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[54] **UNDERWATER CONNECTOR AND METHOD OF MAKING SAME**

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[52] **U.S. Cl.**..... **174/76,** 29/628, 174/75 C, 174/77 R, 339/89 R, 339/94 R, 339/102 R, 339/218 R

[51] **Int. Cl.**.. **H01r 13/36,** H01r 11/02, H01r 17/04

[58] **Field of Search**..... 174/70 S, 74 R, 75 R, 75 C, 174/75 D, 76, 77 R, 77 S; 29/628, 630 R, 630 A; 339/89 R, 89 C, 89 M, 94 R, 94 C, 94 M, 101, 102 R, 218 R, 218 M

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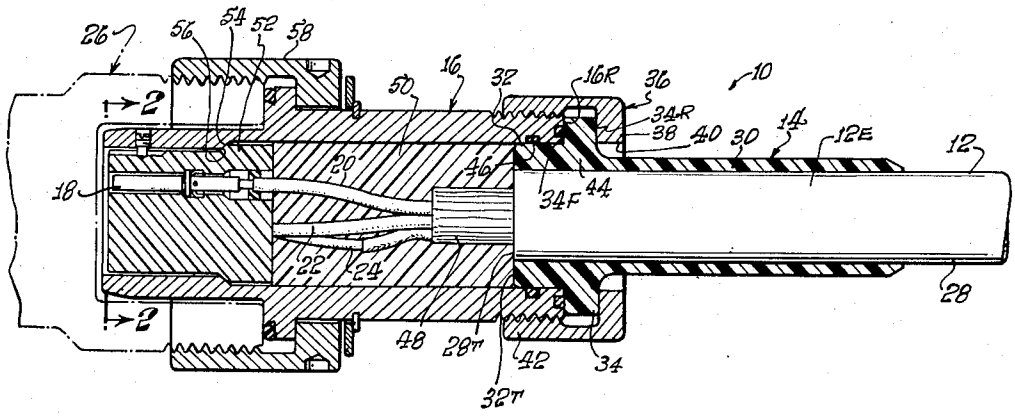
[57] **ABSTRACT**

An underwater connector for communication cables, which can be readily installed in the field and which provides long term high reliability at great undersea depths. The connector includes a tubular preform of the same thermoplastic material as the sheath of the cable and which is heat-bonded to the cable so that the materials of the preform and cable sheath merge. The preform has a flange near its forward end which is installed facewise against the rear end of a metal shell into which the cable extends, and a cap threaded onto the shell presses against the rear face of the flange to lock it in place against the shell. The conductors of the cable extend through a hard member which abuts the extreme forward ends of the preform and cable sheath to prevent either of them from being forced further into the shell under the high underwater pressures.

