NOAA Pacific Marine Environmental Laboratory
Ocean Climate Stations Project

TECHNICAL NOTE 4.1

Capacity Issue with AA Li Batteries in SBE37's

Update: Reassessment of custom battery packs following sbe37 sensor failures on KE014

NOTICE

Seabird SBE37 Battery Failures on KE014

P. Berk December 2018

Introduction

This report outlines the investigation into the performance of custom battery packs used by the PMEL Ocean Climate Stations (OCS) project in Seabird SBE37 oceanographic instruments. These custom packs were originally implemented in 2012 after excessive battery failures during the KEO08 deployment were attributed to capacity issues of the standard Saft AA lithium batteries (See OCS Technical Note 4). However, following a 50% battery failure rate during the KE014 deployment, effectiveness of this very expensive and inconvenient solution was reassessed.

Background

In 2011, the KE008 mooring was recovered with 10 of 13 SBE37's offline due to low battery voltage. The OCS group worked together with PMEL's Engineering Design and Development group (EDD), and Seabird Scientific engineers to investigate this issue and decided to remove the standard lithium AA battery packs (12 Li AAs per pack) from all OCS-owned SBE37 instruments and replace them with custom 2x lithium D-cell packs in hopes of increasing battery capacity. These new packs were deployed on KE010 in 2012 and all subsequent deployments until KE016 in 2018.

Follow Up

About a year after the custom D-cell battery packs had been developed, Jennifer Keene from PMEL spoke with Joel Reiter at Seabird. He was the engineer who had been performing the in-house battery testing, and was deeply involved in the custom pack replacement. She asked him how this problem had been addressed for the rest of the Seabird customers around the world. Mr. Reiter explained that he had stopped working on the battery tests, because early battery failures had ceased to be an issue. He determined that there had been a temporary manufacturing problem with the Saft AA Li cells which was resolved. This agreed with the performance of the KE009 deployment, which followed the KE008 problematic deployment, which had no issues and was prior to implementation of the D-cell packs. No other Seabird user in the world uses the D-cell battery packs.

In 2017, while investigating the latest instrument failures, Ms. Keene contacted Karen Grissom at NDBC to inquire whether NDBC had ever experienced similar battery failures in v3 SBE37-IMP instruments. Ms. Grissom responded that NDBC had never had a major failure, and they continue to use the standard Seabird AA battery packs.

Summary of D-cell Battery Pack Performance and Recent Battery Failures

The first deployment with the custom D-cell battery packs, KE010 in 2012, had excellent battery performance with all recovered sensors still logging data on recovery and nearly 100% data returns. However, KE011 (2013), and most recently KE014 (2016) both had large numbers of battery failures, with five and seven SBE37 failures (of 14 instruments) respectively. Data downloads from KE014 instruments ranged from 17-56% of expected data returns (Table 2). These data correspond with the subsurface real-time data return rates.

Historical Battery Performance:

Table 1 shows battery failures of all SBE37's deployed from 2008 through 2016

Table 1 - Historical battery failures of SBE37s on KEO mooring

x	recovered low batteries
?	Failure unknown, no coms

Sensors w/ 2 failures	Sensors w/ 3 failures
Sensors with Custon D-cell Packs	

KEO SBE 37 FAILURES

		2008	2009	2010	2011	2012	2013	2014	2015	2016	
Deployed:		2008	2009	2010	2011	2012	2013	2014	2015	2016	
Deployment:		KE006	KE007	KE008	KE009	KE010	KE011	KE012	KE013	KE014	
Flex Box:		7	6	5	8	9	6	8	9	6	
6079	**TC**				X						
6141	**TC**	X									
6142	**TC**	X									
6145	**TC**	X									
6146	**TC**	X									
7093	**TCP**						X		Reverted to AA		
7095	**TCP**						X				
7096	**TCP**						X				
7098	**TCP**		X		X		X		Reverted to AA		
7102	**TCP**			X			X				
7103	**TCP**			X				?		X	
7104	**TCP**			X							
7105	**TCP**			X							
7106	**TCP**			X						X	
7107	**TCP**			X						X	
7108	**TCP**							?		X	
7782	**TCP**			X						X	
7783	**TCP**			X							
7784	**TCP**			?						X	
7785	**TCP**			X							
7793	**TC**									X	**Total**
# OF ISSUES		**4**	**1**	**10**	**2**	**0**	**5**	**2**	**0**	**7**	**27**
# recovered		**7**	**10**	**13**	**15**	**14**	**15**	**14**	**15**	**14**	**110**
Failure Rate		**57.10%**	**10.00%**	**76.90%**	**13.30%**	**0.00%**	**33.30%**	**14.30%**	**0.00%**	**50.00%**	**24.50%**
FLEX Resets		**5**		**6457**	**1**	**1**	**58**	**1**	**8**	**50**	
Lost Sensors		**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	

Table 2 - Battery failures on KE014

Deployment		**KE014A**					
Deployed		**7/31/16**		**Recovered**		**7/15/17**	
Days Deployed		**349**					
Sensor:	**Depth:**	**Last Sample:**	**# of Days**	**# of Samples:**	**# Expected:**	**% Recovered**	**% Real Time**
7784(37)	325	10/1/16	62	8,738	~51,285	17.04%	14.70%
7106(37)	75	11/11/16	103	15,752		30.72%	27.30%
7107(37)	100	11/28/16	120	18,283		35.65%	32.10%
7108(37)	125	1/18/17	171	25,363		49.46%	44.20%
7103(37)	25	2/6/17	190	28,602		55.77%	45.50%
7782(37)	225	2/7/17	191	28,238		55.06%	51.30%
7793(37)	10	2/12/17	196	29,032		56.61%	55.40%

Summary of Testing and Results

After the KE014 failures, PMEL's EDD group was again consulted for assistance. Potential sources of the problem were discussed, as well as testing plans.

