical

terminal outer wall **28** and electrical terminal inner wall **30** can be formed individually and attached to each other in different combinations. In the illustrated exemplary embodiments of FIGS. **2** and **3**, electrical terminal outer wall **28** and electrical terminal inner wall **30** are circular in shape when viewed along a longitudinal axis **32** and are positioned concentrically relative to conductor base outer wall **26**. In FIGS. **2** and **3**, electrical terminal inner wall **30** is spaced radially inward from electrical terminal outer wall **28** and is separated therefrom by an air gap **34**. Electrical terminal outer wall **28** is spaced radially inward from conductor base outer wall **26** and is separated therefrom by an air gap **36**. Air gap **34** provides an electrically nonconductive medium between electrical terminal inner wall **30** and electrical terminal outer wall **28**. Air gap **36** provides an electrically nonconductive medium between electrical terminal outer wall **28** and conductor base outer wall **26**.

Electrical terminal inner wall **30** includes an inner surface **38** and an outer surface **40**. Inner surface **38** of electrical terminal inner wall **30** is located closer to longitudinal axis **32** than outer surface **40** of electrical terminal inner wall **30**. Electrical terminal outer wall **28** includes an inner surface **42** and an outer surface **44**. Inner surface **42** of electrical terminal outer wall **28** is located closer to longitudinal axis **32** than outer surface **44** of electrical terminal outer wall **28**.

Inner surface **38** of electrical terminal inner wall **30** includes first electrically conductive terminal **21**. In the illustrated exemplary embodiment, first electrically conductive terminal **21** is a ring-shaped member conforming in size and shape to the inner surface **38** of electrical terminal inner wall **30**. The bottom edge of electrically conductive terminal **21** is electrically connected to a first terminal connector **46** which lies beneath the electrical terminal inner wall **30**, electrical terminal outer wall **28** and conductor base outer wall **26**. First terminal connector **46** can be electrically connected to a portable electrical energy storage device, a device to be powered by a portable electrical energy storage device or a device for charging a portable electrical energy storage device, thus providing an electrical connection between the device connected to the first terminal connector **46** and the other devices.

Inner surface **42** of electrical terminal outer wall **28** includes second electrically conductive terminal **22**. In the illustrated exemplary embodiment, second electrically conductive terminal **22** is a ring-shaped member conforming to the size and shape of inner surface **42** of electrical terminal outer wall **28**. The bottom edge of electrically conductive terminal **22** is electrically connected to a second electrical terminal connector **48** which lies beneath the electrical terminal outer wall **28** and conductor base outer wall **26**. Second terminal connector **48** can be electrically connected to a portable electrical energy storage device, a device to be powered by the portable electrical energy storage device, or a device for charging a portable electrical energy storage device, thus providing an electrical connection between the device connected to the second terminal connector **48** and the other devices.

In the exemplary embodiment illustrated in FIGS. **2** and **3**, first electrically conductive terminal **21** and second electrically conductive terminal **22** are illustrated as a single terminal, respectively; however, embodiments of the present disclosure are not limited to first electrically conductive terminal **21** and electrically conductive terminal **22** including an integral continuous contact pad. First electrically conductive terminal **21** and second electrically conductive terminal **22** can take different forms, such as a terminal that includes more than one contact pad. An example of such type of terminal having more than one contact pad is illustrated in FIGS. **9**A and **9**B. In addition, while first electrically conductive terminal **21** is illustrated in FIGS. **2** and **3** as being connected to a single first terminal connector **46**, first electrically conductive terminal **21** can be electrically connected to more than one first terminal connector **46**. Similarly, while second electrically conductive terminal **22** is illustrated in FIGS. **2** and **3** as being connected to a single second terminal connector **48**, second electrically conductive terminal **22** can be electrically connected to more than one second terminal connector **48**. When first electrically conductive terminal **21** and/or second electrically conductive terminal **22** are provided in the form of a terminal that includes more than one contact pad, each individual contact pad can be connected to its own first terminal connector **46** or its own second terminal connector **48**.

In the illustrated embodiment of FIGS. **2** and **3**, electrical connection test terminal **24** of electrical connector **16** is an electrically conductive member in the shape of a cylinder centered along longitudinal axis **32**. Electrical connection test terminal **24** is positioned radially inward of first electrically conductive terminal **21**. The top of electrical connection test terminal **24** is recessed below the upper surfaces of a conductor base outer wall **26**, electrical terminal outer wall **28**, electrical terminal inner wall **30**, first electrically conductive terminal **21** and second electrically conductive terminal **22**. The center of electrical connection test terminal **24** includes a bore that passes through electrical connection test terminal **24** along a longitudinal axis **32**. Electrical connection test terminal **24** is electrically connected to connection test terminal connector **50** which is located below conductor base outer wall **26**, electrical terminal outer wall **28**, and electrical terminal inner wall **30**. In the illustrated embodiment, electrical test connection terminal **24** is electrically connected to connection test terminal connector **50** at its bottom; however, electrical connection between electrical test connection terminal **24** and connection test terminal connector **50** need not be at the bottom of connection test terminal connector **50**. Connection between connection test terminal connector **50** and electrical test connection terminal **24** can occur at different locations along the body of electrical test connection terminal **24**. Connection test terminal connector **50** provides electrical connection between electrical test connection terminal **24** and the electrical sensing device that can be connected to connection test terminal connector **50**.

Referring to FIGS. **4**, **5** and **6**, an exemplary electrical connector plug **20** in accordance with embodiments described herein is illustrated. Electrical connector plug **20** includes a nonconductive plug housing or body **100**, a first electrical connection terminal **102** and a second electrical connection terminal **104**. The electrical connection plug housing **100**, first electrical connection terminal **102** and second electrical connection terminal **104** are sized and configured to mate with electrical connector **16** described above with reference to FIGS. **2** and **3**. When mated, an electrical connection is provided between a device electrically connected to electrical connector **16** and a device connected to electrical connector plug **20**.

Nonconductive plug housing body **100** is an electrically nonconductive material, such as an electrically nonconducting plastic, and has a cylindrical shape centered along plug housing longitudinal axis **111**. At a plug end **107**, a first electrical connection terminal **102** and a second electrical connection terminal **104** protrude from nonconductive plug housing body **100**. First electrical connection terminal **102** and second electrical connection terminal **104** are formed out of an electrically conductive material, such as an electrically conductive metal. At the opposite terminal end **105** of nonconductive plug housing **100**, a first terminal connector **106**

and a second terminal connector **108** protrude from nonconductive plug housing **100**. First terminal connector **106** and second terminal connector **108** are formed out of an electrically conductive material, such as an electrically conductive metal. Intermediate first connection terminal **102** and first terminal connector **106** comprise a first terminal body **110**. First terminal body **110** is formed out of an electrically conductive material, such as an electrically conductive metal. First terminal body **110** provides an electrical connection between a first connection terminal **102** and first terminal connector **106**. Intermediate second connection terminal **104** and second terminal connector **108** comprise a second terminal body **112**. Second terminal body **112** is formed out of an electrically conductive material, such as an electrically conductive metal. Second terminal body **112** provides an electrical connection between the second connection terminal **104** and second terminal connector **108**. In order to avoid obscuring aspects of the subject matter described herein, details of how first terminal connector **106** and second terminal connector **108** are electrically connected to a portable electrical energy storage device or an electrically powered device are omitted.

The specific example of embodiments described herein illustrated in FIGS. **4-6** illustrates a first terminal body **110** that is offset radially from the plug housing longitudinal axis **111**. Similarly, secondary terminal body **112** is offset radially from the plug housing longitudinal axis **111**. In addition to the specific examples of the shapes and locations of first terminal body **110** and second terminal body **112** illustrated in FIGS. **4-6**, first terminal body **110** and second terminal body **112** can be shaped differently and located in other locations. For example, first terminal body **110** could be annular shaped like second terminal body **112** or a different shape, and/or second terminal body **112** need not be annular shaped, for example, second terminal body **112** could have a shape similar to first terminal body **110** or a different shape.

First electrical connection terminal **102** is annular in shape. Second electrical connection terminal **104** is also annular in shape and has a diameter greater than the diameter of the first electrical connection terminal **102**. In the illustrated embodiment, first electrical connection terminal **102** and second electrical connection terminal **104** are concentric relative to each other. First electrical connection terminal includes an inner electrical contact pad surface **114** and an outer electrical contact pad surface **116**. Similarly, second electrical connection terminal **104** includes an inner electrical contact pad surface **118** and an outer electrical contact pad surface **120**. In the illustrated embodiment, inner electrical contact pad surface **114** and outer electrical contact pad surface **116** are separated by an electrically nonconductive medium, e.g., air or an electrically nonconductive plastic.

In the exemplary embodiment illustrated in FIGS. **4-6**, first electrical connection terminal **102** and second electrical connection terminal **104** are illustrated as a single terminal, respectively; however, embodiments of the present disclosure are not limited to first electrical connection terminal **102** and second electrical connection terminal **104** being in the form of a single integral terminal. First electrical connection terminal **102** and second electrical connection terminal **104** can take different forms, such as a terminal that includes more than one contact pad. An example of such type of terminal is illustrated in FIGS. **10**A-**10**C. In addition, while first electrical connection terminal **102** is illustrated in FIGS. **4-6** as being connected to a single first terminal connector **106**, a plurality of first terminal connectors **106** can be provided and electrical connection terminal **102** connected to more than one first terminal connector **106**. In addition, first terminal connector **106** can be of a different shape than illustrated in FIGS. **4-6** and first terminal body **110** can be of a different shape than illustrated in FIGS. **4-6**. Similarly, while second electrical connection terminal **104** is illustrated in FIGS. **4-6** as being connected to a single second terminal connector **108**, second electrical connection terminal **104** can be electrically connected to more than one second terminal connector **108**. Furthermore when first electrically first electrical connection terminal **102** and/or second electrical connection terminal **104** are provided in the form of a terminal that includes more than one electrical contact pad, the individual contact pads can be electrically isolated from other contact pads and electrically connected to different first terminal connectors **106** and second terminal connectors **108**, respectively.

