JOINTING OF ARMORED POLYETHYLENE-INSULATED CABLE TO NEOPRENE JACKETED CONNECTORS[1]

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ABSTRACT

Low cost, waterproof, easily implemented jointing of armored electrical cable to neoprene jacketed cable has been required for power/signal cables deployed in the nearshore zone. The primary difficulty in jointing was associated with bonding to polyethylene insulation within the armored cable. The most troublesome problems encountered were field reliability and deterioration with prolonged storage. Four methods of jointing with histories of variable performance have been used by the Shore Processes Laboratory (SPL) of Scripps Institution of Oceanography; these techniques were all inexpensive, and readily implemented in the field. Two methods used encapsulations, one used a heat shrink tubing while another consisted of a mechanical device. Recently the encapsulation methods developed a high failure rate; consequently these splicing methods are no longer used at SPL. The mechanical and the heat shrink methods have performed well in the field and have potential for future applications.

INTRODUCTION

Low-cost, reliable, waterproof jointing of neoprene jacketed connectors to the ends of armored electrical cables has been a serious problem. In some cables polyethylene is extruded around individual conductors to form a water barrier and electrical insulation. While this material provides a good, inexpensive, lightweight water barrier and electrical insulation, it does present some unique jointing difficulties. Few readily available chemical compounds will bond to this insulating material, hence a long-lasting, waterproof joint of this cable to a neoprene jacketed connector is hard to achieve. A literature search revealed a number of articles on marine cable splicing and jointing (i.e.: 1) Allen, R.W., 1976, 2) Meyers, et. al., 1969, 3) Basile and Kubis, 1976), but no articles treating this particular jointing problem were found.

Between 1972 and 1980 W. Spencer was involved in cable installation activities at the Shore Processes Laboratory (SPL) of Scripps Institution of Oceanography, La Jolla, CA. The primary responsibility imposed on cable systems by the lab was that of conveying signals and power (low voltage and current) to and from instruments located in the nearshore zone. These cables would typically be connected to data recording stations or data telemetry stations (Lowe, et. al., 1972). Cables were often required to penetrate the surf zone on a sandy beach, which subjected the cables to severe mechanical stresses as well as pressure fluctuations, both of which can cause failure in cable terminations and joints.

In 1975 the Shore Processes Laboratory decided to standardize to an armored cable that was readily available, inexpensive, and that could be handled by divers and beach personnel with relative ease. An armored cable using polyethylene, extruded around the individual conductors, for the only water barrier and electrical insulation was selected. Jointing of this cable to neoprene jacketed pigtail connectors had to be inexpensive as well as watertight. Joints had to be watertight in a nearshore ocean environment over periods ranging from 30 days to one year. The joints had to be inexpensive (less than $50 per joint), and relatively easy to construct; some were required for reuse, without rejointing, after prolonged storage. The cables were mechanically terminated by a system external to the joint, therefore the major mechanical requirements imposed were that the joint withstand transport in an open truck and the abuse received during operations in a sandy nearshore ocean environment.

TESTING

Cables were tested for 24 hours in a 9.1 m. (30 foot) tank of fresh water (tests during early years 1974-1977 were conducted in other tanks with lesser depths and shorter submergence times). An insulation tester was used at a voltage of 500 volts. A test criteria of 1000 meg ohms of resistance to current flow across the conductor insulation was used to separate acceptable cables from unacceptable cables.

JOINTING TECHNIQUES

Four jointing techniques were used by SPL with histories of varying performance: epoxy encapsulation, polyurethane encapsulation, a mechanical joint, and a heat shrink joint (listed in chronological order of their development). Table 1 describes performances and attributes of the four jointing techniques.

