Breakthrough Advances in Cable Termination Technology

Robert E. Lindberg
President & CTO, RELTEK LLC

***Abstract* - New molding materials and technology lead to breakthroughs in terminating and splicing cables for harsh environments. Simplicity is key - simple surface preparation and no primers, even for substrates of polyethylene, polyolefin, polyurethane, and rubber. The new technology provides high moisture and chemical resistance, reliability, cost reductions and faster turn-around. True water blocking for deep sea deployment is achieved, even for on-board ship repairs of flooded cables. Examples of results in naval and marine applications illustrate that the versatility achieved in design engineering and application is extraordinary.**

I. INTRODUCTION

In sealing electrical cable for marine environments, we all know the issue is to seal an electrical signal from damage by the environment it is measuring or moving through. Probably every conceivable method of accomplishing this has been tried, including the use of chewing gum (not such a bad idea because chewing gum is made from polybutyldiene [PBD], a very moisture resistant resin system).

And sometimes it works and sometimes it doesn't.

I'm sure we've all got multiple real life examples of both results.

II. PRINCIPLES OBSERVED

Let me say a little about the requirements of previous technology available. There are some basic principles of what makes a seal work, or not. And some creative methods of trying to achieve those with the previously available materials.

First the fundamental requirements:

- it needs to resist water, naturally,
- it needs to have sufficient chemical resistance to maintain performance over time,
- it needs to offer sufficient mechanical strength to support the electrical junction from system stresses,
- it needs to be manufacturable at a cost consistent with the system design; and
- it needs to be installable and deployable in a short time when a field or in-situ application is involved.

Now some of the creative historical methods to meet the fundamental requirements:

- using multiple systems, and multiple seals (which may help or hurt reliability);
- using multiple material combinations for chemical resistance which complicates sealing problems, creating the need for different systems and seals to address each material choice;
- not obtaining chemical bonds, just requiring moisture resistant chemistry;
- not stopping moisture permeation but controlling it to tolerable levels.

The most common approach to sealing electrical cables in the marine environment is by over-molding boots with rubbers and thermoplastics. Other methods include premolded boot shells with hose clamps and various filler materials, and mechanical seals. I'm leaving out the more exotic aspects of hermetic seals with glass seals and welded feedthroughs.

Issues come up about material selection in cable and wire insulation, and adhesion to those substrates as well as adhesion to the electrical components and how to make those seals water tight.

Well, let's look at one of the more frustrating aspects of these issues. Essentially it boils down to good chemical resistance leads to material choices that are inherently difficult to bond to substrates in cables. Examples are polyolefin, such as polyethylene and polypropylene and their blends with EPDM, flouropolymer based materials, and other exotic resins. Chemical resistance implies resistance to chemical reactions and hence resistant to chemical bonds. So special surface preparation is usually required to get water tight seals. Here's the thing -- with modern resins and reactive agents that isn't necessarily so!

III. THE NEW TECHNOLOGY

What if it were possible to rely on materials or systems that you know will seal off water or chemical invasion every time without surface preparation or primers?

For some time now it has been possible to form water tight seals with many such substrates with no special surface preparation. This applies even to cables that are water logged -- filled with water from a jacket penetration during deployment. The cables can even be repaired without removing the water!

The new resin systems are based on a unique proprietary reactive epoxy resin that incorporates multiple chemical components in the backbone to provide high chemical resistance and flexibility without the need for plasticizers or other additives that typically compromise performance in chemical resistance, mechanical properties or adhesion. Combine that with new curing systems and an amazing technology is born that can be used as a potting compound, sealant, coating, adhesive and even primer for almost any substrate.

IV. DEMONSTRATED SUCCESSES

It sounds too good to be true. So here's some data.

This new resin and curing system has been implemented in many of our customer's cable termination designs as a direct replacement for conventional polyurethane. It bonds to polyethylene, polypropylene, polyurethane -- including two-part elastomers -- and thermoplastic urethanes (TPU), most black rubbers -- including EPDM, -- Neoprene and Butyl rubber, flouropolymers -- including Tefzel, PVDF, Hytrel, Halar, you name it, with only simple abrasion and an IPA wipe for preparation. These applications of the new system have deployed to full ocean depth, in chemical environments like sewer pipes and even in Taiwan Bay. They have survived thermocycling between -50°C and 150°C, and have withstood acid solutions of pH 4 to alkaline solutions of pH 11, among other stressors, since first introduced at the beginning of 2001.

