United States Patent [19]

Cole et al.

[11] **3,845,450**

[45] **Oct. 29, 1974**

[54] **UNDERWATER ELECTRICAL CONNECTOR**

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[22] Filed: **Dec. 26, 1972**

[21] Appl. No.: **318,342**

[52] **U.S. Cl.** ..... **339/42,** 339/94 M, 339/117 R

[51] **Int. Cl.** **H01r 33/36,** H01r 13/52

[58] **Field of Search** 339/16, 15, 42, 94, 60, 339/182, 117, 116

[56] **References Cited**

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3,271,725	9/1966	Bloch	339/42
3,491,326	1/1970	Pfister et al.	339/42
3,508,188	4/1970	Buck	339/42
3,524,160	8/1970	Robinson	339/42 X
3,621,447	11/1971	Taylor et al.	339/94 M

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Assistant Examiner—Terrell P. Lewis
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[57] **ABSTRACT**

A disconnectable electrical connector assembly capable of being connected and disconnected under water, at any depth, during the presence of a voltage potential applied to one or more contacts of the connector. The connector assembly includes two mateable halves wherein the contacts of one half or both halves are immersed in an oil bath. The mateable halves are designed so that, after mating, the contacts of each respective half are immersed in a common oil bath. Both halves of the connector assembly are connected to resiliently deformable plastic cable conduits that contain a nonconducting fluid which when submerged in water, to any depth, is pressurized to ambient pressure thereby eliminating any differential pressures across the fluid-tight seals in the connector assembly.

6 Claims, 2 Drawing Figures

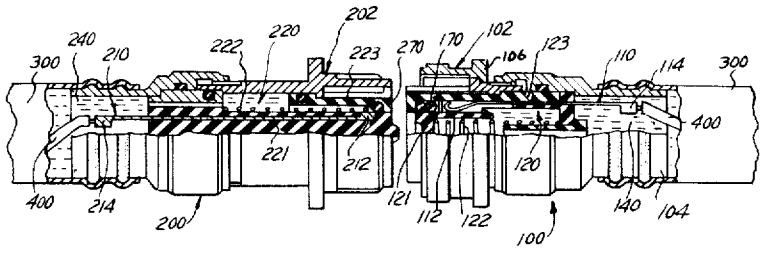

FIG. 1

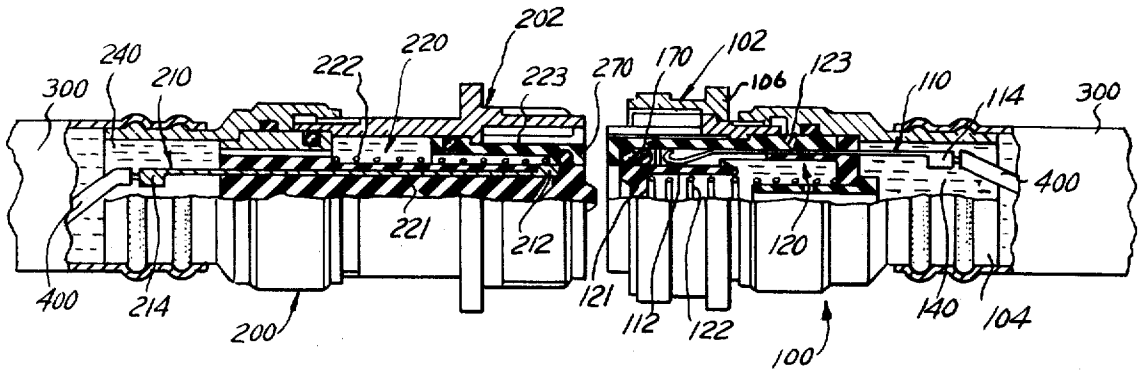
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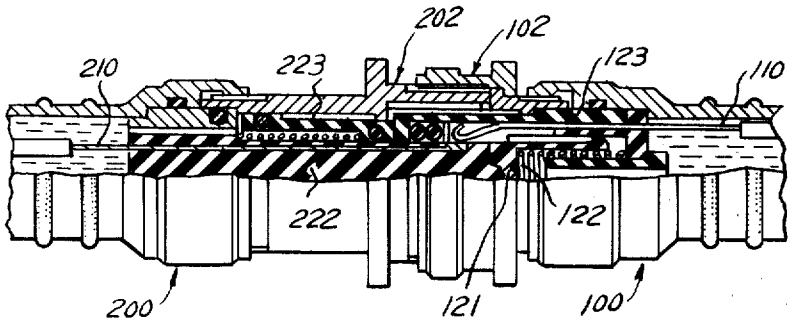
FIG. 2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UNDERWATER ELECTRICAL CONNECTOR

