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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 November 2017 (23.11.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/201017 A2

(51) International Patent Classification:
H01B 7/42 (2006.01)

(21) International Application Number:
PCT/US2017/032859

(22) International Filing Date:
16 May 2017 (16.05.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/339,321 20 May 2016 (20.05.2016) US

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

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

Published:
— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) Title: LIQUID COOLED CHARGING CABLE SYSTEM

(57) Abstract: A liquid cooled charging cable system may be provided. The liquid cooled charging cable system may comprise a source, a load, a liquid cooled charging cable, and a cooling device. The liquid cooled charging cable may connect the source to the load, and may supply electric energy from the source to the load. The liquid cooled charging cable may comprise a supply conductor and a return conductor. The cooling device may pump a coolant around the supply conductor and the return conductor where the supply conductor and the return conductor may be immersed in the coolant.

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LIQUID COOLED CHARGING CABLE SYSTEM

[001] This application is being filed on May 16, 2017, and claims the benefit of priority to U.S. Provisional Application No. 62/339,321 filed May 20, 2016, which is incorporated herein by reference.

BACKGROUND

[002] An electric vehicle (EV) charging system, also called an electric recharging point, a charging point, a charging station a charge point, and an EVSE (Electric Vehicle Supply Equipment), is an element in an infrastructure that supplies electric energy for recharging electric vehicles, such as plug-in electric vehicles, including electric cars, neighborhood electric vehicles, and plug-in hybrids. Because plug-in hybrid electric vehicles and battery electric vehicle ownership is expanding, there is a growing need for widely distributed publicly accessible charging stations, some of which support faster charging at higher voltages and currents than are available from residential EVSEs. Many charging stations are on-street facilities provided by electric utility companies or located at retail shopping centers and operated by private companies. These charging stations provide one or a range of heavy duty or special connectors that conform to the variety of electric charging connector standards.

BRIEF DESCRIPTION OF THE FIGURES

[003] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate various embodiments of the present disclosure. In the drawings:

[004] FIG. 1 shows a liquid cooled charging system;

[005] FIG. 2 shows a liquid cooled charging system;

[006] FIG. 3 shows a liquid cooled charging cable;

[007] FIG. 4 shows a liquid cooled charging cable;

[008] FIG. 5A and FIG. 5B show an output terminal; and

[009] FIG. 6A and FIG. 6B show an input terminal.

DETAILED DESCRIPTION

OVERVIEW

[010] A liquid cooled charging cable system may be provided. The liquid cooled charging cable system may comprise a source, a load, a liquid cooled charging cable, and a cooling device. The liquid cooled charging cable may connect the source to the load, and may supply electric energy from the source to the load. The liquid cooled charging cable may comprise a supply conductor and a return conductor. The cooling device may pump a coolant around the supply conductor and the return conductor where the supply conductor and the return conductor may be immersed in the coolant.

[011] Both the foregoing overview and the following example embodiments are examples and explanatory only, and should not be considered to restrict the disclosure's scope, as described and claimed. Further, features and/or variations may be provided in addition to those set forth herein. For example, embodiments of the disclosure may be directed to various feature combinations and sub-combinations described in the example embodiments.

EXAMPLE EMBODIMENTS

[012] The following detailed description refers to the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the following description to refer to the same or similar elements. While embodiments of the disclosure may be described, modifications, adaptations, and other implementations are possible. For example, substitutions, additions, or modifications may be made to the elements illustrated in the drawings, and the methods described herein may be modified by substituting, reordering, or adding stages to the disclosed methods. Accordingly, the following detailed description does not limit the disclosure. Instead, the proper scope of the disclosure is defined by the appended claims.

[013] A charging system may be used to charge a battery or batteries, for example, an electric vehicle's batteries. Consistent with embodiments of the disclosure, electric vehicles may comprise, but are not limited to, electric cars, neighborhood electric vehicles, fork lifts, plug-in hybrids, etc. When batteries are charged, the time required to charge the batteries may be governed by the amount of current that a charging system can deliver to the batteries. One of the limiting factors

for increasing the amount of charge current to the batteries and therefore reducing the amount of charge time may be the cable that connects an electric power source to the batteries.

[014] Conventional systems may use an air cooled charging cable in battery charging applications, for example, in applications where the charging current is below 200A. As the electric charging current increases above 200A, the corresponding required size of the charging cable used to charge the batteries may become too large, too heavy, and too inflexible for a consumer to use. Consistent with embodiments of the disclosure, a liquid cooled charging cable may be provided. The liquid cooled charging cable may supply currents (e.g., 400A to 1,000A) that may be 2 to 5 times as much as the currents supplied by the conventional air cooled charging cable, but unlike the conventional air cooled charging cable, in a size, weight, and flexibility suitable for a consumer to use. Conventional liquid cooled charging cables electrically isolate the cooling liquid from metallic conductor components to prevent shorts between conductors or to ground through the liquid. The conventional approach limits the benefit of liquid cooling by adding a thermally insulating layer between the conductor and the cooling liquid.

[015] Consistent with embodiments of the disclosure, liquid coolant from a cooling device may be pumped directly around an electrical conductor (e.g., bare, uninsulated) and into an input terminal connector and an output terminal connector attached to the electrical conductor in order to cool these components. Accordingly, cooling of the electrical conductor, the input terminal connector, and the output terminal connector by the coolant may greatly limit thermal resistance in the electrical conductor, the input terminal connector, and the output terminal connector associated with these components due to heating caused by high electrical currents in the these components.

[016] The liquid coolant maybe provided by either two independent isolated cooling devices or by one cooling device that has a sufficient liquid column length from the conductor to the cooling device or bifurcation point of the liquid coolant. The liquid column length along with an appropriate coolant conductivity may provide the required electrical isolation between a supply conductor and a return conductor and either of these conductors to grounded cooling pumps or associated hardware.

[017] FIG. 1 shows a liquid cooled charging system 100 consistent with embodiments of the disclosure. As shown in FIG. 1, liquid cooled charging system 100 may comprise a source 102, a load 104, a liquid cooled charging cable 106, and a cooling device 108. Source 102 may connect to liquid cooled charging cable 106 via a source supply connection 110 and a source return connection 112. Load 104 may connect to liquid cooled charging cable 106 via a load supply connection 114 and a load return connection 116. Liquid cooled charging cable 106 may comprise a supply conductor 118 and a return conductor 120. Source 102 may comprise a power supply capable of charging load 104 comprising an energy storage device, for example, a battery or bank of batteries.

[018] Coolant may be provided to both supply conductor 118 and return conductor 120 of liquid cooled charging cable 106 by cooling device 108 via coolant supply conduit 122 and coolant return conduit 124. Supply conduit 122 and coolant return conduit 124 may be made from electrically non-conductive material and may have sufficient length to minimize the leakage current to ground or between supply conductor 118 and return conductor 120. Coolant supply conduit 122 may comprise a coolant supply conduit main section 126, a coolant supply conduit bifurcation point 128, a coolant supply conduit first section 130, and a coolant supply conduit second section 132. Coolant return conduit 124 may comprise a coolant return conduit main section 134, a coolant return conduit bifurcation point 136, a coolant return conduit first section 138, and a coolant return conduit second section 140.

[019] Source 102 may connect to liquid cooled charging cable 106 via source supply connection 110 and a source return connection 112 at a source end 142 of liquid cooled charging cable 106. Load 104 may connect to liquid cooled charging cable 106 via a load supply connection 114 and a load return connection 116 at a load end 144 of liquid cooled charging cable 106. The coolant may be supplied from coolant supply conduit 122 and returned to coolant return conduit 124 at source end 142 of liquid cooled charging cable 106.

