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Deep-Submergence Electrical Connectors For 4,500-Meter-Rated AUV

BIRNS Develops Cable Assemblies for High-Pressure Environments

By Amy Brown

Subsea connector technology has advanced apace with the increase in the use of sophisticated new vehicles to explore the ocean. Connector systems for these innovative submersibles can now provide faster, more accurate communication, increased options in power and signal, and enhanced performance capabilities for sensors, cameras and sonar. As today's underwater vehicles are also becoming more compact and powerful, so too are the connectors serving as conduits for their wide ranges of complex systems.

As an example of such synergy, BIRNS, Inc. (Oxnard, California) was asked by Bluefin Robotics (Quincy, Massachusetts) to develop 12 deep-submergence custom cable assemblies with BIRNS Millennium electrical connectors. The cable assemblies were for its new 4,500-meter-rated Bluefin-21 AUV. This Bluefin vehicle was custom configured for marine services contractor Phoenix International Holdings, Inc. (Largo, Maryland). Phoenix needed an air-shippable AUV with a small onboard footprint capable of seamless mobilization on vessels of opportunity. Delivered in 2013, the AUV provided highly accurate, high-resolution seafloor imagery for a range of Phoenix customer requirements, from subsea research and offshore applications to military and archaeological investigations. In late 2013, Phoenix used the AUV, called Artemis, on a successful mission to find a U.S. Air Force F-15 plane lost at a depth of 3,000 meters off the shore of Okinawa, Japan. The highly modular 17.2-foot-

long vehicle weighed 1,600 pounds and was capable of reaching speeds greater than 4 knots. It could operate at 3 knots for approximately 20 hours with standard payload, and was equipped with field-swappable batteries and sophisticated survey acoustic and optical payloads for highly efficient operations and performance capabilities. Artemis was most recently deployed in the Indian Ocean in search for wreckage of Malaysian Airlines Flight MH370, which had 239 people on board when it went missing in March. Artemis was tasked with imaging a large, focused search area up to 5,000 meters deep.

Since the vehicle would be operating at depths of 4,500 meters up to 20 hours at a time in demanding operational conditions, the most rugged connectivity solutions were necessary. BIRNS created custom connectors and cable assemblies with 48-inch leads for a wide range of systems on the free-flooded design, whose titanium main electronics housing measured approximately 20 inches in outside diameter and approximately 16 inches in inside diameter, resulting in tight tolerances for its cable assemblies.

Functions met by the Connectors

Artemis used a variety of connectors in a range of pin and cable configurations. The most critical pieces of connector

(Left) Six BIRNS Millennium flanged receptacles (FRs) with five 16-AWG pins and eight 20-AWG pins. (Right) Oil-filled cable assembly with an advanced oil-filled adapter integrating double-ferrule hydraulic fittings with a BIRNS Millennium 3O cable plug (CP).





There were a total of six BIRNS Millennium 3M connector pairs throughout the pressure vessel. The BIRNS Millennium 3M connectors each had a 0.58-inch electrical insulation diameter and a flange dimension of 1.5 inches. The 3M connectors had five 16-AWG conductors and eight 20-AWG conductors. Two of the 3M cable assemblies were molded, and four were designed with pressure-balanced oil-filled (PBOF) cables with advanced oil-filled adapters incorporating double-ferrule hydraulic fittings. This system reduced the risk of cut tubing found with the use of hose clamps in PBOF assemblies. It included two small rings that together formed a gentle wedge. When pushed down by the main nut, the rings gently yet securely pressed against the tubing, which was supported internally with a stainless steel tube insert, in turn sealing and retaining it. A right-angle PBOF cable assembly with a mating pair of BIRNS Millennium 3O (0.70-inch electrical diameter) had 23 20-AWG conductors.

The free-flooded architecture necessitated wet cables for individual components. These wet cables were either PBOF assemblies, wherein the individual wires are immersed in an incompressible oil that is encased in a plastic tube, or molded cables where the entire cable is encapsulated in a custom polyurethane sheath. The functions of the wet cables include the emergency dropweight system, Bluefin battery power, propulsion, vehicle power switch, shore power connection, acoustic navigation and communications, nose line release, sound velocity sensor, and sonar or acoustic payloads.

