



Inspection report

Program Number: 901006

BEDS Benthic Even Detector

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Hardware affected:

BEDS#3 (10020895-AS1 SN003 12/2013, 10020895-AS2 SN003 11/26/2013)

Cell Electrochem model CSC93DD part# 3B0036-XB, batch 2334026, SN 7331

Background.

12/6/2013 BEDS#3 was built and deployed in December 2013 in Monterey Canyon at approximate depth of 290 meters. Initial environmental conditions inside of the housing were recorded by on-board sensor set at humidity 9%, temperature 8-9C, internal pressure 14.5 PSI 4/28/2014 an elevated humidity level was detected (85%; 9C; 14.8PSI) and decision was made to recover instrument as soon as possible.

5/1/2014 at about 11:00 PST local time another read of environmental sensors was performed (89%; 9C, 14.8 PSI).

5/1/2014 at about 16:00 PST BEDS instrument was recovered by ROV Tiburon and R/V Western Flyer, brought to Moss Landing and stored on site until next Monday.

5/5/2014 ~ 13:00 PST, the instrument was opened for inspection.

Initial Inspection

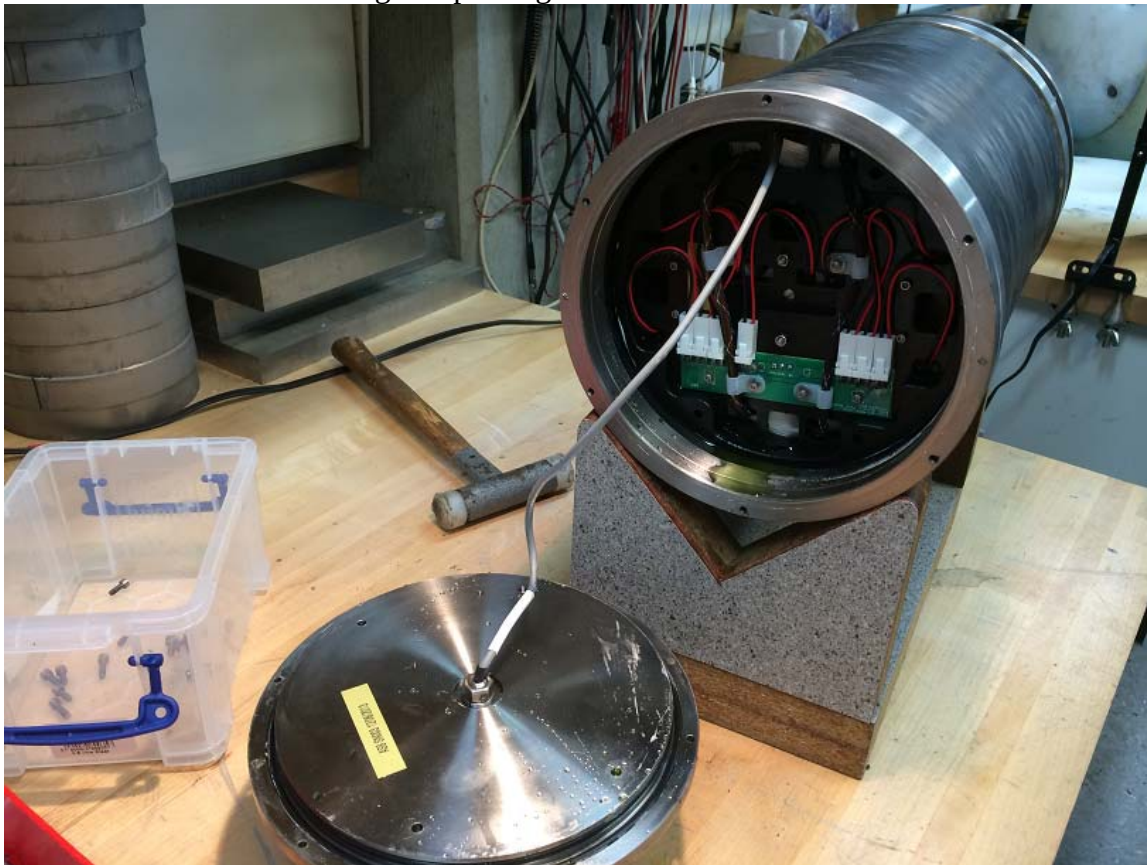
Housing does not have any signs of damage. Pressure slightly elevated, large clamps were used to hold housing's end plates until pressure release as a safety measure (no internal pressure read was performed immediately before opening). Subjectively, internal pressure was not more than 110% of atmospheric pressure.



