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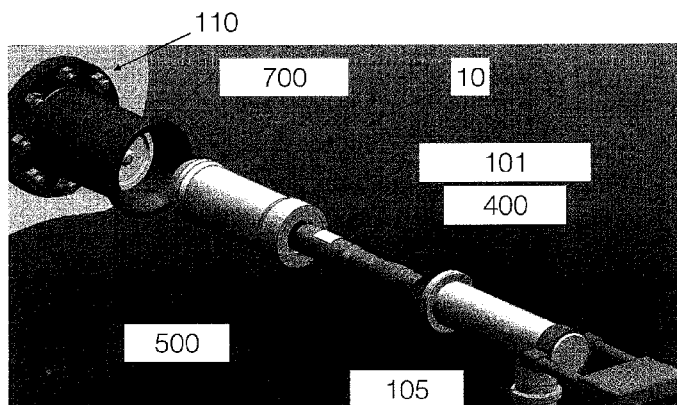
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Figure 3



(57) Abstract: An apparatus includes a receptacle, a plug, a cable termination assembly, and a sensor disposed on one of the receptacle, the plug, or the cable termination assembly to monitor a connection between the receptacle, the plug, and the cable termination assembly. The receptacle includes a receptacle conductor pin disposed therein. The plug includes a plug conductor pin disposed therein and a plunger disposed at a first end of the plug conductor pin. The cable termination assembly includes a cable disposed at least partially therein and a conductor pin interface disposed proximate a first end of the cable termination assembly, the conductor pin interface configured to receive the plug conductor pin. A method includes mating a cable termination assembly with a plug, mating the plug with a receptacle to form a mated wetmate connector, and sending signals from a flexible sensor in the mated wetmate connector indicative of a connection status.



HIGH POWER INTERCONNECT SYSTEM

BACKGROUND

[0001] During subsea operations it is necessary to provide an electrical connection from the surface to subsea equipment. In some applications it is necessary to provide a high power and/or high voltage connection to subsea equipment. For example, power may be supplied to a subsea transformer, motor, variable frequency drive, pump, etc. Wetmate connectors are used in the art to provide electrical connections from the surface to subsea equipment or between two pieces of subsea equipment. Wetmate connectors are used in subsea applications because electrical connections are made after installation of subsea equipment. Thus, wetmate connectors are used to prevent sea water and debris from damaging electrical connections in subsea environments.

SUMMARY

[0002] In one aspect, embodiments disclosed herein relate to an apparatus having a receptacle including a receptacle conductor pin disposed therein; a plug including a plug conductor pin disposed therein and a plunger disposed at a first end of the plug conductor pin, wherein the plunger is configured to receive the receptacle conductor pin; a cable termination assembly including a cable disposed at least partially therein and a conductor pin interface disposed proximate a first end of the cable termination assembly, wherein the conductor pin interface is configured to receive the plug conductor pin; and a sensor disposed on one of the receptacle, the plug, or the cable termination assembly to monitor a connection between the receptacle, the plug, and the cable termination assembly.

[0003] In another aspect, embodiments disclosed herein relate to an apparatus having a cable termination assembly module including a cable termination assembly body having a first end and a second end and a cable disposed at least partially within the cable termination assembly body; a plug module including a plug body having a first end and a second end, wherein the second end of the plug body mates with the first

end of the cable termination assembly body, and a plug conductor pin disposed at least partially within the plug body, wherein the plug conductor pin is in electrical contact with the cable when the second end of the plug body is mated with the first end of the cable termination assembly body; and a receptacle module including a receptacle body having a first end and a second end, wherein the second end of the receptacle body mates with the first end of the plug body, and a receptacle conductor pin disposed at least partially within the receptacle body, wherein the receptacle conductor pin is in contact with the plug conductor pin when the second end of the receptacle body is mated with the first end of the plug body, wherein each module is separately replaceable.

[0004] In another aspect, embodiments disclosed herein relate to a method including mating a cable termination assembly with a plug such that the cable termination assembly and the plug are in electrical contact; mating the plug with a receptacle, thereby forming a mated wetmate connector such that the plug and the receptacle are in electrical contact; and sending signals from a flexible sensor disposed within the mated wetmate connector, the signals indicative of a connection status of the wetmate connector.

[0005] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

BRIEF DESCRIPTION OF DRAWINGS

[0006] FIGS. 1 and 2 show schematic views of subsea processing systems in accordance with embodiments of the present disclosure.

[0007] FIG. 3 is an exploded view of a wetmate connector with a condition performance monitoring sensor location in accordance with embodiments of the present disclosure.

[0008] FIG. 4 is a cross-section view of a cable termination assembly in accordance with embodiments of the present disclosure.

[0009] FIG. 5 is a cross-section view of a wetmate connector plug in accordance with embodiments of the present disclosure.

[00010] FIG. 6 is a partial cross-section view of a wetmate connector plug in accordance with embodiments of the present disclosure.

[00011] FIG. 7 is a cross-section view of a wetmate connector receptacle in accordance with embodiments of the present disclosure.

[0010] FIG. 8 is a flow chart in accordance with embodiments of the present disclosure.

DETAILED DESCRIPTION

[0011] Generally, embodiments disclosed herein relate to an interconnect apparatus and methods of using said apparatus for providing power to equipment. More specifically, the present disclosure relates to a wetmate connector for providing power to subsea electrical equipment. A wetmate connector in accordance with embodiments disclosed herein provides a modular high power wetmate connector and may provide the capability to determine a status of a connection (*i.e.*, whether there is or is not a connection) by monitoring, for example, a current, a voltage, a partial discharge, and/or, physical engagement of the wetmate connector.

[0012] Referring to Figure 1, a subsea system 100 in accordance with embodiments of the present disclosure is illustrated. A wetmate connector 10 is provided to subsea processing system 100 to provide a high voltage connection between subsea equipment. For example, as shown, a wetmate connector 10 may be located at a first and second end of a high voltage cable 103. The wetmate connector 10 includes at least a wetmate receptacle 700, a wetmate plug 500, a cable termination assembly 400, and a sensor 101. The high voltage cable 103 may be received in a cable termination assembly 400 of the wetmate connector 10.

[0013] The high voltage cable 103 connects an umbilical termination assembly 115 to subsea equipment 110. Subsea equipment 110 may include, for example, but is not limited to, a motor, a variable frequency drive, and/or a pump. Additionally, low volt-

age wirings 106 may be provided to the subsea system 100 to connect sensors 101 to the umbilical termination assembly 115. The umbilical termination assembly 115 includes an umbilical 120 to provide a connection to the surface.

[0014] Figure 2 illustrates another subsea processing system 201 in accordance with embodiments of the present disclosure. Subsea system 201 illustrates a wetmate connector 10 located on a first and second end of high voltage cable 103 to connect a subsea transformer 203 to subsea equipment 110, for example, but not limited to a motor, a variable frequency drive, and/or a pump. The transformer 203 is provided with an umbilical 120 to connect the subsea components, *i.e.*, the transformer 203, subsea equipment 110, and sensors 101, to the surface. Low voltage wirings 106 are provided to connect sensors 101 of the wetmate connector 10 to the subsea equipment 110. In one or more embodiments, the low voltage wirings 106 are coupled between an instrument control panel of the subsea equipment 110 and the wetmate connector 10.

[0015] Referring to Figure 3, an exploded view of a wetmate connector 10 is shown. The wetmate connector 10 includes at least a cable termination assembly 400, a wetmate plug 500, a wetmate receptacle 700, and a sensor 101. As shown, the wetmate receptacle 700 may be mounted to subsea equipment 110, for example, a motor, pump, transformer, variable frequency drive, etc., by, for example, a flange bolted to the subsea equipment and having a sealing gasket, threaded engagement, mechanical fasteners, such as screws or bolts, welding, or the like. An end of the wetmate receptacle 700 opposite the subsea equipment 110 may receive the wetmate plug 500. As illustrated in Figure 3, the cable termination assembly 400 resides within an outer casing of wetmate plug 500. The cable termination assembly 400 may couple to the wetmate plug 500 at an angle of about 0-90 degrees. The sensor 101 may be a flexible sensor embedded in the cable termination assembly 400. An ROV handle 105 may be disposed on a distal end of the wetmate plug 500 and/or cable termination assembly 400, thereby providing an attachment to allow an ROV to manipulate the wetmate connector 10. In one or more embodiments, the wetmate connector 10 may have a stabmate configuration where the connection between the wetmate plug 500

and the wetmate receptacle 700 is made when one piece of subsea equipment is landed onto another piece.

