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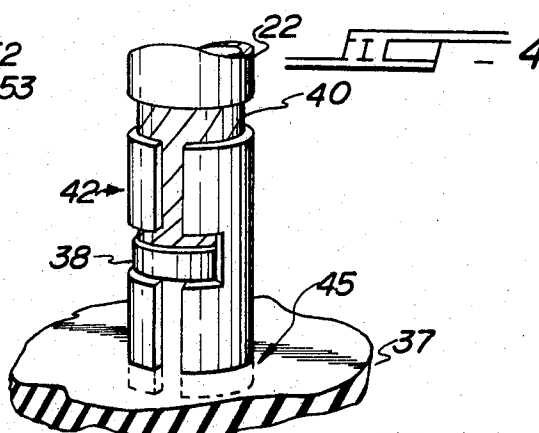
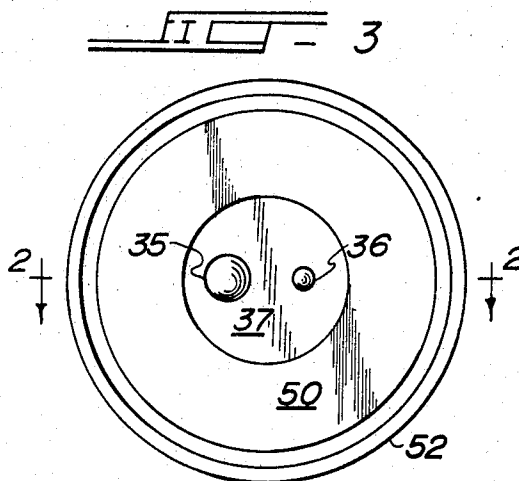
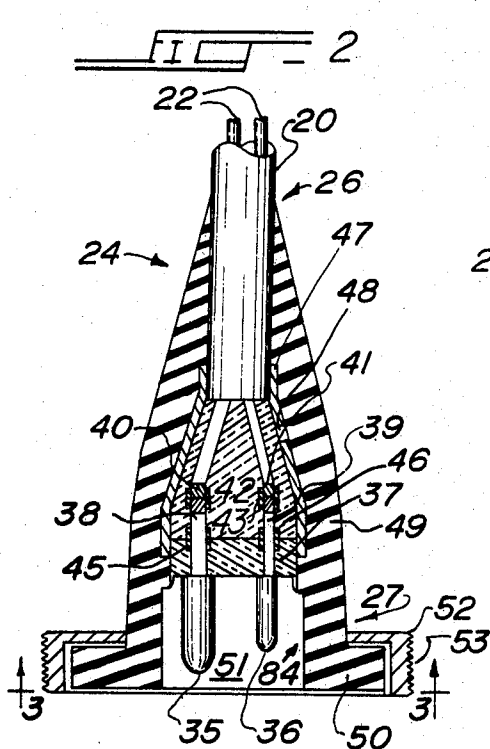
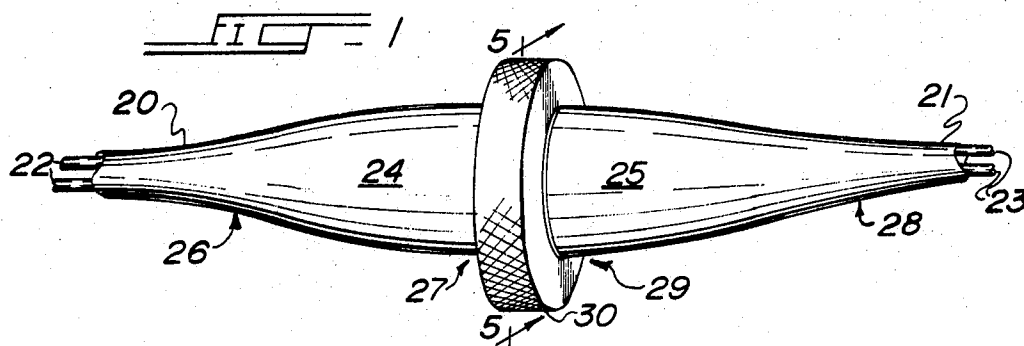
F. MASSA

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UNDERWATER SEPARABLE CONNECTOR

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2 Sheets-Sheet 1



INVENTOR

FRANK MASSA

BY *Louis Bernat*

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UNDERWATER SEPARABLE CONNECTOR

Frank Massa, Cohasset, Mass., assignor to Massa Division, Dynamics Corporation of America, Hingham, Mass.