BACKGROUND OF THE INVENTION

This invention relates to sealed, water-tight electrical connectors and in particular to connectors and connector assemblies which may be coupled or uncoupled under water at any depth without exposing electrical contacts to the water and thereby eliminating the need for disconnecting the electrical power from the attached cables. This invention is more particularly related to a disconnectable underwater electrical connector and cable assembly that is capable of withstanding pressures up to at least 2,500 PSIG without failure.

With the advent of rapid growth in oceonographic exploration, it has become necessary to provide underwater electrical equipment which is both reliable and relatively inexpensive. While underwater electrical connectors have previously been developed which allow mating or unmating while submerged, most successful underwater connectors to date require that the mating occur above the water surface prior to an exposure to an underwtaer environment. However, with the use of electronic equipment at greater and greater depth, it has become a necessary expedient that mating and unmating occur below the water surface and at depths that would subject the connector to high hydrostatic pressures.

Disconnectable underwater electrical connector assemblies generally consist of two connector halves that are mateable, each of which including some type of sealing means to prevent sea water from entering the electrical connector when mated and/or separated. Obviously, the limitation on the effectiveness of the connectors assembled or disassembled is a function of the effectiveness of the sealing means, i.e. as the sealing means is subjected to greater and greater differential pressures when it is lowered into water, it is more prone to failure and, in fact, does fail when a differential pressure exceeds the sealing capacity of the sealing means. usually, underwater connector devices use interference-type fittings and "0" ring type sealing members to prevent the entrance of liquid into the electrified portion of the mated connectors.

Examples of disengageable electrical connectors having protected contacts and/or sealing means to protect the contacts from exposure to moisture and water may be found in U.S. Pat. No. 3,491,326 entitled "Disengageable Electrical Connector with Contact Protecting Means" issued Jan. 20, 1972, to F. Pfister et al.; and U.S. Pat. No. 3,508,188 entitled "Underwater Electrical Quick Disconnect" issued Apr. 21, 1970 to J. R. Buck. In both the aformentioned patents, as the plug and receptacle, either mated or unmated, are lowered into the sea and subjected to greater and greater pressures, a differential pressure builds up across the sealing means until eventually the seal fails and water enters the connectors, thereby causing an electrical failure. A further disadvantage of a connector built in accordance with the teachings of the Pfister patent is that the surfaces that engage the "0" ring to form the fluid-tight seals are exposed and therefore subject to damage from external sources. Any scratches and/or dents in the sealing surface results in a bad seal with the "0" ring which will further result in leakage and failure of the connector.

SUMMARY OF THE INVENTION

This invention provides an underwater electrical connector and cable assembly capable of being mated under water, at any depth, without failure because of the elimination of differential pressures across the sealing means of the connector.

The invention is an underwater electrical connector/cable assembly characterized by a resiliently deformable cable conduit **300** containing an electrically nonconducting fluid that fills the voids within the conduit and the electrical connector so that when the assembly is submerged, to any dpeth, no differential pressures of any significance arise between the outside and the inside of the connector and cable assembly.

