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# IMPROVED UNDERSEA CABLE CONNECTOR

## STATEMENT OF GOVERNMENT INTEREST

**[0001]** The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

## CROSS REFERENCE TO OTHER PATENT APPLICATIONS

**[0002]** None.

## BACKGROUND OF THE INVENTION

### (1) Field of the Invention

**[0003]** The present invention is directed to connectors for undersea cables and more particularly to a method for increasing the lifespan for such connectors.

### (2) Description of the Prior Art

**[0004]** FIG. 1 shows a prior art electrical connector 10 joined to a cable 12 for use in the marine environment. Cable 12 has a plurality of electrical elements 14 that terminate in a connector body 16. Connector body 16 consolidates elements 14 so that they can be attached to a fixture or another cable. Connector body 16 is hollow with a terminal connector 18 and a mounting portion 20. Terminal connector 18 can be joined using many different methods. Connector body 16 is typically made from a corrosion resistant metal; however, other anticorrosion measures are taken, as described hereafter. Elements 14 from cable 12 extend into hollow mounting portion 20. In this embodiment, elements 14 are terminated as male pins 22 within connector body 16, but these can also be terminated as female sockets (not shown). Pins 22 or other terminations are sealed to prevent water leaking into the connector body 16 hollow. Pins 22 or other terminations can be joined to a complementary connector on a platform.

**[0005]** After assembly of the cable 12 with connector body 16, an encapsulant 24 is molded around mounting portion 20 and cable 12 in order to seal the junction between cable 12 and connector body 16. Encapsulant 24 is typically polyurethane or another polymer. Encapsulant 24 is bonded to the cable 12 and mounting portion 20 of connector body 16 and fills substantially all of the volume of this junction. Bonding of the encapsulant to the cable 12 and the connector body 16 is critical for preventing leakage of seawater into the region where the elements 14 extend into hollow mounting portion 20.

**[0006]** Cathodic debonding (sometimes also called "cathodic delamination”) is a major cause for the premature failure of these connectors in the marine environment. Preventing this failure has been a subject of extensive research. This research has determined that the process occurs because the hulls of ships and submarines are deliberately cathodically polarized via sacrificial anodes or an induced current cathodic protection (ICCP) system to prevent hull corrosion in seawater. The net effect is the conversion of the hull from being an anode (i.e., subject to corrosion) to being a cathode (i.e., protected from corrosion). At the voltages normally used, the cathodically protected hulls support the following half-cell reaction on their exposed metal surfaces:

$$O_2 + 2H_2O + 4e^- \rightarrow 4(OH)^- \qquad (1)$$

Equation (1) does not harm the metal surface. It does, however, result in the generation of a very high pH environment immediately above the metal surface. Any hardware (such as a cable connector or hull penetrator) electrically connected to the cathodically polarized metal surface of the platform can pick up the cathodic current and thus becomes cathodically polarized itself. The concentrated alkaline environment that forms immediately above cathodically polarized metal surfaces can destabilize metal-oxide layers, break metal-polymer bonds, and in some cases, attack or damage polymers directly. High pH environments are detrimental to most polymer-metal bonds. They can cause paint to fall off of cathodically polarized hardware, and they can cause polymer encapsulants to debond from connector backshells such as mounting portion 20. This often results in flooding of the connector and failure.

**[0007]** Referencing FIG. 1, cathodic debonding on outboard cable connectors proceeds inward from the exposed metal-polymeric encapsulant bond-line/interface 26. Since the required reactants for the debonding process, water and oxygen, can permeate through the polymeric encapsulant, and the electrons (current) come through the metal substrate, it has been a longstanding mystery as to why cathodic debonding only occurs through exposed bond lines. Cathodic debonding doesn’t happen where encapsulant 24 contacts cable 12 because the cable jacket and encapsulant 24 are insulators.