Potential Sources of Failure

- Instrument Malfunction
- Batteries – Faulty batteries causing early failure
- Current drain by inductive system – Additional queries from data acquisition (FLEX) system, length of wire, bad modems, etc.

Objectives of the Investigation

- Identify other possible causes of battery failure
- Create a plan of experiments to test hypotheses
- Once probable cause has been determined, work to resolve issue to avoid future failure

Broken Batteries

When removing the old batteries from the failed sensors to prepare for testing, an important discovery was made. The metal tab that connects the two D-cells inside the pack had separated on all seven of the failed instruments from KE014. Four of the tabs had broken at the weld to the top of the battery, and on three instruments the tabs themselves broke in the middle. No broken tabs were found on any other instruments that did not experience early failure. These broken tabs were presumably caused by vibrations in the mooring line causing repeat strain on the relatively thin connection between cells.

Poor or intermittent contact between the cells would almost certainly have a negative effect on battery performance. Charring was found on a number of the batteries indicating arcing between the cells due to a broken connection.

Figure 1. Broken Tab Between Cells

Figure 2. Broken Tabs & Welds

Figure 3. Broken Tab

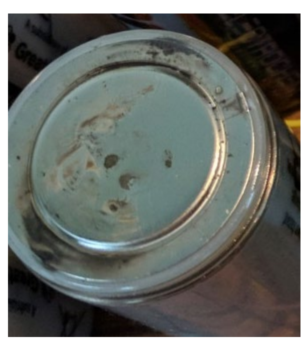

Figure 4. Broken Weld, Scorching

Current Drain Testing

Six sensors from KE014, three that failed early and three with 100% returns, were installed on an inductive loop on FLEX006, the same data acquisition system deployed during KE014. Each sensor and the data acquisition system were powered by a power supply, and the current drain of all sensors were monitored independently. If high current drains were seen in any sensors, the same test would be run using a different data acquisition system, with no prior indication of issues. This test would indicate if the issue was with the sensor itself or with the inductive system. However, no increased current drain was seen in any sensors over a four week test period. All sensors performed as they should while on constant power, indicating that the failures were likely caused by the broken packs rather than high instrument current drain.

Conclusions and Recommendations

It is believed now that the failures in inductive instruments on KE008, KE011 & KE014 were isolated incidents caused by independent factors with no recurring source of failure.

1. KE008 failures in 2010 were likely caused by a bad batch of AA lithium batteries.
    - This has been confirmed by Seabird and has been validated by a drop in reported failures after 2010.
2. KE011 failures in 2013 are undetermined, but are believed to be related to a high number of Flex system resets during that deployment.
    - In 2014, all Flex systems were updated. By cleaning up the system wiring and power, as well as some software functions, certain best practices have been implemented to improve reliability and decrease frequency of system resets.
3. KE014 failures in 2016 were likely caused by broken tabs and spot welds in the OCS custom battery packs causing poor and intermittent battery contact.

With no clear indication that there is, or ever was, an inherent issue with the AA lithium battery packs designed to power SBE37s, it is recommended that OCS revert instruments back to original AA configuration. OCS has conferred with the Global Tropical Moored Buoy Array (GTMBA) and the National Data Buoy Center (NDBC), both of whom use 100's of AA powered SBE37's across dozens of buoys. Neither agency has reported any abnormal trends of battery failure.

Custom D-cell packs are significantly more expensive and time consuming than AA. The D-cell packs are $115 and take eight weeks to build, while the AA configuration costs about $50 with batteries that are on the shelf at more than a dozen vendors.

As proven by the most recent failures, the D-cell packs also provide more sources for failure. There are four spot welds, two solder joints and four crimped wires in every D-cell pack, any of which would cause total failure if broken. The AA's are inserted into a secure cartridge designed for the SBE37 that have no loose wires, welds or connectors of any kind. The AA cartridge is a much more robust packaging for batteries.

Reversion to AA battery packs in SBE37's

- All SBE37s deployed by OCS in 2018 (KE016 & PA012) were sent to Seabird Scientific for reversion to factory AA packs before 2018 deployments.
    - As of January 15th, 2019 no sensors have failed early on KE016 or PA012
        - 1 sensor failed on deployment
- Sensors recovered during 2018 have all been reverted to AA packs in preparation for 2019 deployments.
- As of January 2019, all sensors have been reverted back to AA packs.
    - Seabird reverted sensors for only the materials cost of the battery pack (~$150).

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