[0016] A cable termination assembly 400 as disclosed herein may be a pressure compensated subsea enclosure that enables a cable (*e.g.*, cable 103 in Figure 1) to be connected to the wetmate plug 500 and wetmate receptacle 700. The cable termination assembly 400 is connected to the wetmate plug 500 or wetmate receptacle 700 before the assembly is deployed subsea. Figure 4 illustrates a detailed cross-section view of a cable termination assembly 400 in accordance with embodiments of the present disclosure. The cable termination assembly includes at least cable 412 and conductor pin interface 418. The conductor pin interface 418 is designed to mate with the wetmate plug 500 (Figure 3) and receptacle 700 (Figure 7). The cable 412 may be rated at, for example about 6.6 kV and about 1000A. However, one skilled in the art will understand that any medium or high power rated cable may be used without departing from the scope of the present disclosure.

[0017] The cable termination assembly 400 includes a body 401 housing internal cable termination components as described herein. The cable termination assembly body 401 may be made from steel and includes a first end 440 and a second end 450. In some embodiments, the cable termination assembly body 401 may be formed from two separate pieces: a front section and a rear section corresponding to the first end 440 and a second end 450, respectively. As shown in Figure 4, screw 413 secures the first end 440 of the cable termination assembly body 401 to the second end 450 of the cable termination assembly body 401. The conductor pin interface 418 may be located proximate the first end 440, while the cable 412 may be received through the second end 450.

[0018] The first end 440 includes an opening 441 for receiving the wetmate plug 500 (Figure 3) or receptacle 700 (Figure 7). The opening 441 may be formed in an insulating split bushing 402. The insulating split bushing 402 may be made from a rigid, electrically insulating polymer (*e.g.*, polyether ether ketone (PEEK), ethylene propylene rubber (EPR)) and provide mechanical and electrical support to the conductor pin interface 418. The conductor pin interface 418 provides an electrical pathway between the cable 412 and the wetmate plug 500 (Figure 3) or receptacle 700 (Figure 7)

from high voltage cable 412 to the wetmate plug 500 or receptacle 700. The conductor pin interface 418 is positioned within the insulating split bushing 402 and is made from an electrically conductive material (*e.g.*, copper). The conductor pin interface 418 includes an electrical contact band 410 at a first end 445 of the conductor pin interface 418, which facilitates power transmission between the conductor pin interface 418 and the wetmate plug 500 or receptacle 700. For example, when the cable termination assembly 400 is mated with the wetmate plug 500, a plug conductor pin (501 in Figure 5) may be received in the electrical contact band 410 to establish an electrical connection between the cable termination assembly 400 and the wetmate plug 500.

[0019] A second end 455 of the conductor pin interface 418 may be attached to a crimp barrel 419. The crimp barrel 419 is formed from electrically conductive material (*e.g.*, copper) and is crimped to a stripped portion of cable 412 to provide an electrical pathway for the current carried by the cable 412. Mastic 411 may be applied between the crimp barrel 419 and the stripped portion of cable 412 to fill in any gaps and manage electric field.

[0020] The cable termination assembly 400 may also include a cable ground contact 407 to ground the cable 412. The cable ground contact 407 may be made from an electrically conductive material and provide electrical contact between a cable grounding layer of the cable 412 to the cable termination assembly body 401. Mastic 411 may be applied to the cable 412, where the cable 412 is stripped to the grounding layer. The cable ground contact 407 may include an electrical contact band 410 to facilitate the electrical conduction between the cable ground layer of the cable 412 and the cable ground contact 407. A grounding strap 406 may be included in the cable ground contact 407 to carry the ground potential from the cable grounding layer of the cable 412 to the body 401 of the cable termination assembly 400.

[0021] Various components are positioned around the cable 412, mastic 411, crimp barrel 419, conductor pin interface 418, and cable ground contact 407 to electrically isolate and keep said components in the correct relative position. For example, heat shrink tubing 405 may be positioned around areas containing mastic 411 to aid in holding the above noted components in place and managing the electric field. Sealing gland 404 may be positioned around the cable 412, mastic 411, and/or heat shrink tub-

ing 405 to provide a sealing barrier to the cable 412 to prevent water ingress. Additionally, forward bushing 403 located concentrically around the sealing gland 404 and at least a portion of the crimp barrel 419 provides electrical insulation to said components. The forward bushing 403 may also provide a stop for the sealing gland 404. A rear bushing 408 may be positioned concentrically around mastic 411 and/or a portion of cable ground contact 407. The forward bushing 403, rear bushing 408, and sealing gland 404 are made from electrically insulating material (*e.g.*, PEEK), however one skilled in the art will understand the type of material used is not intended to limit the scope of the present disclosure.

[0022] As noted above, the cable termination assembly 400 is pressure compensated. The cable 412 is fed through a hose fitting 417. The hose fitting 417 is connected to a hose and filled with dielectric fluid from chamber 423. As the external pressure around the cable termination varies, dielectric fluid will flow from chamber 423 into and/or out of the hose fitting 417 and to the hose that will expand and contract to compensate for the volume difference. The hose fitting 417 may also provide mechanical protection for the cable 412. A series of seals and sleeves may be provided to regulate the movement of the dielectric fluid. For example, gland seal 421 is provided proximate the rear bushing 408 to prevent dielectric fluid from contacting the stripped back portion of the cable 412. A seal sleeve 415 may also be provided proximate the second end 450 of the cable termination assembly to prevent water ingress and dielectric fluid egress.

[0023] Various nuts, sleeves, and screws are also included in the cable termination assembly 400 to secure the above mentioned cable termination assembly components in place. For example, first retaining nut 409 may be threaded to the first end 440 of the body 401 to secure the front components, *e.g.*, the insulating split bushing 402 and conductor pin interface 418 in place. Compression sleeve 416 formed from a flexible polymer (*e.g.*, VITON synthetic rubber or fluoropolymer elastomer, ethylene propylene diene monomer (EPDM) rubber, AFLAS fluoropolymers) may be compressed against the cable 412 with the compression sleeve retainer 420 to prevent axial movement of the cable 412 within the cable termination assembly 400. The compression sleeve retainer 420 may include a clamp and bracket to secure the compression

sleeve 416 to the cable 412. Sealing module internal nut 414 may thread to the second end 450 of the body 401 to secure the compression sleeve retainer 420 and seal sleeve 415. Second retaining nut 422 may thread on to the second end 450 of the body 401 of the cable termination assembly 400 to provide a hard stop for the seal sleeve 415, compression sleeve retainer 420, and compression sleeve 416. In one or more embodiments, the second retaining nut 422 may be welded to the hose fitting 417.

[0024] Referring to Figures 3 and 5, a wetmate plug 500, also referred to as plug 500, is shown in accordance with embodiments of the present disclosure. A wetmate plug 500 as disclosed herein may be a pressure compensated subsea enclosure that enables an electrical connection to be made between the cable termination assembly 400 and the receptacle 700. The wetmate plug 500 may include at least a plug conductor pin 501 having a plunger 503. The wetmate plug 500 may also include a plug body 512 having a first end 540 and a second end 550. At least one port 524 formed in the plug body 512 provides pressure compensation between an interior of the plug 500 and the environment exterior to the plug 500. The plug conductor pin 501 may be positioned within the plug body 512 such that a first end 545 of the plug conductor pin 501 is located between the first end 540 and the second end 550 of the plug body 512 and the second end 555 of the plug conductor pin 501 extends past the second end 550 of the plug body 512.

[0025] The plug conductor pin 501 may be formed from copper. A portion of the plug conductor pin 501 may be overmolded with an insulating plastic 531 (*e.g.*, polyether ether ketone (PEEK)) to provide insulation and aid in mounting the plug conductor pin 501 within the plug 500. The plug conductor pin 501 may include an internal chamber 520 to receive the plunger 503 and at least one biasing mechanism 504, 505 to provide a biasing force for the plunger 503. The inner diametric surface of the internal chamber 520 may include at least one groove to guide motion of the plunger 503 within the internal chamber 520. At least one port 522 may be drilled or otherwise formed or provided in a wall of the plug conductor pin 501 proximate the internal chamber 520 to allow dielectric fluid to move in and out of the internal chamber 520.

[0026] The plug conductor pin 501 may also include a conductor pin cap 502 made from, for example, copper, and threaded on to a first end 545 of the plug conductor pin 501. The conductor pin cap 502 may include a plug electrical contact band 519. The plug electrical contact band 519 provides a highly conductive region to receive the wetmate receptacle 700, particularly, a receptacle conductor pin (701 in Figure 7).