[020] Cooling device 108 may pump the coolant into coolant supply conduit main section 126. The coolant by then feed into both coolant supply conduit first section 130 and coolant supply conduit second section 132 at coolant supply conduit bifurcation point 128. Coolant supply conduit first section 130 may feed coolant to supply conductor 118 of liquid cooled charging cable 106. Coolant supply conduit

second section 132 may feed coolant to return conductor 120 of liquid cooled charging cable 106. The coolant may circulate through liquid cooled charging cable 106. A portion of the coolant may return into coolant return conduit first section 138 and a portion of the coolant may return into coolant return conduit second section 140. The returned coolant may come together at coolant return conduit bifurcation point 136 into coolant return conduit main section 134 and back into cooling device 108. Cooling device 108 may cool the returned coolant that may have absorbed heat from liquid cooled charging cable 106. Cooling device 108 may reuse the returned coolant by pumping it back into coolant supply conduit main section 126.

[021] FIG. 2 shows a liquid cooled charging system 200 consistent with embodiments of the disclosure. Liquid cooled charging system 200 may be similar to liquid cooled charging system 100; however, liquid cooled charging system 200 may comprise two cooling devices rather than one cooling device. As shown in FIG. 2, liquid cooled charging system 200 may comprise a first cooling device 202 and a second cooling device 204. Coolant may be provided to supply conductor 118 of liquid cooled charging cable 106 by first cooling device 202 via a first coolant supply conduit 206 and returned from supply conductor 118 to first cooling device 202 via a first coolant return conduit 208. Similarly, coolant may be provided to return conductor 120 of liquid cooled charging cable 106 by second cooling device 204 via a second coolant supply conduit 210 and returned from return conductor 120 to second cooling device 204 via a second coolant return conduit 212. The conduits (e.g., first coolant supply conduit 206, first coolant return conduit 208, second coolant supply conduit 210, and second coolant return conduit 212) may be made from electrically non-conductive material and have sufficient length to minimize the leakage current to ground or between supply conductor 118 and return conductor 120.

[022] FIG. 3 shows a cross-section of a liquid cooled charging cable 300. Liquid cooled charging cable 300 may comprise liquid cooled charging cable 106 as described above with respect to FIG.1 and FIG. 2. As shown in FIG. 3, liquid cooled charging cable 300 may comprise a jacket 302. Jacket 302 may comprise a first supply hose 304, a first return hose 306, a second supply hose 308, a second return hose 310, a pilot cable 312, and a ground wire 314. First supply hose 304 may comprise a first supply sub-conductor 316, first return hose 306 may comprise a second supply sub-conductor 318, second supply hose 308 may comprise a first return sub-conductor 320,

and second return hose 310 may comprise a second return sub-conductor 322. Pilot cable 312 may comprise a first pilot wire 324, a second pilot wire 326, and a third pilot wire 328.

[023] FIG. 4 shows a cross-section of a liquid cooled charging cable 400. Liquid cooled charging cable 400 may comprise liquid cooled charging cable 106 as described above with respect to FIG.1 and FIG. 2. As shown in FIG. 4, liquid cooled charging cable 400 may comprise a jacket 402. Jacket 402 may contain a first supply hose 404, a first return hose 406, a second supply hose 408, and a second return hose 410. In addition, jacket 402 may contain a first pilot wire 412, a second pilot wire 414, a third pilot wire 416, and a ground wire 418. First supply hose 404 may comprise a supply conductor 420 and second supply hose 408 may comprise a return conductor 422.

[024] Pilot cable 312 (i.e., first pilot wire 324, second pilot wire 326, and third pilot wire 328) of FIG. 3 may be used to send control signals or supply power to elements located at source 102 and load 104. Similarly, first pilot wire 412, second pilot wire 414, and third pilot wire 416 of FIG. 4 may be used to send control signals or supply power to elements located at source 102 and load 104. The pilot wires may be located at the center of liquid cooled charging cable 300 as pilot cable 312 as shown in FIG. 3 or the pilot wires may be located individually at any location within jacket 402 as shown in FIG. 4 as pilot wire 412, second pilot wire 414, and third pilot wire 416. Embodiments of the disclosure may comprise any number of pilot wires and is not limited to three. Ground wire 314 of liquid cooled charging cable 300 and ground wire 418 of liquid cooled charging cable 400 may be used to connect source 102 and load 104 and maintain them at a common ground.

[025] FIG. 5A and FIG. 5B show an output terminal 500 that may comprise load supply connection 114 and load return connection 116 as shown in FIG. 1 and FIG. 2. Output terminal 500 may be made of an electrically conductive material. As shown in FIG. 5A and FIG. 5B, output terminal 500 may comprise an output terminal tab 502, a first output terminal tube 504, and a second output terminal tube 506. Output terminal tab 502 may comprise an output terminal tab opening 508. First output terminal tube 504 may comprise a first output terminal tube port 510, a plurality of first output terminal tube barbs 512, a first output terminal tube first end 514, and a first output terminal tube second end 516. Second output terminal tube 506 may comprise a

second output terminal tube port 518, a plurality of second output terminal tube barbs 520, a second output terminal tube first end 522, and a second output terminal tube second end 524.

[026] Output terminal 500 may comprise load supply connection 114. As described in greater detail below, output terminal 500 may be installed on supply conductor 118 of liquid cooled charging cable 106 at load end 144 of liquid cooled charging cable 106. A fastener (e.g., a bolt) may be placed through output terminal tab opening 508 in order to fasten output terminal tab 502 (load supply connection 114) to, for example, a positive lead of load 104. Similarly, output terminal 500 may comprise load return connection 116. As described in greater detail below, output terminal 500 may be installed on return conductor 120 of liquid cooled charging cable 106 at load end 144 of liquid cooled charging cable 106. A fastener (e.g., a bolt) may be placed through output terminal tab opening 508 in order to fasten output terminal tab 502 (as load return connection 116) to, for example, a negative lead of load 104.

[027] Consistent with embodiments of the disclosure, the coolant may cool output terminal tab 502. The coolant may enter first output terminal tube 504 at first output terminal tube port 510, pass through first output terminal tube 504 to first output terminal tube second end 516, enter second output terminal tube 506 at second output terminal tube second end 524, and exit second output terminal tube 506 at second output terminal tube port 518. Consequently, the coolant may absorb heat from output terminal tab 502. Consistent with embodiments of the disclosure, the coolant may flow in an opposite direction entering second output terminal tube port 518 and exiting first output terminal tube port 510.

[028] FIG. 6A and FIG. 6B show an input terminal 600 that may comprise source supply connection 110 and source return connection 112 as shown in FIG. 1 and FIG. 2. Input terminal 600 may be made of an electrically conductive material. As shown in FIG. 6A and FIG. 6B, input terminal 600 may comprise an input terminal tab 602, a first input terminal tube 604, and a second input terminal tube 606. Input terminal tab 602 may comprise an input terminal tab opening 608. First input terminal tube 604 may comprise a first input terminal tube port 610, a first plurality of first input terminal tube barbs 612, a second plurality of first input terminal tube barbs 614, a first input terminal tube first end 616, and a first input terminal tube second end 618. Second input terminal tube 606 may comprise a second input terminal tube port 620, a

first plurality of second input terminal tube barbs 622, a second plurality of second input terminal tube barbs 624, a second input terminal tube first end 626, and a second input terminal tube second end 628.