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ABSTRACT OF THE DISCLOSURE

A block of rigid insulating material has a number of precisely located holes drilled therein, each to receive an electrical terminal, which may be either a plug or a socket. Then, wires are attached to the terminals. After the wires are so attached, the region of attachment is cast in a rigid potting compound to provide mechanical protection for the points of attachment. Finally, a waterproof jacket is molded around the entire assembly of insulating material, wires, and potting compound, thus leaving only the terminals exposed outside the jacket. Then, two cables may be joined by making suitable plug and socket connections, after which a pair of threaded clamping rings are joined to prevent the connections from being pulled apart.

This invention relates generally to separable electrical connectors and more particularly to new and improved connectors for use in underwater applications.

Underwater electrical connectors of the described type generally have a rubber-like jacket which is bonded to the outer covering of an underwater cable. The cable includes a number of insulated conductors which are attached to a connector having either a set of plug terminals or a set of socket terminals. Another similar cable has its insulated conductors connected to a similar connector including the mating terminals. Thus, these two cables may be joined together by making simple plug and socket connections. Both the plug and socket terminals are molded within a rubber-like envelope which fills the space between the insulated conductors and these terminals with a waterproof bond. The molded envelope also surrounds and makes a waterproof bond with the rubber-like jacket of the cable.

There are many problems where this type of construction is used. A first problem is that the junction between cable wires and connector terminals experiences an undue amount of mechanical stress when heat is applied during the molding of the rubber-like envelope. There is a tendency for the heated rubber-like compound to exert high pressures against the conductors, thus causing them to be crushed together. Also, the heated compound causes a considerable stretching of the copper strands. In some cases, there is a complete separation of the strands which form the conductors. Worse still, the separation of the strands might not be complete, and the joint may pass inspection. In these instances, perhaps only a single strand remains for completing the electrical circuit. Then, if an appreciable current flows through the cable, the reduced area of the copper conductor causes localized heating with a resulting failure during operation. Usually, these potential faults may be found by an X-ray inspection, but that is an expensive manufacturing step.

The second problem that results from the conventional construction is that the locations of the plugs and sockets cannot be accurately maintained within the rubber-like compound. Although the plugs and sockets are held in the mold during the molding operation, a variation in the dimensions of the rubber-like compound sometimes oc-

curs during cooling after the part is removed from the mold. These variations tend to cause the terminals to shift somewhat from their ideal location, and that shift, in turn, requires larger tolerances between the plug and socket parts. These relaxed tolerances are particularly disadvantageous when several terminals are located within a relatively small size connector.

A third problem arises when the rubber-like compound flows through clearance portions of the mold to form an unwanted thin layer or fin of material, often called a "flash." This flow is especially troublesome in the regions where the plugs and sockets are mounted because the flash which might surround a portion of the plugs and sockets is extremely difficult to remove especially when it is located within a recessed region of the connector assembly. As a result, an intermittent trouble occurs because there is an electrical contact which makes and breaks at random due to the high resistance of the rubber flash between various surfaces of the plugs and sockets.

Still another problem found in the conventional construction results when the connector is used in deep water applications where the hydrostatic pressure may exceed 1000 p.s.i. This high pressure is impressed on the rubber-like jacket in the region of the junctions between the cable conductors and terminals. In some instances, this impression has caused a jacket deformation to an extent which forces the conductors together and causes an electrical breakdown under high pressure conditions.