8 Claims, 6 Drawing Figures



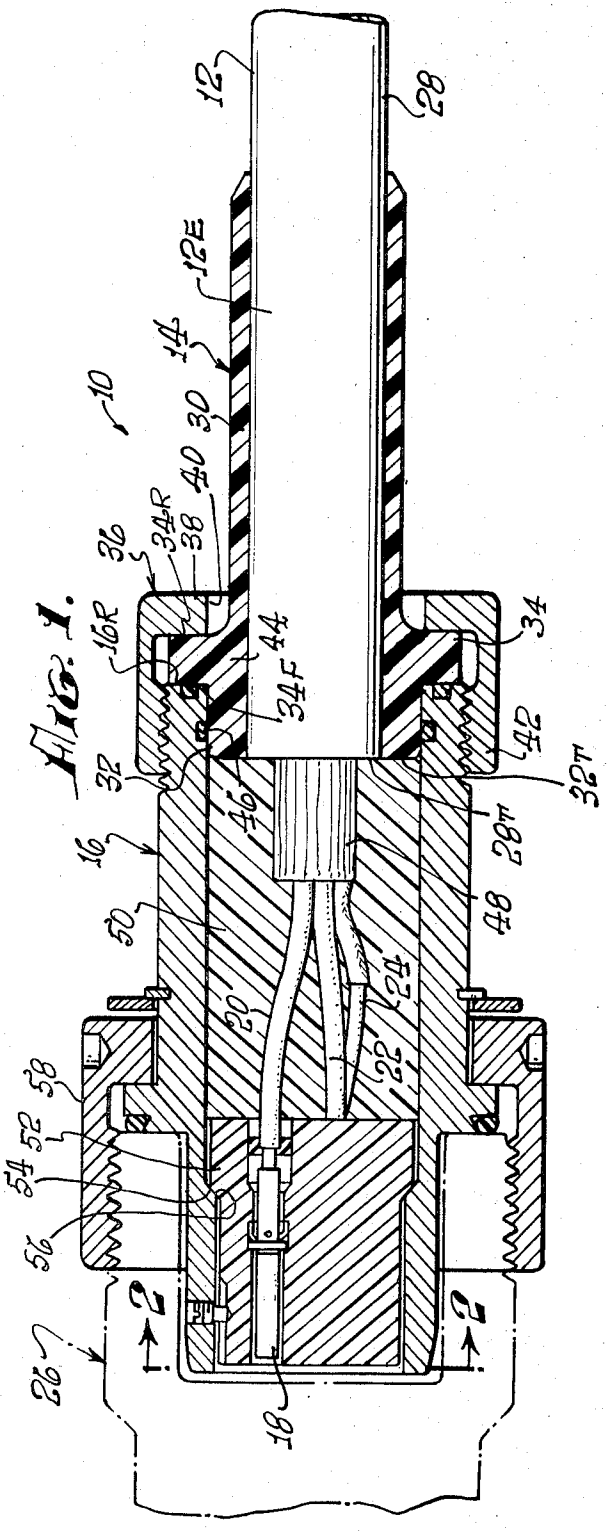


FIG. 1.

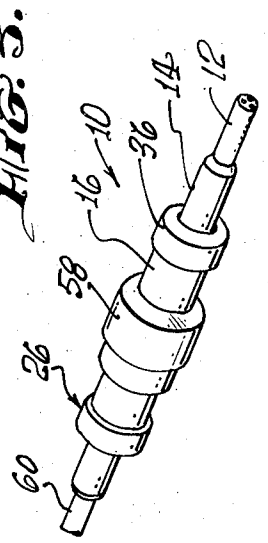


FIG. 3.

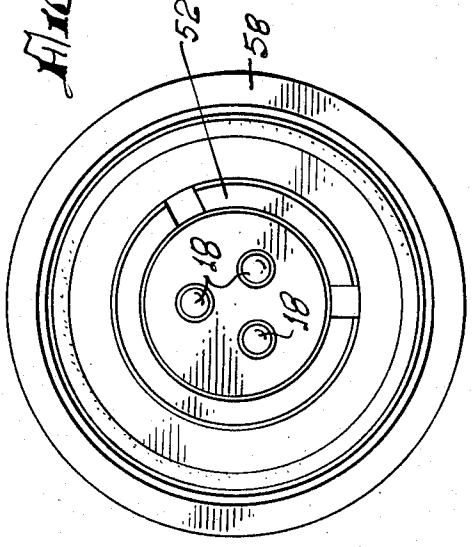


FIG. 2.

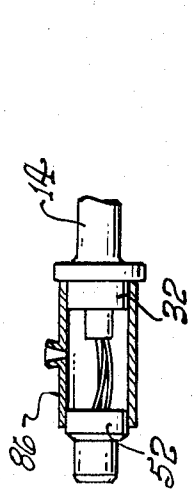


Fig. 5.

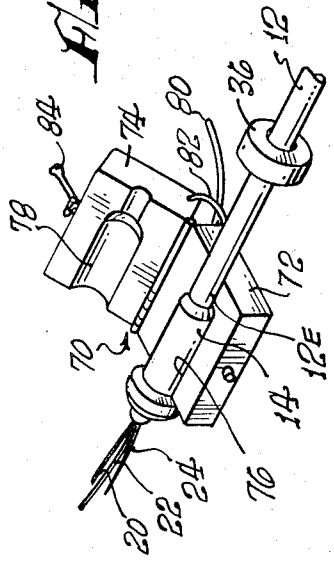


Fig. 4.