[029] Input terminal 600 may comprise source supply connection 110. As described in greater detail below, input terminal 600 may be installed on supply conductor 118 of liquid cooled charging cable 106 at source end 142 of liquid cooled charging cable 106. A fastener (e.g., a bolt) may be placed through input terminal tab opening 608 in order to fasten input terminal tab 602 (source supply connection 110) to, for example, a positive lead of source 102. Similarly, input terminal 600 may comprise source return connection 112. As described in greater detail below, input terminal 600 may be installed on return conductor 120 of liquid cooled charging cable 106 at source end 142 of liquid cooled charging cable 106. A fastener (e.g., a bolt) may be placed through input terminal tab opening 608 in order to fasten input terminal tab 602 (as source return connection 112) to, for example, a negative lead of source 102.

[030] Consistent with embodiments of the disclosure, the coolant may cool output terminal tab 602. The coolant may enter first input terminal tube 604 at first input terminal tube port 610, pass through first input terminal tube 604, and exit first input terminal tube 604 at first input terminal tube second end 618. Similarly, the coolant may enter second input terminal tube 606 at second input terminal tube port 620, pass through second input terminal tube 606, and exit second input terminal tube 606 at second input terminal tube second end 628. Consequently, the coolant may absorb heat from input terminal tab 602.

[031] Consistent with embodiments of the disclosure, cooling device 108, first cooling device 202, and second cooling device 204 may pump the coolant into liquid cooled charging cable 106, receive the coolant back from liquid cooled charging cable 106, remove heat from the coolant that was received back, and then re-pump the cooled coolant back into liquid cooled charging cable 106. The coolant may be pumped at 0.8 GPM with coolant temperature rise of 6.7 degrees C.

[032] The coolant may comprise a liquid that has a low conductivity and that is capable of cooling cable 106. For example, the coolant may provide cable 106 with: i) a calculated leakage current of 18 micro-amps for 15 feet of cable 106 at 50 micro-Siemens; and ii) a calculated power loss at 350a of 1.498kw considering both supply conductor 118 and return conductor 120. The coolant may have a -35 degrees C

freezing point, conductivity of 0.36 micro-Siemens per centimeter, and a life of 2 to 3 years. The coolant may comprise Koolance LIQ-705, manufactured by Koolance of 2840 W Valley Hwy N, Auburn, WA 98001.

[033] Consistent with embodiments of the disclosure, cooling device 108, first cooling device 202, and second cooling device 204 may pump the coolant directly around a bare (e.g., no insulation, no covering, etc.) electrical conductor (e.g., first supply sub-conductor 316, second supply sub-conductor 318, first return sub-conductor 320, second return sub-conductor 322, supply conductor 420, and return conductor 422), into a input terminal 600 attached to the electrical conductor, and into output terminal 500 attached to the electrical conductor in order to cool these components. Accordingly, cooling of the electrical conductor, input terminal connector 600, and output terminal connector 500 by the coolant may limit thermal resistance in the electrical conductor, input terminal connector 600, and output terminal connector 500 associated with these components due to heating caused by high electrical currents in the these components.

[034] The liquid coolant may be provided by either two independent isolated cooling devices (e.g., first cooling device 202 and second cooling device 204) or by one cooling device (e.g., cooling device 108) that has a sufficient liquid column length from the conductor (e.g., liquid cooled charging cable 106) to the cooling device or bifurcation point of the liquid coolant. The liquid column length along with an appropriate coolant conductivity may provide the required electrical isolation between a supply conductor (e.g., supply conductor 118) and a return conductor (e.g., load return connection 116) and either of these conductors to grounded cooling pumps (e.g., cooling device 108, first cooling device 202, and second cooling device 204).

Source End 142 Connections to Cooling Device 108 for the FIG. 1 Configuration

[035] One input terminal 600 may be used as source supply connection 110 on supply conductor 118 at source end 142. For the configuration shown in FIG. 1, coolant supply conduit first section 130 may be connector to first input terminal tube second end 618 and over second plurality of first input terminal tube barbs 614 forming a watertight seal around first input terminal tube 604 at first input terminal tube second end 618. Also, coolant return conduit first section 138 may be connector to second input terminal tube second end 628 and over second plurality of second input terminal

tube barbs 624 forming a watertight seal around second input terminal tube 606 at second input terminal tube second end 628.

[036] Another input terminal 600 may be used as source return connection 112 on return conductor 120 at source end 142. For the configuration shown in FIG. 1, coolant supply conduit second section 132 may be connector to first input terminal tube second end 618 and over second plurality of first input terminal tube barbs 614 forming a watertight seal around first input terminal tube 604 at first input terminal tube second end 618. Also, coolant return conduit second section 140 may be connector to second input terminal tube second end 628 and over second plurality of second input terminal tube barbs 624 forming a watertight seal around second input terminal tube 606 at second input terminal tube second end 628.

Source End 142 Connections to Cooling Devices for the FIG. 2 Configuration

[037] One input terminal 600 may be used as source supply connection 110 on supply conductor 118 at source end 142. For the configuration shown in FIG. 2, first coolant supply conduit 206 may be connector to first input terminal tube second end 618 and over second plurality of first input terminal tube barbs 614 forming a watertight seal around first input terminal tube 604 at first input terminal tube second end 618. Also, first coolant return conduit 208 may be connector to second input terminal tube second end 628 and over second plurality of second input terminal tube barbs 624 forming a watertight seal around second input terminal tube 606 at second input terminal tube second end 628.

[038] Another input terminal 600 may be used as source return connection 112 on return conductor 120 at source end 142. For the configuration shown in FIG. 2, second coolant supply conduit 210 may be connector to first input terminal tube second end 618 and over second plurality of first input terminal tube barbs 614 forming a watertight seal around first input terminal tube 604 at first input terminal tube second end 618. Also, second coolant return conduit 212 may be connector to second input terminal tube second end 628 and over second plurality of second input terminal tube barbs 624 forming a watertight seal around second input terminal tube 606 at second input terminal tube second end 628.

Using Liquid Cooled Charging Cable 300 as Liquid Cooled Charging Cable 106 At Source End 142

[039] At source end 142 of liquid cooled charging cable 106, regarding liquid cooled charging cable 300 as liquid cooled charging cable 106, first supply sub-conductor 316 may be crimped or otherwise electrically attached to first input terminal tube 604 at first input terminal tube first end 616. Consequently, first supply sub-conductor 316 may be in electrical connection with input terminal tab 602. First supply hose 304 may be pulled over first plurality of first input terminal tube barbs 612 forming a watertight seal around first input terminal tube first end 616. Similarly, second supply sub-conductor 318 may be crimped or otherwise electrically attached to second input terminal tube 606 at second input terminal tube first end 626. Consequently, second supply sub-conductor 318 may be in electrical connection with input terminal tab 602. First return hose 306 may be pulled over first plurality of second input terminal tube barbs 622 forming a watertight seal around second input terminal tube first end 626. In this embodiment, first supply sub-conductor 316 and second supply sub-conductor 318 may together function as two parallel conductors comprising supply conductor 118.

[040] At source end 142 of liquid cooled charging cable 106, regarding liquid cooled charging cable 300 as liquid cooled charging cable 106, first return sub-conductor 320 may be crimped or otherwise electrically attached to first input terminal tube 604 at first input terminal tube first end 616. Consequently, first return sub-conductor 320 may be in electrical connection with input terminal tab 602. Second supply hose 308 may be pulled over first plurality of first input terminal tube barbs 612 forming a watertight seal around first input terminal tube first end 616. Similarly, second return sub-conductor 322 may be crimped or otherwise electrically attached to second input terminal tube 606 at second input terminal tube first end 626. Consequently, second return sub-conductor 322 may be in electrical connection with input terminal tab 602. Second return hose 310 may be pulled over first plurality of second input terminal tube barbs 622 forming a watertight seal around second input terminal tube first end 626. In this embodiment, first return sub-conductor 320 and second return sub-conductor 322 may together function as two parallel conductors comprising return conductor 120.