[0027] The plunger 503 is formed from electrically non-conductive material and may be positioned at least partially within the internal chamber 520 of the plug conductor pin 501. The plunger 503 may include at least one tab and/or protrusion on an outer diametric surface thereof to interact with the grooves formed in the inner diameter of the plug conductor pin 501, *e.g.*, along the wall of the internal chamber 520. Biasing mechanism 504, 505 may be located within the internal chamber 520, between the plunger 503 and a back wall 530 of the internal chamber 520. As shown, the back wall 530 of the internal chamber 520 may be an internal end surface, shoulder, or the like of the plug conductor pin 501. As illustrated in Figure 5, the biasing mechanism 504, 505 includes an outer spring 504 and an inner spring 505. One skilled in the art will understand that any number of springs and/or types of biasing mechanisms may be used to achieve the desired biasing force without departing from the scope of the present disclosure. A first end 547 of the plunger 503 is provided to receive the receptacle 700.

[0028] When the plug 500 is not mated with the receptacle 700, the plunger 503 may interact with a wiper seal 508 located proximate a first end 540 of the plug body 512. Particularly, the wiper seal 508 exerts positive pressure on the plunger 503 to prevent water ingress in an unmated position. Wiper seal 508 is held in place with wiper seal retainer 509, which prevents relative movement of the wiper seal 508 with respect to the plug 500 during mating. When the receptacle 700 is mated with the plug 500, the receptacle 700 may depress the plunger 503, *i.e.*, cause the plunger to travel into the internal chamber 520. The wiper seal 508 may aid in removing sea water and debris from the receptacle 700 (*i.e.*, receptacle conductor pin 701 in Figure 7) and the mating area (*e.g.*, area proximate the plunger 503 and contact band 519) during mating. As the receptacle 700 and the plug 500 are mated, at least a portion of the receptacle 700 comes into contact with the plug electrical contact band 519 to establish an electrical

connection between the plug 500 and the receptacle 700. The receptacle 700 (*i.e.*, receptacle conductor pin 701 in Figure 7) may exert a positive pressure on the wiper seal 508 during mating to prevent water ingress.

[0029] As noted above, the wetmate plug 500 is pressure compensated to adapt to the high pressures of the subsea environment. A plurality of ports, bladders, and retainers may be provided to the wetmate plug 500 to ensure structural integrity of the plug 500 in high pressure environments and during mating operations (*i.e.*, mating the plug 500 with the receptacle 700 and the cable termination assembly 400). For example, as illustrated in Figure 5, at least an inner bladder 506, a bladder retainer 507, an insulating bladder sleeve 513, and an outer bladder 514 are provided as a part of the wetmate plug pressure compensation system. Each component of the wetmate plug pressure compensation system is made from an electrically non-conductive material (*e.g.*, fluorosilicone, PEEK).

[0030] The inner bladder 506 (also referred to as the inner insulation bladder 506) may be positioned to contact the plunger 503 and act as a secondary wiper seal. For example, during mating between the plug 500 and the receptacle 700, the inner insulation bladder 506 may remove sea water and debris as the plunger 503 moves within the internal chamber 520. In one or more embodiments, the receptacle conductor pin 701 (in Figure 7) will not come into contact with the plug contact band 519 until the receptacle conductor pin has moved past the inner insulation bladder 506.

[0031] Bladder retainer 507 is located proximate a first end 540 of the plug body 512 to provide a mechanical hard stop for the inner bladder 506, the outer bladder 514, and the insulating bladder retainer 513. An inner bladder sealing collar 515 and outer bladder sealing collar 517 are located near a second end 550 of the plug body 512 to secure a second end of the inner bladder 506 and outer bladder 514. The bladder retainer 507 includes an excess fluid port 523 to transport sea water not removed by the wiper blade 508 during mating operations and/or excess dielectric fluid from the mating area to a third chamber 527. The excess fluid port 523 prevents dielectric oil in the mating area to be diluted. A portion of the excess fluid port 523 is located through a wall of the insulating bladder sleeve 513, described below.

[0032] The insulating bladder sleeve 513 is provided to hold the inner bladder 506 in place during mating of the plug 500 and receptacle 700. Particularly, the inner bladder 506 may expand during mating and contract during de-mating. The insulating bladder sleeve 513 is provided to mitigate the expansion of the inner bladder 506 during mating. The insulating bladder retainer 513 includes a plurality of ports 525 formed in a wall of the insulating bladder sleeve 513. The plurality of ports 525 allow dielectric fluid to move between a second chamber 526, formed between the inner bladder 506 and the insulating bladder sleeve 513, and the third chamber 527, formed between the insulating bladder sleeve 513 and the outer bladder 514.

[0033] The outer insulation bladder 514 (also referred to as the outer bladder 514) may be mounted to the insulating bladder sleeve 513. The outer insulation bladder 514 provides a barrier between the dielectric oil contained within the plug 500 and ambient fluid in the environment (*e.g.*, sea water). Similar to the inner insulation bladder 506, the outer insulation bladder 514 expands and contracts during mating and de-mating, respectively. The expansion volume accommodated by the outer insulation bladder 514 may correspond to the volume of fluid displaced from the internal chamber 520 caused by movement of the plunger 503. As noted above, the excess fluid port 523 may allow dielectric fluid to move from the internal chamber 520 to at least one of the second chamber 526 and third chamber 527 to compensate for movement of the plunger 503.

[0034] Referring still to Figure 5, a variety of components are provided to the wetmate plug 500 to maintain the relative position of components contained within the plug body 512 of the plug 500. For example, first plug retaining nut 511 threads into the first end 540 of the plug body 512 and is used with the first thrust washer 510 to secure components located near the first end 540 of the plug body 512, *e.g.*, wiper seal 508, wiper seal retainer 509, bladder retainer 507, etc. Second plug retaining nut 518 and second thrust washer 516 thread into the second end 550 of the plug body 512 and are to secure components located near the second end 550 of the body 512, *e.g.*, inner bladder sealing collar 515, outer bladder sealing collar 517, insulating bladder sleeve 513, etc. The first thrust washer 510 and second thrust washer 516 act

to distribute the load of the first plug retaining nut 511 and the second plug retaining nut 518, respectively, over a larger area.

[0035] According to some embodiments, the plug pressure compensation system may include a series of inner and outer bellows. Referring to Figure 6, a wetmate plug 600 has a pressure compensation system that includes at least an inner series of bellows 606, an insulating bellow sleeve 613, and an outer series of bellows 614. One skilled in the art will understand that wetmate plug 600 is similar to wetmate plug 500 unless otherwise indicated.

[0036] Similar to the plug 500 illustrated in Figure 5, plug 600 includes, among other components, a plug conductor pin 601 having ports 622, a plug body 612 having ports 624, and an insulating bellow sleeve 613 having ports 625. An internal chamber 620 is formed within the plug conductor pin 601, a second chamber 626 is formed between an outer surface of the plug conductor pin 601 and the insulating bellow sleeve 613, and a third chamber 627 is formed between an outer surface of the insulating bellow sleeve 613 and the plug body 612. According to one or more embodiments, and as shown in Figure 6, the internal chamber 620 and the second chamber 626 are in fluid communication with each other. The inner series of bellows 606 is in fluid communication with the third chamber 627 through the ports 625 located in the insulating bellow sleeve 613. The outer series of bellows 614 is in fluid communication with the environment through the ports 624 located in the wall of the plug body 612.

[0037] During mating operations, the plunger 603 may stroke within the internal chamber 620, thereby displacing the dielectric fluid located therein. As the internal chamber 620 is in fluid communication with the second chamber 626, the dielectric fluid displaced from the internal chamber 620 will flow through ports 622 into the second chamber 626. The influx of fluid in the second chamber will cause the inner series of bellows 606 to compress. Fluid contained in the volume of the inner series of bellows 606 will flow through ports 625 into the third chamber 627. The influx of fluid into the third chamber 627 may cause the outer series of bellows 614 to compress, accordingly. Because this system is a pressure compensated system, the external environmental pressure is not greater than the internal pressure.

[0038] Referring now to Figures 3 and 7, a wetmate receptacle 700, also referred to as receptacle 700, in accordance with embodiments of the present disclosure is shown. The wetmate receptacle 700 may include a body 702 and at least a receptacle conductor pin 701 positioned therein. The body 702 has a first end 740 and a second end 750. The body 702 includes a funnel-shaped opening 753 proximate the second end 750 for receiving and guiding the plug 500 during mating.

[0039] The receptacle conductor pin 701 may be located within the body 702. As shown in Figure 7, a first end 745 of the receptacle conductor pin 701 may extend past the first end 740 of the body. A second end 755 of the receptacle conductor pin 701 may be located between the first 740 and second end 750 of the receptacle body 702. The receptacle conductor pin 701 may be formed from copper. A portion of the receptacle conductor pin 701 may be overmolded with an insulating plastic (*e.g.*, polyether ether ketone (PEEK)) to provide insulation and aid in mounting the receptacle conductor pin 701 within the receptacle 700.

