THE INDUSTRY'S RECOGNIZED AUTHORITY FOR DESIGN, ENGINEERING AND APPLICATION OF EQUIPMENT AND SERVICES IN THE GLOBAL OCEAN COMMUNITY

SEA TECHNOLOGY

JULY 2013

SINGLE ISSUE PRICE $4.50

www.sea-technology.com

WORLDWIDE INFORMATION LEADER FOR MARINE BUSINESS, SCIENCE & ENGINEERING

REPRINT

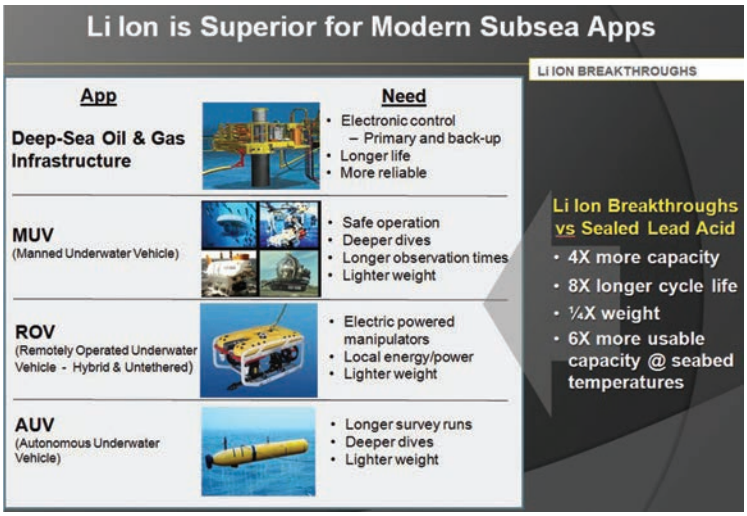
DECK GEAR
CABLE
CONNECTORS & POWER SYSTEMS

Lithium-Ion Subsea Battery System

SeaSafe Modules, BMS are Pressure-Tolerant, Reliable to 6,000 Meters

By Leon Adams • David White

The subsea industrial equipment, vehicle and oceanography markets need battery solutions that deliver more electrical capacity at less weight than old technology sealed lead acid (SLA). Lithium-ion technology offers four times the energy density of SLA, but the batteries need to be safe, reliable and easy to use in subsea deployment. Also important are achieving configurable size and capacity flexibility, long-lasting subsea operating life, subsea pressure tolerance, and precertified testing for shipping standards. Project time and cost savings by avoiding custom battery development are also preferred.



Meeting these needs challenged SouthWest Electronic Energy's (Missouri City, Texas), or SWE, research and development team to create SeaSafe, a safe, modular, flexible and reliable battery system. SeaSafe lithium-ion batteries deliver longer life and longer missions than lead acid, with four times more energy, six times more available energy at colder temperatures typical of the seabed and eight times longer cycle life.

SeaSafe in WHOI's under-ice ROV.

SeaSafe's advantages over sealed lead-acid batteries are that lithium ion does not outgas during charge. SWE incorporates smart, automatic battery management in each battery module that monitors constantly, preventing charging and discharging errors. SeaSafe also provides health and status reporting on demand, unlike most SLA batteries.

The benefits for subsea applications include longer operating life for deep-sea oil and gas infrastructure electronics, lights, and backup; safer, longer-lasting missions for manned underwater vehicles; lighter weight and local instant power for ROVs; and deeper dives and longer missions for AUVs.

SeaSafe battery solutions are implemented in two commercial off-the-shelf battery product configurations: SWE SeaSafe Smart Battery Modules, which are lithium-ion battery module building blocks, and SWE SeaSafe Battery System, which is pressure-tolerant and constructed using a pressure equalization case designed to hold four SeaSafe Modules with parallel integrator isolators (PII). Support software includes SeaSafe Observer, which is PC-based and monitors the health and status of battery modules and/or systems.

