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UNDERWATER REPAIR OF ELECTROMECHANICAL CABLES

By

G. A. Edgerton

April 1976

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Procedures have been developed which will allow the underwater repair of electromechanical cables by divers with a minimum amount of training and with off-the-shelf materials. These simple techniques allow repair of electrical systems in-situ as opposed to resurfacing before effecting repairs. The technique combines the use of standard electrical wire crimping equipment, Tygon tubing, and RTV. The splices have been successfully tested in the Civil Engineering Laboratory's (CEL) pressure vessel facility with cyclic pressures to

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INTRODUCTION

A recurring problem for the ocean engineer is electrical system failure by water intrusion at electrical connections, terminations, or splices. The Civil Engineering Laboratory (CEL) has recently developed a technique that allows the in-situ repair of a faulted system. This paper describes the technique and testing procedure and discusses how this technique can be used for other types of electrical cable conductors. The emphasis of discussion is on the basic rules that must be addressed when making underwater splices.

FUNDAMENTAL CONCEPT

Before a reliable splice can be performed underwater, five basic rules must be applied:

1. All air voids within the splice must be eliminated.
2. All ground paths must be eliminated.
3. The splice must be pressure-equalized (no pressure gradient across the splice).
4. A good electrical contact must be made.
5. A wiping action must be supplied when the splice is made to eliminate water from the conductors.

A variety of materials are available for the actual splice, but they must meet the following criteria: (1) they must not be affected by pressure; (2) they must not be affected by oceanic temperature change; (3) the bulk modulus of the compensating material must be less than the conductor insulation to prevent cold-working during cycling; (4) the compensating material must not cause corrosion of the electrical conductor; and (5) the compensating material must not absorb water.

There may be many techniques and materials that can be used if the basic problems are understood and addressed. This report describes two such techniques. Both techniques work well, but the second requires some special order materials, while the first requires only off-the-shelf material.

SPLICE METHODS

First Technique

The first technique utilizes two 2-inch (5-cm) pieces of Tygon tubing, a nylon butt-crimp connector, two plastic ties (ICO/Rally), and a tube of 3140 RTV (see Figure 1A). The 3140 RTV, a Dow Corning product, is a silicone base rubber with a noncorrosive alcohol solvent that vulcanizes at room temperature. To prepare the splice, the Tygon tubing is cemented to each end of the butt connector. This is accomplished as follows. A small amount of RTV is smeared on the outer nylon surface of the butt and the inside surface of the Tygon tubing for a distance of approximately 3/16 inch (4.7 mm) to 1/4 inch (6 mm). Using only the fingers, the Tygon tubing is slipped over the end of the nylon butt. Then a small amount of RTV is applied to form a head on the edge of the tubing to bond to the nylon. This piece is then put aside for 24 hours to allow the RTV to cure. After curing, the Tygon tubing (held in a vertical position) is slipped over the special applicator supplied with the tube of RTV. The RTV is slowly forced into the splice butt, allowing any air bubbles formed to rise to the surface. The ends are then sealed with the plastic ties, and the splice is stored until needed.

When the splice is to be used, the ends, including the plastic ties used for sealing, are cut off by the divers, and the conductors (prepared as would be done for any normal crimp splice) are carefully placed through the RTV inside the Tygon tubing and pushed firmly into the butt connector. Holding both parts in place, new plastic ties are applied near the ends to hold the two pieces in place and to keep the RTV from running out. The butt is then crimped. Most normal tie rap and crimping equipment can be used repeatedly under water by divers as long as care is taken to clean the equipment after use. Since the RTV has an alcohol base, it cures underwater. The completed splice is shown in Figure 1B.

This simple technique does not violate any of the five rules. The RTV remains flexible after curing and, therefore, allows the completed splice to maintain a zero-pressure gradient. The RTV also provides a wiping action to remove any seawater from the conductors. In early splice attempts with techniques where wiping action was not provided, corrosion failure was experienced when power was transmitted through the conductor. Visual observations made of the failed splices indicated that a two-stage mechanism could be responsible for the failures. First, entrapped seawater at the electrical junctions causes a small amount of corrosion which results in the loss of the metal-to-metal electron path in the connection, but does not result in a loss of continuity because of the conductivity of the entrapped seawater. Second, gross corrosion results from the electric current passing through the seawater electrolyte, which is responsible for the ultimate failure of the splice.

Second Technique

Although the technique just described works quite well, the fabrication of the Tygon/butt connector/Tygon sequence is inconvenient, and, if not done with care, the splice can leak. To eliminate this, a butt connector, which consists of a butt-crimp connector inserted halfway into a 6-inch (15-cm) nylon tube, was designed and fabricated (Figure 2A). The procedure for filling the butt connector assembly with RTV and the technique of performing the underwater splice itself are identical to the technique described above. The finished splice is shown in Figure 2B. Using this extended butt connector assembly eliminates any inconvenience and allows the entire splice preparation to be done at sea. If necessary, these butt connectors can be filled with RTV just prior to use if the RTV is allowed to set for an hour to start curing.