Accordingly, an object of the invention is to provide new and improved separable connectors for underwater cables. More particularly, an object is to provide underwater connectors which are much more reliable than those used heretofore. In this connection, an object is to provide connectors which are reinforced at the junction point between the wires in the cable and the terminals in the connector.

Still further, an object is to provide improved structures which are not subject to failures caused by heating, pressures, stresses, and the like, which normally occur during conventional manufacturing processes. Here, an object is to provide a rigid mounting structure for holding the connector terminals in accurate alignment during molding operation while the connector is being covered by a waterproof jacket. A further object is to encase the wires of the cable in a rigid, protective, potting compound at the points where they join the connector terminals.

In keeping with an aspect of the invention, these and other objects are accomplished by the use of a rigid block of insulating material having holes accurately drilled therein for receiving either plug or socket terminals. The wires in the underwater cable are connected to these terminals. Then the junctions between these wires and the terminals are encased by a potting material which surrounds, strengthens, and reinforces the wires to protect them—especially during the manufacturing process. Thereafter, a molded rubber-like jacket is formed around the entire assembly to make it waterproof.

The nature of a preferred embodiment of the invention may become more apparent from a study of the attached drawings, in which:

FIG. 1 is a perspective view of two cable sections joined by the inventive connector;

FIG. 2 is a cross-sectional view (taken along line 2—2 of FIG. 1) of the plug half of an underwater connector embodying the teachings of this invention;

FIG. 3 is an end view of the plug half of the connector taken along the line 3—3 of FIG. 2;

FIG. 4 is a perspective view of a clip used to interconnect a cable wire and a terminal plug;

FIG. 5 is a cross-sectional view (taken along the line 5—5 of FIG. 1) showing the socket half of the connector

corresponding to the mating portion of the plug half illustrated in FIG. 2;

FIG. 6 is a perspective view of the socket terminal; and

FIG. 7 is an end view taken along the line 7—7 of FIG. 6.

FIG. 1 shows two underwater cables 20, 21 each of which includes any suitable number of wires—such as the exemplary two wires shown at 22, 23. These cables preferably have waterproof, rubber-like outer jackets. These wires are, respectively, connected to terminals in a plug half of a connector 24 and a socket half of a connector 25. Then, a waterproof jacket is molded over each of these connector halves. For example, the plug half 24 is covered by a jacket beginning at 26 with a waterproof bond to the cable 20 and ending at 27 in a molded flange (not visible in FIG. 1). Likewise, the socket half 25 is also covered by a jacket beginning at 28 with a waterproof bond to the cable 21 and ending at a molded flange near 29. A pair of mating threaded ring clamps fit over the jacket flanges. When these threaded ring clamps are joined and the knurled ring 30 is turned, the jacket flanges are squeezed together to make a waterproof bond between the two halves 24, 25.

For a better understanding of the plug half 24 of the connector, reference may be made to FIG. 2 which also shows the cable 20, wires 22, and jacket 26—27. In addition, it shows two plug terminals 35, 36. The plug terminal 36 is smaller, both in length and diameter, than the plug 35 to provide an index so that the two halves 24, 25 may not be joined improperly to reversely interconnect the wires in the two cables. Of course, the invention also contemplates other forms of indexing such as keys and key slots, for example. Or the plugs 35, 36 could be unsymmetrically located about the central axis of the connector half.

Means are provided for maintaining accurate terminal positions—especially during the manufacturing process. In greater detail, a rigid block of insulating material 37 (conveniently in the form of a cylinder) is provided with precisely drilled clearance holes for receiving the stem portions 38, 39 of the plug terminals 35 and 36. During manufacture, the plug terminal stems 38, 39 are inserted into the clearance holes in the block of insulating material 37. Then, the insulation on the conductors 22 is stripped, and the conductor wires 40, 41 are electrically connected to the plug stems 38, 39, as by means of metal clips 42, 43. These clips form mechanical and electrical junctions between the conductor wires 40 and 41 and the plug stems 38, 39, respectively. An example of such a clip is shown by the large scale detail drawing of FIG. 4. Dotted lines are used at 45 to indicate that the metal clips 42 and 43 may be inserted in the insulating material 37 so that they also serve as an anchor for attaching the plugs 35, 36 to the block of insulating material 37.