Referring to FIG. **7**, electrical connector **16** of FIGS. **2-3** and electrical connector plug **20** of FIGS. **4-6** are illustrated in a mated configuration. In FIG. **7**, outer electrical contact pad surface **116** of first electrical connection terminal **102** makes an electrical connection with first electrically conductive terminal **21** by contacting the exposed surface of first electrically conductive terminal **21**. Outer electrical contact pad surface **120** of second electrical connection terminal **104** makes an electrical connection with second electrically conductive terminal **22** of electrical connector **16** by contacting the exposed surface of second electrically conductive terminal **22**. As a result, a portable electrical energy storage device or a device to be powered by or charge such portable electrical energy storage device that is connected to electrical connector **16** is electrically connected to a portable electrical energy storage device or a device to be powered by or charge such portable electrical energy storage device that is connected to electrical connector plug **20**. Referring to the embodiments illustrated in FIG. **1**, the shape of the electrical connector **16** and electrical connector plug **20** permit the insertion of a portable electrical energy storage device into a receptacle for the portable electrical energy storage device in an unlimited number of rotational orientations, while still establishing an effective and safe electrical connection between the electrical connector **16** and the electrical connector plug **20**.

As seen in FIG. **7**, when electrical connector **16** is mated with electrical connector plug **20**, electrical connection test terminal **24** comes into electrical contact with inner electrical contact pad surface **114** of connection plug **20**. When electrical connection test terminal **24** electrically contacts inner electrical contact pad surface **114** when outer electrical contact pad surface **116** is in electrical contact with first electrically conductive terminal **21** of electrical connector **16**, electrical connection test terminal **24** is at the same voltage as first electrically conductive terminal **21**. This voltage can be detected by a sensor connected to connection test terminal connector **50**. Detection of this voltage provides a confirmation that first electrical connection terminal **102** of connection plug **20** is electrically connected to first electrically conductive terminal **21** of electrical connector **16**.

As seen in FIG. **7**, when electrical connector **16** is mated with electrical connector plug **20**, electrical connection test terminal **24** of electrical connector **16** makes electrical contact with inner electrical contact pad surface **114** of connection plug **20**. When electrical connection test terminal **24** electrically contacts inner electrical contact pad surface **114** when outer electrical contact pad surface **116** is in electrical contact with first electrically conductive terminal **21** of electrical connector **16**, electrical connection test terminal **24** is at the same voltage as first electrically conductive terminal **21**. The electrical connection test terminal **24** is connected to one terminal of a voltage sensor (not shown) via connection test terminal connector **50** for connection test terminal **24**. Second

electrically conductive terminal **22** is electrically connected to the other terminal of the voltage sensor (not shown) via second terminal connector **48**. The voltage sensor is configured to detect the voltage between electrical connection test terminal **24** and second electrically conductive terminal **22**. When electrical connector **16** is electrically connected to a portable electrical energy storage device, comparison of this detected voltage to the voltage of the portable electrical energy storage device to which electrical connector **16** is connected provides an indication of whether an electrical contact has been established between first electrically conductive terminal **21** of electrical connector **16** and first electrical connection terminal **102** of electrical connector plug **20**. An electrical connection between these terminals will be indicated by the voltage detected by the voltage sensor being substantially equal to the voltage of the portable electrical energy storage device. When electrical connector **16** is electrically connected to a device to be powered by or charge a portable electrical energy storage device and the electrical connector plug **20** is electrically connected to the portable electrical energy storage device, comparison of the voltage detected by the voltage sensor to the voltage of the portable electrical energy storage device provides an indication of whether an electrical contact has been established between first electrically conductive terminal **21** of electrical connector **16** and first electrical connection terminal **102** of electrical connector plug **20** and between second electrically conductive terminal **22** of electrical connector **16**, second electrical connection terminal **104** of electrical connector plug **20** and second electrical conductive terminal **22** of electrical connector **16**.

The present description has not identified the polarity of the first electrically conductive terminal **21** and second electrically conductive terminal **22** of the electrical connector **16** or the polarity of the first electrical connection terminal **102** and the second electrical connection terminal **104** of the electrical connector plug **20**. In accordance with embodiments described herein, the polarity of the different terminals can vary provided the first electrically conductive terminal **21** of electrical connector **16** is of the same polarity as the first electrical connection terminal **102** of the electrical connector plug **20**. Similarly, the polarity of the second electrical conductive terminal **22** of electrical connector **16** should be of the same polarity as the second electrical connection terminal **104** of the electrical connector plug **20**.

Referring to FIG. **8**, another example of an electrical connector **126** and the electrical connector plug **128** in accordance with embodiments described herein is illustrated. In FIG. **8**, a battery pack **122** includes an electrical connector **126**, and a battery pack receptacle **124** includes an electrical connector plug **128**. Like battery pack **10** of FIG. **1**, the battery pack **122** contains one or more individual portable electrical energy storage devices. These portable electrical energy storage devices can be arranged in different configurations, including single or multiple layers of individual electrical energy storage devices, each layer including one or more individual portable electrical energy storage devices. Battery pack **122** has a cross-section taken along line **9**A-**9**A that has a shape that is not round, e.g., polygonal. In the illustrated embodiment the battery pack **122** has a cross-section taken along line **9**A-**9**A that is square. Battery packs in accordance with embodiments described are not limited to those that have a square cross-section as shown in FIG. **8**, but include battery packs that have a cross-section of a different polygonal shape, e.g., rectangular, triangular, pentagonal, hexagonal, heptagonal, octagonal and the like. Battery packs in accordance with embodiments described herein can have a cross-section that includes more than eight sides. Like battery pack **10** described with reference to FIGS. **1**-**7** which can be received in battery pack receptacle **18** in more than one rotational orientation, battery pack **122** can be received in battery pack receptacle **124** in more than one rotational orientation. For example, illustrated battery pack **122** can be received in battery pack receptacle **124** in up to four different rotational orientations by rotating the battery pack in the direction of arrow **130**.

At one end, battery pack **122** includes a handle **132** attached to the battery pack **122**. At an end of battery pack **122** opposite the end containing handle **132**, battery pack **122** includes a multidirectional electrical connector **126** shown in phantom lines. Multidirectional electrical connector **126** is represented schematically and can have a different shape than that shown in phantom lines in FIG. **8**. Receptacle **124** is sized and configured to receive battery pack **122** when a battery pack **122** is moved in the direction of arrow **134** in FIG. **8**, and includes electrical connector plug **128**. Electrical connector plug **128** is represented schematically in FIG. **8** and can have a different shape than that shown in FIG. **8**. An advantage of electrical connector **126** and electrical connector plug **128** is their ability to cooperate with each other and electrically connect to each other when battery pack **122** is received in battery pack receptacle **124** in multiple rotational orientations. The ability to achieve an electrical connection between electrical connector **126** and electrical connector plug **128** in multiple rotational orientations of battery pack **122** relative to battery pack receptacle **124** reduces the likelihood that an ineffective electrical connection between electrical connector **126** and electrical connector plug **128** will result due to insertion of the battery pack **122** into battery pack receptacle **124** in an improper orientation. Thus, in accordance with embodiments described herein, electrical connector **126** and electrical connector plug **128** provide a multidirectional electrical connection system capable of providing an effective electrical connection in a plurality of rotational orientations whose effectiveness is not compromised due to insertion of a battery pack **122** into battery pack receptacle **124** in an improper orientation.

As with battery connector **16** illustrated in FIG. **1**, specific embodiments are described herein with reference to connectors for electrically connecting portable electrical energy storage devices to an electrical system of electrically powered vehicles or devices for charging the portable electrical energy storage devices; however, the present disclosure and the reference to connectors for electrically connecting a portable electrical energy storage device to an electrical system of electrically powered vehicles or devices for charging the portable electrical energy storage devices is not limited to electrical systems for electrically powered vehicles or devices for charging portable electrical energy storage devices. Connectors of the type described herein are also useful for electrically connecting a portable electrical energy storage device to electrical systems of electrically powered devices other than electrically powered vehicles and devices for charging the portable electrical energy storage devices.

Details of another embodiment of the present disclosure are described below with reference to FIGS. **9**A-**9**B, **10**A-**10**C and **11**. FIGS. **9**A-**9**B, **10**A-**10**C and **11** illustrate one exemplary embodiment of an electrical connector **126** electrically connected to a portable electrical energy storage device or to a device to be powered by or for charging the portable electrical energy storage device and an electrical connector plug **128** connected to a portable electrical energy storage device or to a device to be powered by or for charging the portable electrical energy storage device that is not con-

nected to the electrical connector **126**. Electrical connector **126** in the illustrated exemplary embodiment includes an electrically nonconductive connector base **136**, a first electrically conductive terminal **138**, a second electrically conductive terminal **140**, and an electrical connection test terminal **142**.