Once housing was open, presence of light-green liquid and strong chlorine smell became evident.



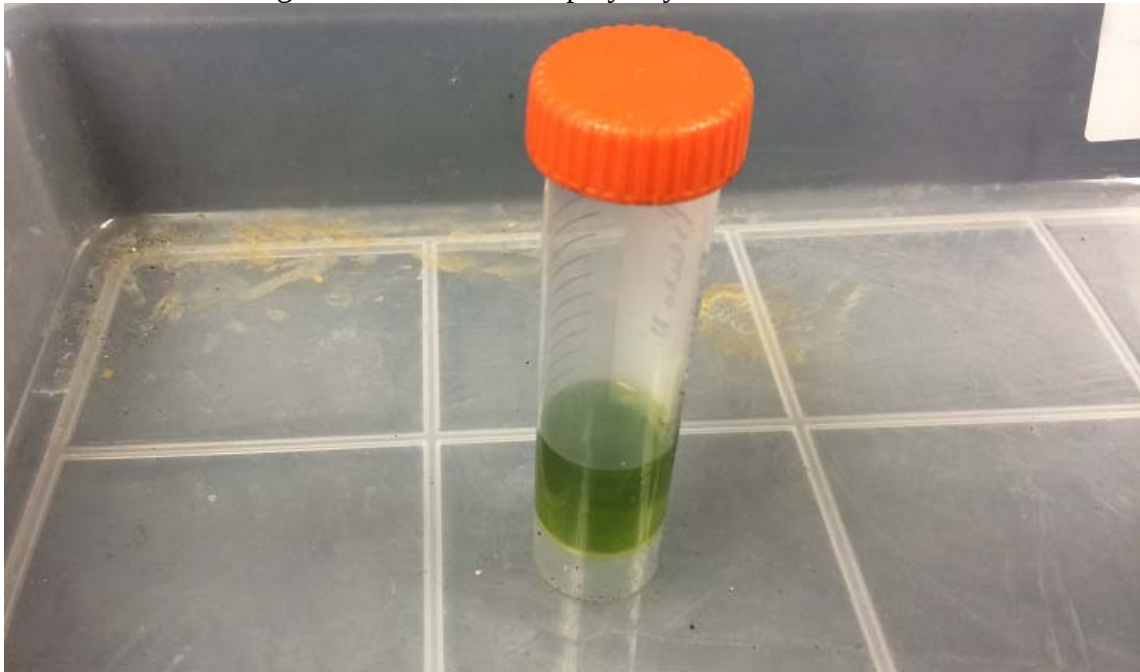
About 25-35mL of the light-green liquid was collected from the housing into polyethylene container. At this point battery failure and electrolyte leak became evident; MBARY Safety Dept had being notified; and the instrument with all the materials had being loaded on a plastic cart and moved out of the building to a parking lot.



Housing does not have any signs of mechanical damage. Inside surface of the housing contaminated with light-green fluid.



About 25-35mL of the light-green liquid was collected from the housing into polyethylene container and then transferred to a vile. About half was spilled on a plastic cart while working outside of the building when wind overturn polyethylene container.



Left Black Delrin endplate holding battery sticks found missing about 1x3 cm section adjacent to Battery Stick marked L2 (means: stick “2”, oriented to the left end plate, assembly AS3-LEFT). Missing section is later found inside of the housing.