At Load End 144

[041] One output terminal 500 may be used as Load supply connection 114 on supply conductor 118 at load end 144. Another output terminal 500 may be used as load return connection 116 on return conductor 120 at load end 144.

[042] At load end 144 of liquid cooled charging cable 106, first supply sub-conductor 316 may be crimped or otherwise electrically attached to first output terminal tube 504 at first output terminal tube first end 514. Consequently, first supply sub-conductor 316 may be in electrical connection with output terminal tab 502. First supply hose 304 may be pulled over plurality of first output terminal tube barbs 512 forming a watertight seal around first output terminal tube first end 514. Similarly, second supply sub-conductor 318 may be crimped or otherwise electrically attached to second output terminal tube 506 at second output terminal tube first end 522. Consequently, second supply sub-conductor 318 may be in electrical connection with output terminal tab 502. First return hose 306 may be pulled over plurality of second output terminal tube barbs 520 forming a watertight seal around second output terminal tube first end 522. In this embodiment, first supply sub-conductor 316 and second supply sub-conductor 318 may together function as two parallel conductors comprising supply conductor 118.

[043] At load end 144 of liquid cooled charging cable 106, first return sub-conductor 320 may be crimped or otherwise electrically attached to first output terminal tube 504 at first output terminal tube first end 514. Consequently, first return sub-conductor 320 may be in electrical connection with output terminal tab 502. Second supply hose 308 may be pulled over plurality of first output terminal tube barbs 512 forming a watertight seal around first output terminal tube first end 514. Similarly, second return sub-conductor 322 may be crimped or otherwise electrically attached to second output terminal tube 506 at second output terminal tube first end 522. Consequently, second return sub-conductor 322 may be in electrical connection with output terminal tab 502. Second return hose 310 may be pulled over plurality of second output terminal tube barbs 520 forming a watertight seal around second output terminal tube first end 522. In this embodiment, first return sub-conductor 320 and second return sub-conductor 322 may together function as two parallel conductors comprising return conductor 120.

Coolant Flow

[044] For supply conductor 118, the coolant may flow into the inside first input terminal tube 604 from first input terminal tube second end 618. Because first input terminal tube 604 is connected to input terminal tab 602, the coolant may cool input terminal tab 602. The coolant may then flow out of first input terminal tube port 610 and into first supply hose 304. The coolant may surround first supply sub-conductor 316 and flow the length of first supply hose 304 to load end 144. Because first supply sub-conductor 316 is immersed in the coolant, heat from first supply sub-conductor 316 may be transferred into the coolant. At load end 144, the coolant may flow into first output terminal tube 504 at first output terminal tube port 510 to first output terminal tube second end 516 and into second output terminal tube 506 at second output terminal tube second end 524. Because the coolant is in output terminal tab 502, the coolant may also cool output terminal tab 502. The coolant may flow out of second output terminal tube 506 at second output terminal tube port 518 and into first return hose 306. The coolant may flow the length of first return hose 306 back to source end 142. Because second supply sub-conductor 318 is immersed in the coolant, heat from second supply sub-conductor 318 may be transferred into the coolant. The coolant may flow into second input terminal tube 606 at second input terminal tube port 620. Because second input terminal tube 606 is connected to input terminal tab 602, the coolant may cool input terminal tab 602. The coolant may then flow out of second input terminal tube 606 at second input terminal tube second end 628 back to cooling device 108 (e.g., FIG. 1 configuration) or first cooling device 202 (FIG. 2 configuration) to be cooled and reused.

[045] For return conductor 120, the coolant may flow into the inside first input terminal tube 604 from first input terminal tube second end 618. Because first input terminal tube 604 is connected to input terminal tab 602, the coolant may cool input terminal tab 602. The coolant may then flow out of first input terminal tube port 610 and into second supply hose 308. The coolant may surround first return sub-conductor 320 and flow the length of second supply hose 308 to load end 144. Because first return sub-conductor 320 is immersed in the coolant, heat from first return sub-conductor 320 may be transferred into the coolant. At load end 144, the coolant may flow into first output terminal tube 504 at first output terminal tube port 510 to first output terminal tube second end 516 and into second output terminal tube 506 at

second output terminal tube second end 524. Because the coolant is in output terminal tab 502, the coolant may also cool output terminal tab 502. The coolant may flow out of second output terminal tube 506 at second output terminal tube port 518 and into second return hose 310. The coolant may flow the length of second return hose 310 back to source end 142. Because second return sub-conductor 322 is immersed in the coolant, heat from second return sub-conductor 322 may be transferred into the coolant. The coolant may flow into second input terminal tube 606 at second input terminal tube port 620. Because second input terminal tube 606 is connected to input terminal tab 602, the coolant may cool input terminal tab 602. The coolant may then flow out of second input terminal tube 606 at second input terminal tube second end 628 back to cooling device 108 (e.g., FIG. 1 configuration) or first cooling device 202 (FIG. 2 configuration) to be cooled and reused.

Using Liquid Cooled Charging Cable 400 as Liquid Cooled Charging Cable 106 At Source End 142

[046] One input terminal 600 may be used as source supply connection 110 on supply conductor 118 at source end 142. Another input terminal 600 may be used as source return connection 112 on return conductor 120 at source end 142.

[047] At source end 142 of liquid cooled charging cable 106, regarding liquid cooled charging cable 400 as liquid cooled charging cable 106, supply conductor 420 may be crimped or otherwise electrically attached to first input terminal tube 604 at first input terminal tube first end 616. Consequently, supply conductor 420 may be in electrical connection with input terminal tab 602. First supply hose 404 may be pulled over first plurality of first input terminal tube barbs 612 forming a watertight seal around first input terminal tube first end 616. Then, first return hose 406 may be pulled over first plurality of second input terminal tube barbs 622 forming a watertight seal around second input terminal tube first end 626. In this embodiment, supply conductor 420 may function as supply conductor 118.

[048] At source end 142 of liquid cooled charging cable 106, regarding liquid cooled charging cable 400 as liquid cooled charging cable 106, return conductor 422 may be crimped or otherwise electrically attached to first input terminal tube 604 at first input terminal tube first end 616. Consequently, first return sub-conductor 320 may be in electrical connection with input terminal tab 602. Second supply hose 408

may be pulled over first plurality of first input terminal tube barbs 612 forming a watertight seal around first input terminal tube first end 616. Then second return hose 410 may be pulled over first plurality of second input terminal tube barbs 622 forming a watertight seal around second input terminal tube first end 626. In this embodiment, return conductor 422 may function as return conductor 120.

At Load End 144

[049] One output terminal 500 may be used as load supply connection 114 on supply conductor 118 at load end 144. Another output terminal 500 may be used as load return connection 116 on return conductor 120 at load end 144.

[050] At load end 144 of liquid cooled charging cable 106, supply conductor 420 may be crimped or otherwise electrically attached to first output terminal tube 504 at first output terminal tube first end 514. Consequently, supply conductor 420 may be in electrical connection with output terminal tab 502. First supply hose 404 may be pulled over plurality of first output terminal tube barbs 512 forming a watertight seal around first output terminal tube first end 514. Then first return hose 406 may be pulled over plurality of second output terminal tube barbs 520 forming a watertight seal around second output terminal tube first end 522. In this embodiment, supply conductor 420 may function as supply conductor 118.

