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Custom ABS-Certified Penetrators For Use on Tourist Submarine

Penetrators Provide Safe, Efficient Solution

By Amy Brown

Developing equipment that safely and reliably transmits electrical power or signal through a manned submersible's pressure boundary requires advanced engineering, manufacturing and testing protocols. Penetrators for manned submersibles must pass through the pressure boundary without compromising its integrity and, therefore, become an integral part of the boundary itself. Since the integrity of a penetrator in such an application becomes an essential component of the vehicle's life-support system, penetrators must be certified by an organization like the American Bureau of Shipping (ABS). Once approved, these systems provide an ideal solution, delivering safe, rugged, long-term connectivity options that require nominal maintenance despite long-term operation in seawater. The high cost of downtime for any submarine can potentially be a serious issue, especially for tourist submarines, which work back-to-back tours, providing all income for the entire operation. Therefore, a connectivity solution like penetrators is ideal, eliminating the need to factor in regular maintenance on outboard cables.

DeepSea Submarine Technologies Inc. (Saipan, Northern Mariana Islands) recently contacted BIRNS Inc. (Oxnard, California) to develop 18 ABS-certified custom penetrators and cable assemblies for its 68-foot, 300-FSW-rated manned tourist submarine, Deepstar. The DS-48 class, 68-foot long, ABS-ASME-certified sub is capable of carrying up to 48 passengers on a coastal route in Saipan Lagoon, Northern Mariana Islands, usually with dive durations of 60 minutes. DeepSea Submarine Technologies needed to retrofit the 15-year-old sub to replace its thruster and control cables with BIRNS P3845 straight penetrators (P38 penetrator size, 45-millimeter thread length), in both four (P3845-4-LS) and 10 (P3845-10-LS) conductor configurations. The penetrators were highly customized to include special marine-grade cable stock of various lengths, as well as electrical shielding and special termination. The P38 shell mounting threads were unified thread standard (UTS) UNF-2A; 1.5 to 12 with a 12-threads-per-inch



A J-STD-001 Class 3 certified technician electrically terminates a double-ended insert for a P3845-10-LS penetrator for the submarine.



(Top) After the polyurethane overmolding process, a penetrator is removed from its aluminum mold and ready for testing. (Middle) A six-cycle saltwater hydrostatic pressure test is performed, with the outboard side of the penetrator held to pressure of 1,000 psi. (Bottom) Final custom penetrator cable assemblies for the 68-foot Deepstar.

(TPI) and a 1.5-in. male thread outside diameter. The submarine had a pressure hull thickness penetrator plate of 0.98 inches and a maximum pressure of 108.75 psi (7.5 bar).

All of the penetrators supplied by BIRNS required ABS certification and witnessing, as well as low-smoke, zero halogen (LSZH) wire inboard, where there is 1 atmosphere of air. LSZH cable jacketing is composed of compounds that emit negligible smoke and no halogens when exposed to high levels of heat. Thus, in the case of fire, LSZH cable greatly reduces the amount of toxic or corrosive gases released, which is why most authorities, such as ABS and DNV, require LSZH for pressure vessel for human occupancy (PVHO) use. A PVHO is a pressure vessel that encloses a human being within its pressure boundary while it is under internal or external pressure that exceeds a 2 psi differential pressure. PVHOs include submersibles, diving bells, personnel transfer capsules, decompression chambers, recompression chambers and hyperbaric chambers.

Penetrator Development

BIRNS created the penetrators for Deepstar according to its ABS product design assessment certified electrical penetrator design. However, since the application required straight penetrators versus right-angle, BIRNS first worked with ABS to include the straight design in its existing type designation that covered right-angle designs. The straight configuration represented no technical deviation from the already approved and more common 90-degree configuration. However, particularly in the post-*Deepwater Horizon* era, ABS design requirements for manned submersibles have tightened to become even more specific and involved. BIRNS's design, drawing and test procedures for the new

straight penetrator subsequently received ABS type approval, and then manufacturing began.