After making the electrical connections via clips 42, 43, the region in the vicinity of the clips is filled with a rigid potting compound 46. First, a cap 47 is attached over the end of the cable 20, and then the end of the insulator block 37 is fitted against the end of cap, as illustrated. Next, the space within the cap 47, is filled with a suitable potting compound which is poured through a small hole 48 in the wall of the cap. The cap 47 may consist of a molded rubber-like sleeve which may be left in place permanently after the potting 46 has been poured. Or it could be a separable metal mold. Preferably, the potting compound is an epoxy that can be poured in place and then become rigid without requiring an application of any pressure upon the wires 40, 41 or clips 42, 43.

It should be noted that, at this point in the construction, a rigid subassembly has been achieved to locate the junction between cable wires 22, the plug terminals, and the rigid insulator block 37. This subassembly is very strong and is not subject to the faults of prior art structures. Moreover, it is not easily damaged by any

heat or pressure which may be encountered during further manufacturing.

During a final molding operation, a rubber-like compound is applied over the assembly described thus far in order to form the waterproof outer jacket 49 which covers the rigid insulator block 37 and the tapered epoxy-cast region 46. This compound forms a long tapered portion flaring smoothly from the cable 20 to a jacket flange 50. A relatively heavy wall of rubber is molded to form a recessed cup-like cavity 51 within which the plug terminals are contained. A loose ring clamp 52, fits over the flange 50, is provided with outer threads 53. Among other things, this jacket and ring clamp combination provides a suitable strain relief during bending while the cable is in use.

FIGS. 5–7 illustrate the construction of the socket half 25 of the connector assembly. The general construction of this half is similar to that described in connection with FIG. 2. A rigid block of insulating material 60 is provided with precisely located clearance holes 61, 62 located to correspond with the spacing of the plugs 35, 36. These holes are counterbored from the opposite end, thus leaving a shouldered region 63, 64 near the upper surface. A tubular socket type connector 66, 67 is inserted from the bottom of the counterbored holes 61, 62 and is retained by the shoulder 63, 64 at the top of the hole.

An enlarged illustration of the socket terminal is shown in FIGS. 6 and 7. More particularly, a thin strip or plate of Phosphor bronze, beryllium copper, or any other suitable conductor material, having good spring characteristics, is blanked and then rolled-up to form a cylindrical tube 70. During the blanking step, three windows are semipierced in the cylinder wall to provide three elongated contact terminals 71, 72, 73, each of which remain attached at one end to the wall 70. The other ends of the elongated terminals are pushed inwardly so that they are deflected toward the center of the cylindrical shell 70 with a taper which flares in the direction of plug travel. Thus, the tips of these elongated terminals make good contacts with the plugs. The bottom end of the socket member is provided with a terminal lug 75 which is used to make electrical contact and retain the cable wire 76, which is one of the wires 23.

Another socket terminal in the hole 62 is similar to that illustrated in FIGS. 6, 7 except that it is somewhat smaller in diameter and is dimensioned to receive the plug 36. This prevents reversal of the plug and socket connections because the plug 35 is too large to fit into the socket in hole 62.

Before an attachment of the conductors 76 to the socket terminal lugs 75, a washer 78 (FIG. 5), preferably of a rubber-like material and having small clearance holes for the terminal lugs 75 or wires 76, is slipped over the wires. After the conductors are crimped into the lugs 75 of the socket terminals 66, 67, the washer 78 is cemented to the base of the rigid insulator block 60 by using any one of the many well known rubber cements or epoxies. This washer is provided to seal the bottom of the insulator block 60 to prevent the epoxy 46 from seeping into the socket terminal area. A molded tapered cap 47 is utilized to retain the rigid potting compound 46 and to consolidate the subassembly of the socket terminal assembly 25 into a rigid unit.