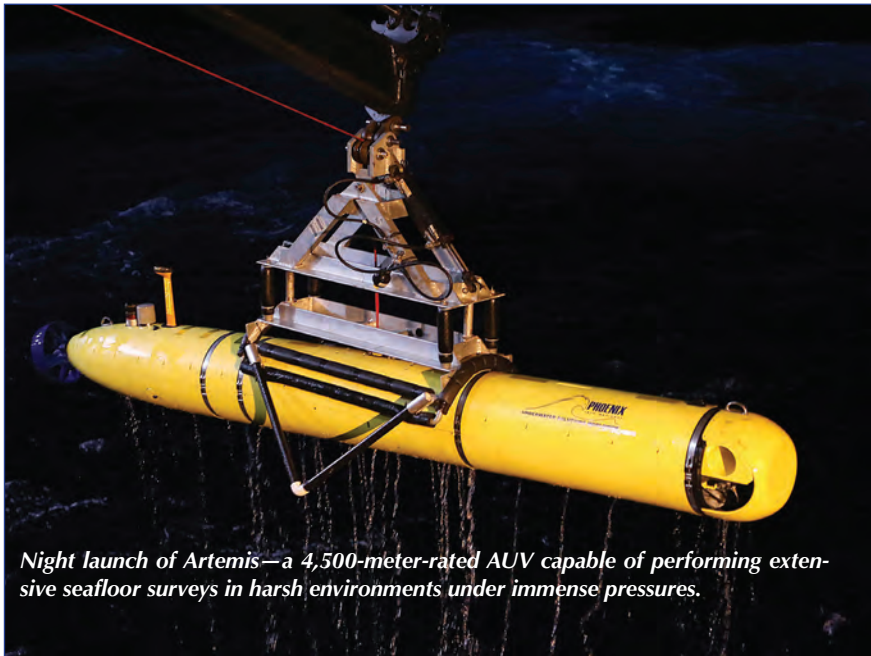


(Top) Minute BIRNS Millennium 3G connector (0.33-inch) insert during rigorous continuity and insulation resistance testing procedures. (Bottom Left) BIRNS Millennium connectors served as the primary connector type for the AUV's main electronics housing (MEH), the air-tight pressure vessel where system-critical electronics reside. (Bottom Right) Bluefin marine operations engineer removing foam to gain access to the MEH.

Connector Development

Developing custom solutions for great depth and extended use required precision engineering, including matching high pin density with glass reinforced epoxy (GRE) inserts capable of performing under great pressure. This provided superior dielectric characteristics and solid construction throughout, as it was developed with exclusive potting and bonding techniques, along with durable O-ring seals, to protect the connections when the AUV would operate in extended missions. The BIRNS Millennium connectors had replaceable electrical inserts for both receptacles and plugs to provide the option for future system modifications if Bluefin opted to change any configurations. Each connector had insulated solder pots to reduce electrical interference, and integrally machined stainless square keys on the cable plug (CP) shells. This keying methodology greatly increased key strength and made the keying process more seamless, secure and user-friendly for AUV operators while mating and unmating connectors at sea. The connectors further provided rugged connectivity by means of hard phosphor bronze

hardware are those installed in the Bluefin sphere. The connectors ranged in size from the BIRNS Millennium 3G to the 3O, with a variety of pin quantities and pin diameters, from 10 22-AWG conductors installed on 3G connectors to combinations of 16-AWG and 20-AWG pinouts in connector pairs of the 3M. The 3G size in particular was an enabling component in that it was highly compact. It had an electrical insulation diameter of 0.33 inches and tight tolerances between pins, with spacing of 0.08 inches center-to-center distance, and socket-to-socket clearance of only 0.02 inches. A slightly larger (0.46 inches) BIRNS Millennium 3K mating pair had 16-AWG conductors.



Night launch of Artemis—a 4,500-meter-rated AUV capable of performing extensive seafloor surveys in harsh environments under immense pressures.

coupling rings, with special Higbee threads and anti-vibration locking set screws.

Testing

In early 2013 BIRNS technicians tested the inserts for continuity, insulation resistance (IR) and open-faced hydrostatic pressure, where they were held at 7,254 pounds per square inch (psi) for one 10-minute cycle. After the successful hydro testing they were given a visual examination. The insert assemblies then underwent rigorous continuity and IR testing procedures with BIRNS's automated Kikusui (Santa Clara, California) 16-channel Hi-Pot and IR testing system. The IR testing requires that all conductors be individually tested at a voltage of 500 VDC between one another. This testing, and the comparison of results to prehydrostatic testing, verified that the inserts achieved BIRNS's demanding Class A rating, i.e., that they completely withstood open-faced hydrostatic pressure testing without any measurable degradation in electrical or mechanical properties. All flanged receptacle (FR) inserts then were given a helium pressure test, where the inserts are fastened to a custom pressure fixture, put in a special hydro tank and submerged for 10 minutes. The inboard sides were subjected to 1,000 psi of helium during the test. Helium pressure resistance is extremely rigorous, as helium atoms have a mass of $4u$, where u is defined as an atomic mass unit ($u = 1.660540 \cdot 10^{-27}$). After the successful helium testing phase, each insert was electrically terminated by BIRNS technicians certified to J-STD-001 Class 3 Requirements for Soldered Assemblies and WHMA-A-620-A Class 3 (Requirements and Acceptance for Cable/Harness Assemblies). The assemblies were then either overmolded in BIRNS's NAVSEA-PRO-20 certified molding facility or attached to the PBOF cabling, and then the complete assemblies were tested for dielectric withstanding voltage (Hi-Pot), continuity, IR and hydrostatic pressure once again.

Conclusion

Phoenix's Artemis completed its mission at the end of May in the ongoing search efforts to locate the Malaysian

flight MH370. The connectors and custom cable assemblies performed well in the demanding, extended operations.

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The Top of the Connectivity Pyramid



We realize that a subsea system is only as strong as its components. That's why BIRNS Millennium™ connectors are engineered to set the benchmark for elevated data and power, and are trusted worldwide. These 6km-rated, high density connectors are rigorously tested and deliver versatile connectivity options for incredibly demanding environments. Whether your application requires titanium or stainless steel, high or low voltage—the BIRNS Millennium series can help you take new depths to new heights.



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