Epoxy Encapsulation:

A watertight joint (Fig. 1) was achieved by surrounding crimped or soldered connections with

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TABLE 1

	Epoxy Encapsulation	Polyurethane Encapsulation	Mechanical	Heat Shrink
Cost/Splice[1] (after development)	$10	$15	$30	$20
Shelf Life[2]	Poor	Poor	Poor	Good
Success in ocean	80%	90%	95%	95%
Field Jointing	Fair	Poor	Excellent	Excellent
Ease of Joint[3] Construction	Good	Poor	Very Good	Excellent
Resistance to Physical Abuse	Very Good	Very Good	Excellent	Poor
Development Cost[4]	Low	Low	High	Very Low

1 1979 Dollars (approximate, does not include development costs)

2 Heat shrink jointings were tested after 3 months storage with better than 80% passing the test (see Testing).

3 About 1.5 man hours are needed per joint in constructing the polyurethane encapsulation.

4 Development cost for the mechanical technique was less than $1000.00.

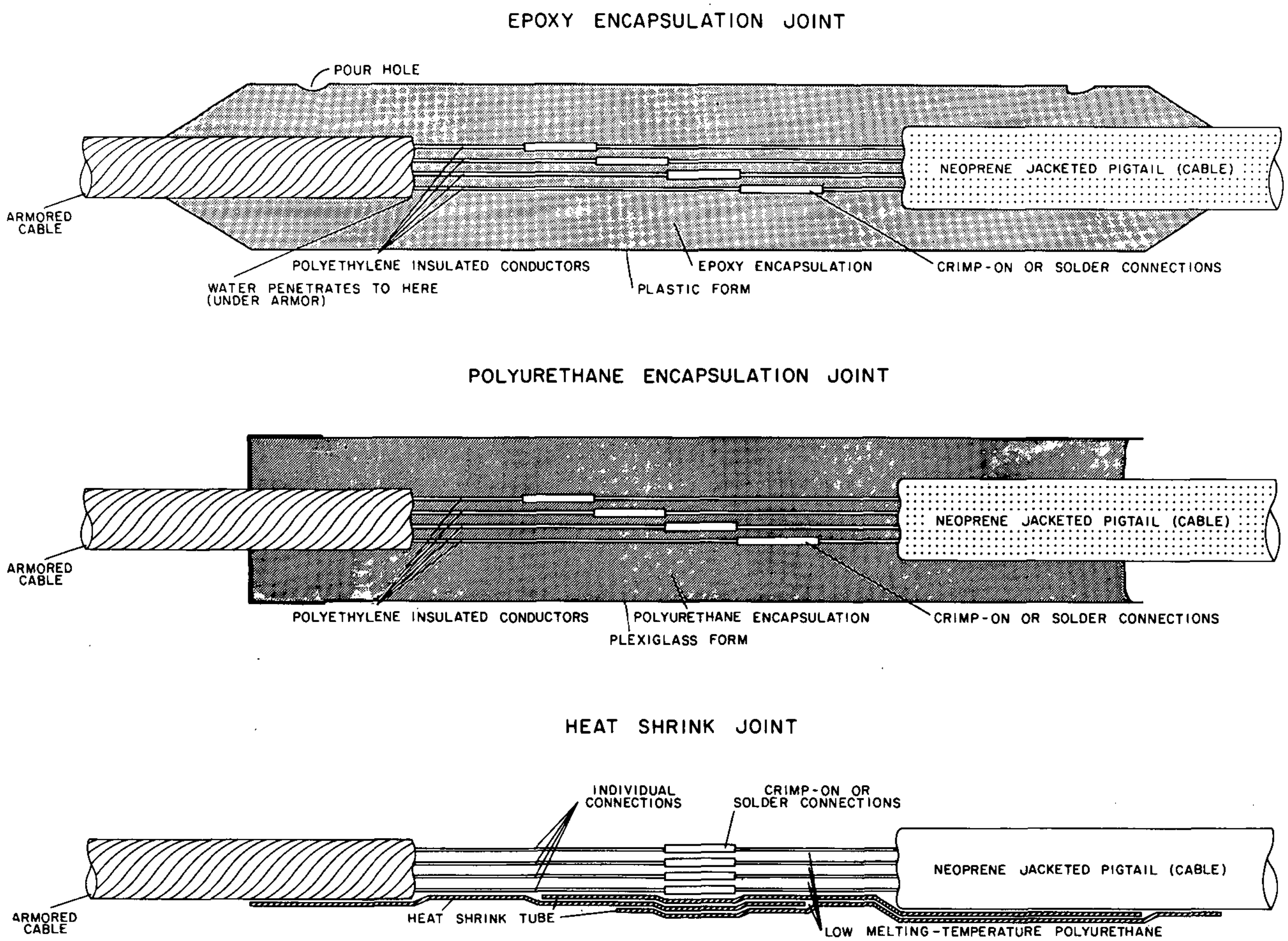

Figure 1. Section view of the encapsulation and heat shrink jointing methods.

an encapsulation of epoxy ("Scotch Cast" Kit No. 82-A2, 3 M Company). This splice served SPL between 1974 and 1979; during this period a success rate[1] of approximately 80% was observed with 50 to 100 joints used. However, this jointing technique failed repeatedly during testing prior to a November 1978 experiment. The cause of this failure was not determined and the technique was subsequently abandoned.