[051] At load end 144 of liquid cooled charging cable 106, return conductor 422 may be crimped or otherwise electrically attached to first output terminal tube 504 at first output terminal tube first end 514. Consequently, return conductor 422 may be in electrical connection with output terminal tab 502. Second supply hose 408 may be pulled over plurality of first output terminal tube barbs 512 forming a watertight seal around first output terminal tube first end 514. Then second return hose 410 may be pulled over plurality of second output terminal tube barbs 520 forming a watertight seal around second output terminal tube first end 522. In this embodiment, return conductor 422 may function as return conductor 120.

Coolant Flow

[052] For supply conductor 118, the coolant may flow into the inside first input terminal tube 604 from first input terminal tube second end 618. Because first input terminal tube 604 is connected to input terminal tab 602, the coolant may cool input terminal tab 602. The coolant may then flow out of first input terminal tube port

610 and into first supply hose 404. The coolant may surround supply conductor 420 and flow the length of first supply hose 404 to load end 144. Because supply conductor 420 is immersed in the coolant, heat from supply conductor 420 may be transferred into the coolant. At load end 144, the coolant may flow into first output terminal tube 504 at first output terminal tube port 510 to first output terminal tube second end 516 and into second output terminal tube 506 at second output terminal tube second end 524. Because the coolant is in output terminal tab 502, the coolant may also cool output terminal tab 502. The coolant may flow out of second output terminal tube 506 at second output terminal tube port 518 and into first return hose 406. The coolant may flow the length of first return hose 406 back to source end 142. The coolant may flow into second input terminal tube 606 at second input terminal tube port 620. Because second input terminal tube 606 is connected to input terminal tab 602, the coolant may cool input terminal tab 602. The coolant may then flow out of second input terminal tube 606 at second input terminal tube second end 628 back to cooling device 108 (e.g., FIG. 1 configuration) or first cooling device 202 (FIG. 2 configuration) to be cooled and reused.

[053] For return conductor 120, the coolant may flow into the inside first input terminal tube 604 from first input terminal tube second end 618. Because first input terminal tube 604 is connected to input terminal tab 602, the coolant may cool input terminal tab 602. The coolant may then flow out of first input terminal tube port 610 and into second supply hose 408. The coolant may surround return conductor 422 and flow the length of second supply hose 408 to load end 144. Because return conductor 422 is immersed in the coolant, heat from return conductor 422 may be transferred into the coolant. At load end 144, the coolant may flow into first output terminal tube 504 at first output terminal tube port 510 to first output terminal tube second end 516 and into second output terminal tube 506 at second output terminal tube second end 524. Because the coolant is in output terminal tab 502, the coolant may also cool output terminal tab 502. The coolant may flow out of second output terminal tube 506 at second output terminal tube port 518 and into second return hose 410. The coolant may flow the length of second return hose 410 back to source end 142. The coolant may flow into second input terminal tube 606 at second input terminal tube port 620. Because second input terminal tube 606 is connected to input terminal tab 602, the coolant may cool input terminal tab 602. The coolant may then flow out of second

input terminal tube 606 at second input terminal tube second end 628 back to cooling device 108 (e.g., FIG. 1 configuration) or first cooling device 202 (FIG. 2 configuration) to be cooled and reused.

[054] Embodiments of the present disclosure, for example, are described above with reference to block diagrams and/or operational illustrations of methods, systems, and computer program products according to embodiments of the disclosure. The functions/acts noted in the blocks may occur out of the order as shown in any flowchart. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

[055] While the specification includes examples, the disclosure's scope is indicated by the following claims. Furthermore, while the specification has been described in language specific to structural features and/or methodological acts, the claims are not limited to the features or acts described above. Rather, the specific features and acts described above are disclosed as example for embodiments of the disclosure.

WHAT IS CLAIMED IS:

1. A cable comprising:

a first supply hose comprising;

a first supply hose interior surface,

a first supply hose interior cavity defined by the first supply hose interior surface, and

a first supply sub-conductor being disposed within the first supply hose interior cavity wherein a first supply hose interior space is formed between the first supply sub-conductor and the first supply hose interior surface within the first supply hose interior cavity;

a first return hose comprising;

a first return hose interior surface,

a first return hose interior cavity defined by the first return hose interior surface, and

a second supply sub-conductor being disposed within the first return hose interior cavity wherein a first return hose interior space is formed between the second supply sub-conductor and the first return hose interior surface within the first return hose interior cavity;

a second supply hose comprising;

a second supply hose interior surface,

a second supply hose interior cavity defined by the second supply hose interior surface, and

a first return sub-conductor being disposed within the second supply hose interior cavity wherein a second supply hose interior space is formed between the first return sub-conductor and the second supply hose interior surface within the second supply hose interior cavity;

a second return hose comprising;

a second return hose interior surface,

a second return hose interior cavity defined by the second return hose interior surface, and

a second return sub-conductor being disposed within the second return hose interior cavity wherein a second return hose interior space is formed

between the second return sub-conductor and the second return hose interior surface within the second return hose interior cavity; and

a jacket comprising;

a jacket interior surface, and

a jacket interior cavity defined by the jacket interior surface wherein the first supply hose, the first return hose, the second supply hose, and the second return hose are disposed in the jacket interior cavity.

2. The cable of claim 1, further comprising a pilot cable disposed in the jacket interior cavity.

3. The cable of claim 2, wherein the pilot cable is disposed between the first supply hose, the first return hose, the second supply hose, and the second return hose.

4. The cable of claim 1, further comprising a plurality of pilot wires disposed in the jacket interior cavity.

5. The cable of claim 1, further comprising a ground wire disposed in the jacket interior cavity.

6. The cable of claim 1, wherein the first supply hose, the first return hose, the second supply hose, and the second return hose are adjacent to the jacket interior surface.

7. A cable comprising:

a first supply hose comprising;

a first supply hose interior surface,

a first supply hose interior cavity defined by the first supply hose interior surface, and

a supply conductor being disposed within the first supply hose interior cavity wherein a first supply hose interior space is formed between the supply

conductor and the first supply hose interior surface within the first supply hose interior cavity;

a first return hose comprising;

a first return hose interior surface, and

a first return hose interior cavity defined by the first return hose interior surface;

a second supply hose comprising;

a second supply hose interior surface,

a second supply hose interior cavity defined by the second supply hose interior surface, and

a return conductor being disposed within the second supply hose interior cavity wherein a second supply hose interior space is formed between the return conductor and the second supply hose interior surface within the second supply hose interior cavity;

a second return hose comprising;

a second return hose interior surface, and

a second return hose interior cavity defined by the second return hose interior surface; and

a jacket comprising;

a jacket interior surface, and

a jacket interior cavity defined by the jacket interior surface wherein the first supply hose, the first return hose, the second supply hose, and the second return hose are disposed in the jacket interior cavity.

8. The cable of claim 7, further comprising a pilot cable disposed in the jacket interior cavity.

9. The cable of claim 8, wherein the pilot cable is disposed between the first supply hose, the first return hose, the second supply hose, and the second return hose.

10. The cable of claim 7, further comprising a plurality of pilot wires disposed in the jacket interior cavity.

11. The cable of claim 7, further comprising a ground wire disposed in the jacket interior cavity.

12. The cable of claim 7, wherein the first supply hose, the first return hose, the second supply hose, and the second return hose are adjacent to the jacket interior surface.