BIRNS precision engineered the P38 penetrators to stand up to long-term use. They were designed with 316 stainless steel shells, the most seawater corrosion resistant of all stainless steel alloys. The shells were then passivated per American Society for Testing and Materials (ASTM) A967-05. When a stainless steel (or any metal) part is machined, tiny particles can infiltrate the surface of the base metal, potentially making it more susceptible to corrosion and more at risk to environmental degradation. The passivation process involves removing unwanted material from the part's surface and then submerging the part into a passivating bath, which provides a coat of protective material. Additionally, each penetrator incorporated a 6-kilometer, open-faced, pressure-rated insert, which would provide absolute failsafe protection, as the inserts alone would serve as a water ingress barrier—especially important for a man-rated vehicle.

Functions Met by the Penetrators

The penetrators were designed for the following systems: aft vertical and lateral power, forward vertical and lateral power, aft vertical and lateral control, forward vertical and lateral control, starboard main control and power, and port main control and power. Each of the penetrators had a BIRNS Millennium series connector 3R shell size insert with



(Photo Credit: DeepSea Submarine Technologies Inc.)

(Top) The pilot compartment in the ABS-, ASME-certified tour-ist submarine. (Photo Credit: DeepSea Submarine Technologies Inc.) (Bottom) Deepstar underway on one of its 60-minute dives in Saipan, Northern Mariana Islands.

double solder pots. Six were 3R-RID-4 inserts, with four 2AWG contacts, developed for the power applications on the Deepstar, and they required a 1,000-volt-rated, 64-amp Mil-STD cable: MIL-DTL-24643/67A-05UO 3 conductor 7AWG shielded cable. Deepstar had three-phase Kohlmorgan motors, one 11.2 horsepower and one 21.4 horsepower, running at 208 volts, with four-conductor cables. The vehicle had a surface speed of 3.2 knots and a surface rotation rate of more than 180° per minute.

The remaining six penetrators had 3R-RID-24 inserts with 24 14-AWG contacts for the control functions on the vehicle. They were terminated to 22 contact 12-AWG twisted shielded pair (TSP) cables. All of the cable assemblies (primes as well as spares) had 8 meters of inboard cabling and had outboard cabling ranging from 2 meters to 20 meters.

Testing

BIRNS tested each penetrator according to its ABS-approved test procedure, ETP-6510-101-Rev H ABS. The testing began with helium pressure testing on the inserts before termination or overmolding. Helium testing is more demanding than similar tests with air, as helium atoms are radically smaller and move much faster than oxygen molecules—ergo, helium diffuses through solid materials three times faster than air. Each insert was attached to a pressure fixture and submerged in a tank where the inboard side of the insert was held at 1.5 times the design pressure of 625 psi for a period of 10 minutes.

The cable conductors were then soldered to both inboard and outboard sides of the insert by J-STD-001 Class 3 and

WHMA-A-620-A Class 3 certified technicians. The insert assemblies are inspected per J-STD-001, Class 3. Next, an insulation resistance (IR) test was performed with BIRNS's automated 16-channel Hi-Pot and IR testing system at 500 +/-50 VDC (707 VAC) between all electrical conductors, as well as between each conductor and the shell.

Once that test was successful, the shell was attached to the penetrator, which was mechanically reinforced with a high-strength potting compound and then overmolded with polyurethane molding on the outboard and inboard sides, which provides maximum resistance to harsh marine environments. An ABS technician inspected the cable assembly to ensure that there were no cracks or defects that might cause a failure of seals. The entire penetrator was then given a dielectric withstanding voltage test on each conductor individually, per MIL-STD-1344A, by applying 1480VDC (1kVDC), plus twice the design voltage of 240 VAC, between the conductor and the penetrator body, held for one minute. The outboard cable end was then potted with polyurethane.

Then, a six-cycle saltwater hydrostatic pressure test was performed, wherein the outboard side of the penetrator was held to pressure of 1,000 psi. During the sixth cycle, the penetrator was given another IR test, while at pressure, to 500 VDC (707 VAC) for a minimum of one minute between the conductors and the shell. A final helium test was performed on each completed penetrator, with its inboard side inserted into a 10-foot-long helium test fixture and pressurized to 1,000 psi of helium to check for any leakage using a MIL-L-25567 compliant gas leak detector.