[0040] According to some embodiments, the copper and or insulating plastic may be plated with gold and/or nickel along various sections of the receptacle conductor pin 701. For example, a middle section of the insulating plastic may be plated with nickel. The plated nickel may be in contact with a receptacle ground ring 711, such that the receptacle ground ring 711 transfers ground potential from the receptacle body 702 to the nickel plated portion of the receptacle conductor pin 701. In some embodiments, the second end 755 of the receptacle conductor pin 701 may be plated with a gold band. The gold band may be positioned to come into contact with the plug electrical contact band (519 in Figure 5). One skilled in the art will understand that the description with respect to the materials used to form the receptacle conductor pin 701 are not intended to be limiting.

[0041] The receptacle body 702 may include a profile 713 (*e.g.*, a recessed profile) proximate the second end 750 of the receptacle body 702 to position a latching mechanism 703 therein. The latching mechanism 703 is provided to secure the plug 500 when mating the receptacle 700 with the plug 500. In one or more embodiments, the latching mechanism 703 may include collet fingers. In one or more embodiments, the latching mechanism 703 may include a plurality of canted coil springs. The geometry

of the profile 713 and the spring design of the canted coil springs may be used to determine a mating force between the receptacle 700 and the plug 500.

[0042] A variety of seals and retainers are provided to the wetmate receptacle 700 to prevent water ingress and maintain the relative position of components contained within the body 702 of the receptacle 700. For example, first boot seal 704 located proximate a first end 740 of the receptacle body 702 is provided to seal against the receptacle conductor pin 701. The first boot seal 704 is secured in place around the receptacle conductor pin 701 with a first boot seal retainer 705 and a first pin retainer 706. The first pin retainer 706 may also provide a load bearing surface for the receptacle conductor pin 701 during mating with the plug 500. Gland seals 712 may be positioned between the receptacle conductor pin 701 and the first pin retainer 706 to prevent water ingress during mating.

[0043] The receptacle 700 may also include a second boot seal 709 located proximate the second end 755 of the receptacle conductor pin 701 within the receptacle body 702. The second boot seal 709 provides a seal around the receptacle conductor pin 701. While the receptacle 700 is mated with the plug 500, the second boot seal 709 may interface with the first end (540 in Figure 5) portion of the plug (500 in Figure 5) (*e.g.*, wiper seal 508 and wiper seal retainer 509 in Figure 5). The second boot seal 709 is secured in place with second boot seal retainer 710 and second pin retainer 708, and retaining nut 711. The second pin retainer 708 may provide a load bearing surface for the receptacle conductor pin 701 during mating with the plug 500. The retaining nut 711 may thread into the receptacle body 702 and secure the second boot seal 709, the second boot seal retainer 710, and the second pin retainer 708 in position within the receptacle body 702. Gland seals 712 may be positioned between the receptacle conductor pin 701 and the second pin retainer 708 as well as the second pin retainer 708 and the receptacle body 702 to prevent water ingress during mating.

[0044] Referring again to Figure 3, in some embodiments, a sensor 101 may be positioned on the outside of the body 401 (Figure 4) of the cable termination assembly 400. In accordance with some embodiments, the sensor 101 may be a flexible type sensor. The flexible sensor may be embedded in the body 401 (Figure 4) of the cable termination assembly 400 to monitor electromagnetic waves radiated by the wetmate

connector 10, *e.g.*, the cable termination assembly 400. The sensor 101 may be capable of monitoring a voltage, a current, and partial discharge of the cable 412 (Figure 4). One skilled in the art will understand that the sensor 101 may be disposed on the body of the wetmate plug 500 and the wetmate receptacle 700 and that the location of the sensor 101 shown in Figure 3 is non-limiting. The sensor 101 may be in communication with a computer located at a remote location, such as at the surface of a body of water such that the measurements taken by the sensor 101 may be monitored by a user at the surface. In some embodiments, a user may determine based on the measurements whether to replace a component of the wetmate connector 10. In certain embodiments, an automated system may determine that a component of the wetmate connector 10 should be replaced and initiate an appropriate response. A second sensor (not shown) may be used to monitor the latching mechanism 703, where the second sensor may be in communication with the flexible sensor and monitored by a user at the surface. Sensors, such as the sensor 101 and/or second sensor, may be electrically connected to an instrument pod, and signals from the instrument pod may be communicated to the surface via an umbilical.

[0045] According to an embodiment of the present disclosure each of the cable termination assembly 400, the wetmate plug 500, and the wetmate receptacle 700 may be modular components. In other words, each of these components may be removed and replaced separately without replacing and/or affecting the functionality of the other components. For example, in the event that the cable termination assembly 400 and/or cable (*e.g.*, cable 103 of Figure 1) is damaged, the cable termination assembly 400 may be replaced without replacing the wetmate plug 500 and the wetmate receptacle 700.

[0046] According to one aspect of this disclosure, a wetmate connector 10 in accordance with Figures 3-7 may include at least a receptacle 700, a plug 500, 600, a cable termination 400 and a sensor 101 positioned on at least one selected from the cable termination assembly 400, the plug 500, 600, and the receptacle 700 to monitor a connection between the receptacle 700, plug 500, 600, and cable termination 400. Referring to Figures 3-7 together, the receptacle 700 includes at least a receptacle conductor pin 701. The plug 500, 600 includes at least a plug conductor pin 501, 601

and a plunger 503, 603 located at a first end of the plug conductor pin 501, 601, such that the plunger 503, 603 receives the receptacle conductor pin 701. The cable termination assembly 400 includes at least a cable 412 positioned partially within the cable termination assembly 400. The cable termination assembly 400 also includes a conductor pin interface 418 located at a first end of the cable 412, such that the conductor pin interface 418 is positioned to receive the plug conductor pin 501, 601. In a fully mated position (*i.e.*, the receptacle 700, the plug 500, 600, and the cable termination assembly 400 are mated to each other as described with respect to Figure 3), the receptacle conductor pin 701, plug conductor pin 501, 601, and cable 412 are in electrical contact.

[0047] According to one aspect of this disclosure, a wetmate connector 10 in accordance with Figures 3-7 may include modular components such that a first module includes a cable termination assembly 400, a second module includes a wetmate plug 500, 600 and a third module includes a wetmate receptacle 700. The cable termination assembly 400 of the first module includes a cable termination body 401 having a first end 440 and a second end 450, and a cable 412 positioned at least partially within the cable termination body 401. The wetmate plug 500, 600 of the second module includes at least, a plug body 512, 612 having a first end 540 and a second end 550, such that the second end 550 of the plug body 512, 612 mates with the first end 440 of the cable termination assembly module 400. The wetmate plug 500, 600 includes a plug conductor pin 501, 601 located at least partially within the plug body 512, 612, such that the plug conductor pin 501, 601 is in electrical contact with the cable 412 when the second end 550 of the plug body 512, 612 is mated with the first end 440 of the cable termination body 401. The wetmate receptacle 700 of the third module includes a receptacle body 702 having a first end 740 and a second end 750. The second end 750 of the receptacle body 702 may mate with the first end 550 of the plug body 512, 612. The wetmate receptacle 700 also includes a receptacle conductor pin 701 located at least partially within the receptacle body 702, such that the receptacle conductor pin 701 is in electrical contact with the plug conductor pin 501, 601 when the second end 750 of the receptacle body 702 is mated with the first end 540 of the plug body. Each of the modules (*i.e.*, the cable termination assembly 400 module, wetmate plug 500, 600 module, and wetmate receptacle 700 module) may be inde-

pendently replaced in the event that at least one of the modules is damaged during use.

[0048] According to this aspect of the disclosure, the plug module 500 may include an outer bladder 514 located within the plug body 512 and an inner bladder 506 located between the outer bladder 514 and the plug conductor pin 501. The inner bladder 506 may act as a wiper seal in accordance with embodiments disclosed herein. According to another aspect of this disclosure, the plug module 600 may include an outer series of bellows 614 located within the plug body 612 and an inner series of bellows 606 located between the outer series of bellows 614 and the plug conductor pin 601.

[0049] According to another aspect of this disclosure there is provided a method for using a wetmate connector 10 as described with respect to Figures 3-7. Referring to Figures 3-8, a method in accordance with embodiments disclosed herein may include mating 801 a cable termination assembly 400 with a plug 500 such that the cable termination assembly 400 and the plug 500 are in electrical contact. In some embodiments, mating the cable termination assembly 400 with the plug 500 may include inserting a first end of a plug conductor pin 501, 601, which protrudes from a first end 545 of the plug 500, into a conductor pin interface 418 of the cable termination assembly 400. Once inserted, the first end of the conductor pin 501, 601 may contact a contact band 410 of the conductor pin interface 418. The contact between the first end of the conductor pin 501, 601 and the contact band 410 of the conductor pin interface 418 of the cable termination assembly 400 facilitates electrical contact between the plug 500 and the cable termination assembly 400.