Polyurethane Encapsulation:

This joint (Fig. 1) used a technique similar to the one used in the epoxy encapsulation joint except a polyurethane product (Polycon 6455, Yale Enterprises, San Diego, California) was used to encapsulate the conductors. A success rate of about 90% for 30 joints during a November 1978 experiment was realized. This joint had a short shelf life (length of time a joint remains waterproof after use; this was established by testing the joint after it had been stored a period of time, see Table 1). Due to this poor shelf life and an unpredictable cure of the Polycon product, this technique was abandoned.

Mechanical Joint:

A mechanical joint (Fig. 2) was conceived and designed by W. Spencer at SPL. The device used washers to seal around the surface of the cable conductors and the jacket of the neoprene pigtail (short cable from the connector). These washers were molded out of pourable polyurethane, to closely fit the surfaces to be sealed. Three washers were stacked along the connector pigtail to seal that end of the joint (Fig. 2). The armored cable conductors were inserted through a four or seven hole washer (four and seven conductor cables were used during some experiments) to seal the other end of the joint. A watertight barrier was formed when force was exerted on these washers by tightening the compression screws located on either end of the plexiglass case. A mechanical termination of slight strength was afforded the armor strands by the beveled fittings (Fig. 2, wedge washer) located just inside of the compression screws (Table 2). This device was used for jointing cables used during an experiment in 1980 at Santa Barbara, CA. Cracking of the plexiglass case was observed (possibly due to plastic deformation and subsequent yield upon exposure to bright sunlight) before cable installation. Hose clamps were tightened at these crack points thereby containing the inside pressure and preventing further cracking. Approximately 95% of the joints were successful in the Santa Barbara experiment (out of a total of about 40 joints). This joint exhibited a poor shelf life (90% failed after 3 months of storage). The major problems with this splice seemed to be that with time the sealing washers were partially extruded into the joint volume, and that cracking occurred in the pressure case. By making the washers of neoprene, the case of metal, and installing springs to compensate for washer volume loss, these problems might be overcome.

Heat Shrink Splice:

From 1976 to 1979 Israel Oceanographic and Limnological Research LTD., at Tel-Shikmona, Haifa, Israel used a heat shrink joint on a type of cable similar to the cable used by the Shore Processes Laboratory. This heat shrink joint (Fig. 1) was installed on about 30 cables and had a success rate of 97%, during a four month long SPL experiment. The heat shrink joint consisted of 3 pieces of heat shrinkable tubing (made of polyethylene and coated inside with low temperature meltable polyurethane). Subsequent testing (see Testing) of jointed cables after three months of storage resulted in less than 10% failure (personal communication, M. Freilich, SPL). This jointing technique seems to offer good potential for success in applications where an armored electrical cable is to be jointed to a neoprene jacketed pigtail connector.

SUMMARY

Over the course of eight years at Shore Processes Laboratory four major jointing techniques were used for marine cable installations. The techniques were used almost exclusively for jointing neoprene jacketed pigtail connectors to armored electrical cables that used polyethylene for the only water seal around individual conductors. Some qualities of these joints are tabulated in Table 1. Of these techniques, the mechanical and the heat shrink techniques show the most potential for success. The mechanical joint has the advantage of being inherently more resistant to the physical abuse often encountered during ocean applications. It has a short shelf life, which could be lengthened by constructing the case of stainless steel (to avoid the plastic deformation of plexiglass), machining more tightly fitting parts, making washers of neoprene instead of polyurethane, and installing compensator springs (to compensate for loss of sealing surface pressure due to partial extrusion of seal washers into the case voids). An increase in cost per splice would result from using a metal case (due to the material cost and increase in labor required to fabricate each case). If a mechanical stress relief were added to the design of the joint (this could be added on one or both ends of the joint with an increase of total case length), the joint would be even more useful.