The next step in the manufacturing procedure is to mold the rubber-like outer jacket 49 around the subassembly of FIG. 5. The molded surfaces 83, 84 around the periphery of the insulating member 60 and the inner diameter of the cavity 51 are preferably made to have an interference fit to increase the waterproof qualities of the connector. A flange portion 80, which corresponds in shape and size to the flange portion 50, is provided as part of the jacket 49. The flange 80 also includes a small raised bead 81 which acts as an O-ring seal when the two connector halves 24, 25 are engaged. Surrounding the connector 25 is a rigid ring clamp member 30

that has internal threads 82 which engage the threads 53 on the ring clamp 52. After the two connector halves are engaged, it is impossible to pull the connector halves apart if they are exposed to heavy tensile stresses such as may occur in turbulent seas or when a heavy structure is attached to the opposite end of one of the cables 20, 21. These ring clamps also squeeze the flanges 50, 80 together to form a waterproof seal.

The advantages of the invention should now be clear to those skilled in the art. More particularly, the use of the spring-like contacts 71-73 provides positive a low resistance electrical connection. Due to the relatively long spring that is achieved by the design, it is impossible for the flexible members to take a permanent set when the plugs are inserted. Also, if an oversize plug is inserted into the socket, there is no permanent set to cause an erratically high contact resistance if subsequently an undersized plug is inserted. The location of the plug and socket connectors are accurately and permanently maintained by the rigid insulating block retainer. The use of this rigid block of insulation material, in conjunction with the epoxy potting, consolidates the junction region in which electrical connections are made between the cable conductors and the connector terminals. This prevents the displacement of the conductors during subsequent molding operations and when the connection is subject to high hydrostatic pressures, such as occur in deep water.

Experimental data has shown that the type of connector just described using pin contacts as small as $\frac{1}{16}$ " diameter results in a contact resistance in the order of a few milliohms when unplated brass terminals and Phosphor bronze or beryllium copper sockets are used. When silver plating is employed, this already insignificantly low contact resistance becomes even lower.

This invention has been described in connection with particular embodiments which illustrate the basic principles of the invention. However, it will be obvious to those skilled in the art that numerous deviations are possible without departing from the principles shown and described herein. Therefore, the invention should not be limited to this particular structure, but should be construed to cover all equivalents falling within the true spirit and scope of the invention.

I claim:

1. A separable underwater electrical connector comprising a rigid block of insulating material, terminal means in said block, an electrical cable having at least one electrical conductor therein and which is connected to said terminal means, said cable being surrounded by a waterproof outer jacket, said connection being made in a region bounded at one side by a surface of said block of insulating material and at the opposite side by the cable jacket, a solid electrical insulating material filling the space within said bounded region, and a second material surrounding said block and said electrical insulating material, said second material being bonded to both the periphery of the cable jacket and the periphery of said block of insulating material to form a waterproof covering for said connector.

2. The invention set forth in claim 1, characterized in that said electrical insulating material is a rigid potting compound.

3. A separable underwater electrical connector comprising a solid block of insulating material having holes precisely formed therein, electric terminal means located in said holes, insulated electrical conductor means connected to said terminal means, said conductor means being enclosed within a waterproof jacket, solid electrical insulation potting material surrounding the region occupied by the terminal connections and extending from said block of insulating material to the surface of said cable jacket, and pliable waterproof material surrounding said solid electrical insulation potting material and bonded at one end to said waterproof jacket and at the other end to said block of insulating material.

4. The invention set forth in claim 3 wherein half of said connector includes a plurality of sockets for receiving plugs in another half when said halves are joined, each of said sockets comprising a cylinder of electrically conductive spring material having at least one semi-pierced window defining an elongated tongue of electrically conductive material bending inwardly toward the center of said cylinder, the axis of said cylinder coinciding with the elongated dimensions of said tongue, and a terminal lug on each of said sockets for completing an electrical connection.

5. The connector of claim 4 wherein each of said sockets includes a plurality of semi-pierced windows spaced around the circumference of said cylinder, there being an elongate tongue of electrically conductive material in each of said windows.