At the time this article was written, the penetrators had not yet been installed on Deepstar. However, DeepSea accepted them according to its protocol for electrical penetrators, number 06-ED-402, Rev. 1, 10 MAR 98, which required stringent testing and inspection upon receipt of the assemblies. The testing included an IR test on each penetrator and assembly at 500 VDC, between each conductor and the penetrator body. Minimum acceptance level for this test was 5 megohm (MΩ). BIRNS penetrators passed all tests and inspection, and will be installed at the next scheduled dry dock planned for the sub in 2017, according to ABS and United States Coast Guard procedures for inspected passenger submersibles.

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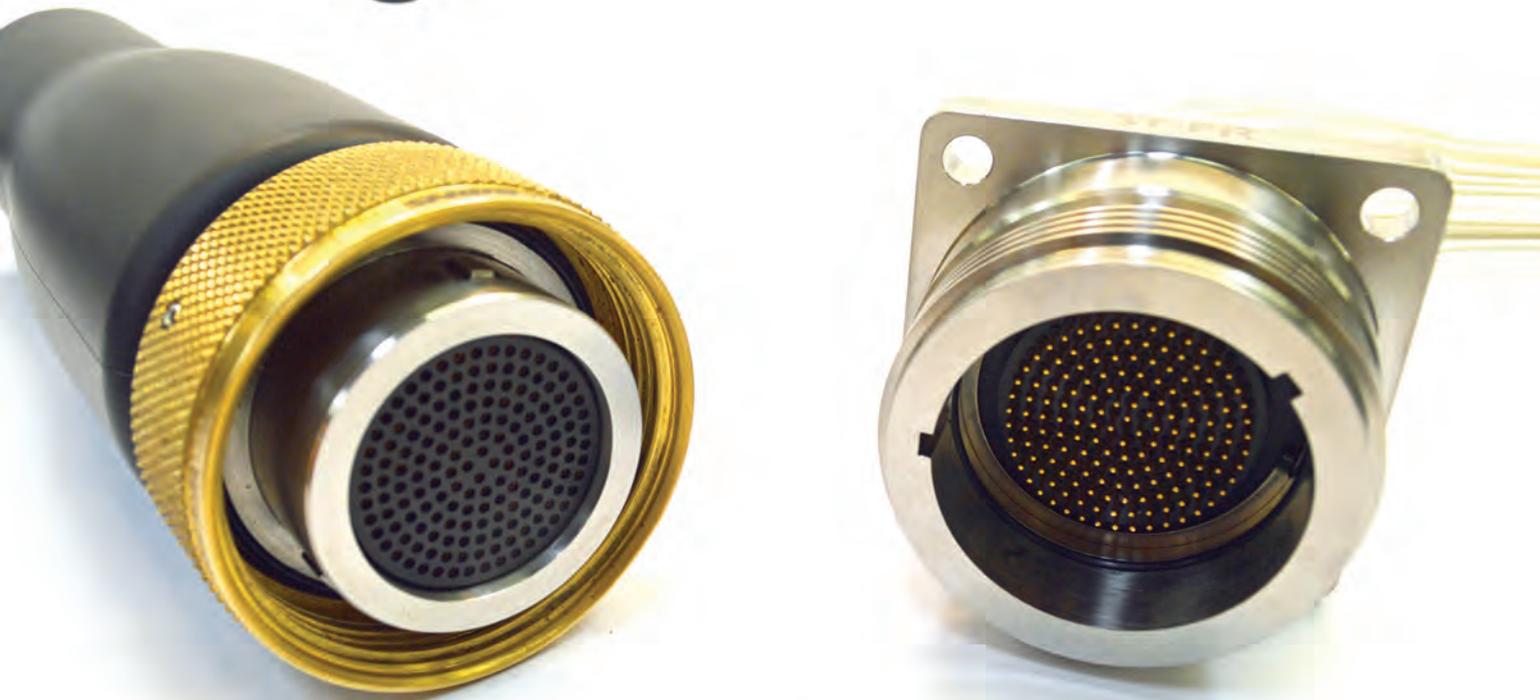
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