The heat shrink joint holds potential for success in cable applications of the type described in the introduction. This joint can be used with no further development, using a commercially available product that is inexpensive and easy to install.

The epoxy and the polyurethane encapsulation techniques are not recommended for the applications described in this paper, based on problems with curing and adhering to polyethylene cable insulation.

PARTS DESCRIPTION FOR MECHANICAL JOINT

(TABLE 2)

1. Compression screw: This screw is used to apply compressive force to the mechanical terminator parts.

[1] Defined as the percent of joints that did not fail during field use.

MECHANICAL JOINT

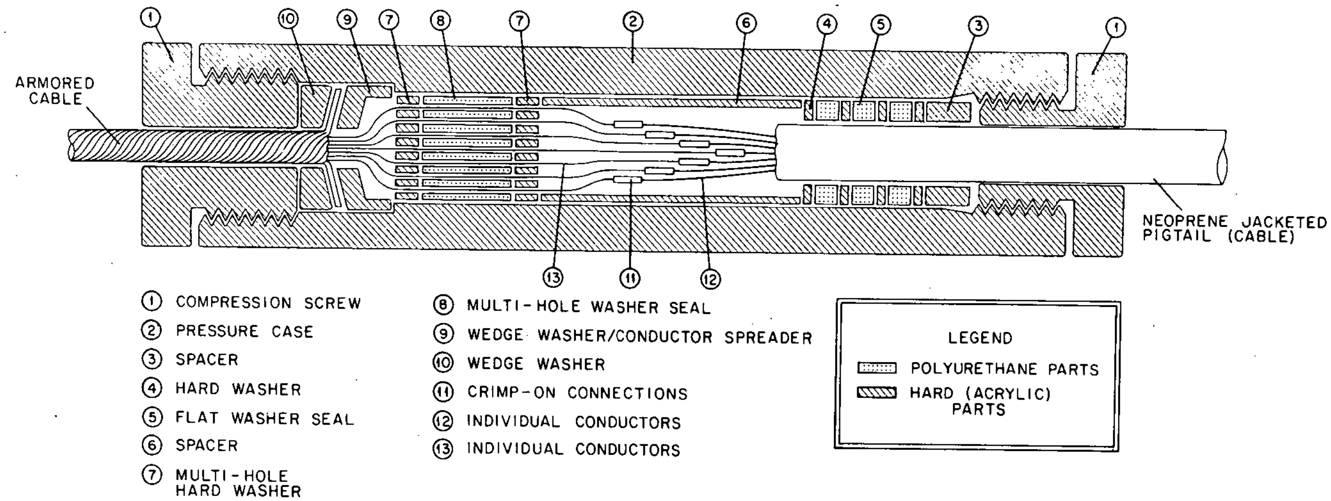

Figure 2. Section view of the mechanical joint.

2. Pressure case: This case houses the assembled parts and A) contains the expansive forces from the compressed washer, B) withstands the compressive forces due to water pressure while C) keeping the water from entering into the joint through its surfaces.
3. Spacer: This spacer is used to ensure washers (5) are not compressed onto case treads.
4. Hard washer: Used to separate sealing washers (5) to ensure 3 separate sealing areas on this end of splice and to transmit compressive forces from screws.
5. Flat washer seal: Compressed between hard washers thereby creating a seal.
6. Spacer: This spacer is used to transmit the compressive force past the electrical connections.
7. Multihole hard washer: This washer is made with the proper number of holes (equal to the number of conductors in the cable and symmetrically spaced) running through it and is used to compress washer (9) uniformly.
8. Multihole washer seal: This washer is used as the "pliable solid" which is compressed around the individual conductors of the armored cable, and against the inside of the case to cause a water block at these surfaces.
9. Wedge washer and conductor spreader: This washer is used as A) a surface to trap and hold the splayed strands of armor and B) a device to allow the individual connectors to spread apart before entering washers (8) and (9).
10. Wedge washer: The washer compliments part (10) in trapping and holding splayed strains of armored cable.
11. Crimp-on connections.
12. Individual conductors.
13. Individual conductors.

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