A Deep Dive for the Right Power Supply

By Michael McClune, Argo Program Engineer (retired), Scripps Institution of Oceanography & Lee Gordon, President Doppler Ltd.

Autonomous profiling float being deployed prior to beginning a dive cycle. (Image credit: Argo Program)

Ultra-long-life batteries are being used throughout the oceanographic industry to power remote wireless devices in applications ranging from GPS tracking to SARSAT/COSPAS distress beacons, animal location and health, seismic devices, sonobuoys, transponders, and data loggers.

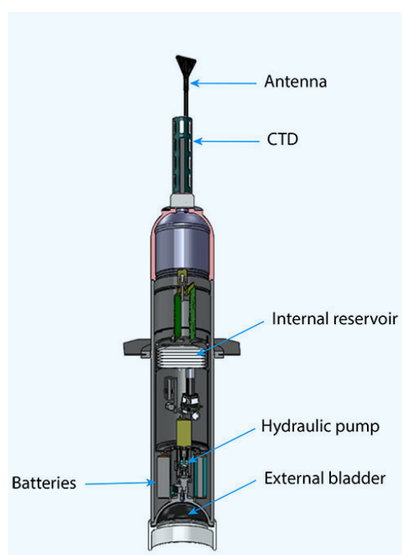
Increasing battery longevity is universally important because it raises the return on investment while improving data integrity. The challenge is to identify the right battery based on various factors, including the choice of chemistry, cell design and manufacturing method, and application-specific performance characteristics.

Doubling Operating Life

A prime example is the SOLO II autonomous profiling float that measures the effects of climate change by monitoring ocean temperature, salinity, and pressure. Operating at depths of up to 2,000 m, the SOLO II float works on 10-day cycles to collect and telemeter accumulated data via satellite to host computers. Autonomous profiling floats were conceived by the late Russ Davis of the Scripps Institution of Oceanography, with the SOLO II representing the latest generation of this technology.

First deployed in 2010, SOLO II is considered the Argo program's gold standard, outperforming nearly half a dozen similarly designed floats. Currently, the Argo program consists of roughly 3,000 floats that are cooperatively managed by an international consortium of nearly 30 countries, forming a worldwide oceanic network of approximately one float for every three degrees of latitude and longitude.

The previous generation of SOLO floats were designed to last 5 years before the battery's end of life. A 5-year battery life meant that 800 new floats had to be produced each year simply to sustain the existing network. At a cost of roughly $20,000 each, this meant that $16 million had to be spent annually for end-of-life replacements, not factoring in the labor and logistical expenses involved with each deployment.



Schematic of a SOLO II float and battery pack. (Image credit: Argo Program)

10-Day Cycles

SOLO II floats operate on a 10-day cycle. The floats spend 9 days (or 90% of the time) drifting at a depth of 1,000 m while monitoring ocean current movement, with the power supply remaining inactive. On day 10, first-generation floats drew power from a spiral-wound lithium sulfuryl chloride (LiSO2Cl2) battery to actuate a valve that introduces sea water to decrease buoyancy, thus initiating a controlled dive to 2,000 m depth and 200 atmospheres of pressure. The battery pack then powered a ballast pump that transfers oil from an internal reservoir into an external bladder, which increases the float's volume to increase buoyancy, initiating a controlled ascent back to sea level.

At first, the spiral-wound LiSO2Cl2 battery packs performed quite well. However, over a period of 2–3 years, they began to operate more unreliably due to two principal factors: limited power supply and excessive passivation.

Passivation Explained

Passivation consists of a layer of LiCl forming on the surface of the lithium metal inside the battery to create a separation barrier that reduces chemical reactivity. This lowers the battery's self-discharge rate. While essential to extending battery life, passivation also involves trade-offs.

As all LiSO2Cl2 batteries age, the passivation effect becomes more pronounced, causing the separation layer to grow progressively thicker. In this case, during the 9 days of inactivity, excessive passivation caused the voltage to drop below the minimum threshold required to power the ballast pump.

In search of a permanent and more cost-effective solution, Scripps collaborated with Doppler Ltd. to test the use of Tadiran PulsesPlus™ bobbin-type LiSO2Cl2 battery pack as an alternative to the spiral-wound cells that utilized the same chemistry.

One major benefit of bobbin-type battery construction is its higher energy density and capacity compared to spiral-wound cells. However, bobbin-type cells are not designed to deliver the continuous high-rate current required to power the ballast pump due to their low-rate design. To address this challenge, PulsesPlus batteries deliver a hybrid solution that combines a standard bobbin-type LiSO2Cl2 cell with a patented Hybrid Layer Capacitor (HLC). The HLC slowly draws sufficient energy from the primary battery to generate the on-demand power required to actuate the ballast pump. This energy transfer process is highly efficient, resulting in minimal waste.

SIO and WHOI personnel prepare a float for deployment from the RV *Revelle*. (Image credit: Chris Sabine)

Rigorous Product Testing

Prototype battery packs were first tested in two floats, one containing the standard complement of three battery packs and another using only two battery packs. Each pack consisted of 8 bobbin-style D cells and 4 AA HLCs.

Both test floats performed extremely well under a wide variety of simulated power requirements and operating environments, experiencing none of the 'drama' and extra labor associated with the spiral-wound batteries.

While the initial implementation plan was to transition annual production to the PulsesPlus packs over several years, the redesigned power supply performed so well that the program chose to convert the entire second year's production to the PulsesPlus packs. In addition to performing more reliably, the PulsesPlus battery pack increased each float's service life from 5 to 12 years.

Broader Implications

Demand for low-power remote wireless devices has increased exponentially, especially among applications that require two-way communications.

Most remotely deployed oceanographic instruments work similarly to the SOLO II floats. They spend most of their time in 'standby' mode, drawing minimal power, then require high pulse energy to periodically wake up and collect data and, in many cases, to telemeter the data home. Pulses Plus batteries were developed specifically for such applications. In certain instances, where the average current is extremely low, remote wireless devices can operate for up to 40 years on these batteries due to an extremely low self-discharge rate.

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