In one embodiment of the invention, the underwater electrical connector and cable assembly comprises: a housing **100** having a forward mating end **102** a rear conduit receiving end **104** and a central axis from said forward end to the rear end; a plurality of electrical contacts (**110** having a mating end **112** and a conductor receiving end **114**; means for mounting **123** the electrical contacts **110** in spaced relationship around said housing central axis so that the mating ends **112** of said contacts **110** are at the mating end **102** of said housing **100**; means for establishing a fluid-tight seal **170, 121, 123** at the mating end of said housing **100,** said sealing means including a forwardly biased **122** portion **121** that covers the mating end **112** of said contacts **110** and maintains the fluid-tight seal when the contacts **110** are covered and is rearwardly movable upon mating with a receptacle **200** to expose the contacts **110** and engage corresponding receptacle contacts **210,** said covering means **121** defining with said housing **100** a cavity **120** within which at least a portion of the mating ends **112** of the electrical contacts **110** are disposed, the cavity **120** communicating with the rear conductor receiving cavity poriton **140** of the housing **100**; a water-tight resiliently deformable conduit **300** connected to the conduit receiving end **104** of the housing **100,** the conduit **300** including therein a plurality of electrical conductors **400** connected to the respective conductor receiving ends **114** of said contacts **110**; and electrically nonconducting fluid filling the remaining space in said conduit **300** and said housing cavities **120, 140,** whereby the mating ends **112** of said electrical contacts **110** are substantially surrounded by said nonconductive fluid, said forward mating end **102** of said housing **100** adapted to receive within said housing **100,** in fluid-tight relationship, a portion **202, 223** a receptacle **200** having receptacle contacts **212** so that the housing **100** and receptacle **200** contacts **112, 212** are in contact with the nonconducting fluid in said housing cavity **120** upon mating within said housing **100.**

Accordingly, it is an object of this invention to provide an electrical connector and cable assembly for use under water that is not subject to high differential pressures between the internal portions of the connector and external sea water when the connector and cable are submerged to great depths.

It is another object of this invention to provide a disconnectable electrical connector assembly that is mateable under water.

It is still another object of this invention to provide an underwter electrical connector that is mateable under water while an electrical potential is present at

the electrical contacts of at least one half of the electrical connector assembly.

It is a further object of this invention to provide an electrical connector/cable assembly for high voltage applications.

It is still a further object of this invention to provide an electrical connector assembly that contains oil or a similar dielectric medium between the electrical contacts therein so that the connector is useful at much higher voltages than ordinary connectors.

The above and other objects and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings and claims which form a part of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an axial partial cross-sectional view of an electrical connector and cable assembly embodying the invention, the respective connector parts being shown in the unmated position.

FIG. 2 is a view similar to FIG. 1 but showing two connector halves in the mated position.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, FIG. 1 illustrates a connector and cable assembly that includes a plug **100** and receptacle **200** and conduits **300** connected in fluid-tight relationship to the end of a respective plug and receptacle. The plug portion of the assembly includes a housing **100** having a forward mating end **102** and a rear conduit receiving end **104.** A resiliently deformable conduit **300,** e.g. made from an elastomer is attached to the conduit receiving end **104** to form a fluid-tight seal. Within the housing **100,** a plurality of electrical contacts **110** having a forward mating end **112** and a rear wire receiving end **114** are mounted in a circumferential manner and in spaced relationship around the central axis of the housing **123.** In this embodiment the contacts are mounted within a generally tubular housing **123** that has telescoped therein a second generally cylindrical housing **121** that is forwardly biased by a spring **122** to a first contact covering position. The generally cylindrical inner housing **121** in its forward biased and contact covering position is in pressure contact with "**0**" rings **170** to form a fluid-tight seal between the outer tubular housing **123** & inner cylindrical housing **121,** thereby protecting the contacts **110** and their forward mating ends **112** from coming into contact with external fluid. All voids **120, 140** within the housing **100** and resiliently deformable conduit **300** are filled with a nonconducting fluid, such as mineral oil. The fluid in the housing **100** and cable **300** communicating with the mating ends **112** and ocnductor receiving ends **114** of the contacts and with the wires **400** in the conduit **300** so that, at all times, the mating ends **112** of the contacts are immersed in the nonconducting fluid. Electrical contacts **110** are circumferentially arranged so as to be in contact with the outside of the tubular housing **121** which is telescoped within housing **123.** The cylindrical housing **121** is rearwardly movable within tubular housing **123.** The remaining structure of the plug assembly being similar to and serving the same functions as any other electrical connector plug assembly.