Electrically nonconductive connector base **136** includes a connector base outer wall **144**. In the illustrated exemplary embodiment of FIGS. **9**A-**9**B, **10**A-**10**C and **11**, electrically nonconductive connector base **136** is circular in shape when viewed along its longitudinal axis **147**. The electrically nonconductive connector base **136** including connector base outer wall **144** is formed of a nonconductive material, such as plastic. Conventional techniques such as extrusion or injection molding can be used to form nonconductive connector base **136** and connector base outer wall **144**. Electrically nonconductive connector base **136** further includes an annular shaped electrical contact housing **146** that includes an inner surface **148** and an outer surface **150**. Electrical contact housing **146** is formed out of an electrically nonconductive material, such as an electrically nonconductive plastic. In the illustrated embodiment, the electrical contact housing **146** is integral with the electrically nonconductive connector base **136**. Thus, in the illustrated embodiment, electrically nonconductive connector base **136** including connector base outer wall **144** and electrical contact housing **146** is an integral element; however, electrically nonconductive connector base **136** need not be an integral element, for example, conductive base outer wall **144** and electrical contact housing **146** can be formed separately and attached to each other. In the exemplary embodiment illustrated in FIG. **9**A, annular shaped electrical contact housing **146** is a quadrilateral with equal opposing angles when viewed along longitudinal axis **147**. In the illustrated embodiment, the quadrilateral has all sides of equal length. Annular shaped electrical contact housing **146** can be of other polygonal shapes besides a square, for example, annular shaped electrical contact housing **146** can have the shape of a rectangle, pentagon, hexagon, heptagon, octagon or other polygon with more than eight sides. Inner surface **148** of the electrical contact housing **146** is located closer to longitudinal axis **147** than outer surface **150** of the electrical contact housing **146**. Outer surface **150** of the electrical contact housing **146** is separated from connector base outer wall **144** by an electrically nonconductive medium, such as air or other electrically nonconductive medium, such as a nonconductive plastic.

Inner surface **148** of electrical contact housing **146** includes first electrically conductive terminal **138**. In the illustrated exemplary embodiment, first electrically conductive terminal **138** is a ring-shaped member conforming to the shape of the inner surface **148** of the electrical contact housing **146**. First electrically conductive terminal **138** includes a plurality of electrical contact pads **152**. In the exemplary embodiment illustrated in FIGS. **9**A and **9**B, first electrically conductive terminal **138** includes four electrical contact pads **152**, one positioned on each of the four inner surfaces **148** of the square shaped annular electrical contact housing **146**. First electrically conductive terminal **138** can include more than four or less than four electrical contact pads **152**. Embodiments described herein are not limited to first electrically conductive terminal **138** including four electrical contact pads **152**. As illustrated in FIG. **9**B, the contact pads **152** of first electrically conductive terminal **138** are electrically connected along their base. In the illustrated embodiment, first electrically conductive terminal **138** is electrically connected at its base to a first terminal connector **154**. First terminal connector **154** can be electrically connected to a portable electrical energy storage device or a device to be powered by or for charging the portable electrical energy storage device, thus providing an electrical connection between the portable electrical energy storage device or the device to be powered by or for charging the portable electrical energy storage device and the first electrically conductive terminal **138**.

Outer surface **150** of electrical contact housing **146** includes a second electrical conductive terminal **140**. In the illustrated exemplary embodiment, second electrical conductive terminal **140** is a ring-shaped member conforming to the shape of outer surface **150** of the electrical contact housing **146**. Second electrically conductive terminal **140** includes a plurality of electrical contact pads **156**. In the exemplary embodiment illustrated in FIGS. **9**A and **9**B, second electrically conductive terminal **140** includes four electrical contact pads **156**, one positioned on each of the four outer surfaces **150** of the square shaped annular electrical contact housing **146**. Second electrically conductive terminal **140** can include more than four or less than four electrical contact pads **156**. Embodiments described herein are not limited to second electrical conductive terminal **140** including four electrical contact pads **156**. As illustrated in FIG. **9**B, contact pads **156** of second electrically conductive terminal **140** are electrically connected along their base. Second electrically conductive terminal **140** is electrically connected at its base to a second terminal connector **158**. Second terminal connector **158** can be electrically connected to a portable electrical energy storage device or a device to be powered by or for charging a portable electrical energy storage device, thus providing an electrical connection between the portable electrical energy storage device or the device to be powered by or for charging the portable electrical energy storage device and the second electrically conductive terminal **140**. In order to avoid obscuring aspects of the subject matter described herein, details of how first terminal connector **154** and second terminal connector **158** are electrically connected to a portable electrical energy storage device or an electrically powered device are omitted.

In the exemplary embodiment illustrated in FIGS. **9**A and **9**B, electrical connection test terminal **142** of electrical connector **126** is an electrically conductive member in the shape of a cylinder centered along longitudinal axis **147**. Electrical connection test terminal **142** is positioned radially inward of first electrically conductive terminal **138**. The upper surface of electrical connection test terminal **142** is recessed below the upper surfaces of conductive base outer wall **144**, electrical contact housing **146**, first electrically conductive terminal **138** and second electrically conductive terminal **140**. Electrical connection test terminal **142** is electrically connected to connection test terminal connector **160**. In the illustrated embodiment, electrical connection test terminal **142** is electrically connected to connection test terminal connector **160** at its bottom; however, electrical connection between electrical connection test terminal **142** and connection test terminal connector **160** need not be at the bottom of connection test terminal **142**. Connection between connection test terminal **142** and electrical connection test terminal connector **160** can occur at different locations along the body of electrical connection test terminal **142**.

Referring to FIGS. **10**A-**10**C and **11**, an exemplary electrical connector plug **128** in accordance with embodiments described herein is illustrated. Electrical connector plug **128** includes a nonconductive plug housing **162**, a first electrical terminal **164** and a second electrical terminal **166**. The first electrical terminal **164** and second electrical terminal **166** are sized and shaped to mate with the electrical connector **126**

and its respective components. When mated, electrical connection is made between electrical connector **126** and electrical connector plug **128**.

Nonconductive plug housing **162** includes a plug body **170** comprising an electrically nonconductive material, such as an electrically nonconductive plastic. Plug body **170** has a cylindrical shape and is centered along plug housing longitudinal axis **168**. From one end of plug body **170** (the top end in FIG. **10**A), first electrical terminal **164** and a second electrical terminal **166** protrude. First electrical terminal **164** and second electrical terminal **166** are formed out of an electrically conductive material, such as an electrically conductive metal. At the end of plug body **170** where first electrical terminal **164** and second electrical terminal **166** protrude, an annular terminal housing **172** protrudes from plug body **170** beyond the ends of first electrical terminal **164** and second electrical terminal **166**. In the embodiment illustrated in FIG. **10**A, annular terminal housing **172**, when viewed along longitudinal axis **168**, has a round shape; however, the shape of annular terminal housing is not limited to a round shape. For example, when the shape of the gap between outer surface **150** of electrical contact housing **146** and conductor-base inner wall **145** of connector **126** in FIG. **9**A is something other than round, annular terminal housing **172** will have a complementary non-round shape. For example, if the shape of the gap between the outer surface **150** of the electrical contact housing **146** and conductor base inner wall **145** is square, annular terminal housing **172** will have a complementary square shape and will be sized to be received into that gap. One of the reasons the shapes are complementary is so annular terminal housing **172** can be received into the gap between outer surface **150** of electrical contact housing **146** and conductor base inner wall **145**, thus allowing connector **126** and plug **128** to mate with each other.

At the end of nonconductive plug housing **162** opposite annular terminal housing **172** (the bottom end in FIG. **10**A), first terminal connector **174** of first electrical terminal **164** and second terminal connector **175** of second electrical terminal **166** protrude from nonconductive plug body **170**. Alternatively, first terminal connector **174** and second terminal connector **175** do not protrude from nonconductive plug body **170**, but rather are accessible within nonconductive body **170**. In FIG. **10**B the interior of nonconductive plug body **170** is shown as being hollow. In accordance with other embodiments described herein, nonconductive plug body **170** is filled with a nonconductive material, such as a nonconductive plastic, and the first terminal connector **174** and second terminal connector **175** extend through and protrude from this nonconductive material at an end of the nonconductive plug body **170** that is opposite annular electrical terminal housing **172**. First terminal connector **174** and second terminal connector **175** provide electrical connectors for making an electrical connection with first electrical terminal **164** and second electrical terminal **166**. In order to avoid obscuring aspects of the subject matter described herein, details of how first terminal connector **174** and second terminal connector **175** are electrically connected to the portable electrical energy storage device or an electrically powered device are omitted.

In the embodiment illustrated in FIGS. **10**A-**10**C, first electrical terminal **164** is formed out of an electrically conductive material, such as a conductive metal. When viewed along longitudinal axis **168**, first electrical terminal **164** has a square shape and includes a cylindrical bore centered on longitudinal axis **168** that passes through first electrical terminal **164**. First electrical terminal **164** may have a shape other than the illustrated square shape, for example, first electrical terminal **164** can have a circular shape when viewed along longitudinal axis **168** or it can have a polygon shape other than a square, for example, a triangle, rectangle, pentagon, hexagon, octagon, or a polygon having more than eight sides. Preferably, first electrical terminal **164** has a shape that complements the shape of the electrical contact housing **146** of electrical connector **126** in FIG. **9**A. When the shape of first electrical terminal **164** complements the shapes of the electrical contact housing **146** (e.g., the shape of first electrical terminal **164** and the shape of electrical contact housing **146** are related in a male plug/female receptacle relationship), first electrical connection terminal **164** can be received in electrical contact housing **146** and the two are able to mate with each other.