6. The connector of claim 4 wherein a potting material surrounds and reinforces the area where the electrical connections are made with said terminal lugs.

7. In combination in a separable underwater electrical connector formed by first and second halves for providing plug and socket connections, each of said halves including a block of insulating material, each of said blocks having a common axis of reference, a plurality of plug terminal means located within a block in a first of said halves, a plurality of socket terminal means located within a block in a second of said halves, said plug and socket terminals having the same relative spacing with respect to said common axis of reference so that said terminals will engage each other when the two halves are brought together, an electrical cable having a plurality of insulated conductors surrounded by a waterproof outer jacket, a first length of said cable having its conductors connected to said plug terminals, another length of said cable having its conductors connected to said socket terminals, rigid insulation potting material surrounding the junction regions occupied by the connections between the conductors and terminals, said potting material extending from the surface of said insulating blocks to the surface of the waterproof cable jacket, and a pliable waterproof material surrounding the said rigid insulation potting materials and bonded to the cable jackets and said blocks of insulating materials.

8. The invention set forth in claim 7 characterized in that said pliable waterproof material is molded of a rubber-like material.

9. The invention set forth in claim 7 in which said pliable waterproof material on each of said halves has a rugged flange portion, each of said flanges having a plane face at right angles to said axis of reference, and further characterized in that said plane faces of said flange portions meet when the halves are assembled.

10. The invention set forth in claim 9 further characterized in that a circular bead is molded into the face of at least one of the flange portions to serve as an O-ring seal when the two flange faces are pressed together.

11. In combination in a separable underwater electrical connector formed by first and second halves for providing plug and socket connections, each of said halves including a block of insulating material, each of said blocks having a common axis of reference, a plurality of plug terminal means located within a block in a first of said halves, a plurality of socket terminal means located within a block in a second of said halves, said plug and socket terminals having the same relative spacing with respect to said common axis of reference so that said terminals will engage each other when the two halves are brought together, an electrical cable having a plurality of insulated conductors surrounded by a waterproof outer jacket, a first length of said cable having its conductors connected to said plug terminals, another length of said cable having its conductors connected to said socket terminals, rigid insulation potting material surrounding the junction regions occupied by the connections between the conductors and terminals, a pliable waterproof material surrounding the said rigid insulation potting materials and

bonded to the cable jackets and said blocks of insulating materials, said pliable waterproof material on each of said halves having a rugged flange portion, each of said flanges having a plane face at right angles to said axis of reference, characterized in that said plane faces of said flange portions meet when the halves are assembled, and a threaded ring clamp fitted over each flange portion, said ring clamps having mating threads for making a mechanical connection between said halves when said threaded ring clamps are joined whereby the mating flange surfaces of said halves are squeezed tightly together in a sealed face-to-face contact.

12. In combination in a separable underwater electrical connector formed by first and second halves for providing plug and socket connections, each of said halves including a block of insulating material, each of said blocks having a common axis of reference, a plurality of plug terminal means located within a block in a first of said halves, a plurality of socket terminal means located within a block in a second of said halves, said plug and socket terminals having the same relative spacing with respect to said common axis of reference so that said terminals will engage each other when the two halves are brought together, an electrical cable having a plurality of insulated conductors surrounded by a waterproof outer jacket, a first length of said cable having its conductors connected to said plug terminals, another length of said cable having its conductors connected to said socket terminals, rigid insulation potting material surrounding the junction regions occupied by the connections between the conductors and terminals, a pliable waterproof material surrounding the said rigid insulation potting materials and bonded to the cable jackets and said blocks of insulating materials, said pliable waterproof material on each of said halves having a rugged flange portion, each of said flanges having a plane face at right angles to said axis of reference, characterized in that said plane faces of said flange portions meet when the halves are assembled, and further characterized in that a circular bead is molded into the face of at least one of the flange portions to serve as an O-ring seal when the two flange faces are pressed together, and a threaded ring clamp fitted over each flange portion, said ring clamps having mating threads for completing a mechanical connection between said threaded rings whereby the mating flange surfaces of said halves are held tightly together in sealed face-to-face contact.