The receptacle includes a housing **200** that has a forward mating end **202** and a rear conduit receiving end **204.** Mounted within the receptacle housing **200** are a plurality of electrical contacts **210** circumferentially arranged around the central axis of cylindrical housing **221** in the same spaced relationship as the corresponding plug contacts **110.** In the receptacle assembly, the inner cylindrical housing **221** which is telescoped within the outer tubular housing **223** forms a fluid-tight seal at the front of the receptacle with tubular housing **223** by means of "O" rings **270.** In the receptacle half the outer tubular housing **223** is forwardly biased by a spring **222** which maintains the "O" ring **270** in pressure contact with the wall of inner housing **221,** thereby assuring a fluid-tight seal and protecting the electrical contacts **210** from exposure to sea water when the receptacle is immersed therein. The tubular housing **223** is rearwardly movable upon the application of a rearward force supplied to the front end of the tubular housing **223.** The "O" ring **270** maintains a fluid-tight seal along the outside of the cylindrical inner housing **221.** In this embodiment, the cylindrical housing **221** generally comprises a smooth rod of insulating material with the matching ends **212** of the contacts flush with the surface of the housing **221.** All the voids within the conduit **300** and the connector housing **200** are filled with a nonconducting fluid and the "O" rings **270** maintain a fluid-tight seal between the fluid within the connector assembly and conduit and the water in which the assembly is immersed.

FIG. 2 illustrates the connector assembly in its mated position. In the mated position, the receptacle tubular housing **223** is forced rearwardly of the receptacle housing **200** and the cylindrical housing **121** of the plug assembly **100** is forced rearwardly with respect to housing **100** so as to allow the receptacle contacts **210** to mate with the plug contacts **110** at their respective mating ends **212, 112.** It should be noted at this point that the contacts are mated within the plug housing **100** and in the nonconducting fluid common to the plug housing **100** and plug conduit **300.** "O" rings **270** and **170** prevent the nonconducting fluid in the receptacle from entering the plug and conversely the nonconducting fluid in the housing **100** from entering the receptacle housing **200.** A preferable nonconducting fluid would be oil, Freon, or any other suitable electrically nonconductive fluid.

OPERATION

Referring now to the drawings, the connector assembly is mateable under water as follows: a key way (not shown) aligns the receptacle contacts **210** with the plug contacts **110** when the receptacle is inserted into the forward end **102** of the plug housing **100.** As the receptacle is pushed into the plug housing, the tubular housing **223** abuts against the tubular plug housing **123** forcing the receptacle housing **223** rearwardly. Simultaneously, the receptacle cylindrical housing **221** abuts against the cylindrical plug housing **121** forcing the plug cylindrical housing **121** rearwardly with respect to the housing **100.** As the forward portion of the receptacle cylindrical housing **221** moves into the plug housing **100** the receptacle contacts **212** are wiped by the "O" rings **170** which are in pressure contact with the cylindrical housing **221** to form a fluid-tight seal therewith. As the plug cylindrical housing **121** moves rearwardly, the receptacle contact mating end **212** comes into contact with the forward mating end **112** of the plug contact **110.** Lock ring **106** maintains both halves of

the connector assembly in their mated position by threadably engaging the forward portion **202** of the receptacle housing.

To disconnect the connector assembly, the locking nut **106** is disengaged and the connector halves are pulled apart. If the connector halves were under water at this time, no water would enter the contact containing portions of the respective connector halves. This is because the action of the resiliently deformable conduits which, when subjected to pressure, increase the pressure of the nonconducting fluid within the connector against the "O" ring seals **170, 270** so that the pressure of the nonconducting fluid within the conduit **300** and the housings **100,200** equals the pressure of the sea water external to the housings **100, 200.** Since there is little or no differential pressure across the "O" ring seals **170, 270,** sea water will not enter the plug or receptacle housing. Obviously, if the conduit **300** was not deformable, there would be no way of equalizing the internal nonconducting fluid pressure to sea water pressure. Since the conduit **300** is resiliently compressible, as the cable and connector assembly go to greater and greater depths and the sea water pressure against the conduit **300** increases, the conduit **300** compresses, thereby increasing the pressure of the nonconducting fluid so as to prevent sea water from entering into the connector assembly through the "O" ring seals.

To establish the effectiveness of this new connector, the following tests were performed:

TEST NO. 1

Pairs of adjacent electrical contacts and their attached wires were connected together in series and a 5 amp current was passed through the resultant circuit. The following voltage drops (millivolts) were measured across the contacts when the assembly was immersed in water and pressurized to 2,500 PSIG and then removed:

CIRCUIT	INITIAL VOLTAGE DROP	VOLTAGE DROP AFTER SUBJECTION TO HYDROSTATIC PRESSURE OF 2500 PSIG FOR ONE HOUR
Contacts A-B	567 MV	575 MV
Contacts C-D	569 MV	585 MV
Contacts E-F	564 MV	567 MV

TEST NO. 2

An ac voltage of 4,800 volts r.m.s. was applied to two adjacent connector contacts, electrically isolated from each other, while the connector was subjected to a hydrostatic pressure of **2500** PSIG. No flashover occurred between the contacts and the interfaces between the plug and receptacle when unmated were free of water.