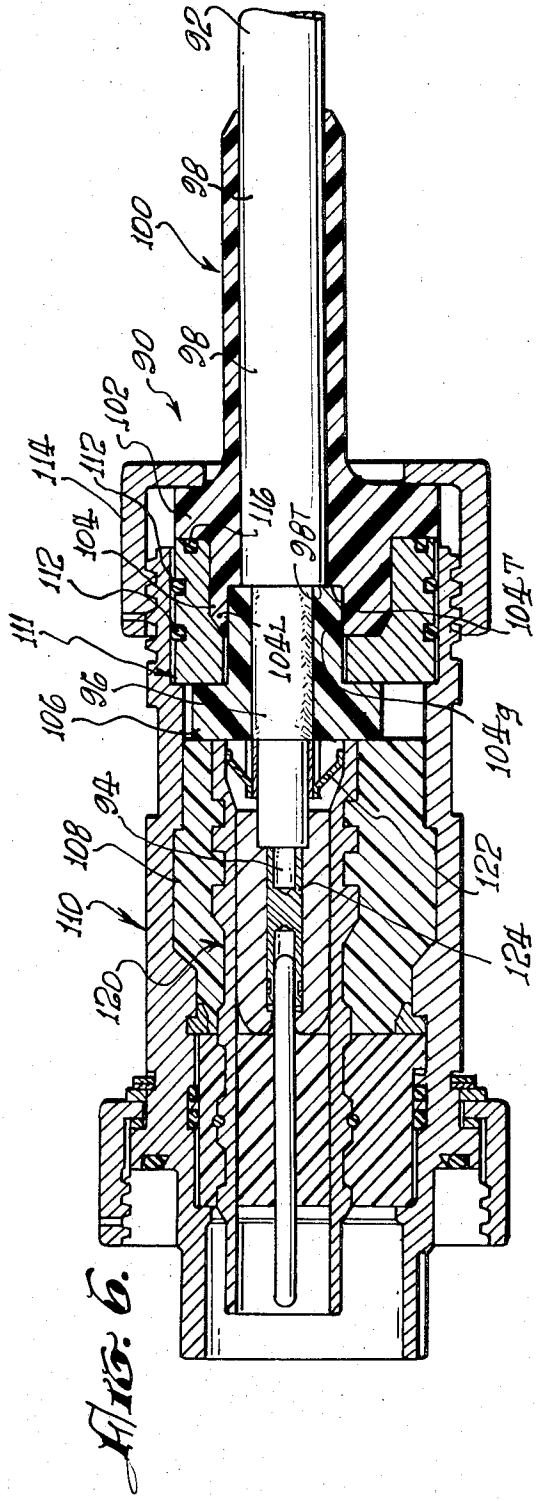


Fig. 6.

UNDERWATER CONNECTOR AND METHOD OF MAKING SAME

BACKGROUND OF THE INVENTION

This invention relates to underwater cable connectors.

Underwater telephone cables must often be spliced to one another or joined to other undersea equipment by crews of a maintenance vessel. A variety of cable types may be used, including coaxial cables and those with solid conductors, but most cables utilize a surrounding sheath of a thermoplastic material such as polyethylene to provide flexibility and high resistance to corrosion. Connections of cables to one another or to repeaters or to other equipment can be reliably made within shells of a metal that resists corrosion. However, it has been difficult to form a reliable seal at the location where the cable enters the metal shell, which can be assured of remaining water tight over a long period of service. One problem is that the thermoplastic material cannot be readily bonded to metal of the shell. In addition, the very great difference in pressure between the surrounding sea water and the atmosphere within the metal shell tends to cause the cable any any sealing device to be pushed into the metal shell. One technique that has been employed to seal the cable sheath to the shell included the use of a sealing member which was chemically bonded to the cable sheath and which was sealed by epoxy cement and a tightening clamp to the sheath. That type of connection is difficult to reliably install in the field so as to assure great reliability at extreme high undersea pressures that are encountered at the greatest ocean depths.