SeaSafe Battery Modules

The SeaSafe Smart Battery Modules are available in a 29-volt, 28-ampere-hour or a 24-volt, 28-ampere-hour size. The modules are based on industrial-grade, long-lasting lithium-ion polymer cells. Safety, reliability, flexibility and ease of use are achieved because each module has a built-in autonomous battery management system (BMS) with safety protection. No external connections or controls are required to manage critical safety features.

Multiple modules can be connected in series for total battery system voltage and/or parallel for total battery system amp-hour capacity. The BMS and battery modules have been developed and tested for more than three years, with extensive internal validation testing on short-circuit behavior, safety functional behavior, communications and capacity gauging. In addition, the modules completed pressure verification tests of multiple cycles to 6,000-meter depth capability (10,000 pounds per square inch) at an indepen-

dent mechanical engineering firm in Texas. Maximum state-of-charge is configurable and is managed by the BMS to optimize extended operating life up to 15 years. Charge is provided by off-the-shelf constant-voltage/constant-current power supplies.

The module enclosure is fiberglass filled with thermally conductive, flame-retardant polyurethane potting material. In addition to its thermal benefits, the potting material also dampens shock and vibration. The modules are UN DOT 38.3 certified for transportation. They can be configured in customer-designed cases or within an SWE-supplied SeaSafe battery case.

		SeaSafe Modules	
		29V	24V
Cells in series		8	7
Dimensions (in)	H	9.4	9.4
	W	3.2	3.2
	L	9.3	9.3
Weight (lbs)	Total Module (air)	20.0	20.0
	Total Module (sea)	9.7	9.7
Voltage (V)	Min	24	21
	Nom	29	25
	Max	32	28
Current (A)	Max Dschg (continuous)	40	40
	Max Dschg (30s pulse)	75	75
	Max Dschg (1s pulse)	90	90
Power (W)	Dschg (nom)	1160	1015
Capacity @ 90% SOC	Ah	28	28
	Wh	812	711

SeaSafe Battery Systems

SWE SeaSafe Battery Systems are built with SeaSafe Battery Modules installed in an SWE-designed pressure-equalized case. Up to four SeaSafe Modules can be configured within one case in a series/parallel combination of modules to meet voltage and amp-hour capacity needs, delivering up to 132 volts or 112 amp-hours maximum. Multiple cases can be stacked and connected to increase voltage and/or amp-hour capacity. The system is pressure tolerant down to 6,000 meters. The pressure-equalized case is built rugged from 316 stainless steel and incorporates SEA CON (El Cajon, California) WET-CON connectors.

Observer software for SeaSafe Modules.

The case has a translucent urethane bladder that equalizes ocean-depth pressure with the battery modules immersed within the case in pressure-compensation oil. The dimensions of the case are 14.8 by 15.6 by 17.8 inches.

When SeaSafe Battery Modules are connected in a series string, many autonomous safety features are redundant, thus increasing reliability. For instance, if one string of two series-connected modules is accidently shorted, both modules monitor the shorting current, with two opportunities for the short to be autonomously interrupted.

The SeaSafe PII can be used when the battery system has parallel strings of modules or cases. The PII is a diode O-ring circuit and enables increase in battery system amp-hour capacity with redundancy. If one string should fail, other parallel strings would continue to function normally. The PII also allows faster charging of multiple strings and isolates multiple strings during discharge, thereby preventing potential high-current discharge from one parallel string to another. One PII is used with each module string connected in parallel. PIIs are not needed for single-string configurations.

Safety, Reliability Features

The SeaSafe Battery System has safety and reliability features that assure safe operation, protect the module's cells from damage and prolong cell life. Autonomous safety and reliability features include three types of intra- and inter-module balancing to assure cell safety and reliability, algorithms to detect internal cell shorts to notify and/or prevent failures from lithium dendrites, algorithms to prevent formation of metal dendrites subsequent to copper dissolution, configurable control of charge level within each battery module to extend battery cycle life and safety, thermal control of cells and modules to assure battery safety and extend operating life, short circuit fuse protection for safety redundancy should system electronics fail, and classic lithium-ion safety features configurable to specific applications and missions.