In the exemplary embodiment illustrated in FIGS. **10**A-**10**C, an inner surface of annular electrical terminal housing **172** includes a second electrical connection terminal **166**. Second electrical terminal **166** is formed out of an electrically conductive material, such as an electrically conductive metal. As illustrated in FIG. **10**C, second electrical terminal **166** includes three contact pads **178** that are offset from each other by 90° along inner surface **176** of electrical terminal housing **172**. While the exemplary embodiment of FIGS. **10**A-**10**C illustrates three contact pads **178**, a greater number or a lesser number of contact pads **178** can be employed in accordance with embodiments described herein. For example, only one or two contact pads **178** can be utilized. As illustrated in FIG. **10**C, contact pads **178** are electrically connected to each other at their base **179**. In the embodiment illustrated in FIG. **10**A-**10**C, base **179** extends through the nonconductive plug body **170** to the end of nonconductive plug body **170** opposite annular electrical terminal housing **172**.

Located adjacent inner surface **176** of annular electrical terminal housing **172** is a connection test terminal **180**. Connection test terminal **180** is an electrically conductive material such as an electrically conductive metal. In the embodiment illustrated in FIGS. **10**A-**10**C, connection test terminal **180** is spaced apart 90° from two contact pads **178** of second electrical terminal **166** and extends from annular electrical terminal housing **172** through nonconductive plug body **170**, and in the illustrated embodiment protrudes from an end of nonconductive plug body **170** that is opposite the end of nonconductive plug body **170** adjacent annular electrical terminal housing **172**. This protruding end of connection test terminal **180** provides an electrical connector **182** for making an electrical connection to connection test terminal **180**.

First terminal connector **174** and second terminal connector **175** provide electrical connection points for connecting first electrical terminal **164** and second electrical terminal **166** to a portable electrical energy storage device or to a device to be powered by or for charging the portable electrical energy storage device.

Referring to FIG. **11**, electrical connector **126** of FIGS. **9**A and **9**B and electrical connector plug **128** of FIGS. **10**A-**10**C are illustrated in a mated configuration. In this mated configuration, first electrical terminal **138** of electrical connector **126** makes electrical contact with first electrical terminal **164** of the electrical connector plug **128**. Second electrical terminal **140** of electrical connector **126** makes electrical contact with second electrical terminal **166** of electrical connector plug **128**. As a result, a portable electrical energy storage device or a device to be powered by or for charging such portable electrical energy storage device that is connected to electrical connector **126** is electrically connected to a portable electrical energy storage device or a device to be powered by or for charging such portable electrical energy storage device that is connected to electrical connector plug **128**.

Referring to FIG. **8**, the size and shape of electrical connector **126** and the complementary size and shape of electri-

cal connector plug **128** permit a user to insert the battery pack **122** into the battery pack receptacle **124** in a plurality of rotational orientations relative to each other, while establishing a useful and safe electrical connection between the electrical connector **126** and the electrical connector plug **128**.

As seen in FIG. **11**, when electrical connector **126** is mated with electrical connector plug **128**, electrical connection test terminal **142** of electrical connector **126** makes electrical contact with first electrical terminal **164** of electrical connector plug **128**. When electrical connector **126** is mated with electrical connector plug **128**, electrical connection test terminal **180** of electrical connector plug **128** makes electrical contact with second electrical terminal **140** of electrical connector **126**. Electrical connection test terminal **180** is electrically connected to one terminal of a voltage sensor (not shown) via electrical connector **182** for connection test terminal **180**. When electrical connector **126** is mated with electrical connector plug **128**, electrical connection test terminal **142** of electrical connector **126** makes electrical contact with first electrical terminal **164** of electrical connector plug **128**. Electrical connection test terminal **142** of electrical connector plug **128** is electrically connected to another terminal of the voltage sensor (not shown) via electrical connection test terminal connector **160** for connection test terminal **142**. When electrical connection test terminal **180** contacts second electrical terminal **140** and electrical connection test terminal **142** contacts first electrical terminal **164**, electrical connection test terminal **180** will be at the same voltage as second electrical terminal **140** and electrical connection test terminal **142** will be at the same voltage as first electrical terminal **164**. The voltage sensor is configured to detect the voltage between electrical connection test terminal **180** and electrical connection test terminal **142**. Comparison of this detected voltage to the voltage of the portable electrical energy storage device to which electrical connector **126** or electrical connector plug **128** are connected provides an indication of whether an electrical contact has been established between first electrical terminal **164** of electrical connector plug **128** and first electrical terminal **138** of electrical connector **126** and second electrical terminal **166** of electrical connector plug **128** and second electrical terminal **140** of electrical connector **126**. Electrical connection between these terminals will be indicated by the voltage detected by the voltage sensor being substantially equal to the voltage of the portable electrical energy storage device. The configuration of an independent electrical connection test terminal **180** illustrated in FIGS. **10**A-C and **11** can also be implemented in the electrical connection system described with reference to FIGS. **1-7**. For example an independent connection test terminal can be provided in electrical connector plug **20**.

In accordance with embodiments described herein, portable electrical energy storage devices can be removably received by receptacles for the portable electrical energy storage devices. In FIGS. **1** and **8** electrical connectors **16** and **126** are illustrated as part of portable electrical energy storage devices **12** and **122**, respectively. The same figures illustrate electrical connector plugs **20** and **128** as part of portable electrical energy storage device receptacles **18** and **128**, respectively. Embodiments described herein are not limited to electrical connectors **16** or **126** being part of portable electrical energy storage devices. For example, electrical connectors **16** and **126** may be part of receptacles **18** or **128** for receiving portable electrical energy storage devices. When receptacles **18** or **128** include electrical connectors **16** or **126**, portable electrical energy storage devices **12** or **122** will include the counterpart electrical connector plug **20** or **128**.

An advantage of an electrical connection system including the electrical connector and electrical connection plug in accordance with embodiments described herein is the ability to establish an electrical connection between a portable electrical energy storage device and a device to be powered by or for charging the portable electrical energy storage device in a plurality of rotational orientations and, in the embodiments of FIGS. **1-8**, an infinite number of rotational orientations. In accordance with embodiments described herein, a multidirectional or omni-directional electrical connection system is provided whereby electrical connection between an electrical connector and an electrical connection plug can be established in a plurality of rotational orientations and in some cases in an infinite number of rotational orientations. The ability to make electrical connections in a plurality or infinite number of rotational orientations reduces the likelihood of a faulty electrical connection due to a user inserting a battery pack into a battery pack receptacle in an improper rotational orientation. Electrical connections between a device including an electrical connector and a device including an electrical connector plug in accordance with embodiments described herein can be made when the devices are mated with each other in a plurality of rotational orientations. The ability to make electrical connections in a plurality of rotational orientations has other advantages, such as reducing the likelihood that damage will be done to the electrical connector or electrical connector plug due to the portable electrical energy storage device being inserted into the receptacle in an orientation in which an electrical connection cannot be made between the electrical connector and electrical connection plug or an orientation in which the electrical connector and electrical connection plug cannot mate physically with each other.

In accordance with additional embodiments of the subject matter described herein, multidirectional electrical connection systems capable of establishing an electrical connection between a portable electrical energy storage device and a device to be powered by or for charging the portable electrical energy storage device in a plurality of rotational orientations include electrical terminal patterns such as those illustrated in FIGS. **12-14**.

Referring to FIGS. **12**A-**12**C, FIG. **12**A is a schematic illustration of a top of a receptacle **184** for receiving a portable electrical energy storage device **194** and making electrical connection between electrical terminals of the receptacle and electrical terminals of a portable electrical energy storage device in two different rotational orientations of the portable electrical energy storage device **194** relative to receptacle **184**. More specifically, FIG. **12**A is a top down schematic illustration of the bottom of a receptacle **184** for receiving a portable electrical energy storage device (not shown). In the illustrated embodiment, the bottom of receptacle **184** includes two positive electric terminals **186** arranged in a horizontal row and two negative terminals **188** arranged in a horizontal row below positive electric terminals **186**. FIG. **12**B illustrates an arrangement of a positive terminal **190** and a negative terminal **192** located on the bottom of a portable electrical energy storage device **194** that has been received by receptacle **184** in a first rotational orientation. In this exemplary embodiment, positive terminal **190** is located in an opposite corner of portable electrical energy storage device **194** from negative terminal **192**. Dotted line **196** identifies the outline of receptacle **184**. Dotted lines **198** and **200** identify positive terminals **186** and negative terminals **188** of receptacle **184**. FIG. **12**C illustrates the position of positive terminal **190** and negative terminal **192** after portable electrical energy storage device **194** is rotated counterclockwise by 90°,

placing portable electrical energy storage device **194** in a second rotation orientation relative to receptacle **184**.