SUMMARY OF THE INVENTION

In accordance with one embodiment of the present invention, an underwater cable connection is provided which can be readily constructed in the field and which is highly reliable for use at great ocean depths. The connection includes a tubular preform disposed about an end of the cable, the preform constructed of the same thermoplastic material as the cable sheath and heat bonded to the sheath so that the material of the preform and sheath merge into one another. The preform has an outwardly extending flange at a forward end thereof which is nearest the cut end of the cable. The forward ends of the preform and cable are received in a metal shell where connections are made to the signal conductors of the cable. The forward face of the preform flange presses against rearward end of the shell that carries an O-ring, and a cap threaded onto the shell presses against the rearward face of the flange to hold it securely against the rearward end of the shell. The forward ends of the preform and cable sheath are prevented from "hosing in" under high undersea pressure by a position fixing member of rigid insulative material that abuts the extreme forward end of the sheath and the forward end of the preform, the position-fixing member being supported against forward axial movement by a ledge formed on the shell.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional side view of an underwater connector assembly constructed in accordance with the invention;

FIG. 2 is a view taken on the line 2—2 of FIG. 1;

FIG. 3 is a perspective view of the connector of FIG. 1, showing it assembled to another connector for splicing two underwater cables;

FIG. 4 is a perspective view of the cable end and preform of the connector assembly of FIG. 1, showing the manner in which the preform is joined to the cable;

FIG. 5 is a sectional side view of the cable end and preform of FIG. 4 showing the manner in which the position fixing and potting member is formed therein; and

FIG 6 is a sectional view of a connector assembly constructed in accordance with another embodiment of the invention, for a coaxial cable.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates an underwater connection assembly **10** for splicing the end of an underwater cable **12** to the end of another length of underwater cable. The connection assembly **10** includes a preform **14** mounted on the end portion **12E** of the cable for holding the cable securely in a connector shell **16,** and three socket contacts **18** for connection to three wires **20, 22** and **24** of the cable. The connector assembly **10** is designed to be connected to another similar connector assembly **26** which has plugs that fit into the sockets **18.** Both of the connector assemblies **10, 26** are designed so that they can be readily attached in the field, on a maintenance vessel or the like, and to provide an assembly that reliably resists leakage or other degradation over a long period of time even when subjected to the extremely high pressures that exist at great ocean depths.

The cable **12** includes a sheath **28** of a flexible thermoplastic material such as polyethylene, which resists degradation in the underwater environment over long periods of time. The preform **14** is constructed of the same thermoplastic material as the cable sheath. The preform is of tubular shape and has a long rearward portion **30** which surrounds the cable sheath **28** and which is heat sealed thereto so that the inner wall of the preform merges with the outer wall of the cable sheath. The preform **14** has a forward end portion **32** which fits within the connector shell **16** and which extends to a position even with the extreme forward end or tip **28T** of the cable sheath. An outwardly extending flange **34** formed on the preform near its forward end abuts the rearward end **16R** of the connector shell. A cap **36** has an end wall **38** which bears against the rearward face **34R** of the preform flange to press the forward face **34F** of the preform tightly against the connector shell. The cap has a hole **40** through which the preform extends, and has an internally threaded tubular portion **42** which is threaded onto the rearward end portion of the shell **16.** Further sealing of the shell is provided by O-rings **44, 46** mounted in grooves in he connector shell. The O-rings engage the forward face of the flange **34** and the front portion **32** of the preform which is received in the shell.