There are custom thresholds for over- and under-voltage detection and prevention, excessive charge and discharge current detection and prevention, ensuring charge is allowed only within the temperature window defined by the cell specification, ensuring discharge occurs only within the temperature window specified by the customer's mission requirements, detecting and preventing short circuits, and allowing high-current pulse discharge to prevent nuisance power interruption.

Observing Battery Status

SeaSafe Modules and Battery Systems are supported by SeaSafe Observer PC software to monitor their status. Battery status checks can be done after the mission is complete or in real time during the mission. It should be noted that real-time monitoring and an active communications link are for mission-information purposes only and are not required for autonomous, safe and reliable battery operation.

SeaSafe Observer delivers status at three levels: multiple SeaSafe Battery System cases connected together, single SeaSafe Battery Systems case or module level when multiple SeaSafe Battery Modules are in a custom configuration.

Module data is concurrently available in raw-data table format for storage or parsing by a separate user-written analysis program.

WHOI Modules

After more than a year of discussion on ideas and requirements for the ideal pressure-tolerant subsea battery modules, which evolved into the SeaSafe Module, WHOI's first target application was an under-ice Arctic ROV. WHOI required the battery system to deliver safe and reliable operation at 2,000 meters depth at 88 volts, with 100 recharge cycles, a -20° to +50° C temperature range and 12 hours recharge time. WHOI also needed the module to have internal protection and balancing and external diagnostic information logging.

WHOI decided that three modules in a series string

would provide the voltage required and nine parallel sets of three series strings would provide the battery capacity needed at that voltage. This is called a 3S9P battery, meaning a three-series-by-nine-parallel configuration of the SeaSafe Battery Modules.

The SeaSafe Modules met or exceeded WHOI's requirements, proving 6,000-meter depth capability, far beyond the 2,000 meters needed for the under-ice ROV but in alignment with expected future needs. In addition, the three-series configuration of modules provided 87 volts nominal voltage (3-times-29 volts), or 96 volts peak voltage (3-times-32 volts), meeting or exceeding the 88-volt requirement. Furthermore, the 1,000 cycles of recharge were 10 times the 100-cycle minimum that WHOI requested. Meanwhile, the battery delivered 22 kilowatt-hours, or about 50 percent more than the minimum 15 kilowatt-hours required, and fit within the 36-by-24-by-12-inch space allocation.

Meanwhile, yet another application for a battery-powered ROV became fast-track priority at WHOI. Six SeaSafe Modules were deployed in this high-definition 3D cinematography ROV, with a box frame designed by WHOI to house the modules in the middle of the ROV. While six SeaSafe Modules were used in the original cinematography mission completed in late 2012, future missions plan to carry nine modules.

As WHOI works on additional subsea vehicle deployments with SeaSafe Modules, SWE is also engaging other subsea vehicle customers for their vehicle battery solutions for future deployments.

Furthermore, as oil and gas subsea production development increases, customers are engaging in design considerations of SeaSafe for subsea primary and backup electrical power. ■

Leon Adams is the chief sales and marketing officer at SouthWest Electronic Energy, where he has more than four years of experience in lithium and lithium-ion battery applications, product definition, sales and marketing management, and customer support experience. Previously, he spent 28 years at Texas Instruments, leading embedded processing and digital signal processing product lines for industrial and consumer applications, including battery-powered solutions. He is a member of the Marine Technology Society and has a master's from the University of Texas at Austin and a bachelor's in engineering physics from Murray State University.

David White is a senior member of technical staff at SouthWest Electronic Energy in Missouri City, Texas. He graduated from Texas A&M University in 1970 with a bachelor's in electrical engineering. He has been designing state-of-the-art computer, seismic and battery systems for Texas Instruments, Halliburton, Input/Output, SouthWest Electronic Energy and others for more than 40 years. He is a Marine Technology Society member, an emeritus member of the Society of Exploration Geophysicists and a life senior member of the Institute of Electrical and Electronics Engineers.