**[0008]** Experimental testing has confirmed that cathodic debonding rates are dependent on electrolyte concentration. As the concentration of the electrolyte increases, so does the rate of debonding. The debonding rate drops to zero when the concentration of the electrolyte drops to zero. The dependence of the debonding rate on the concentration of the electrolyte is interesting, because in equation (1), the cathodic reaction that causes debonding, does not include sodium ($Na^{+}$) or chlorine ($Cl^{-}$) ions, the two ions comprising the electrolyte. Experimental testing also found that the debonding relationship is linear with respect to the square root of time. This suggests some kind of diffusion reaction is in control of the debonding rate.

**[0009]** A possible reason for the dependence of the debonding rate on the electrolyte concentration is that the right side of equation (1) is not charge-balanced. The cathodic debonding reaction generates negatively charged hydroxide ions ($OH^-$). Those negative charges need to be cancelled out or balanced by an equal number of positive charges. The only significant source of positively charged ions is the electrolyte. Some of its positively charged metal ions ($M^+$) need to migrate to the region of active debonding to provide the needed charge balance.

**[0010]** The size of the $M^+$ cation also influences the rate of cathodic debonding. When the $M^+$ cation is lithium ($Li^+$), the rate of cathodic debonding is lower than when the $M^+$ cation is potassium ($K^+$). This is unexpected because the +1 cation for lithium is smaller than the +1 cation for potassium. Smaller species such as lithium ions should diffuse faster than larger species such as potassium ions; however, if one considers the size of the M+ cation and its associated sphere of hydration, the results make better sense. The sphere of hydration is the volume of water molecules associated with the $M^+$ cation when dissolved in water. Lithium ions ($Li^+$) have a larger sphere of hydration than potassium ions ($K^+$). Because they have much larger spheres of hydration due to their greater positive charge, $M^{+2}$ cations (e.g., zinc, $Zn^{+2}$ from sacrificial zinc anodes) would not be expected to play much of a role in providing charge balance for the cathodic debonding reaction.

**[0011]** This analysis has determined that the $M^+$ charge balancing cations diffuse through the bond-line/interface 26 between the metal surface of the connector mounting portion 20 and encapsulant 24 to keep the actively debonding region electrically neutral. Thus, the $M^+$ ions move between connector mounting portion 20 and encapsulant 24 after the debonding front has passed through. The need for this cation migration to occur would also explain the diffusion-control of the rate of the debonding, and it also explains that cathodic debonding on outboard electronic cable connectors begins at an exposed polymeric encapsulant/metal backshell interface/bond line 26 because charged species like $M^+$ cannot diffuse through encapsulant 24 polymers. These species must diffuse through the disrupted, former bondline. The resulting equation is:

$$O_2 + 2H_2O + 4e^- + 4M^+ \rightarrow 4(OH^-) + 4M^+ \qquad (2)$$

**[0012]** Controlling this action provides a method for avoiding cathodic debonding and preserving the life of marine electrical connectors.

## SUMMARY OF THE INVENTION

**[0013]** It is a first object of the present invention to provide a connector that has extended life when joined to a cathodically protected platform.

**[0014]** Another object is to provide a method for protecting existing connectors that will be joined to cathodically protected platforms.

**[0015]** Accordingly, there is provided an electrical connector for joining a cable to a cathodically protected body in a marine environment that includes a connector body having a terminal connector for joining to the cathodically protected body and a mounting portion for receiving the cable. An encapsulant is formed around and bonded to the body mounting portion and the cable. A means for applying radially inward compressive force is provided to the outer surface of the encapsulant outside of said connector body mounting portion. This force should be sufficient to prevent transfer of positive metallic ions from the marine environment to the bonding region between the encapsulant and the mounting portion.

**[0016]** A method for making and modifying existing connectors is also provided. In such a method, a fixture is provided around a marine connector having a polymer encapsulant bonded to the exterior of a metallic portion of the marine connector. The fixture applies a compressive force to the polymer encapsulant with sufficient force to prevent positive metallic ions from entering the region between the polymer encapsulant and the exterior of the metallic portion of the marine connector.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0017]** Reference is made to the accompanying drawings in which are shown an illustrative embodiment of the invention, wherein corresponding reference characters indicate corresponding parts, and wherein:

**[0018]** FIG. 1 is a diagram showing a prior art connector subject to cathodic delamination;

**[0019]** FIG. 2 is a diagram showing a first embodiment of a connector protected against cathodic delamination;

**[0020]** FIG. 3 is a diagram showing a second embodiment of a connector protected against cathodic delamination; and

**[0021]** FIG. 4 is a diagram showing a third embodiment of a connector protected against cathodic delamination.

## DETAILED DESCRIPTION OF THE INVENTION

**[0022]** FIG. 2 suggests a method by which cathodic debonding can be stopped. If the flow of $M^+$ charge balance cations to the site of active debonding is disrupted, the cathodic debonding process slows or completely stops. This is easier than trying to stop the movement of the oxygen ($0_2$) and water ($H_20$) needed for the cathodic delamination reaction to occur. Because oxygen and water are either uncharged or possess a small dipole, they can diffuse through polymers, whereas $M^+$ cations, being charged, cannot.

**[0023]** FIG. 2 shows application of a band 28 applying a radial compression to the polymer encapsulant 24. Band 28 should be applied in the region of encapsulant 24 that is surrounding mounting portion 20. If band 28 is applied over elements 14 or cable 12, application will not be effective to stop debonding, and this may damage the cable connection. Band 28 can have a variety of constructions and materials that can provide sufficient radial compressive force to prevent metallic ions from passing between encapsulant 24 and mounting portion 20. Radial compressive force should not result in deformation of the encapsulant 24 under band 28. Band 28 can sized and made from a material so it expands on heating and applies the required compressive force at ambient or normal operating temperature of the connector. When heated, band 28 can fit over encapsulant 24. Upon cooling to ambient temperature band 28 will provide the required compressive force to retain encapsulant 24 against mounting portion 20. Heat shrinking in this manner is not ideal because of the tolerances required. Alternative methods and apparatus are described below.

**[0024]** In a second embodiment, shown in FIG. 3, a non-corrosive metallic belt 30 is wrapped around the encapsulant 24 until belt 30 overlaps itself. A buckle 32 is provided at the first end of the belt 30 and wrapped over overlapping the second end of belt 30. Belt 30 is pulled tightly with sufficient force to secure it against encapsulant 24. Portions of buckle 32 wrapped over belt 30 and deformed by indenting in order to compress overlapping belt portions against each other thereby retaining belt 30 in compression against encapsulant 24. Other forms of buckling can be used to retain belt 30 about encapsulant 24.

**[0025]** In another embodiment, a hose clamp 34 is provided around encapsulant 24. Hose clamp 34 has a band portion 36 having slots 38 formed therein. A fastening portion 40 overlaps band portion 34 and has a worm screw 42 configured having threads that interface with band portion 36 at slots 38. Expanded hose clamp 34 can fit readily over terminal connector 18 and encapsulant 24. Rotating worm screw 42 causes threads to apply force to band portion 36 at slots 38 to tighten clamp 34 around encapsulant 24. Again, hose clamp 34 tightening should be limited to avoid deformation of encapsulant 24 surface.

**[0026]** A variety of other methods can be used to provide compressive force to the encapsulant 24 around the mounting portion 20. A non-deformed crimp ring could be provided around encapsulant 24 over mounting portion 20 and crimped to provide the required compressive force. An expanded helical spring can also be positioned around the encapsulant 24 over mounting portion 20 and released to provide compressive loading. In any case, care should be taken to insure that the compressive force completely surrounds encapsulant 24 to ensure consistent sealing and to avoid damaging mounting portion 20.

**[0027]** Installation of a band or other fixture over the outside of the connector overmold or encapsulant material to physically compress the encapsulant against the metal of the mounting portion prevents the diffusion of M+ cations through the region directly under the band. This stops cathodic debonding from progressing past the banded region.

**[0028]** It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

**[0029]** The foregoing description of the preferred embodiments of the invention has been presented for purposes of illustration and description only. It is not intended to be exhaustive, nor to limit the invention to the precise form disclosed; and obviously, many modification and variations are possible in light of the above teaching. Such modifications and variations that may be apparent to a person skilled in the art are intended to be included within the scope of this invention as defined by the accompanying claims.