TEST NO. 3

The connector/cable assembly was immersed in a salt water solution and repeatedly mated and unmated under water. The following data shows the initial resistance measured (gigaohms) between adjacent contacts before immersing the assembly in water compared to the resistance measured after each cycle (unmating-mating):

ADJACENT CONTACTS	INITIAL RESISTANCE GIGAOHMS	1st CYCLE	3d CYCLE	5th CYCLE	7th CYCLE	9th CYCLE	15th CYCLE
A-B	9.0	9.8	10.0	5.3	6.0	6.1	5.3
C-D	5.8	6.9	6.7	5.5	5.5	6.3	4.8
E-F	7.8	8.6	8.9	5.2	5.2	5.9	4.7

The foregoing tests show that the connector and cable assembly was capable of withstanding pressures up to and including 2,500 PSIG with little or no adverse effects and that the unit functioned satisfactorily, both mechanically and electrically when mated repeatedly under water.

While a preferred embodiment of the invention has been disclosed, it will be apparent to those skilled in the art that changes may be made to the invention as set forth in the appended claims, and, in some cases, certain features of the invention may be used to advantage without corresponding use of other features. For example, in some applications, it may be desirable to just have a nonconducting fluid within only the plug or receptacle half of the electrical connector and cable assembly. In this regard, the plug portion of the electrical connector assembly is preferred to have the nonconducting fluid therein. Accordingly, it is intended that the illustrative and descriptive materials herein be used to illustrate the principles of the invention and not to limit the scope thereof.

Having thus described the invention, what is claimed is:

1. An underwater electrical connector and cable assembly comprising:

a plug housing having a forward mating end, a rear conduit receiving end and a central axis from said forward end to said rear end;

a first plurality of electrical contacts having mating ends and conductor receiving ends;

means for mounting said first plurality of electrical contacts in said plug housing and in spaced relationship around said plug housing central axis so that the mating end of said contacts are at the mating end of said housing;

sealing means for establishing a fluid-tight seal at the mating end of said plug housing, said sealing means including a forwardly biased portion that covers said contacts and maintains a fluid-tight seal when said contacts are covered and is rearwardly movable to expose said contacts, said sealing means defining with said plug housing a cavity within which at least a portion of the mating ends of said contacts mounted in said plug are disposed, said cavity communicating with the rear conduit receiving end of said plug housing;

a first water-tight resiliently deformable, conduit connected at one end to the conduit receiving end of said plug housing, said conduit including therein a plurality of electrical conductors, each having one end connected to a respective conductor receiving end of said contact mounted in said plug;

an electrically nonconducting fluid filling the remaining space in said conduit and said plug cavity whereby the mating ends of said contacts mounted in said plug are substantially surrounded by said nonconducting fluid, said forward mating end of said plug adapted to receive a receptacle having contacts within said plug housing so that said contacts mounted in said plug are in contact with the nonconducting fluid in said plug cavity upon mating of said plug with a receptacle;

a receptacle housing having a forward mating end, a rear conduit receiving end and a central axis from said forward end to said rear end;

a second plurality of electrical contacts having mating ends and conductor receiving ends;

means for mounting said second plurality electrical contacts in said receptacle housing and in spaced relationship around said receptacle housing central axis so that the mating end of said contacts are at the mating end of said receptacle housing and said contacts mounted in said receptacle engage said contacts mounted in said plug upon mating of said plug and receptacle;

sealing means for establishing a fluid-tight seal at the mating end of said receptacle housing, said sealing means including a forwardly biased portion that covers said contacts mounted in said receptacle and maintains a fluid-tight seal when said contacts mounted in said receptacle are covered and is rearwardly movable to expose said contacts mounted in said receptacle upon mating, said receptacle covering means defining with said receptacle housing a cavity within which at least a portion of the mating ends of said contacts mounted in said receptacle are disposed, said cavity communicating with the rear conduit receiving portion of said receptacle housing;

the other end of said first water-tight, resiliently deformable conduit connected to the conduit receiving end of said receptacle housing, said nonconducting fluid filling said receptacle cavity also, whereby at least a portion of the mating ends of said contacts mounted in said receptacle are surrounded by said nonconducting fluid and whereby said nonconducting fluid in said conduit communicates with said plug cavity and said receptacle housing.