[0050] The plug 500 may also be mated 802 with the wetmate receptacle 700 such that the plug 500 and the receptacle 700 are in electrical contact, thereby forming a mated wetmate connector 10. In some embodiments, mating the plug 500 with the receptacle 700 may include inserting a second end of the plug 500 into the receptacle 700. A plunger 503, 603 of the plug 500, 600 conductor pin receives the first end 745 of the receptacle conductor pin 701. The receptacle conductor pin 701 depresses the plunger 503, 603 of the plug conductor pin 501, 601. This movement of the plunger 503, 603 of the plug conductor pin allows the receptacle conductor pin 701 to contact a contact band 519 of the plug conductor pin 501, 601. Additionally, a latching mech-

anism 703 of the receptacle body 702 may secure the plug 500 in the wetmate receptacle 700.

[0051] Signals may be sent 803 from a sensor 105, *e.g.*, flexible sensor, disposed within the mated wetmate connector 10. The signals sent from the sensor 101 may be used to determine a connection status, of the wetmate connector 10, *i.e.*, if there is or is not a connection. The signals from the sensor 101 may monitor at least one selected from a current, a voltage, a partial discharge, and/or the physical engagement of the wet mate connector 10.

[0052] In the event that an unconnected status or electrical fault of the wetmate connector 10 is determined, the wetmate connector 10 may be retrieved to the surface. In some embodiments, a portion of the wetmate connector 10 may be retrieved, *e.g.*, the cable termination 400 and the plug 500. An ROV may be used to retrieve the wetmate connector 10 and/or a portion of the wetmate connector. In other embodiments, each component, the cable termination, 400, the plug 500, and the receptacle 700 may be retrieved. At the surface at least one component of the wetmate connector 10 may be replaced. An ROV may be used to reinsert the wetmate connector 10 at a previous subsea position.

[0053] Embodiments disclosed herein may provide an apparatus and method for creating a reliable subsea connection. Particularly, a wetmate connector in accordance with this disclosure may allow a user to remove and replace one or more components without retrieving or replacing the entire wetmate connection. Embodiments disclosed herein may also allow a user to monitor remotely from the surface to assess which component to replace or how to adjust the connection.

[0054] While the disclosure includes a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised which do not depart from the scope of the present disclosure. Accordingly, the scope should be limited only by the attached claims.

CLAIMS

What is claimed is:

1. An apparatus comprising:
 - a receptacle including a receptacle conductor pin disposed therein;
 - a plug including a plug conductor pin disposed therein and a plunger disposed at a first end of the plug conductor pin, wherein the plunger is configured to receive the receptacle conductor pin;
 - a cable termination assembly including a cable disposed at least partially therein and a conductor pin interface disposed proximate a first end of the cable termination assembly, wherein the conductor pin interface is configured to receive the plug conductor pin; and
 - a sensor disposed on one of the receptacle, the plug, or the cable termination assembly to monitor a connection between the receptacle, the plug, and the cable termination assembly.
2. The apparatus of claim 1, wherein the sensor is configured to monitor at least one selected from a current, a voltage, a physical engagement, and a partial discharge.
3. The apparatus of claim 1, wherein the sensor is a flexible sensor.
4. The apparatus of claim 3, wherein the flexible sensor is in communication with a computer disposed at a surface of a body of water.
5. The apparatus of claim 1, wherein the receptacle conductor pin, the plug conductor pin, and the cable are in electrical contact when the receptacle, the plug, and the cable termination assembly are mated.
6. An apparatus comprising:
 - a cable termination assembly module comprising:
 - a cable termination assembly body having a first end and a second end; and
 - a cable disposed at least partially within the cable termination assembly body;
 - a plug module comprising:

a plug body having a first end and a second end, wherein the second end of the plug body mates with the first end of the cable termination assembly body;
and
a plug conductor pin disposed at least partially within the plug body, wherein the plug conductor pin is in electrical contact with the cable when the second end of the plug body is mated with the first end of the cable termination assembly body; and
a receptacle module comprising:
a receptacle body having a first end and a second end, wherein the second end of the receptacle body mates with the first end of the plug body; and
a receptacle conductor pin disposed at least partially within the receptacle body, wherein the receptacle conductor pin is in contact with the plug conductor pin when the second end of the receptacle body is mated with the first end of the plug body,
wherein each module is separately replaceable.

7. The apparatus of claim 6, wherein the plug module further comprises:
an outer bladder disposed within the plug body; and
an inner bladder disposed between the outer bladder and the plug conductor pin.
8. The apparatus of claim 7, wherein the inner bladder provides a seal against the plug conductor pin in an unmated position.
9. The apparatus of claim 6, wherein the plug module further comprises:
an outer bellows system disposed within the plug body; and
an inner bellows system disposed between the outer bladder and the plug conductor pin.
10. The apparatus of claim 6, wherein the plug conductor pin comprises:
an internal chamber formed in the plug conductor pin;
a conductor pincap coupled to a first end of the plug conductor pin;
a plunger disposed at least partially in the internal chamber; and
a biasing mechanism disposed within the internal chamber between the plunger and a back wall of the internal chamber.

11. The apparatus of claim 6, wherein the receptacle module further comprises:
 - a latching mechanism disposed in a profile proximate the second end of the receptacle body.
12. The apparatus of the 11, wherein the latching mechanism is a canted coil spring.
13. The apparatus of claim 6, wherein the cable termination assembly module further comprises:
 - a conductor pin interface disposed proximate a first end of the cable termination assembly body; and
 - a contact band disposed within the conductor pin interface in electrical contact with the cable.
14. A method comprising:
 - mating a cable termination assembly with a plug such that the cable termination assembly and the plug are in electrical contact;
 - mating the plug with a receptacle, thereby forming a mated wetmate connector such that the plug and the receptacle are in electrical contact; and
 - sending signals from a flexible sensor disposed within the mated wetmate connector, the signals indicative of a connection status of the wetmate connector.
15. The method of claim 14, wherein the mating the cable termination assembly with the plug comprises:
 - inserting a first end of a plug conductor pin, protruding from a first end of the plug, into a conductor pin interface of the cable termination assembly; and
 - contacting the first end of the conductor pin of the plug with a contact band of the conductor pin interface, thereby providing the electrical contact between the plug and the cable termination assembly.
16. The method of claim 14, wherein the mating the plug with the receptacle comprises:
 - inserting a second end of the plug into the receptacle;
 - receiving a first end of a receptacle conductor pin with a plunger of the plug conductor pin;
 - depressing the plunger of the plug conductor pin with the receptacle conductor pin;

contacting the receptacle conductor pin with a contact band of the plug conductor pin;
and
securing the plug in the receptacle with a latching mechanism of the receptacle.

17. The method of claim 14, further comprising monitoring, using the flexible sensor, at least one selected from a current, a voltage, a partial discharge, and a physical engagement of the mated wetmate connector.
18. The method of claim 14, further comprising determining the connection status of the wetmate connector as either connected or unconnected.
19. The method of claim 14, further comprising determining an unconnected status of the wetmate connector and retrieving the mated wetmate connector to a surface and replacing at least one selected from the cable termination assembly, the plug, and the receptacle.
20. The method of claim 14, wherein each of the cable termination assembly, the plug, and the receptacle are separately replaceable.