The forward ends of the wires **20–24,** and of a braided shield **48** of th cable that extends beyond the cable sheath **28,** project through a position fixing mem-

ber **50.** The member **50** is constructed of a hard insulative material, such as an epoxy compound, and is potted around the wires and braided shield **48.** The member **50** also abuts the extreme forward ends of the preform and cable at **32T** and **28T.** The forward end of the position fixing member **50** abuts an insulative holder **52** which holds the sockets **18** to which the wires are connected. The holder **62** has a ledge portion **54** which abuts a rearwardly facing ledge **56** that is formed on the inside of the shell. Accordingly, the ledge **56** on the shell supports the holder **52** against forward movement, the holder **52** supports the position-fixing member **50** against forward movement, and the member **50** supports both the preform **14** and cable sheath **28** against forward movement further into the connector shell **16.**

The assembly **10** also includes a coupling ring **58** with a threaded forward end which can be screwed onto the other connector assembly **26** to securely hold it against the assembly **10.** The complete cable splice is shown in FIG. **3,** wherein the two connector assemblies **10, 26** are shown joined together to splice the cable **12** to another cable **60.** In some cable systems, a repeater unit may be located between the ends of the two cables that are to be spliced, so that the connector assembly **10** would connect directly to the repeater unit.

The connection assembly **10** is designed to facilitate reliable construction in the field, as where a maintenance ship pulls up a damaged cable and must remove the damaged section and splice the cable ends. A repairman first strips away the cable sheath **28** from the end of the cable and strips away part of the braided shield **48.** He must then attach the preform **14** to the forward end portion **12E** of the cable about the sheath thereof. This is accomplished in the manner shown in FIG. **4,** with the aid of an attaching apparatus **70.** The attaching apparatus **70** includes a pair of dies **72, 74** with recesses **76, 78** that match the preform. The dies have heating elements that are energized by current applied through cords **80, 82.** A workman first slips the cap **36** onto the cable **12** and then inserts the forward end **12E** of the cable into the preform **14** so that the extreme front ends of the cable sheath and preform are even with one another. He then places the preform **14** with the cable therein in the attaching apparatus **70** as illustrated, and closes the dies **72, 74** and locks them together with a toggle lock **84.** The dies are heated to a fusion temperature at which the polyethylene material of the preform and cable sheath become softened and can merge into one another. After a sufficient period of time, the dies are opened and the cable and preform assembly is removed. The wires **20-24** of the cable are then attached to the sockets **18** and the sockets are mounted in the holder **52.** The assembly is then placed in a cylindrical mold **86,** as shown in FIG. **5,** of the same diameter as the forward end **32** of the preform and the rearward end of the holder **52.** An epoxy compound is then poured into the mold to form the position-fixing member **50.** The apparatus is then inserted into the connector shell **16,** and the cap **36** is screwed into place to complete the connector assembly **10.**

The connector assembly **10** can be constructed in the field, and yet provide high reliability against leakage under the high water pressure existing at deep ocean depths. The provision of a reliable connection at such an environment requires that a strong and reliable waterproof seal be provided between the preform **14** and the cable sheath **28,** and between the preform and the connector shell **16.** The lont tubular portion **30** of the preform is bonded to the cable sheath all along their adjacent areas by the combination of heat that softens the preform and pressure that forces the preform portion **30** uniformly into contact with the cable sheath. In addition, the fact that the preform and sheath are constructed of the same thermoplastic material means that at the softening temperature of the preform, the sheath is also softened and the preform and sheath merge into each other to form a large unitary member.

Sealing of the preform flange **34** to the connector shell **16** is largely accomplished by deformation of the thermoplastic material of the flange **34** against the rear end **16R** of the shell. The O-rings **44,** and **46** serve to provide additional protection against leakage.

The high pressure existing at great ocean depths could cause damage by forcing the cable **12** and/or the preform **14** further into the shell **16,** this movement often being referred to as "hosing in." The hard position fixing member **50** which abuts the extreme forward ends **28T** and **32T** of the cable sheath and preform prevents such movement. The fact that the same member **50** abuts both the cable sheath and preform means that it prevents relative axial movement of the sheath with respect to the preform, to prevent separation of the preform from the sheath along their cylindrical areas of contact.