In one example, a 3.5 KVA cable flooded at sea and shut down operations for building an oil platform for Shell Oil. Its usual deployment was to 1600 meters - a mile deep in the ocean -- and back -- time after time. Our new resin system was implemented in a kit for field repair of the cable, while it was still flooded. Requirements in the assembly included bonding and sealing to polyethylene wire insulation, EPDM cable jacket, urethane and PVC, HDPE high voltage pin insulators, Teflon connector insert, polyolefin shrink tubing, gold, nickel, solder and brass metals. The sealed design has continued in operation successfully for several years, and been replicated with multiple other flooded cables which were repaired with this system because of the success of the initial repair.

In another application, for the U.S. Navy, an onboard repair kit was developed for fast repair of multiple flooded cables for power and signal applications. The materials in the flooded cable included polyethylene wire insulation, polyurethane cable jacket, polyolefin shrink tubing, gold, nickel and brass metals. The system was used at the factory to over-mold new connectors to a pigtail. Then the pigtails are taken to sea and over-molded with the new resin system -- and immediately thrown overboard to allow curing underwater, fully deployed. The five repair jobs for five 19-conductor cables can be performed on site at sea in two days from start to finish.

In another application for deployment on equipment for cleaning out sewer pipes, the cable providing signal transmission was a 9-conductor subminiature cable made of polyethylene wire insulation and polyurethane cable jacket. The new resin system is the sole protection for the connector termination -- providing backfill of the connector, over-mold and sealing of the cable, strain relief and abrasion resistance.

The same resin system is employed as a seal for polypropylene piping, used in clean rooms for semiconductor manufacturing carrying highly acidic and highly caustic liquids. The polypropylene pipe moves the chemicals throughout one of the largest major semiconductor manufacturer's facility. The pipe joints originally were welded together. Then the welds cracked and leaked chemicals onto the clean room floor -- something unacceptable in a Class V clean room. Equally unacceptable was closing down production of such a large operation to repair the pipes. The new resin system was used to reseal the leaking pipes with nothing more than a simple abrasion of the cracked area and application of the resin. It cured and sealed without stopping operations.

The new resin system is even used as a primer and adhesion promoter for other over-molded sealing systems, such as polyurethane rubbers. The system is used for bonding UHMW polyethylene and rubber to the sides of steel-clad barges and used are bumpers for aircraft carriers -- with nothing more than the resin as the adhesion system -- no mechanical fasteners. The system has been used to bond UHMW and fiberglass to create metal-less composite hulls for ROVs and make successive deep-sea deployments for the past four years.

This resin system has evolved to provide a whole range of materials -- from water blocking of cables as a highly elastic, high-tack material (i.e.BONDiT™ B-46 and B-4682), to medium flexible high-strength materials used for connector-cable-transducer terminations (i.e. BONDiT™ B-45, B-482 and B-4681), to very high strength semi-rigid materials for structural applications (i.e. BONDiT™ B-481). It is also a primerless, direct replacement for polyurethane rubber with high chemical resistance.

Without the use of primers, adhesion promoters or special preparation, this amazing resin system will bond to virtually anything -- almost all metals including silver-coated acoustic ceramics and copper (and is stronger than the ceramic), titanium, brass, stainless steel -- all the common metals. It also bonds to most thermoplastics and thermoset plastics, many rubbers and urethanes, glass, ceramic, concrete, aggregate, wood and cellulose. It will bond in the presence of moisture, apply and cure underwater. It is even used in a caulking version for patching old boat hulls still in the water.

The system may be made electrically insulative or conductive -- and without the use of metal, so it is suitable for stealth applications (the system is qualified in life critical applications on military fighter aircraft) - and can be made thermally conductive and/or colored. It can applied via spraying like a paint, dipping, pouring, brushing, or applied with a spatula - there is no particular limit on application methods. It can be ambient cured in 24 hours, and thermally cured in a few hours. It can even be catalyzed to thermally set in ten minutes at only 65°C.

Development of this system continues with a new "polyurethane look-alike" for saltwater acoustic applications and high temperature versions.

V. CONCLUSION

In conclusion, as we've discussed, this system was designed to address and provide a solution for the fundamental requirements of a sealing system, ie. water resistance, chemical resistance, mechanical strength, cost effectiveness, and deployable quickly in the field. But better yet, it addresses the inherent problems identified in the creative workarounds we discussed – simplicity reigns, this is a single system, multiple materials (previously needed to provide chemical resistance) can be done away with, cohesive chemical bonds are obtained and moisture resistance is both very high and sustained. It succeeds where others fail in making the job of terminating cables, connectors and transducers very easy -- with no other materials required and no special preparation of the substrate. Use of this system can thus reduce the cost of production and provide superior durability and reliability in the field. It offers the four benefits that we are all looking for: simplicity, reliability over time, repeatability and cost effectiveness.