2. An underwater disengageable electrical connector for interconnecting a plurality of electrical conductors, the electrical connector comprising:

a receptacle element;

a plug element disengageably insertable into said receptacle element, said plug element having a housing assembly carrying circumferentially spaced electrical contacts, a mating end, a conduit receiving end, and sealing means for establishing a fluid-tight seal at the mating end of said housing assembly, said sealing means including movable means for covering said contacts on said plug element and means for biasing said contact covering means in a contact covering position, said covering means biased to a contact covering position upon disengagement of said elements and a contact exposing position upon mating of the plug and receptacle;

said receptacle element having a housing assembly carrying circumferentially spaced electrical contacts each engageable with a respective contact in said plug, a mating end, a conduit receiving end, and sealing means for establishing a fluid-tight seal at the mating end of said receptacle housing assembly, said sealing means including movable means for covering said contacts in said receptacle and means for biasing said receptacle contact covering means in a contact covering position, said receptacle contact covering means biased to a receptacle contact covering position upon disengagement of said elements and a contact exposing position upon mating of said plug and receptacle;

said contacts in said plug and receptacle having a mating end and a conductor receiving end;

a cavity within each of the plug and receptacle elements defined by said respective sealing means and said contact carrying housing assembly;

a water-tight resiliently deformable conduit connected at one end to the conduit receiving end of said plug and connected at the other end to the conduit receiving end of said receptacle, said conduit including therein a plurality of electrical conductors connected to respective conductor receiving ends of said contacts in said plug and said contacts in said receptacle; and

an electrically nonconducting fluid filling the remaining space in said conduit and said cavities in said housing assemblies.

3. A disengageable electrical connector, as claimed in claim **2**, in which said plug element includes a tubular housing having an open outer end and an inner surface, said inner surface mounting said plug contacts; said plug contact covering means comprising a hollow member telescoped inside said tubular housing; said plug biasing means comprising a first spring biasing said hollow member to a contact covering position; and at least one sealing ring mounted in said housing inner surface adjacent said housing open outer end and engageable with the external surface of said hollow member to form a seal therewith.

4. A disengageable electrical connector as claimed in claim **2** in which said receptacle contact carrying part has an outer surface mounting said receptacle contacts; said receptacle contact covering means comprising a member telescoped over the receptacle contact carrying part and displaceable axially relative to said receptacle part; an annular seal mounted between said receptacle part and said member to form a seal therebetween; and said receptacle biasing means comprising a second spring biasing said member to a contact covering position.

5. A disengageable electrical connector as claimed in claim **3** in which said receptacle contact carrying part has an outer surface mounting said receptacle contacts; said receptacle contact covering means comprising a member telescoped over the receptacle contact carrying part and displaceable axially relative to said receptacle part; an annular seal mounted between said receptacle part and said member to form a seal therebetween; and said receptacle biasing means comprising a second spring biasing said member to a contact covering position.

6. An underwater electrical connector and cable assembly comprising:

a housing having a forward mating end, a rear conduit receiving end, a rear conductor receiving portion, and a central axis from said forward end to said rear end;

a plurality of electrical contacts having a mating end and a conductor receiving end;

means for mounting said electrical contacts in spaced relationship around said housing central axis so that the mating end of said contacts are at the mating end of said housing;

sealing means for establishing a fluid-tight seal at the mating end of said housing, said sealing means including a forwardly biased portion that covers said contacts and maintains a fluid-tight seal when said contacts are covered but is rearwardly movable to expose said contacts, said sealing means defining with said mounting means and said housing a cavity within which at least a portion of the mating end of said electrical contacts are disposed, said cavity communicating with the rear conductor receiving portion of said housing;

a water-tight, resilient deformable conduit connected to the conduit receiving end of said housing, said conduit including therein a plurality of electrical conductors connected to respective conductor receiving ends of said contacts; and

an electrically nonconducting fluid filling the remaining space in said conduit and said housing cavity whereby the mating ends of said electrical contacts are substantially surrounded by said nonconducting fluid.

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