13. An apparatus comprising:

an output terminal tab;

a first output terminal tube attached to the output terminal tab, the first output terminal tube comprising;

a first output terminal tube port,

a first output terminal tube first end, and

a first output terminal tube second end disposed inside the output terminal tab;

a second output terminal tube attached to the output terminal tab, the second output terminal tube comprising;

a second output terminal tube port,

a second output terminal tube first end, and

a second output terminal tube second end disposed inside the output terminal tab; and

a fluid pathway extending from the first output terminal tube port through an interior of the first output terminal tube, into an interior of the output terminal tab, though an interior of the second output terminal tube, to the second output terminal tube port.

14. The apparatus of claim 13, wherein the first output terminal tube further comprises a plurality of first output terminal tube barbs.

15. The apparatus of claim 13, wherein the second output terminal tube further comprises a plurality of second output terminal tube barbs.

16. The apparatus of claim 13, wherein the output terminal tab further comprises an output terminal tab opening.

17. An apparatus comprising:

a first input terminal tube comprising,

a first input terminal tube first end,

a first input terminal tube second end,

a first input terminal tube port disposed near the first input terminal tube first end, and

a first input terminal tube fluid pathway being inside the first input terminal tube and extending between the first input terminal tube port and the first input terminal tube second end;

a second input terminal tube comprising,

a second input terminal tube first end,

a second input terminal tube second end,

a second input terminal tube port disposed near the second input terminal tube first end, and

a second input terminal tube fluid pathway being inside the second input terminal tube and extending between the second input terminal tube port and the second input terminal tube second end; and

an input terminal tab connecting the first Input terminal tube to the second input terminal tube.

18. The apparatus of claim 17, wherein the input terminal tab further comprises an input terminal tab opening.

19. The apparatus of claim 17, wherein the first output terminal tube further comprises:

a first plurality of first input terminal tube barbs disposed at the first input terminal tube first end; and

a second plurality of first input terminal tube barbs disposed at the first input terminal tube second end.

20. The apparatus of claim 17, wherein the second output terminal tube further comprises:

a first plurality of second input terminal tube barbs disposed at the second input terminal tube first end; and

a second plurality of second input terminal tube barbs disposed at the second input terminal tube second end.

21. An apparatus comprising:

a source;

a load;

a liquid cooled charging cable connecting the source to the load, the liquid cooled charging cable supplying electric energy from the source to the load, the liquid cooled charging cable comprising;

a supply conductor, and

a return conductor;

a cooling device that pumps a coolant around the supply conductor and the return conductor, the supply conductor and the return conductor being immersed in the coolant.

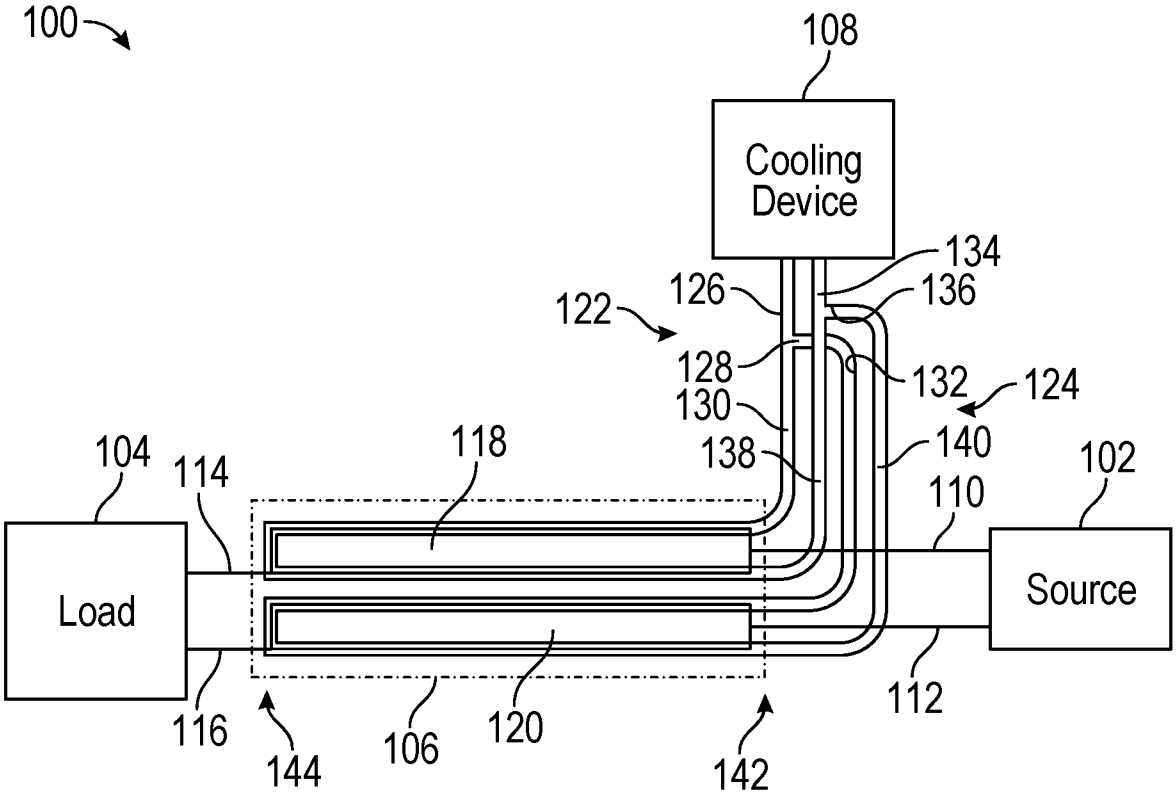

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Cooling Device
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Load
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FIG. 1