# IMPROVED UNDERSEA CABLE CONNECTOR

## ABSTRACT OF THE DISCLOSURE

An electrical connector for joining a cable to a cathodically protected body in a marine environment includes a connector body having a terminal connector for joining to the cathodically protected body and a mounting portion for receiving the cable. An encapsulant is formed around and bonded to the body mounting portion and the cable. A means for applying radially inward compressive force is provided to the outer surface of the encapsulant outside of said connector body mounting portion. This force should be sufficient to prevent transfer of positive metallic ions from the marine environment to the bonding region between the encapsulant and the mounting portion.  A method for modifying existing connectors is also provided.

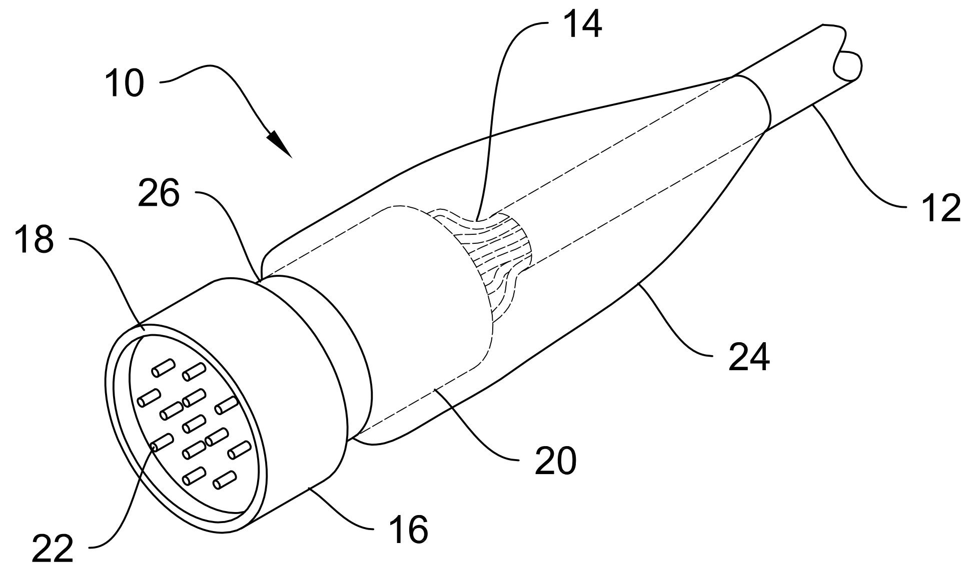


FIG. 1
(PRIOR ART)