FIG. **13**A is a schematic illustration of a different configuration of electrical terminals in a receptacle **184** for receiving a portable electrical energy storage device **194** and electrical terminals on the portable electrical energy storage device for making electrical connection between the receptacle and the portable electrical energy storage device in two different rotational orientations. More specifically, FIG. **13**A is a top down schematic illustration of the bottom of a receptacle **184** for receiving a portable electrical energy storage device (not shown). In the illustrated embodiment, the bottom of receptacle **184** includes two positive electric terminals **186** and two negative electric terminals **188**. Positive electric terminals **186** are located in opposite corners of the receptacle and negative terminals **188** are located in the remaining opposing corners. FIG. **13**B illustrates an arrangement of a positive terminal **190** and a negative terminal **192** located on the bottom of a portable electrical energy storage device **194** that has been received by receptacle **184**. In this exemplary embodiment, positive terminal **190** is located in a corner of portable electrical energy storage device **194** above a corner occupied by negative terminal **192**. Dotted line **196** identifies the outline of receptacle **184**. Dotted lines **198** and **200** identify positive terminals **186** and negative terminals **188** of receptacle **184** respectively. FIG. **13**C illustrates the position of positive terminal **198** and negative terminal **192** after portable electrical energy storage device **194** has been rotated counterclockwise by 180°. In this manner, receptacle **184** and portable electrical energy storage device **194** cooperate so that an electrical connection between the electrical terminals of receptacle **184** and the electrical terminals of portable electrical energy storage device **194** can be made in two different rotational orientations of the receptacle **184** relative to the portable electrical energy storage device **194**.

FIG. **13**D illustrates another arrangement of a positive terminal **190** and a negative terminal **192** located on the bottom of a portable electrical energy storage device **194** that has been received by receptacle **184**. In FIG. **13**D, the arrangement of positive terminals **186** and negative terminals **188** at the bottom of receptacle **184** are the same as described and illustrated in FIGS. **13**A-**13**C. In this exemplary embodiment, positive terminal **190** is located in a corner of portable electrical energy storage device **194** adjacent a corner occupied by negative terminal **192**. Dotted line **196** identifies the outline of receptacle **184**. Dotted lines **198** and **200** identify positive terminals **186** and negative terminals **188** of receptacle **184**. FIG. **13**E illustrates the position of positive terminal **190** and negative terminal **192** after portable electrical energy storage device **194** has been rotated counterclockwise 180°. In this manner, receptacle **184** and portable electrical energy storage device **194** cooperate so that an electrical connection between the electrical terminals of receptacle **184** and the electrical terminals of portable electrical energy storage device **194** can be made in two different rotational orientations of the receptacle **184** relative to the portable electrical energy storage device **194**.

Though not illustrated, electrical connections between the receptacle **184** and portable electrical energy storage device **194** illustrated in FIGS. **12**A-**12**C and **13**A-**13**D in at least two rotational orientations can also be achieved if the illustrated arrangement of positive and negative terminals at the bottom of receptacle **184** are provided on the bottom of portable electrical energy storage device **194** and the arrangement of positive and negative terminals at the bottom of portable electrical energy storage device **194** are provided at the bottom of receptacle **184**.

In contrast to the embodiments illustrated in FIGS. **12**A-**12**C and **13**A-**13**E, electrical connection systems illustrated in FIGS. **14**A-**14**D do not include positive terminals and negative terminals located at the same end of a portable electrical energy storage device or a receptacle for the portable electrical energy storage device, but rather positive terminals **203** are located at one end **204** of portable electronic storage device **202** and negative terminals **205** are located at an opposite end **206** of portable electrical energy storage device **202**. In the embodiment illustrated in FIG. **14**A, positive terminals **210** are located in the bottom (schematically illustrated as **208**) of a receptacle for receiving portable electrical energy storage device **202**. The top of the receptacle (schematically illustrated as **212**) includes four negative terminals **214**. With the arrangement of positive terminals **203** and negative terminals **205** on portable electrical energy storage device **202** shown in FIG. **14**A and the arrangement of positive terminals **210** and negative terminals **214** at the bottom and top of the receptacle for receiving portable electrical energy storage device **202** shown in FIG. **14**A, the portable electrical energy storage device **202** can be received into the receptacle in at least four different rotational orientations relative to the receptacle. FIGS. **14**B-**14**D illustrate further arrangements of positive electrical terminals **203** on the bottom of portable electrical energy storage device **202** and arrangement of negative electrical terminals **205** on the top of portable electrical energy storage device **202**. In FIG. **14**B, two negative terminals **205** are located along one edge of the top end **206** of portable electrical energy storage device **202** and two positive electrical terminals are located along the same edge of the bottom end **204** of portable electrical energy storage device **202**. In accordance with embodiments of the subject matter described herein, the pair of negative electrical terminals **205** need not be positioned along the same edge as the pair of positive electrical terminals **203**. For example, the pair of positive electrical terminals **203** can be positioned along an edge of portable electrical energy storage device **202** that is opposite the edge along which negative terminals **205** are located or adjacent the edge along which negative terminals **205** are located. FIG. **14**C illustrates embodiments in accordance with the present disclosure that include a pair of negative terminals **205** located in opposite corners of the top end **206** of portable electrical energy storage device **202** and a pair of positive terminals **203** located in the same opposite corners of the bottom end **204** of portable electrical energy storage device **202**. In accordance with embodiments of the subject matter described herein, the pair of negative electrical terminals **205** need not be located in the same opposite corners as the pair of positive electrical terminals **203**. For example, the pair of negative electrical terminals **205** can be located in unoccupied opposing corners of the top **206** of portable electrical energy storage device **202**.

FIG. **14**D illustrates embodiments in accordance with the present disclosure that include a single negative terminal **205** located in a corner of the top end **206** of portable electrical energy storage device **202** and a single positive terminal **203** located in the same corner of the bottom end **204** of portable electrical energy storage device **202**. In accordance with embodiments of the subject matter described herein, negative electrical terminal **205** need not be located in the same corner as the positive electric terminals **203**. For example, negative electrical terminal **205** can be located in an unoccupied corner of the top **206** of portable electrical energy storage device **202**.

In FIGS. **14**A-**14**D, fewer negative electrical terminals **214** can be provided at the top **212** of the receptacle for portable electrical energy storage device **202** and fewer positive elec-

trical terminals **210** can be provided at the bottom **208** of the receptacle for portable electrical energy storage device **202**. Such negative electrical terminals **214** and positive electrical terminals **210** can be provided at numerous locations, provided such locations cooperate with the locations of negative terminals **205** and positive terminals **203** of portable electrical energy storage device **202** and provide for making an electrical connection between the terminals of the receptacle and the terminals of the portable electrical energy storage device **202** in more than one rotational orientation of portable electrical energy storage device **202** relative to the receptacle.

While the embodiments of FIGS. **12**A-**12**C, **13**A-**13**E and **14**A-**14**D have been described with reference to specific locations of the positive terminals and negative terminals relative to the portable electrical energy storage device and the receptacle for the portable electrical energy storage device, in accordance with embodiments of the present disclosure, the locations of the positive electrical terminals and the negative electrical terminals relative to the portable electrical energy storage device and the receptacle for the portable electrical energy storage device can be reversed. For example, described arrangements of positive electric terminals and negative electric terminals on a portable electrical energy storage device can alternatively be provided on the receptacle for the portable electrical energy storage device and described arrangements of positive electric terminals and negative electric terminals on the receptacle can be provided on the portable electrical energy storage device.

Details of another embodiment of the present disclosure are described below with reference to FIGS. **15-18**, **19**A-**19**C and **20-23**. FIGS. **15-16** illustrate one exemplary embodiment of an electrical connector **326** electrically connected to a portable electrical energy storage device or to a device to be powered by or for charging the portable electrical energy storage device and an electrical connector plug **328** connected to a portable electrical energy storage device or to a device to be powered by or for charging the portable electrical energy storage device that is not connected to the electrical connector **326**. Electrical connector **326** in the illustrated exemplary embodiment includes an electrically nonconductive connector base **336**, a first electrically conductive terminal **338**, a second electrically conductive terminal **340**, an electrical connection test terminal **342** and a resilient electrically conductive connector **343**.

Electrically nonconductive connector base **336** includes a connector base outer wall **344**. In the illustrated exemplary embodiment of FIGS. **15** and **16**, **19**A-**19**C and **20**, electrically nonconductive connector base **336** is circular in shape when viewed along its longitudinal axis **347**. The electrically nonconductive connector base **336** including connector base outer wall **344** is formed of a nonconductive material, such as plastic. Conventional techniques such as extrusion or injection molding can be used to form nonconductive connector base **336** and connector base outer wall **344**. Electrically nonconductive connector base **336** further includes an annular shaped electrical contact housing **346** that includes an inner surface **348** and an outer surface **350**. Electrical contact housing **346** is formed out of an electrically nonconductive material, such as an electrically nonconductive plastic. In the illustrated embodiment, the electrical contact housing **346** is integral with the electrically nonconductive connector base **336**. Thus, in the illustrated embodiment, electrically nonconductive connector base **336** including connector base outer wall **344** and electrical contact housing **346** is an integral element; however, electrically nonconductive connector base **336** need not be an integral element, for example, conductive base outer wall **344** and electrical contact housing **346** can be formed separately and attached to each other. In the exemplary embodiment illustrated in FIG. **15**, annular shaped electrical contact housing **346** is a round when viewed in cross-section along longitudinal axis **347**. Annular shaped electrical contact housing **346** can be polygonal shaped and not round when viewed in cross-section along longitudinal axis **347**. For example, electrical contact housing **346** can have the shape of a rectangle, pentagon, hexagon, heptagon, octagon or other polygon with more than eight sides. Inner surface **348** of the electrical contact housing **346** is located closer to longitudinal axis **347** than outer surface **350** of the electrical contact housing **346**. Outer surface **350** of the electrical contact housing **346** is separated from connector base inner wall **345** by an electrically nonconductive medium, such as air or other electrically nonconductive medium, such as a nonconductive plastic.