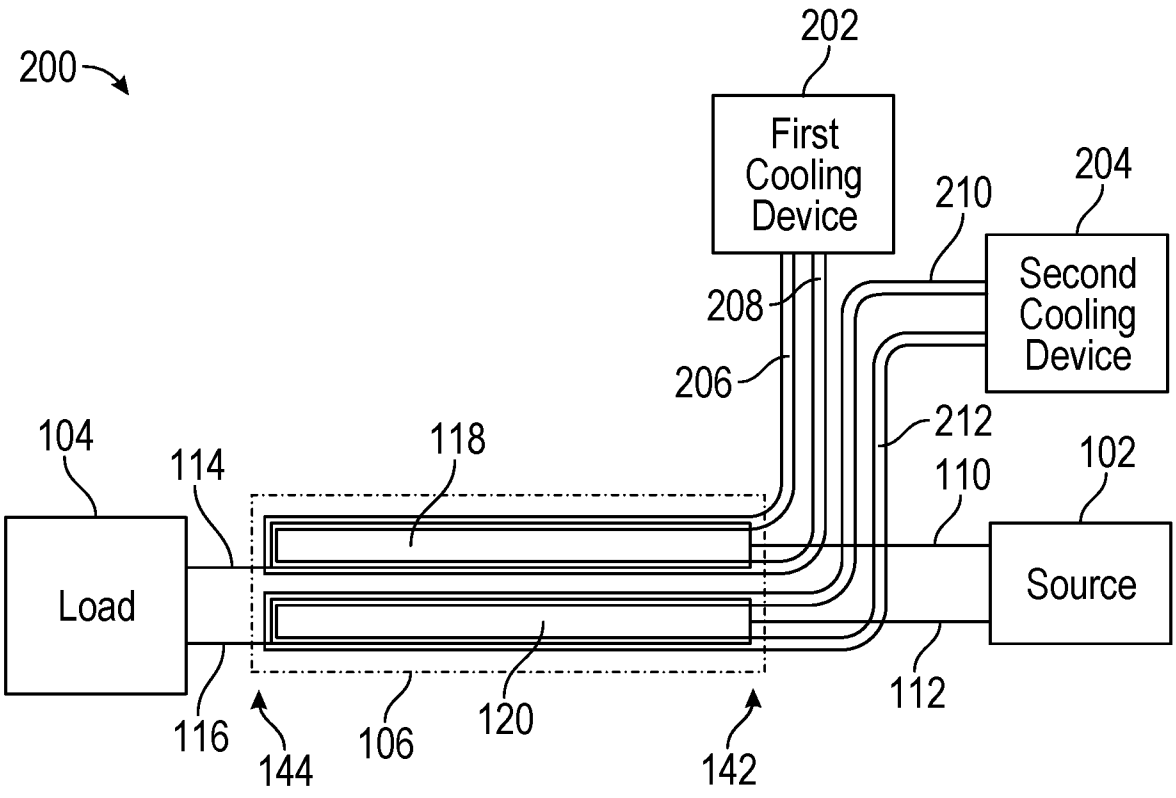

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First Cooling Device
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Second Cooling Device
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FIG. 2