FIG. **6** illustrates another connector assembly **90** which forms a connection with a cable **92** of the coaxial type that has a pair of coaxial conductors **94, 96** that are enclosed in a sheath **98.** The assembly includes a preform **100** that is heat-bonded to the cable sheath and which is of the same thermoplastic material as the cable sheath. The preform has a flange **102** near its forward end, and a front portion **104** in front of the flange. The front portion **104** has a groove **104***g* at the forward end which extends to a depth at **104T** which is even with the extreme front end or tip **98T** of the cable sheath. The preform front end also has a lip portion **104L** that extends beyond the cable sheath. A hard insulative position fixing member **106** received within the preform lop **104L** and closely centered by the preform lip, abuts the adjacent tips or ends **98T** and **104T** of the cable sheath and preform. The forward end of the position-fixing member **106** abuts a holding member **108,** which may be constructed of a molded epoxy, and which is mounted within a connector shell **110** to prevent forward movement therealong. The forward end portion **104** of the preform and the rearward end of the position-fixing member **106** are both held within a sealing base **111** of rigid material, which may be a conductive material such as a metal. The sealing base **111** fits within the rearward end of the shell **110** and is sealed thereto by O-rings **112.** A cap **114** threaded onto the rearward end of the shell forces the preform flange **102** against the rearward end of the sealing base **111.** The preform flange can deform to provide a watertight fit against the sealing base, and in addition an O-ring **116** is provided to form an even more secure watertight seal.

As in the case of the connector assembly of FIG. **1,** the forward end of the assembly is constructed to permit joining to another similar connector assembly. To accomplish this, the connector assembly **90** is provided with a plug apparatus **120** which connects to the coaxial conductors of the cable **92** and which forms a plug

that can be received into a corresponding socket on the other connector assembly.

The connector assembly **90** is assembled by slipping the preform **100** over the cable sheath **98** and placing them in a heat and pressure applying apparatus similar to the attaching apparatus **70** of FIG. **4.** A potting apparatus of the type illustrated in FIG. **5** is not required, because the position-fixing member **106** is a factory-manufactured article. The shell **110** is also supplied with the holder **108** and plug apparatus **120** in place. It is only necessary to slip the sealing base **111** onto the preform, insert the position-fixing member, attach a braid clamp **122** and socket contact **124** and solder them in place on the coaxial conductors, and insert the assembly into the shell. The assembly is completed by screwing the cap **114** onto the shell.

Thus, the invention provides an underwater connector apparatus and construction method which permits the construction of a reliable underwater connection assembly in the field. This is accomplished by utilizing a cable with a thermoplastic sheath and a preform of the same thermoplastic material, and by bonding them together with heat and pressure so that the two members merge into one another along a large surface area. The preform is constructed with an outwardly extending flange that permits sealing to a connector shell or a sealing base within the shell. Axial movement or "hosing in" of the cable sheath with respect to the shell or with respect to the preform is prevented by utilizing a position fixing member that abuts the extreme forward end of the cable sheath and a forwardly facing surface on the preform. The underwater connection is useful for a variety of cables, including those which have conductors that carry light or current signals or power.

Although particular embodiments of the invention have been described and illustrated herein, it is recongized that modifications and variations may readily occur to those skilled in the art and consequently, it is intended that the claims be interpreted to cover such modifications and equivalents.

What is claimed is:

1. A method for making a connection to the end of an undersea cable which has a plastic sheath, comprising:

installing a cap onto the cable;

installing on the cable sheath, a tubular preform of the same plastic material as the cable sheath and which has an inside diameter approximately equal to the outside diameter of the cable sheath and which has a flange near one end;

placing the preform with the cable projecting therethrough, between a pair of dies;

heating the dies to approximately the fusion temperature of said plastic material of said cable and preform;

pressing the heated dies against the preform to squeeze the preform onto the cable sheath;

removing the preform and cable from between the dies and inserting the preform and cable into a shell; and

installing the cap onto the shell and against the flange of the preform.