13. The method of fabricating a separable underwater connector including the following steps: (1) assemble a plurality of electrical terminals within a rigid block of insulating material, (2) mechanically and electrically connect the conductors of a jacketed cable to said terminals, (3) confine a region in the vicinity of the terminal and conductor connections by means of a surrounding sealed enclosure which extends from the surface of the insulating terminal block to the surface of the cable jacket, (4) pour an electrically insulating liquid potting compound into said sealed enclosure to form a body member, said compound being one which sets up solid without an application of pressure, and (5) mold a rubber-like material around the potted conductor and terminal assembly, said rubber-like material being bonded to the periphery of the cable jacket and enclosing the body member to form a waterproof jacket.

14. A separable underwater electrical connector formed by first and second halves for providing plug and socket connections, each of said halves including a rigid block of insulating material, a plurality of plug terminal means located within the rigid block in a first of said halves, a plurality of socket terminal means located within the rigid block in a second of said halves, said plug and socket terminals engaging each other when the two halves are brought together, a first length of waterproof jacketed cable having its conductors connected to said plug terminals, another length of waterproof jacketed cable having its conductors connected to said socket terminals,

rigid insulation potting material surrounding the junction regions occupied by the connections between the conductors and terminals, said potting material filling the entire region from the cable jacket to the rigid insulating block, a pliable waterproof material surrounding the said rigid insulation potting materials and said blocks of insulating materials, the waterproof material surrounding said plug terminals forming a cavity in which said plug terminals are completely recessed, and the waterproof material surrounding said socket terminals forming a plug-section having contours which are complementary to the contours of said cavity and dimensioned to have an interference fit with said cavity when said first and second halves come together.

15. A separable underwater electrical connector formed by first and second halves for providing plug and socket connections, each of said halves including a rigid block of insulating material, a plurality of plug terminal means located within the rigid block in a first of said halves, a plurality of socket terminal means located within the rigid block in a second of said halves, said plug and socket terminals engaging each other when the two halves are brought together, a first length of cable having its conductors connected to said plug terminals, another length of cable having its conductors connected to said socket terminals, rigid insulation potting material surrounding the junction regions occupied by the connections between the conductors and terminals, a pliable waterproof material surrounding the said rigid insulation potting materials and said blocks of insulating materials, the waterproof material surrounding said plug terminals forming a cavity in which said plug terminals are completely recessed, the waterproof material surrounding said socket terminals forming a plug-section having contours which are complementary to the contours of said cavity and dimensioned to have an interference fit with said cavity when said first and second halves come together, said pliable waterproof material on each of said halves having a rugged flange portion, each of said flanges having a plane face at right angles to the plug and socket terminals respectively so that said plane faces of said flange portions meet when the halves are assembled, and a ring clamp surrounding each of said flanges to lock said two halves together.

16. The invention set forth in claim 15 and a circular bead molded into the face of at least one of the flange portions to serve as an O-ring seal when the two flange faces are pressed together by said ring clamp.

17. In combination in a separable underwater electrical connector formed by first and second halves for providing plug and socket connections, each of said halves including a block of insulating material, each of said blocks having a common axis of reference, a plurality of plug terminal means located within a block in a first of said halves, a plurality of socket terminal means located within a block in a second of said halves, said plug and socket terminals having the same relative spacing with respect to said common axis of reference so that said terminals will engage each other when the two halves are brought together, an electrical cable having a plurality of insulated conductors surrounded by a waterproof outer jacket and connected to the terminal means in at least one of said halves of said connector, rigid insulation potting material surrounding the junction regions occupied by the connections between the conductors and terminal means, said potting material extending from the surface of said insulating block in said one half to the surface of the waterproof cable jacket, and a pliable waterproof material surrounding the said rigid insulation potting material, said pliable waterproof material being bonded to the cable jacket and said block of insulating material of said one half.

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MARVIN A. CHAMPION, Primary Examiner

J. H. McGLYNN, Assistant Examiner

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