Inner surface **348** of electrical contact housing **346** includes first electrically conductive terminal **338**. In the illustrated exemplary embodiment, first electrically conductive terminal **338** is a ring-shaped member conforming to the shape of the inner surface **348** of the electrical contact housing **346**. First electrically conductive terminal **338** is in electrical contact with a resilient connector **343**A. Resilient connector **343**A is a spring-like member that can be compressed in a lateral direction perpendicular to longitudinal axis **347**. The compressive characteristic of the described resilient connectors allows electrical connector plug **328** to be inserted into electrical connector **326** and achieving low resistance, electrical connection between first electrical terminal **338** and electrical terminal **364** of electrical connector plug **328**. Resilient connector **343**A is electrically conductive and of low electrical resistance. In addition, resilient connector **343**A is resistant to corrosion or other degradation that could negatively affect its electrical conductivity and/or electrical resistance. In the illustrated embodiment, resilient connector **343**A is illustrated as what is known as a crown spring connector. While an embodiment of a resilient connector has been illustrated with reference to a crown spring connector, resilient connectors which are not crown spring connectors are included in embodiments of the resilient connectors described herein. One exemplary embodiment of a resilient connector **343** is illustrated in FIGS. **17** and **18**. In the illustrated embodiment, first electrically conductive terminal **338** is electrically connected at its base to a first terminal connector **354**. First terminal connector **354** can be electrically connected to a portable electrical energy storage device or a device to be powered by or for charging the portable electrical energy storage device, thus providing an electrical connection between the portable electrical energy storage device or the device to be powered by or for charging the portable electrical energy storage device and the first electrically conductive terminal **338**.

Outer surface **350** of electrical contact housing **346** includes a second electrical conductive terminal **340**. In the illustrated exemplary embodiment, second electrical conductive terminal **340** is a ring-shaped member conforming to the shape of outer surface **350** of the electrical contact housing **346**. In the exemplary embodiment illustrated in FIGS. **15** and **16**, second electrically conductive terminal **340** is ring-shaped when viewed in cross-section along axis **347**. Second electrically conductive terminal **340** is electrically connected at its base to a second terminal connector **358**. Second terminal connector **358** can be electrically connected to a portable electrical energy storage device or a device to be powered by or for charging a portable electrical energy storage device, thus providing an electrical connection between the portable electrical energy storage device or the device to be powered

by or for charging the portable electrical energy storage device and the second electrically conductive terminal **340**. In order to avoid obscuring aspects of the subject matter described herein, details of how first terminal connector **354** and second terminal connector **358** are electrically connected to a portable electrical energy storage device or an electrically powered device are omitted. In the illustrated embodiment, tops of first electrically conductive terminal connector **338** and second electrically conductive terminal connector **340** are bridged by an electrically non-conductive cap **341**.

In the exemplary embodiment illustrated in FIGS. **15** and **16**, electrical connection test terminal **342** of electrical connector **326** is an electrically conductive member in the shape of a cylinder centered along longitudinal axis **347**. Electrical connection test terminal **342** is positioned radially inward of first electrically conductive terminal **338**. The upper surface of electrical connection test terminal **342** is recessed below the upper surfaces of conductive base outer wall **344**, electrical contact housing **346**, first electrically conductive terminal **338** and second electrically conductive terminal **340**. Electrical connection test terminal **342** is electrically connected to connection test terminal connector **360**. In the illustrated embodiment, electrical connection test terminal **342** is electrically connected to connection test terminal connector **360** at its bottom; however, electrical connection between electrical connection test terminal **342** and connection test terminal connector **360** need not be at the bottom of connection test terminal **342**. Connection between connection test terminal **342** and electrical connection test terminal connector **360** can occur at different locations along the body of electrical connection test terminal **342**.

Referring to FIGS. **19**A-**19**C and **20**, an exemplary electrical connector plug **328** in accordance with embodiments described herein is illustrated. Electrical connector plug **328** includes a nonconductive plug housing **362**, a first electrical terminal **364** and a second electrical terminal **366**. The first electrical terminal **364** and second electrical terminal **366** are sized and shaped to mate with the electrical connector **326** and its respective components. When mated, electrical connection is made between electrical connector **326** and electrical connector plug **328**. In the illustrated embodiments, first electrical terminal **364** and second electric terminal are provided with resilient connector **343**C and **343**B respectively.

Nonconductive plug housing **362** includes a plug body **370** comprising an electrically nonconductive material, such as an electrically nonconductive plastic. Plug body **370** has a cylindrical shape and is centered along plug housing longitudinal axis **368**. From one end of plug body **370** (the top end in FIG. **19**A), first electrical terminal **364** and a second electrical terminal **366** protrude. First electrical terminal **364** and second electrical terminal **366** are formed out of an electrically conductive material, such as an electrically conductive metal. At the end of plug body **370** where first electrical terminal **364** and second electrical terminal **366** protrude, an annular terminal housing **372** protrudes from plug body **370** beyond the ends of first electrical terminal **364** and second electrical terminal **366**. In the embodiment illustrated in FIG. **19**A, annular terminal housing **372**, when viewed along longitudinal axis **368**, has a round shape; however, the shape of annular terminal housing is not limited to a round shape. For example, when the shape of the gap between outer surface **350** of electrical contact housing **346** and conductor-base inner wall **345** of connector **326** in FIG. **15** is something other than round, annular terminal housing **372** will have a complementary non-round shape. For example, if the shape of the gap between the outer surface **350** of the electrical contact housing **346** and conductor base inner wall **345** is square, annular terminal housing **372** will have a complementary square shape and will be sized to be received into that gap. One of the reasons the shapes are complementary is so annular terminal housing **372** can be received into the gap between outer surface of second electrical terminal **340** and inner surface **345** of electrical contact housing **346**, thus allowing connector **326** and plug **328** to mate with each other.

At the end of annular terminal housing **372** adjacent nonconductive plug body **370** (the bottom end in FIG. **19**A), first terminal connector **374** of first electrical terminal **364** and second terminal connector **375** of second electrical terminal **366** protrude from annular terminal housing **372**. Alternatively, first terminal connector **374** and second terminal connector **375** do not protrude from annular terminal housing **372**, but rather are accessible within terminal housing body **372**. In FIG. **19**B the interior of nonconductive plug body **370** is shown as being hollow. In accordance with other embodiments described herein, nonconductive plug body **370** is filled with a nonconductive material, such as a nonconductive plastic, and the first terminal connector **374** and second terminal connector **375** extend through and protrude from this nonconductive material at an end of the nonconductive plug body **370** that is opposite annular electrical terminal housing **372**. First terminal connector **374** and second terminal connector **375** provide electrical connectors for making an electrical connection with first electrical terminal **364** and second electrical terminal **366**. First terminal connector **374** and second terminal connector **375** are electrically connected to electrical cables **379** and **377** respectively. Cables **377** and **379** may be electrically connected to a portable electrical energy storage device or an electrically powered device.

In the embodiment illustrated in FIGS. **19**A-**19**C, first electrical terminal **364** is formed out of an electrically conductive material, such as a conductive metal. When viewed along longitudinal axis **368**, first electrical terminal **364** has an annular round shape and includes a cylindrical bore centered on longitudinal axis **368** that passes through first electrical terminal **364**. First electrical terminal **364** is in electrical contact with a resilient connector **343**C. Resilient connector **343**C is a spring-like member that can be compressed in a lateral direction perpendicular to longitudinal axis **368**. Resilient connector **343**C is similar to resilient connector **343**A described above. Resilient connector **343**C is smaller in diameter and length than resilient connector **343**A. The compressive characteristic of the described resilient connector **343**C allows test connection terminal **342** to be inserted into electrical connector plug **328** and achieve low resistance, electrical connection between test connection terminal **342** and first electrical terminal **364** of electrical connector plug **328**. One exemplary embodiment of a resilient connector **343** is illustrated in FIGS. **17** and **18**. First electrical terminal **364** may have a shape other than the illustrated round shape, for example, first electrical terminal **364** can have a square shape when viewed along longitudinal axis **368** or it can have a polygon shape other than a square, for example, a triangle, rectangle, pentagon, hexagon, octagon, or a polygon having more than eight sides. Preferably, first electrical terminal **364** has a shape that complements the shape of the electrical contact housing **346** of electrical connector **326** in FIG. **15**. When the shape of first electrical terminal **364** complements the shape of the electrical contact housing **346** (e.g., the shape of first electrical terminal **364** and the shape of electrical contact housing **346** are related in a male plug/female receptacle relationship), first electrical connection terminal **364** can be received in electrical contact housing **346** and the two are able to mate with each other.

In the exemplary embodiment illustrated in FIGS. **19**A-**19**C, an inner surface of annular electrical terminal housing **372** includes a second electrical connection terminal **366**. Second electrical terminal **366** is formed out of an electrically conductive material, such as an electrically conductive metal. As illustrated in FIG. **19**C, second electrical terminal **366** is round when viewed in cross-section perpendicular to central axis **368**. While the exemplary embodiment of FIGS. **19**A-**19**C illustrate a round second electrical terminal **366**, second electrical terminal **366** is in electrical contact with a resilient connector **343**B. Resilient connector **343**B is a spring-like member that can be compressed in a lateral direction perpendicular to longitudinal axis **347**. Resilient connector **343**B is similar to resilient connector **343**A and **343**C described above. Resilient connector **343**B is larger in diameter and length than resilient connectors **343**A and **343**C. The compressive characteristic of the described resilient connector **343**B allows connector plug **328** to be inserted into electrical connector **326** and achieve low resistance, electrical connection between electrical terminal **340** and second terminal **366**. One exemplary embodiment of a resilient connector **343** is illustrated in FIGS. **17** and **18**.