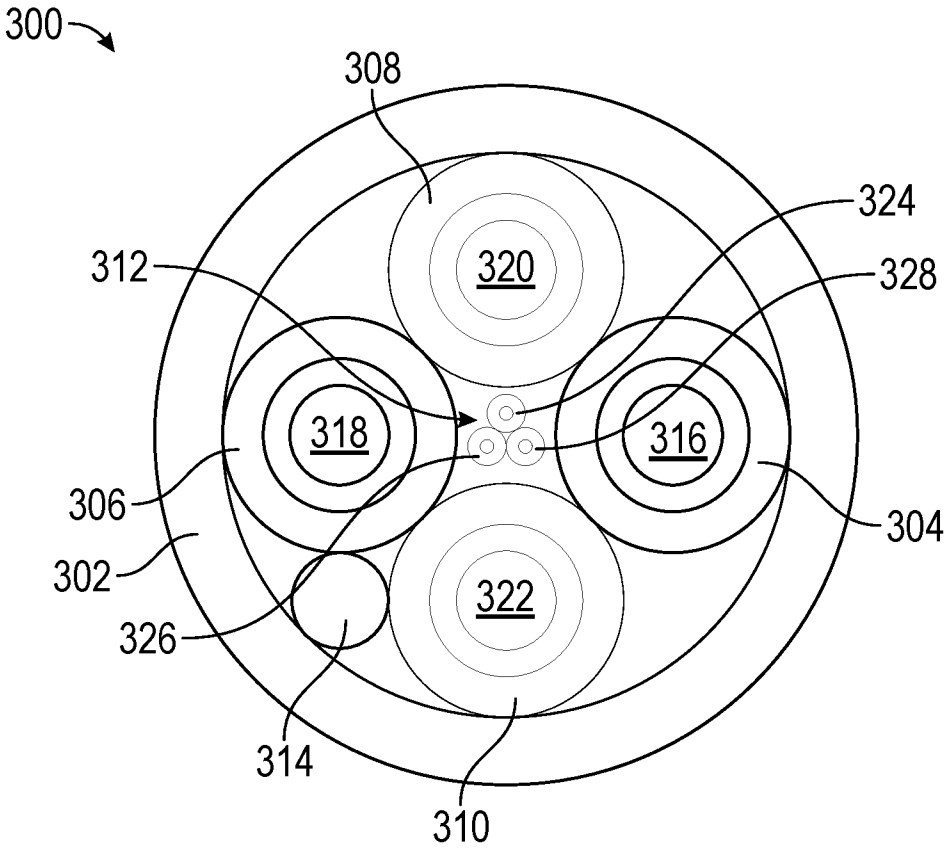

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FIG. 3

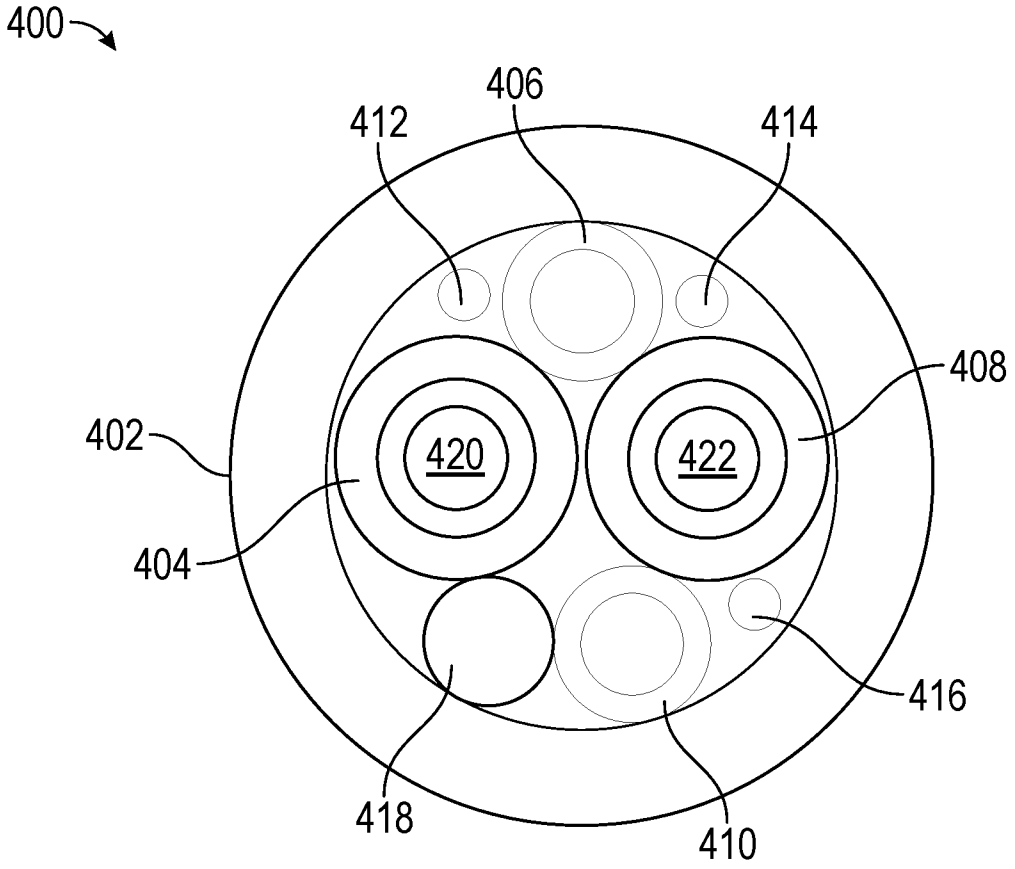

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FIG. 4

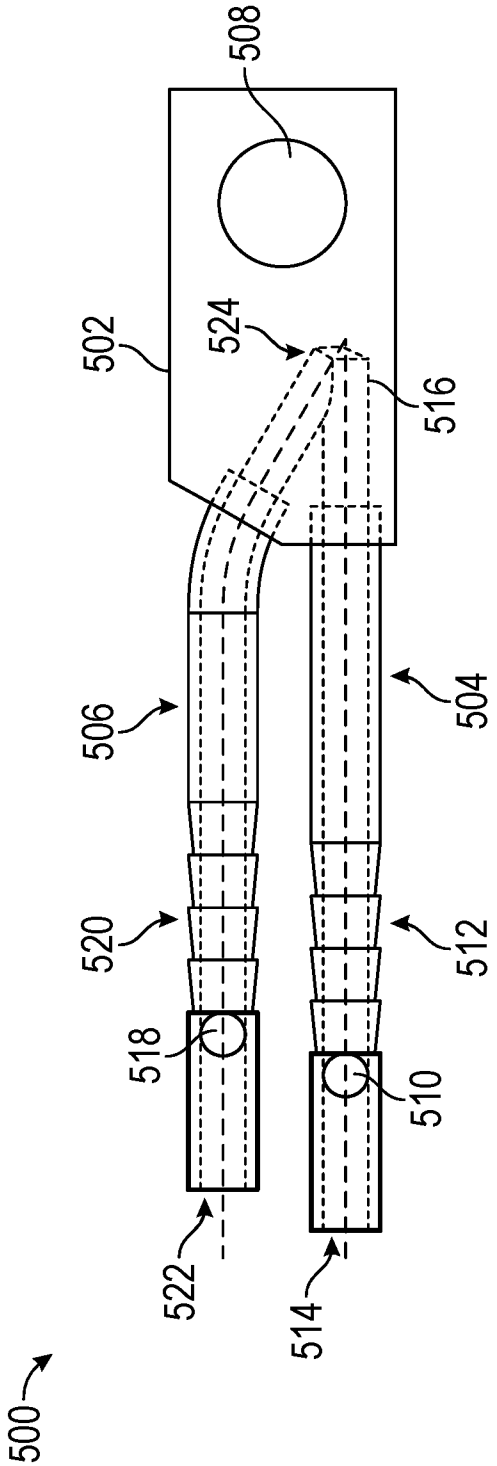

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FIG. 5A

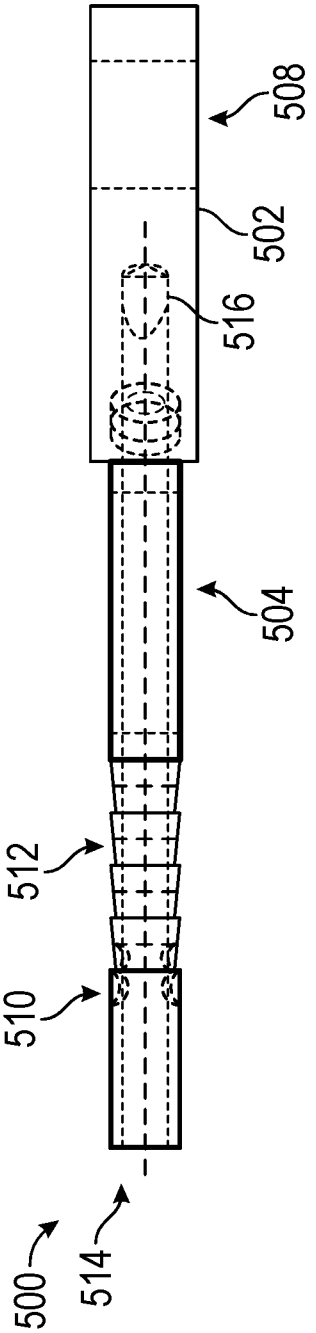

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FIG. 5B

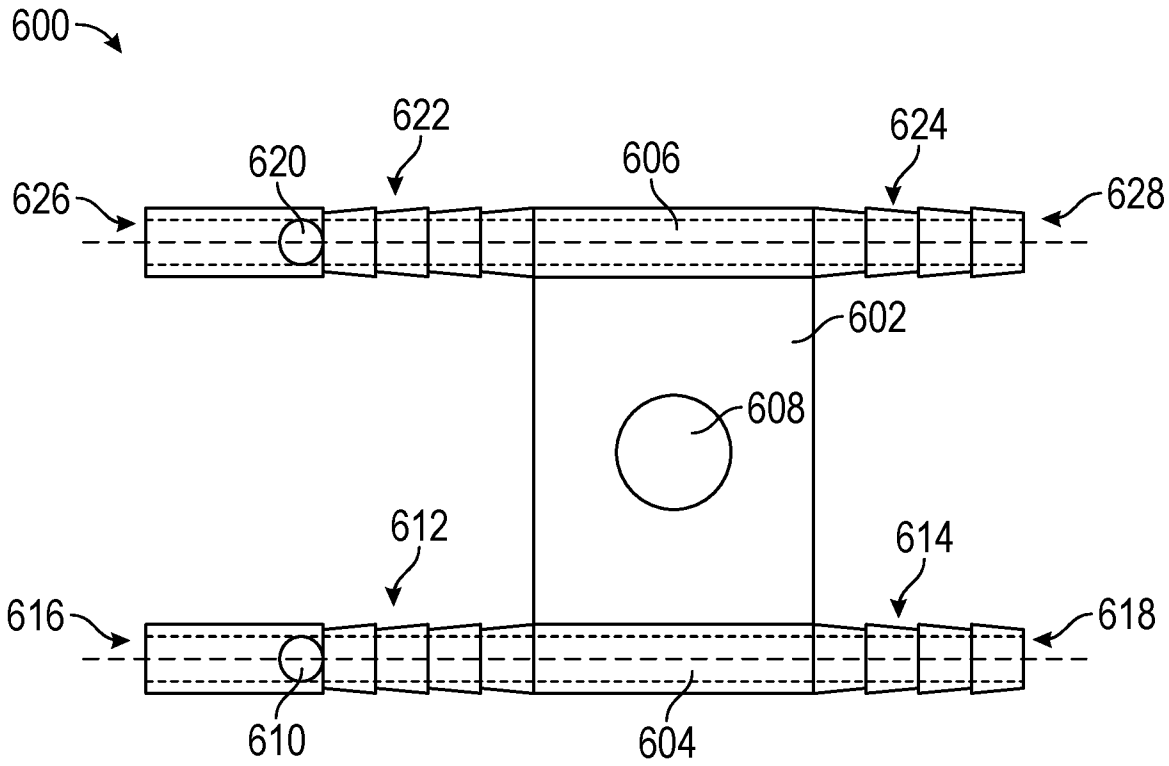

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FIG. 6A

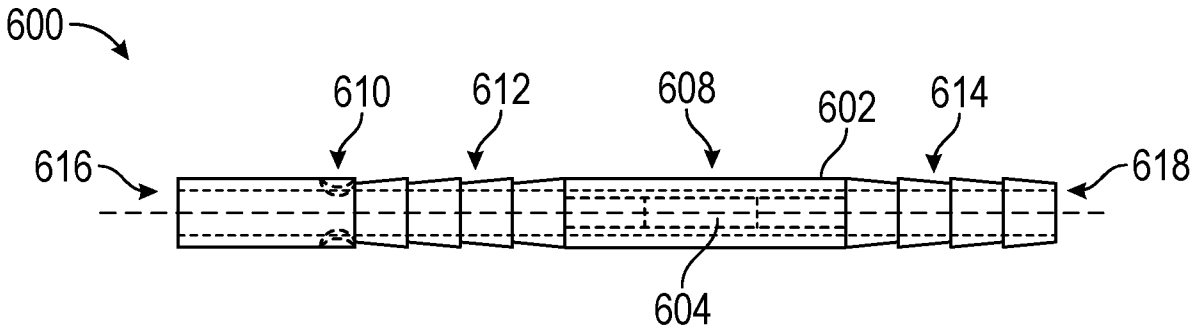

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FIG. 6B