Figure 1

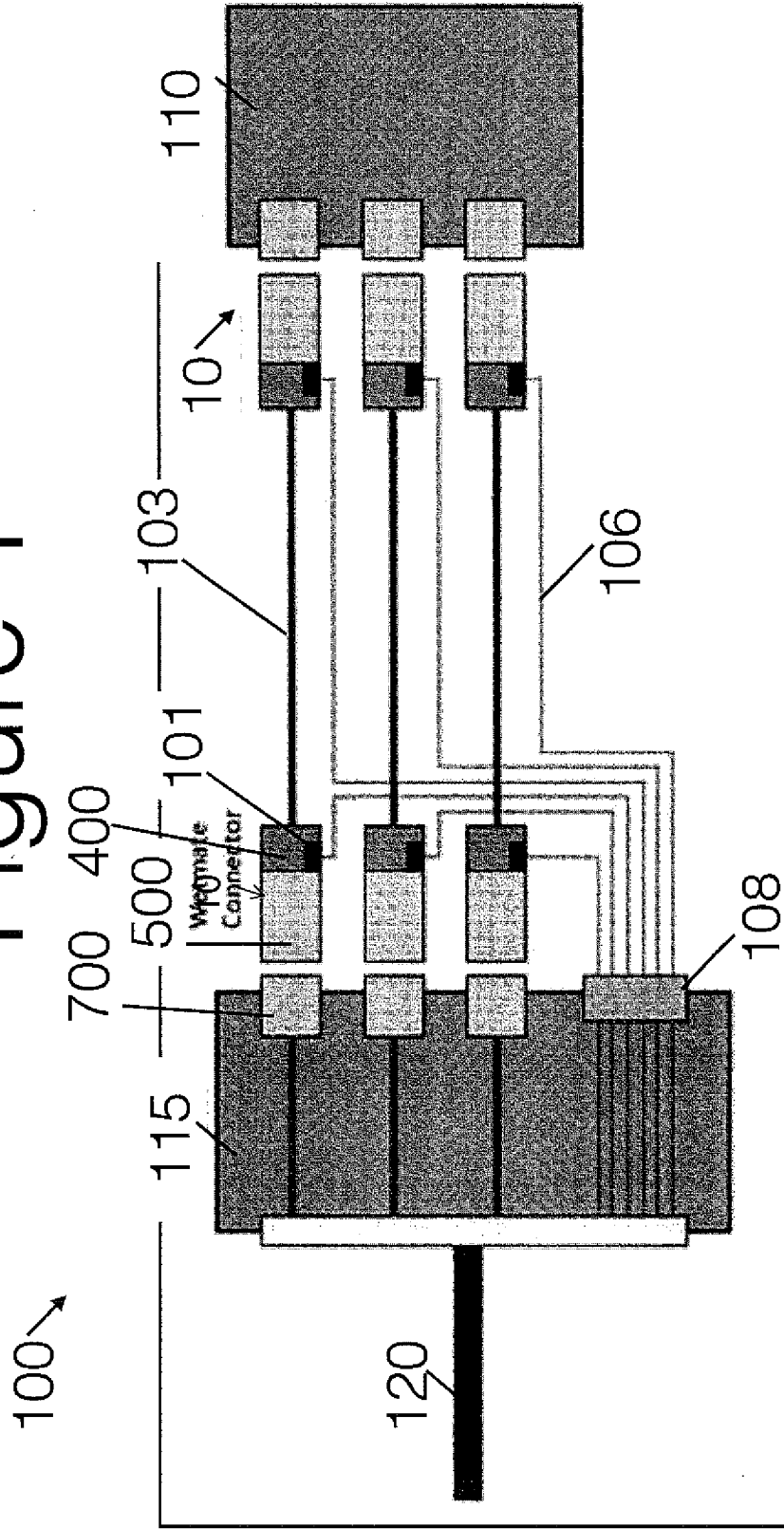


Figure 2

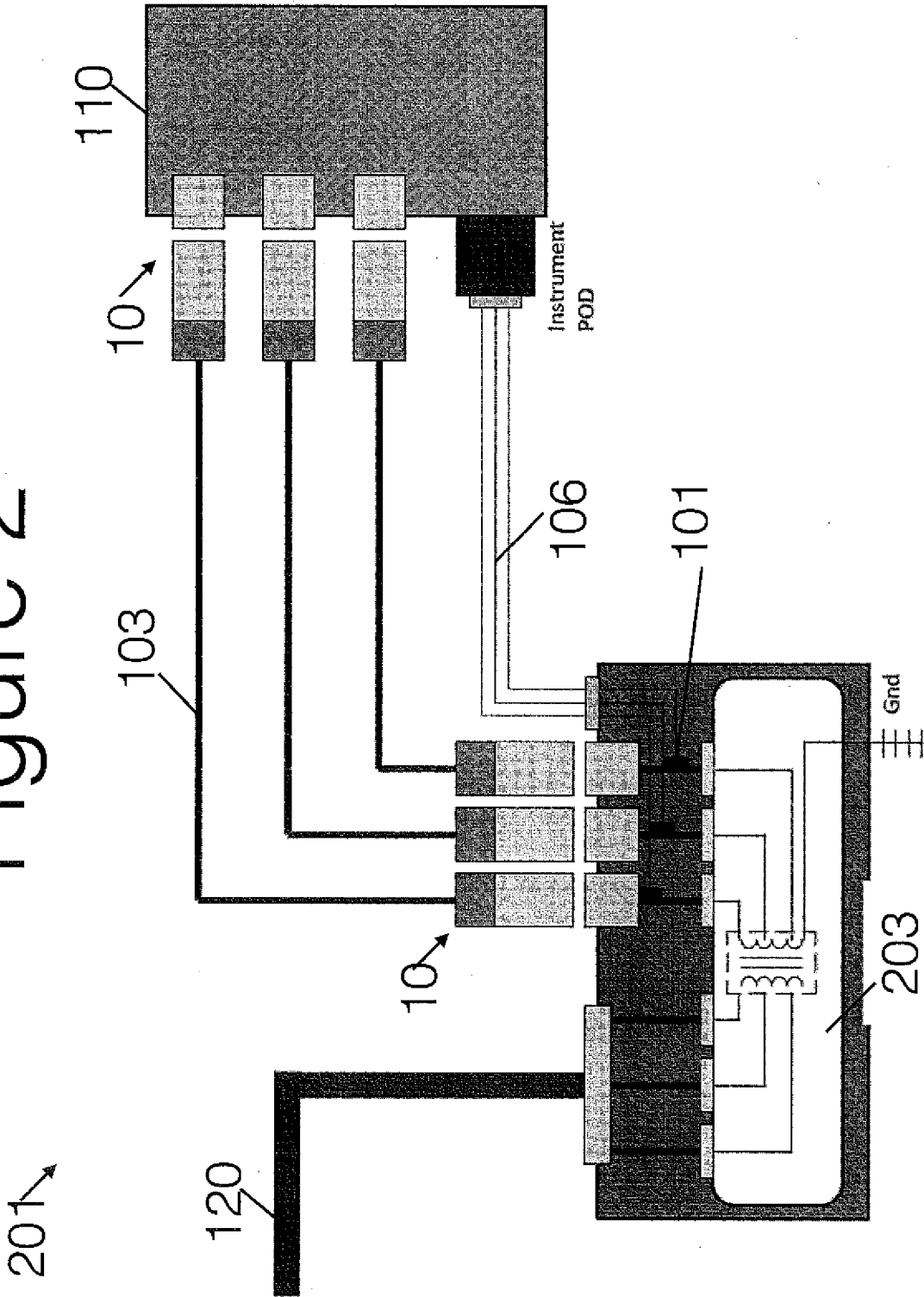


Figure 3

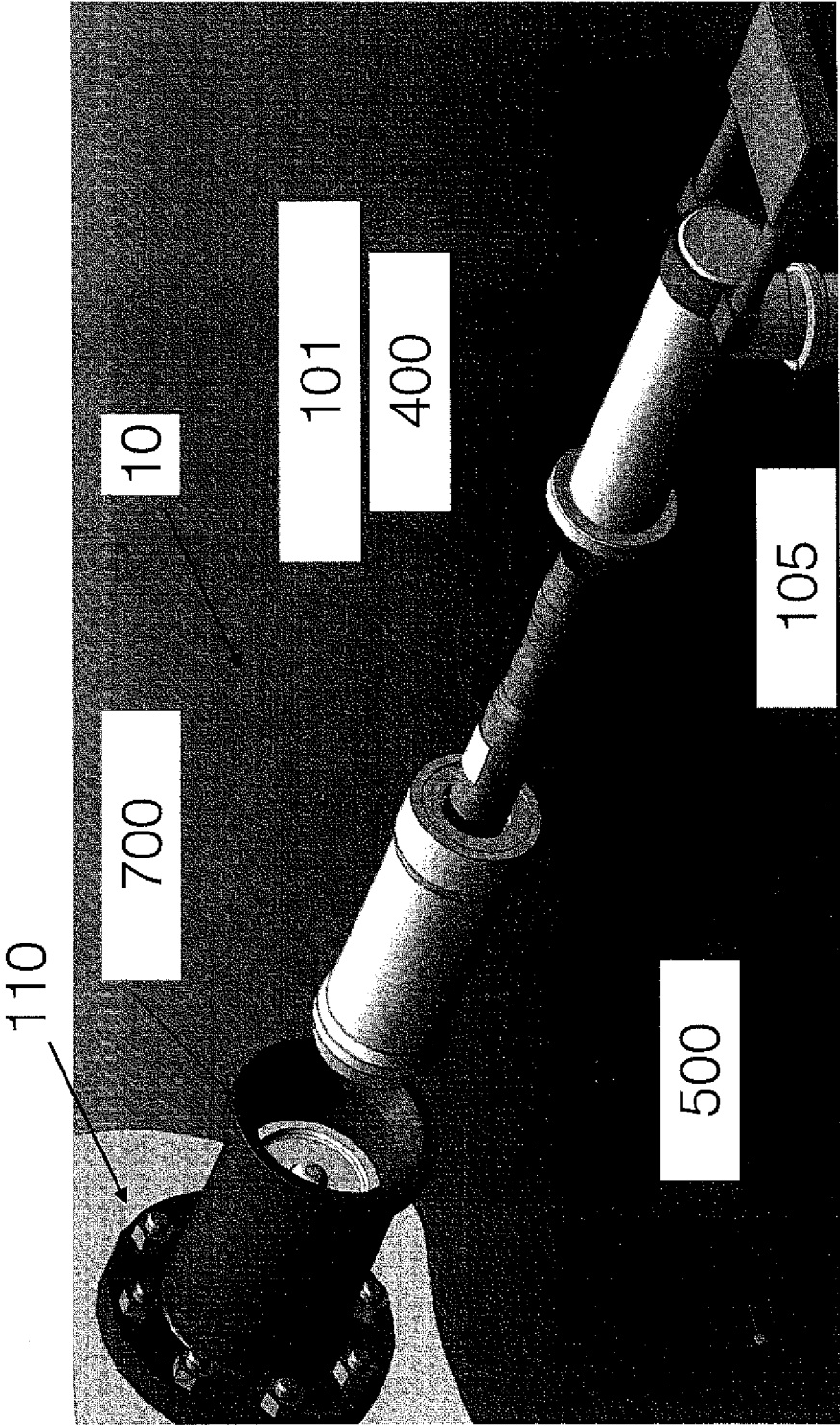


Figure 4

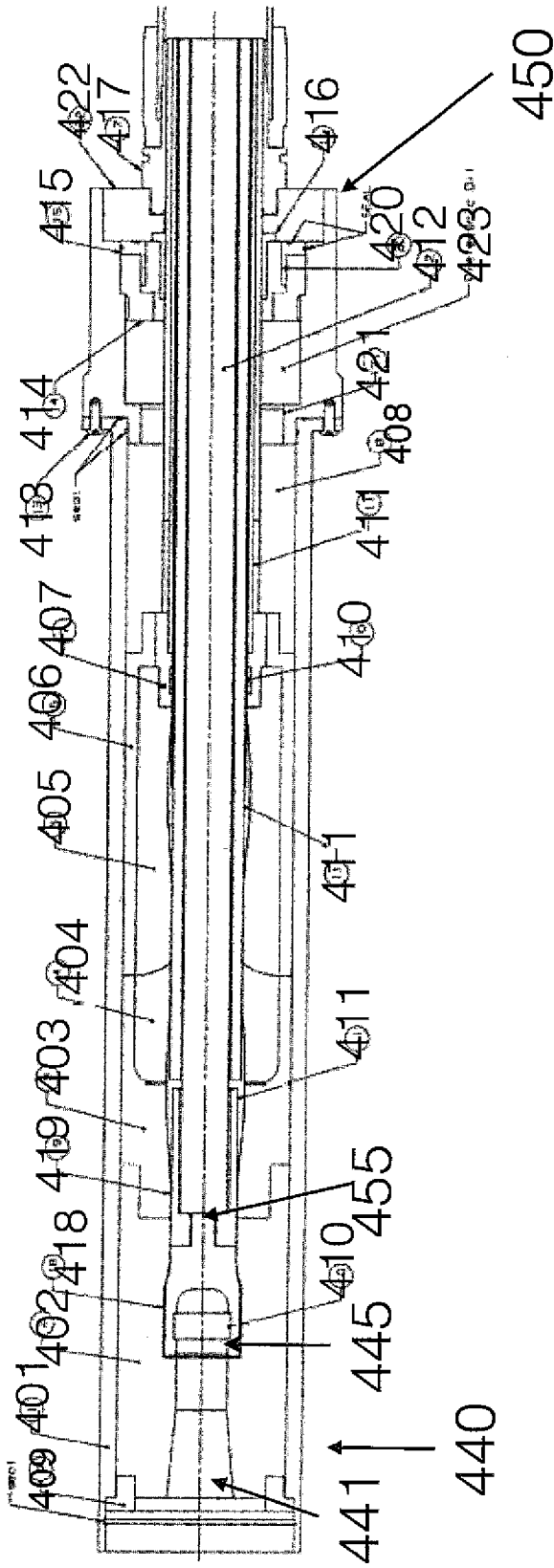


Figure 5

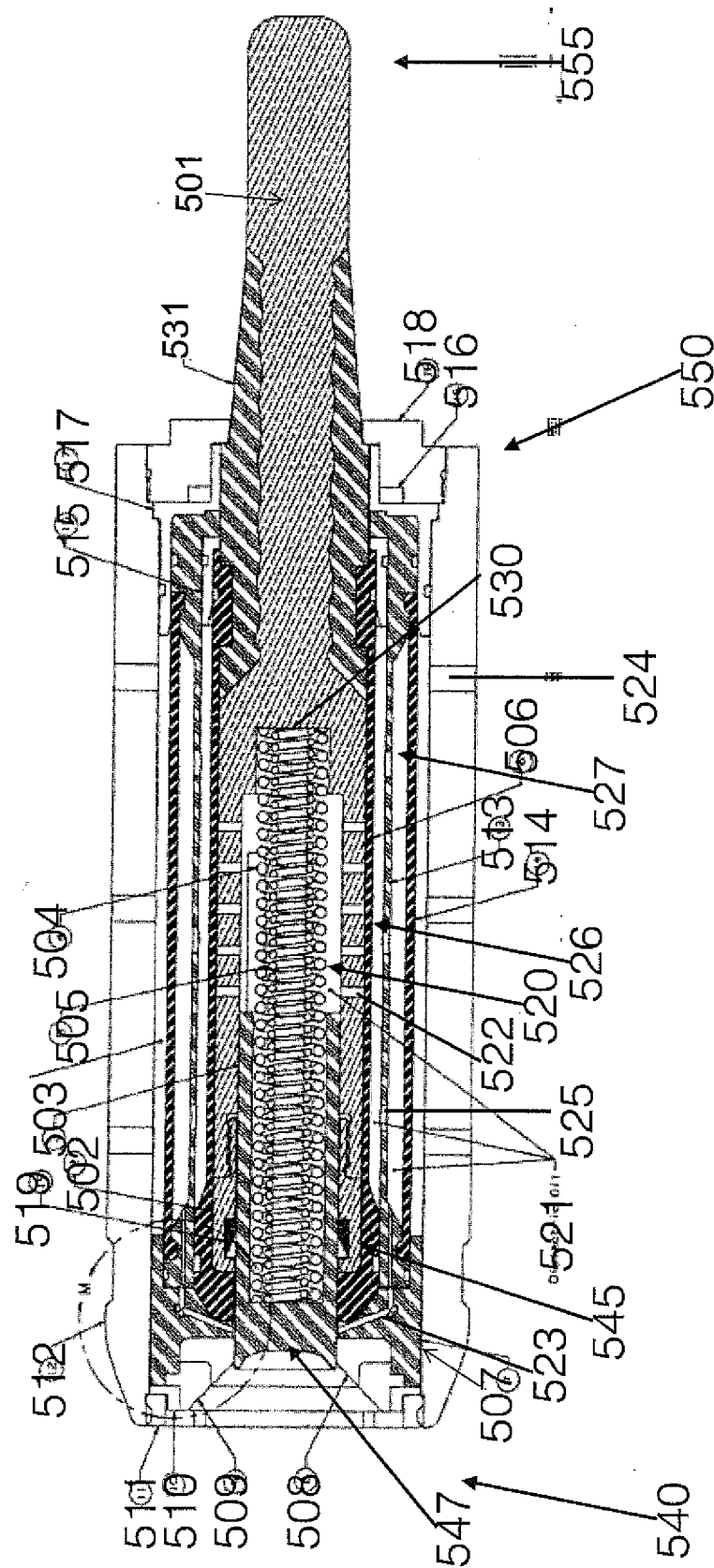


Figure 6

600

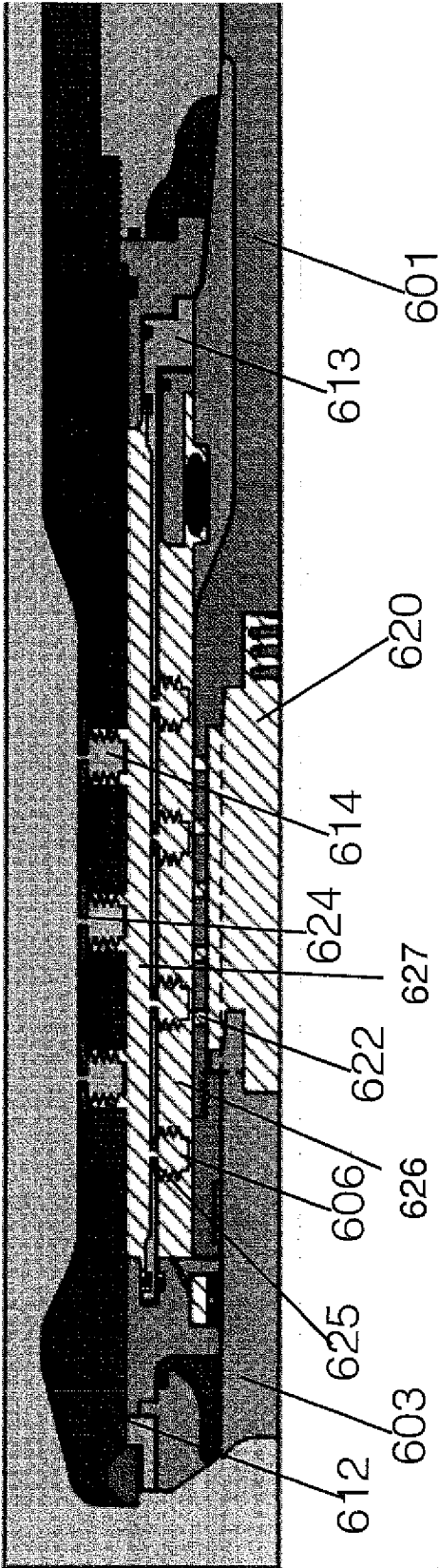


Figure 7

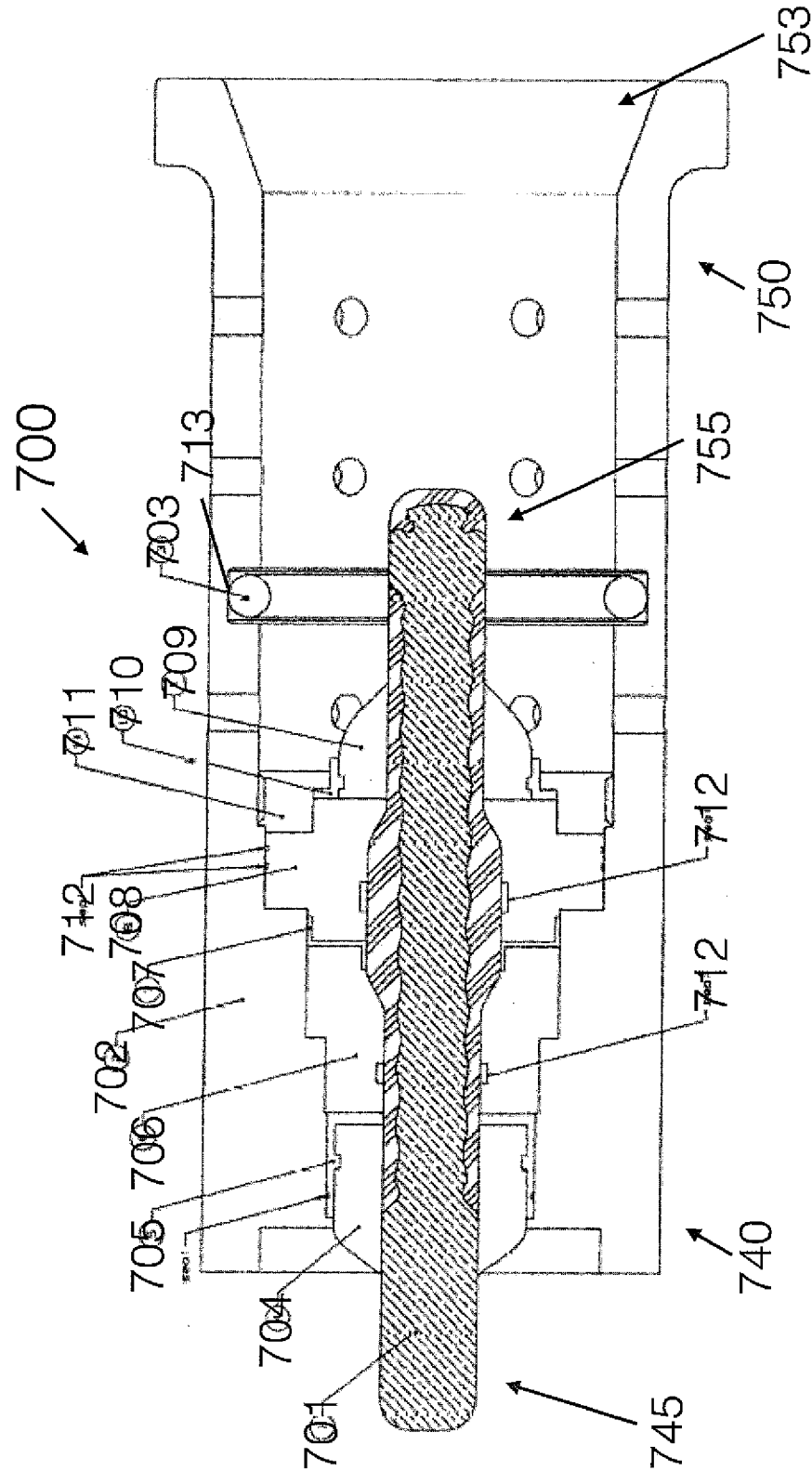
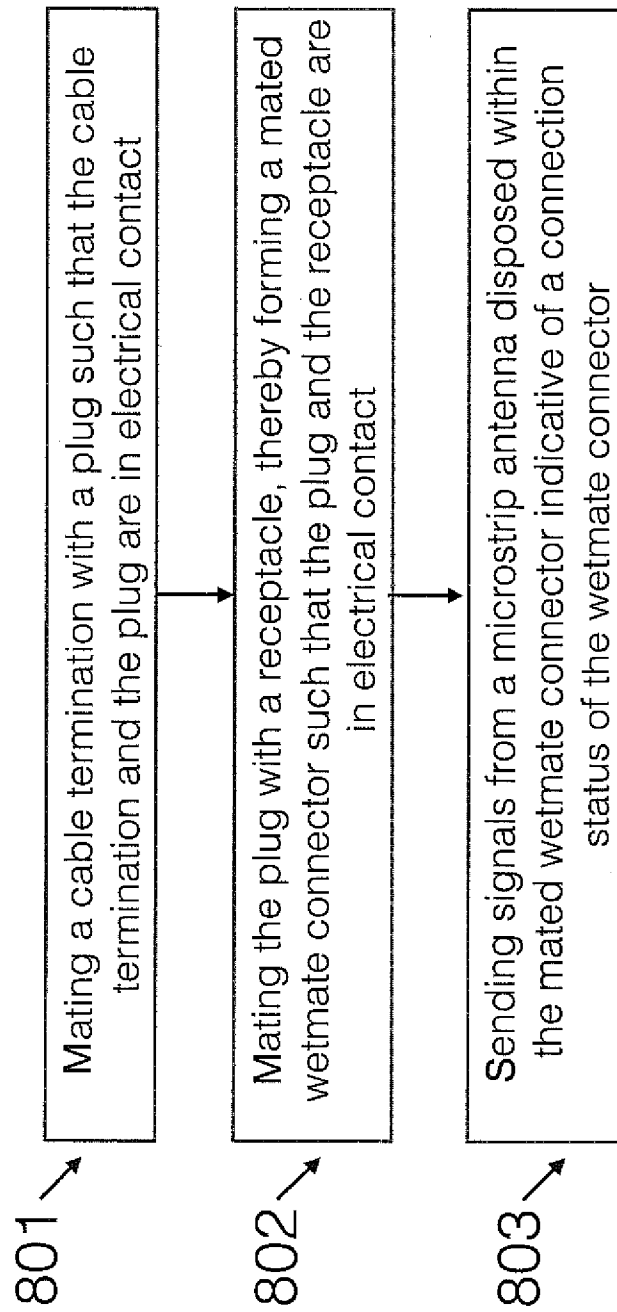


Figure 8



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/061047

A. CLASSIFICATION OF SUBJECT MATTER INV. H01R13/523 H01R31/06 H01R13/193 H01R13/639 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H01R		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 251 598 A1 (DIAMOULD LTD [GB]) 23 October 2002 (2002-10-23) the whole document -----	1-20
X	US 2002/003931 A1 (CAIRNS JAMES L [US] ET AL) 10 January 2002 (2002-01-10) the whole document -----	1,7-10, 16
A	WO 2015/068050 A1 (ONESUBSEA IP UK LTD [GB]) 14 May 2015 (2015-05-14) the whole document -----	7-11,16
A	CN 102 593 640 B (BAOJI OILFIELD MACHINERY CO) 4 December 2013 (2013-12-04) the whole document -----	11,16
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 5 July 2016		Date of mailing of the international search report 13/07/2016
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Gomes Sirenkov E M.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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			WO 2015068050 A1 14-05-2015
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