Second electrical terminal **366** may have a shape other than the illustrated round shape, for example, second electrical terminal **366** can have a square shape when viewed along longitudinal axis **368** or it can have a polygon shape other than a square, for example, a triangle, rectangle, pentagon, hexagon, octagon, or a polygon having more than eight sides. Preferably, second electrical terminal **366** has a shape that complements the shape of the gap between inner wall **345** of non-conductive connector base **336** and the outer surface of second electrical connector **340** in FIG. **15**. In the embodiment illustrated in FIG. **19**A-**19**C, first electrical terminal **364** and second electrical terminal **366** extend through the end of electrical terminal housing **372** adjacent nonconductive plug body **370**. Located adjacent inner surface of annular electrical terminal housing **372** is a connection test terminal **380**. Connection test terminal **380** is an electrically conductive material such as an electrically conductive metal. In the embodiment illustrated in FIGS. **19**A-**19**C, connection test terminal **380** extends from an end of annular electrical terminal housing **372** adjacent nonconductive plug body **370**. This protruding end of connection test terminal **380** provides an electrical connector **382** for making an electrical connection between electric cable **383** and connection test terminal **380**. In the illustrated embodiment, connection test terminal **380** includes a biased tab **381**. Connection test terminal **380** and biased tab **381** are described in more detail below with reference to FIGS. **21**-**23**.

In the embodiment illustrated in FIGS. **21**-**23** another embodiment of a connection test terminal is shown. The embodiment illustrated in FIGS. **21**-**23** includes connection test terminal **380** and connection test terminal housing **385**. Connection test terminal **380** is an elongate conductive metal strip. At one end of connection test terminal **380** is located a connection test terminal tab **381** and disconnect bearing surface **386**. At the opposite end of connection test terminal **380** is connection terminal **382**. Connection test terminal tab **381** is a resilient member biased in a direction towards longitudinal axis **368** of connector plug **328**. Connection test terminal tab **381** is a resilient, electrically conductive material such as an electrically conductive metal. In the illustrated embodiment, connection test terminal tab **381** is formed by removing a portion of the metal strip around three sides of connection test terminal tab **381** while not removing metal along one short edge of the metal strip. Bending the connection test terminal tab **381** along the portion of the metal strip that has not been removed and towards the longitudinal axis **368** causes connection test terminal tab **381** to be biased in an inward direction. In the illustrated embodiment, below connection test terminal tab **381**, test connection terminal **380** includes a disconnect bearing surface **386**. In the illustrated embodiment, disconnect bearing surface **386** is provided by an additional strip of metal bent outward slightly to form a surface that preferably does not snag or catch on outer surface **340** of electrical connector **326** when electrical connector plug **328** is disengaged from electrical connector **326**. In the illustrated embodiment, the metal strip forming disconnect bearing surface **386** is bent at approximately 10 to 45 degrees relative to connection test terminal tab **381**. The resiliency and bias of test connection terminal **380** serves to maintain test connection terminal **380** in contact with outer surface **340** of electrical connector **326**. The bearing surface of connection test terminal tab **381** causes test connection terminal **380** to be pushed away from longitudinal axis **368** when electrical connection plug is inserted into electrical connector **326**.

Connection test terminal tab **381** in the illustrated embodiment is housed within a connection test terminal housing **385**. Connection test terminal housing **385** is formed from a non-conductive material, such as plastic and is received into a cut out **387** formed in second electrical terminal **366**. Cut out **387** is sized to meet him closely with connection test terminal housing **385**. By positioning connection test terminal **380** within connection test terminal housing **385**, connection test terminal **380** is electrically isolated from second conductive terminal **366**. Connection test terminal housing **385** includes a cut out **389** sized to allow connection test terminal tab **381** to be exposed when connection test terminal **380** is positioned within connection test terminal housing **385**. Annular terminal housing **372** also includes a void **390** sized and shaped to receive and retain connection test terminal housing **385**. FIG. **21**-**23** illustrate an exemplary embodiment of the connection test terminal housing **385**; however, it is understood that connection test terminals of different sizes are also encompassed by the embodiments described herein.

First terminal connector **374** and second terminal connector **375** provide electrical connection points for connecting first electrical terminal **364** and second electrical terminal **366** to a portable electrical energy storage device or to a device to be powered by or for charging the portable electrical energy storage device.

Referring to FIG. **20**, electrical connector **326** of FIGS. **15** and **16** and electrical connector plug **328** of FIGS. **19**A-**19**C are illustrated in a mated configuration. In this mated configuration, first electrical terminal **338** of electrical connector **326** makes electrical contact with first electrical terminal **364** of the electrical connector plug **328** via resilient connector **343**A located intermediate first electrical terminal **338** and first electrical terminal **364**. Second electrical terminal **340** of electrical connector **326** makes electrical contact with second electrical terminal **366** of electrical connector plug **328** via resilient connector **343**B located intermediate second electrical terminal **340** and second electric terminal **366**. As a result, a portable electrical energy storage device or a device to be powered by or for charging such portable electrical energy storage device that is connected to electrical connector **326** is electrically connected to a portable electrical energy storage device or a device to be powered by or for charging such portable electrical energy storage device that is connected to electrical connector plug **328**.

In a manner similar to that described with reference to FIG. **8**, the size and shape of electrical connector **326** and the complementary size and shape of electrical connector plug **328** permit a user to insert a battery pack into a battery pack

receptacle in a plurality of rotational orientations relative to each other, while establishing a useful and safe electrical connection between the electrical connector **326** and the electrical connector plug **328**.

As seen in FIG. **20**, when electrical connector **326** is mated with electrical connector plug **328**, electrical connection test terminal **342** of electrical connector **326** makes electrical contact with first electrical terminal **364** of electrical connector plug **328**. When electrical connector **326** is mated with electrical connector plug **328**, electrical connection test terminal **380** of electrical connector plug **328** makes electrical contact with second electrical terminal **340** of electrical connector **326**. Electrical connection test terminal **380** is electrically connected to one terminal of a voltage sensor (not shown) via electrical connector **382** for connection test terminal **380**. When electrical connector **326** is mated with electrical connector plug **328**, electrical connection test terminal **342** of electrical connector **326** makes electrical contact with first electrical terminal **364** of electrical connector plug **328**. Electrical connection test terminal **342** of electrical connector plug **328** is electrically connected to another terminal of the voltage sensor (not shown) via electrical connection test terminal connector **360** for connection test terminal **342**. When electrical connection test terminal **380** contacts second electrical terminal **340** and electrical connection test terminal **342** contacts first electrical terminal **364**, electrical connection test terminal **380** will be at the same voltage as second electrical terminal **340** and electrical connection test terminal **342** will be at the same voltage as first electrical terminal **364**. The voltage sensor is configured to detect the voltage between electrical connection test terminal **380** and electrical connection test terminal **342**. Comparison of this detected voltage to the voltage of the portable electrical energy storage device to which electrical connector **326** or electrical connector plug **328** are connected provides an indication of whether an electrical contact has been established between first electrical terminal **364** of electrical connector plug **328** and first electrical terminal **338** of electrical connector **326** and second electrical terminal **366** of electrical connector plug **328** and second electrical terminal **340** of electrical connector **326**. Electrical connection between these terminals will be indicated by the voltage detected by the voltage sensor being substantially equal to the voltage of the portable electrical energy storage device. The configuration of an independent electrical connection test terminal **380** illustrated in FIGS. **19**A-C and **21-23** can also be implemented in the electrical connection system described with reference to FIGS. **1-14**. For example an independent connection test terminal can be provided in electrical connector plug **20**.

An advantage of an electrical connection system including the electrical connector and electrical connection plug in accordance with embodiments described herein is the ability to establish an electrical connection between a portable electrical energy storage device and a device to be powered by or for charging the portable electrical energy storage device in a plurality of rotational orientations and, in the embodiments of FIGS. **1-8** and FIGS. **15-23**, an infinite number of rotational orientations. In accordance with embodiments described herein, a multidirectional or omni-directional electrical connection system is provided whereby electrical connection between an electrical connector and an electrical connection plug can be established in a plurality of rotational orientations and in some cases in an infinite number of rotational orientations. The ability to make electrical connections in a plurality or infinite number of rotational orientations reduces the likelihood of a faulty electrical connection due to a user inserting a battery pack into a battery pack receptacle in an improper rotational orientation. Electrical connections between a device including an electrical connector and a device including an electrical connector plug in accordance with embodiments described herein can be made when the devices are mated with each other in a plurality of rotational orientations. The ability to make electrical connections in a plurality of rotational orientations has other advantages, such as reducing the likelihood that damage will be done to the electrical connector or electrical connector plug due to the portable electrical energy storage device being inserted into the receptacle in an orientation in which an electrical connection cannot be made between the electrical connector and electrical connection plug or an orientation in which the electrical connector and electrical connection plug cannot mate physically with each other.

In addition, in accordance with embodiments described herein electrical connections made between a device including an electrical connector and different device including an electrical connector plug in accordance with embodiments described herein can do so repeatedly without a significant change in the resistance of the connection that could adversely affect electrical energy delivery from the portable electrical energy storage device and/or charging of the portable electrical energy storage device. In addition, electrical connections provided between a device including an electrical connector and different device including an electrical connector plug in accordance with embodiments described herein are made with low resistance to electrical power discharge or delivery to the portable electrical energy storage device.