2. The method in claim **1** wherein:

said cable includes conductors surrounded by the sheath of the cable; and including

trimming the sheath from around the cable end and molding insulative potting material that becomes hard when solid, around the conductors of the cable and up to the front end of the sheath and preform, said potting material being formed with an outside dimension small enough to fit into said shell; and

installing a fixing means in said shell which can securely prevent forward movement of material; and wherein

said step of inserting the preform and cable into the shell includes inserting the molded potting material into the shell and agains the fixing means so that it can securely prevent any further forward movement of potting material into the shell under high undersea pressures.

3. An underwater cable connection comprising:

a cable having a conductor and an outer flexible sheath surrounding the conductor, said cable having a forward end portion with the conductor extending beyond the sheath at said end portion;

a tubular preform closely surrounding said cable end portion and joined along its internal surface to the outside of the sheath of the cable;

a shell surrounding the ends of said cable and preform, said shell having a rearwardly facing internal surface; and

position fixing means of hard insulative material with a hole through which said conductor extends, said position fixing means abutting the rearwardly facing internal surface of the shell and also aubtting the extreme forward end of said cable sheath and a forward end surface of the preform to prevent forward end movement of the cable sheath and preform, whereby to prevent "hosing in" of the cable or relative axial movement of the preform with respect to the cable under high water pressures.

4. The apparatus described in claim **3** wherein:

said cable is a coaxial cable with a pair of coaxial conductors, a first of the conductors being an electrically conductive tube and a second of the conductors being an electrically conductive wire extending along the center of the tube;

said preform has a front end extending beyond the cable sheath and having a groove at the front end that extends to a depth even with the sheath; and

said position fixing means includes a member which has a tubular rear end portion extending into said groove at the front end of the preform and abutting the preform at the bottom of the groove and the extreme end of the cable sheath.

5. The apparatus described in claim **3** wherein:

said cable has a plurality of flexible wires that can move towards and away from each other; and

said position fixing means includes an insulative potting material extending about the wires and potting them in place and extending to and molded against the front ends of the cable sheath and preform.

6. The apparatus described in claim **3** wherein:

said shell has external threads on its rearward end and a rearwardly-facing groove on its rear end with an O-ring seal therein; and

said preform has an outwardly extending flange near its front end, said flange being of larger diameter

than the O-ring and abutting the O-ring; and including

a cap having a rear end wall against the rear face of the preform flange, the end wall including a hole through which the preform extends, and the cap having a tubular threaded front portion threaded onto said shell so that the rear wall of the cap presses the preform flange against the O-ring.

7. The apparatus described in claim **3** wherein:

said shell has external threads on its rearward end and has a cylindrical rear internal surface at the rear end with a rearwardly facing internal ledge at the forward end of the rear cylindrical internal surface;

said preform has an outwardly-extending flange near its front end; and including

a sealing base of hard material with an outer diameter slightly smaller than the diameter of said rear cylindrical internal surface of the shell and disposed therein, said sealing base having a forward end disposed against the rearwardly facing internal ledge of the shell, said sealing base having an O-ring along its outer surface and sealed against the cylindrical rear internal surface of the shell, and said sealing base having a rearwardly facing rear end with an O-ring groove therein holding an O-ring and abutting the front face of the preform flange; and

a cap having a rear end wall against the rear face of the preform flange, the rear end wall of the cap including a hole through which the preform extends, and the cap having a tubular threaded front portion threaded onto said shell so that the rear wall of the cap presses the preform flange against the rear end of the sealing base.

8. An underwater cable connection comprising:

a cable having a conductor and an outer sheath of a thermoplastic material surrounding the conductor, said cable having a forward end portion;

a tubular preform constructed of thermoplastic material and closely surrounding the forward end portion of the sheath, and with the inner surface of the preform merging into the outer surface of the cable sheath, said tubular preform having an outwardly-extending flange, and the radially inner wall of the preform extending even with the extreme front end of the cable sheath;

a shell assembly receiving the forward ends of the cable and preform and sealed to the flange of the preform; and

position fixing means mounted in said shell to prevent forward movement therein and abutting both the extreme front end of the sheath and the preform portion thereabout.

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