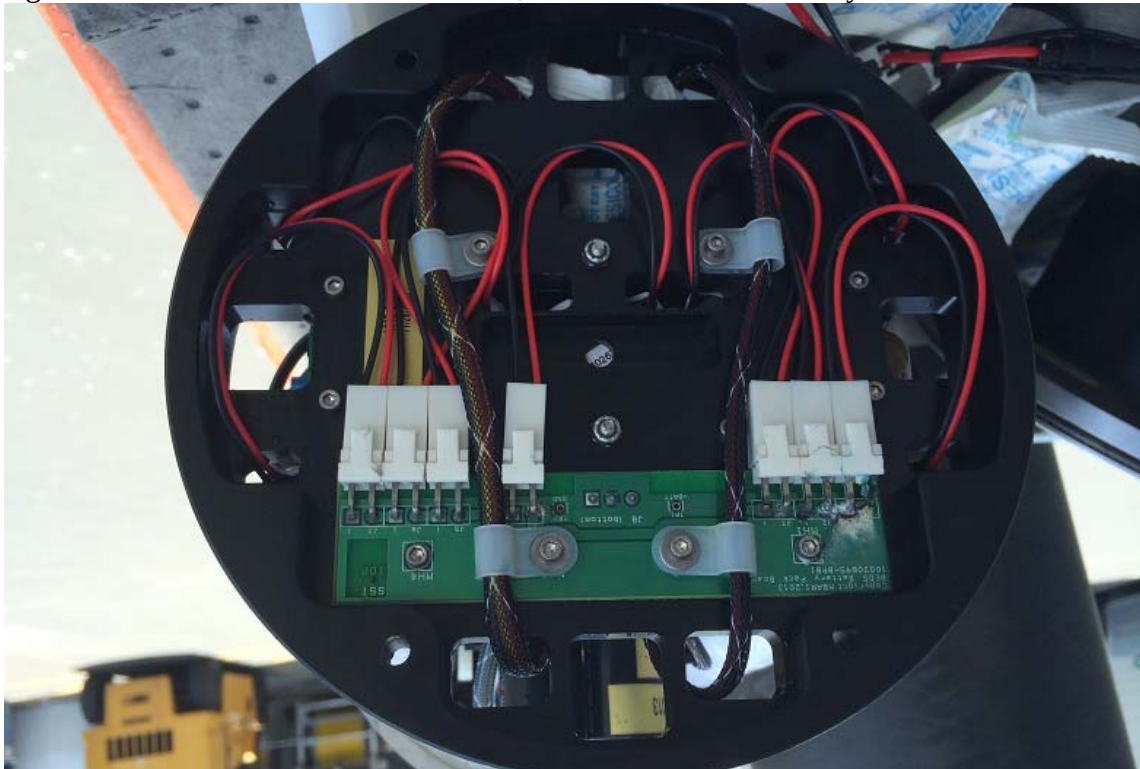
Edges of the missing section appeared “rounded” as if melted or chemically etched.



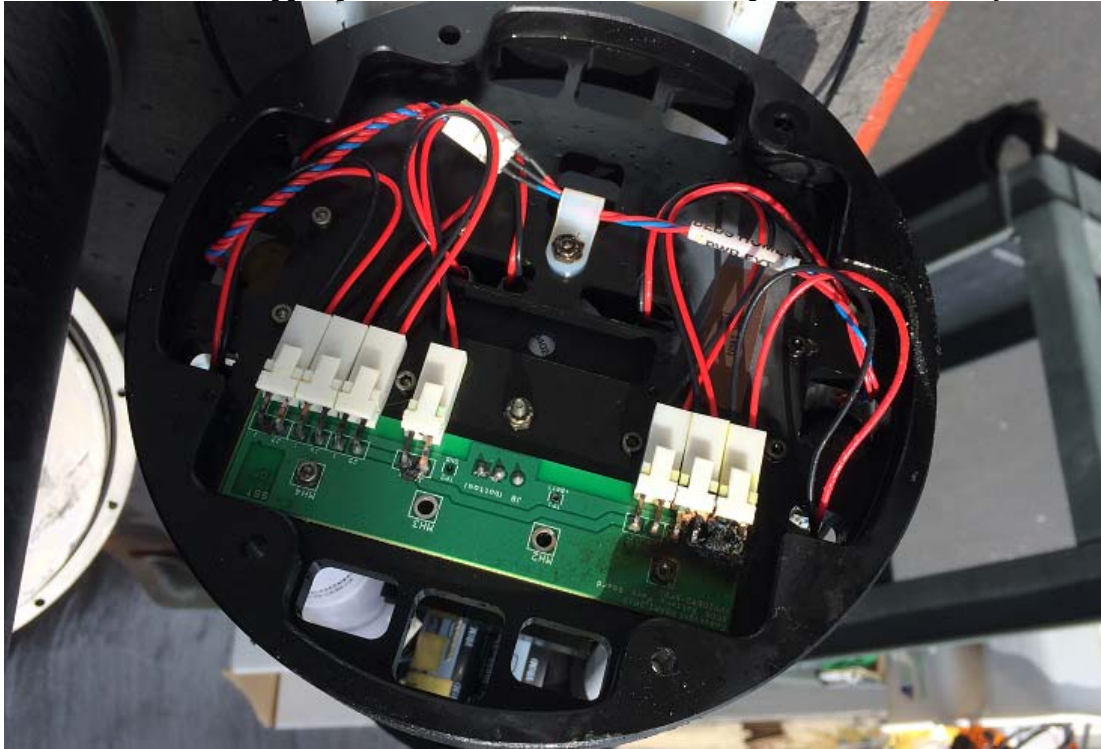
Internals of 10020895-AS2 assembly look undisturbed aside of presence of light-green fluid on some surfaces, and some discoloration of metals: pressure sensor housing, solder on PCB boards and so on:



Battery pack board (10020895-BPB1) mounted on right end plate (10020895-AS3-RIGHT) has signs of corrosion near connectors J1-J2, but later tested to be fully functional



Battery pack board (10020895-BPB1) mounted on LEFT end plate (10020895-AS3-LEFT) is corroded near connectors J1-J2 with black-green deposits covering connectors pins; and later tested NOT to be functional. Damage to the board include dissolved traces between pins J1.1 and J2.2, and J1.1 and copper pour net name "+ BATT" on Top and BOTTOM layers.



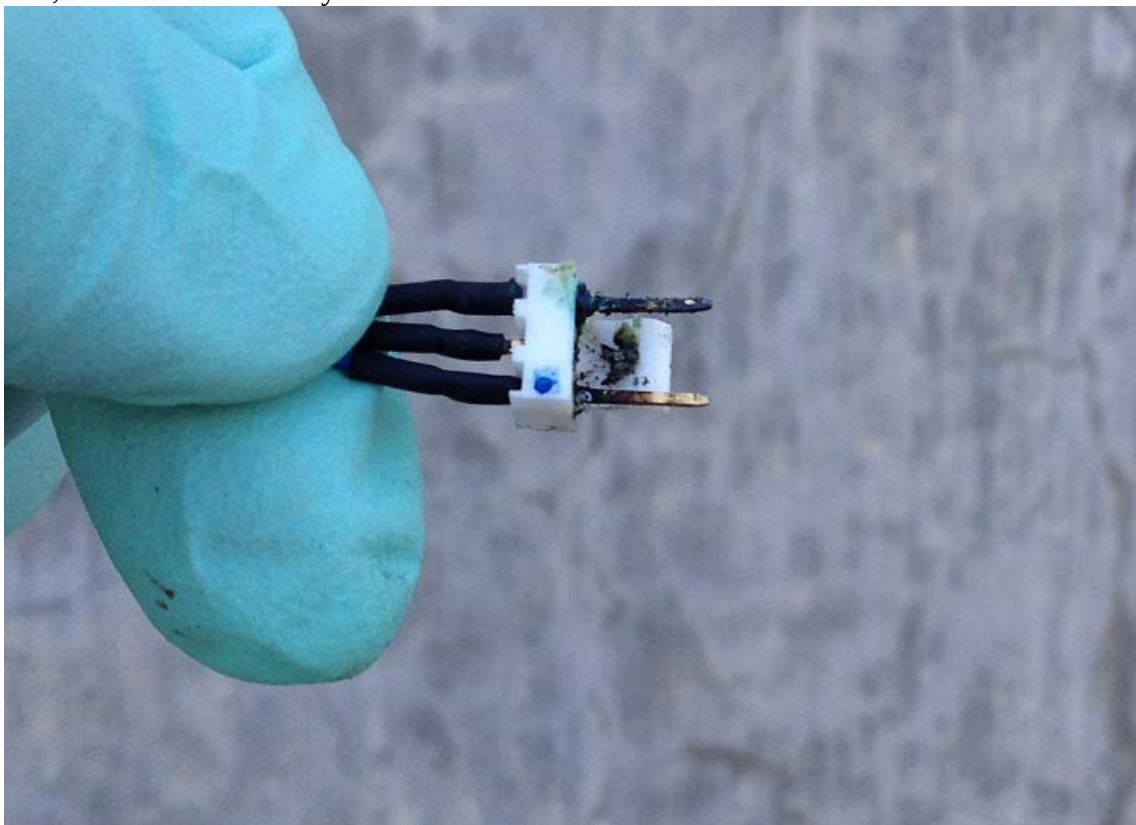
Black Delrin under the LEFT battery pack board is corroded with approximately 15x5x1mm mass missing, with discoloration and pitting in surrounding areas as if the electrolyte was trapped inside the channel under the PCB board enabling galvanic corrosion between energized connector pins.