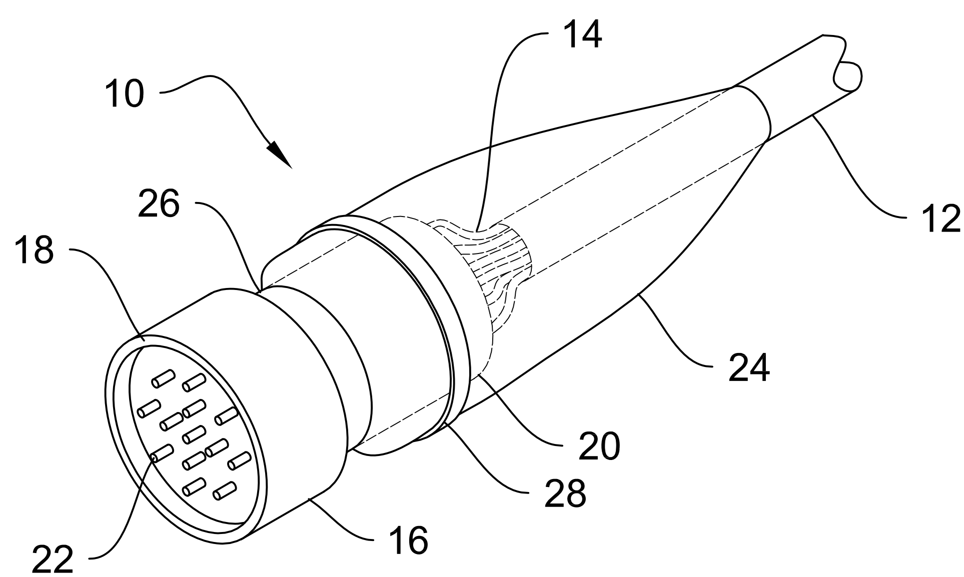


FIG. 2

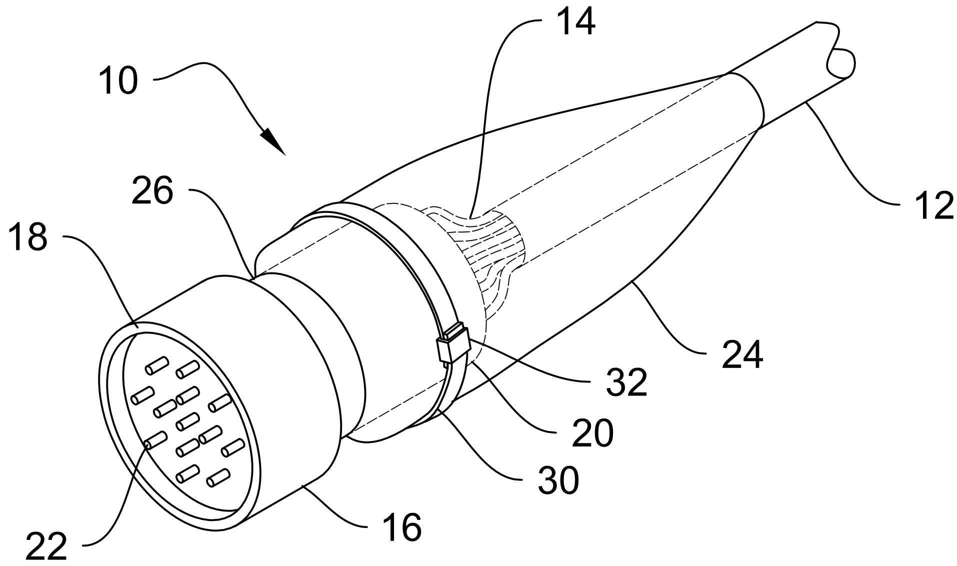
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FIG. 3

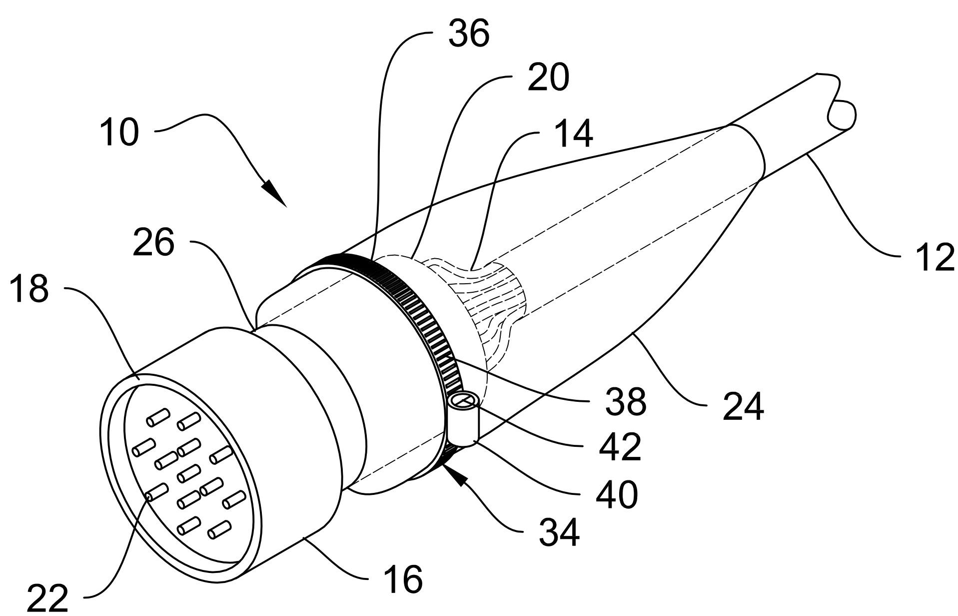
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FIG. 4