TESTING

Pressure Vessel

During the testing, 24 splices were prepared using the technique employing Tygon tubing: six with AWG 16 PVC-insulated wire, six with AWG 18 PVC-insulated wire, and the remaining 12 with Teflon-insulated wires ranging from AWG 22 to AWG 12.

These splices were checked for electrical leakage in the CEL Pressure Vessel while cycling the pressure from 0 to 500 psig (34 atm) at two different temperatures: one near 18°C and the other near 3°C. All leakage measurements were made with a 1-kV DC and 600 volts AC, 60-Hertz, high-voltage insulation tester. The DC measurements were estimated to the nearest 0.25 μA, and the AC to the nearest 0.1 μA. When making leakage resistance measurements dealing with thousands of megohms, the stray leakage of the test vessel wiring becomes an important factor. To take this into account, the wire to be spliced was connected to the pressure vessel plug, and the leakage resistance of the measuring system was taken. Then, the wires and the penetrator plug were removed, and the wire was cut. Splices were then made underwater and again measured for leakage current. The test data indicate that the additional leakage current measured due to the underwater splice is very small, and that the leakage of a normal splice is on the order of thousands of megohms.

All the splices showed a leakage current of less than 1.5 μA at both voltages. The splices were cycled and tested for a period of 2 weeks. They were then tested in the pressure vessel at 500 psig (34 atm) at 3°C to determine long-term performance. After 4 months with no failures the splices were removed from the pressure vessel.

At-Sea Operations

There have been numerous at-sea repairs of electrical cable accomplished by CEL divers. The faulted wires that required repair were single-conductor AWG 18. The insulation was a dual-wall radiation, cross-linked

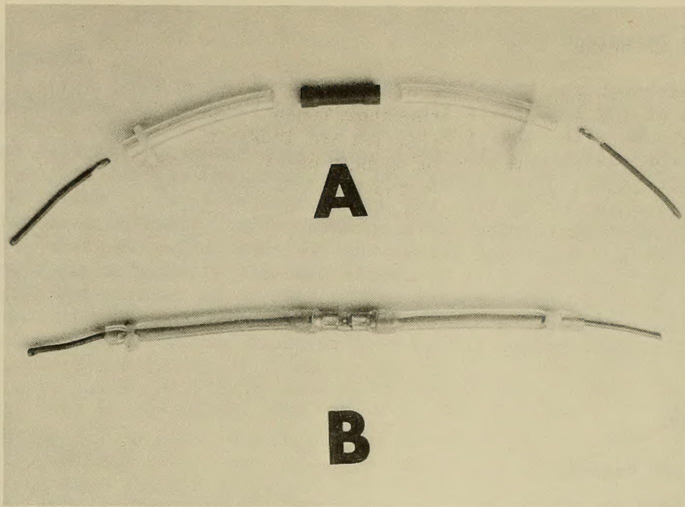

Figure 1. Components for underwater splice using the butt connector/Tygon tubing techniques. Before assembly (A), and after completion of splice (B).

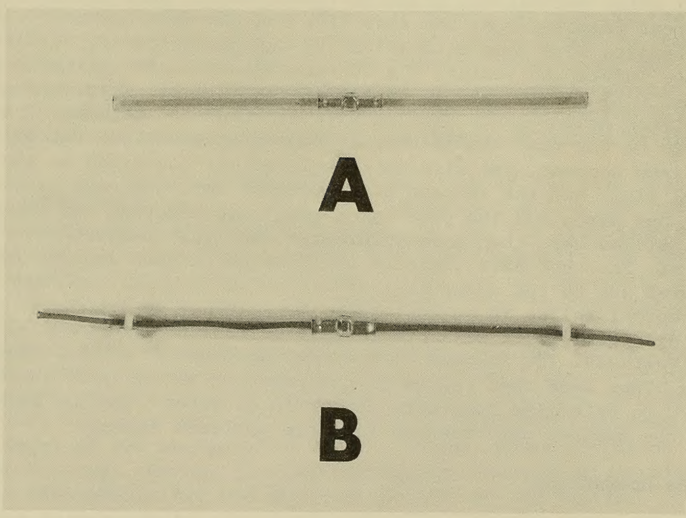

Figure 2. Butt connector centered within 6-inch (15-cm) nylon tube. Before (A), and after completion (B).

poly-alkene and polyvinylidene fluoride. The majority of these have been spliced using the Tygon tubing technique. Some earlier attempts using a slightly different technique failed because of two problems. First, when the butt splice was crimped, the crimping tool tore the Tygon tubing, allowing a ground path to exist. Second, there was sea-water trapped inside the splice, and the splice failed due to corrosion.

Using the improved techniques, at-sea splices were made at depths between 50 and 100 feet (16 and 31 meters) by divers. The underwater splices, for both power and data conductors, have been continuously in operation at the site for 4 months with no failures.

CONCLUSIONS

As shown by the results of the testing program CEL has developed a technique which allows underwater repair of both data and power electrical, single or multiconductor, cables. These repairs can be reliable accomplished by divers having a minimum amount of training, at any diver depth, using off-the-shelf materials.

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