In accordance with additional embodiments of the subject matter described herein, multidirectional electrical connection systems capable of establishing an electrical connection between a portable electrical energy storage device and a device to be powered by or for charging the portable electrical energy storage device in a plurality of rotational orientations include electrical terminal patterns such as those illustrated in FIGS. **12-14**.

The headings and Abstract of the Disclosure provided herein are for convenience only and do not interpret the scope or meaning of the embodiments.

The various embodiments described above can be combined to provide further embodiments. All of the U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications referred to in this specification and/or listed in the Application Data Sheet are incorporated herein by reference, in their entirety. Aspects of the embodiments can be modified, if necessary to employ concepts of the various patents, applications and publications to provide yet further embodiments.

These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

The invention claimed is:

1. A connector for making electrical connection between a portable electrical energy storage device electrically connected to the connector or an electric powered device electrically connected to the connector and a plug electrically connected to an electric powered device or a portable electrical energy storage device that is not electrically connected to the connector, the connector comprising:

a. an electrically nonconductive connector base having a connector central axis;

b. an electrical contact housing including an outer sidewall extending in a direction parallel to the connector central axis and an inner sidewall extending in a direction parallel to the connector central axis, the inner sidewall located closer to the connector central axis than the outer sidewall, the electrical contact housing centered on the connector central axis;

c. a first terminal including at least two electrically conductive contact pads located adjacent the inner sidewall of the electrical contact housing; and

d. a second terminal including at least one electrically conductive contact pad located adjacent the outer sidewall of the electrical contact housing.

2. The connector of claim **1**, further comprising a connection test terminal located closer to the connector central axis than the first terminal and configured to be electrically connected to the first terminal when the connector is electrically connected to the plug.

3. The connector of claim **1**, wherein the outer sidewall and the inner sidewall are concentric.

4. The connector of claim **1**, wherein the at least two electrically conductive contact pads of the first terminal and the at least one electrically conductive pad of the second terminal are concentric.

5. The connector of claim **1**, wherein the connector is configured to mate with the plug in two or more orientations and make an electrical connection to the plug in each of the two or more orientations, the two or more orientations corresponding to different positions of the connector relative to the plug, each different position of the connector relative to the plug corresponding to different rotational positions of the connector relative to the connector central axis.

6. The connector of claim **5**, wherein the two or more orientations are three or more orientations.

7. The connector of claim **1**, wherein a periphery of the electrical contact housing lies in a plane perpendicular to the connector central axis, the periphery defining a quadrilateral with opposing angles that are equal.

8. The connector of claim **7**, wherein the quadrilateral includes adjacent sides, the adjacent sides being equal in length.

9. The connector of claim **1**, wherein the outer sidewall of the electrical contact housing comprises four outer sidewalls, each outer sidewall arranged perpendicular to adjacent outer sidewalls and extending parallel to the connector central axis, and the inner sidewall of the electrical contact housing comprises four inner sidewalls, each inner sidewall arranged perpendicular to adjacent inner sidewalls and extending parallel to the connector central axis, the four inner sidewalls located closer to a connector base axis than the four outer sidewalls.

10. The connector of claim **9**, wherein the at least two electrically conductive contact pads of the first terminal comprise four electrically conductive contact pads, one electrically conductive contact pad of the first terminal located adjacent each of the four inner sidewalls of the electrical contact housing.

11. The connector of claim **9**, wherein the at least one electrically conductive contact pad of the second terminal comprises four electrically conductive contact pads, one electrically conductive contact pad of the second terminal located adjacent each of the four outer sidewalls of the electrical contact housing.

12. A plug for making electrical connection between an electric powered device electrically connected to the plug or a portable electrical energy storage device electrically connected to the plug and a connector electrically connected to an electric powered device or a portable electrical energy storage device that is not electrically connected to the plug, the plug comprising:

a. an electrical plug housing including a plug end, a terminal end and a plug housing central axis, the plug end located at an end of the electrical plug housing that is opposite an end of the electrical plug housing where the terminal end is located;

b. a first terminal located at the plug end and including at least two electrically conductive contact pads, each contact pad of the first terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis; and

c. a second terminal located at the plug end and including at least two electrically conductive contact pads, each contact pad of the second terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis, the first terminal of the plug located closer to the plug housing central axis than the second terminal of the plug, each contact pad of the first terminal separated from the contact pads of the second terminal by an electrically nonconductive medium.

13. The plug of claim **12**, further comprising a connection test terminal located at the plug end further from the plug housing central axis than the contact pads of the first plug terminal, the connection test terminal configured to be electrically connected to the connector when the connector mates with the plug.

14. The plug of claim **12**, wherein the at least two contact pads of the first terminal and the contact pads of the second terminal are concentric.

15. The plug of claim **12**, wherein the at least two contact pads of the first terminal are three contact pads.

16. The plug of claim **12**, wherein the plug is configured to mate with the connector when the connector is in one of two or more orientations and the plug is configured to make an electrical connection to the connector in each of the two or more orientations, each of the connector's two or more orientations corresponding to a different position of the connector relative to the plug, each different position of the connector relative to the plug achieved by rotating the connector around the plug housing central axis.

17. The plug of claim **16**, wherein the two or more orientations are three or more orientations.

18. A system for electrically connecting a portable electrical energy storage device to an electrically powered device, the system comprising a connector including:

a. an electrically nonconductive connector base, the electrically nonconductive connector base including a connector central axis;

b. an electrical contact housing including an outer sidewall extending in a direction parallel to the connector central axis and an inner sidewall extending in a direction parallel to the connector central axis, the inner sidewall located closer to the connector central axis than the outer sidewall, the electrical contact housing centered on the connector central axis;

c. a first connector terminal including at least one electrically conductive contact surface located adjacent the inner sidewall of the electrical contact housing;

d. a second connector terminal including at least one electrically conductive contact surface located adjacent the outer sidewall of the electrical contact housing; and

e. a plug including:

f. an electrical plug housing including a plug end, a terminal end and a plug housing central axis, the plug end

located at an end of the electrical plug housing that is opposite an end of the electrical plug housing where the terminal end is located;

g. a first plug terminal located at the plug end and including at least one electrically conductive contact pad, the at least one contact pad of the first plug terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis; and

h. a second plug terminal located at the plug end and including at least one electrically conductive contact pad, the at least one contact pad of the second plug terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis, the first plug terminal located closer to the plug housing central axis than the second plug terminal and the at least one contact pad of the first plug terminal separated from the at least one contact pad of the second plug terminal by an electrically nonconductive medium.

19. The system of claim **18**, wherein the connector is configured to mate with the plug in two or more orientations and make an electrical connection to the plug in each of the two or more orientations, each of the two or more orientations corresponding to a different position of the connector relative to the plug, each different position achieved by rotating the connector around the connector central axis.

20. The system of claim **18**, wherein the outer sidewall of the electrical contact housing and the inner sidewall of the electrical contact housing are concentric.

21. The system of claim **18**, wherein the at least one electrically conductive contact surface of the first connector terminal and the at least one electrically conductive contact surface of the second connector terminal are concentric.

22. The system of claim **18**, wherein the connector further comprises a connection test terminal located closer to the connector central axis than the first connector terminal and configured to be electrically connected to the first plug terminal when the connector is mated with the plug.

23. The system of claim **18**, wherein the plug is configured to mate with the connector when the connector is in one of two or more orientations and the plug is configured to make an electrical connection to the connector in each of the two or more orientations, each of the connector's two or more orientations corresponding to a different position of the connector relative to the plug, each different position of the connector relative to the plug achieved by rotating the connector around the plug housing central axis.

24. A connector for making electrical connection between a portable electrical energy storage device electrically connected to the connector or an electric powered device electrically connected to the connector and a plug electrically connected to an electric powered device or a portable electrical energy storage device that is not electrically connected to the connector, the connector comprising:

a. an electrically nonconductive connector base having a connector central axis;

b. an electrical contact housing including an outer sidewall extending in a direction parallel to the connector central axis and an inner sidewall extending in a direction parallel to the connector central axis, the inner sidewall located closer to the connector central axis than the outer sidewall, the electrical contact housing centered on the connector central axis;

c. a first terminal including at least one electrically conductive contact pad located adjacent the inner sidewall of the electrical contact housing;

d. a second terminal including at least one electrically conductive contact pad located adjacent the outer sidewall of the electrical contact housing;

e. a resilient electrically conductive connector adjacent the second terminal.

25. A plug for making electrical connection between an electric powered device electrically connected to the plug or a portable electrical energy storage device electrically connected to the plug and a connector electrically connected to an electric powered device or a portable electrical energy storage device that is not electrically connected to the plug, the plug comprising:

a. an electrical plug housing including a plug end, a terminal end and a plug housing central axis, the plug end located at an end of the electrical plug housing that is opposite an end of the electrical plug housing where the terminal end is located;

b. a first terminal located at the plug end and including at least one electrically conductive contact pad, the at least one contact pad of the first terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis;

c. a second terminal located at the plug end and including at least one electrically conductive contact pad, the at least one contact pad of the second terminal extending parallel to the plug housing central axis and positioned around the plug housing central axis, the first terminal of the plug located closer to the plug housing central axis than the second terminal of the plug, the at least one contact pad of the first terminal separated from the at least one pad of the second terminal by an electrically nonconductive medium;

d. a resilient electrically conductive connector adjacent the first terminal; and

e. a resilient electrically conductive connector adjacent the second terminal.

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