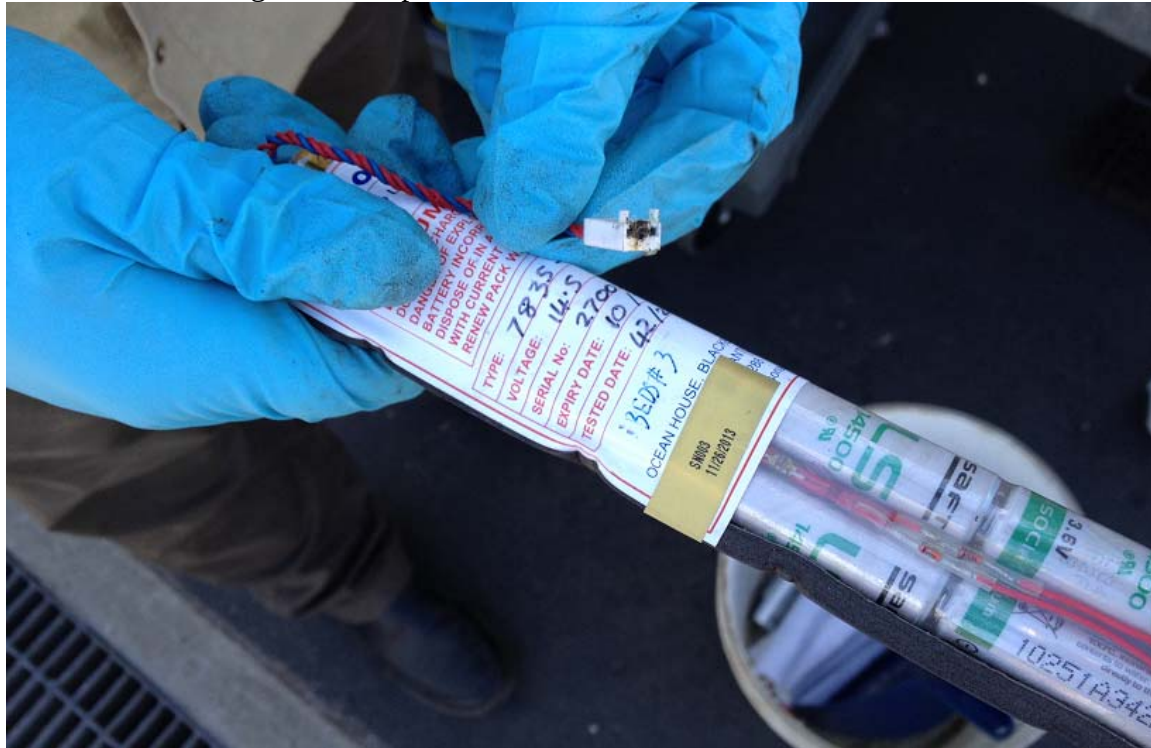
Fused Power Harnesses delivering power from each Battery Pack Board to Mother Board are intact and later tested to be functional.



Connector pins in Homer power harness are damaged but since central pin is redundant positive line, Homer is most likely functional



Other side of damaged Homer power harness connector

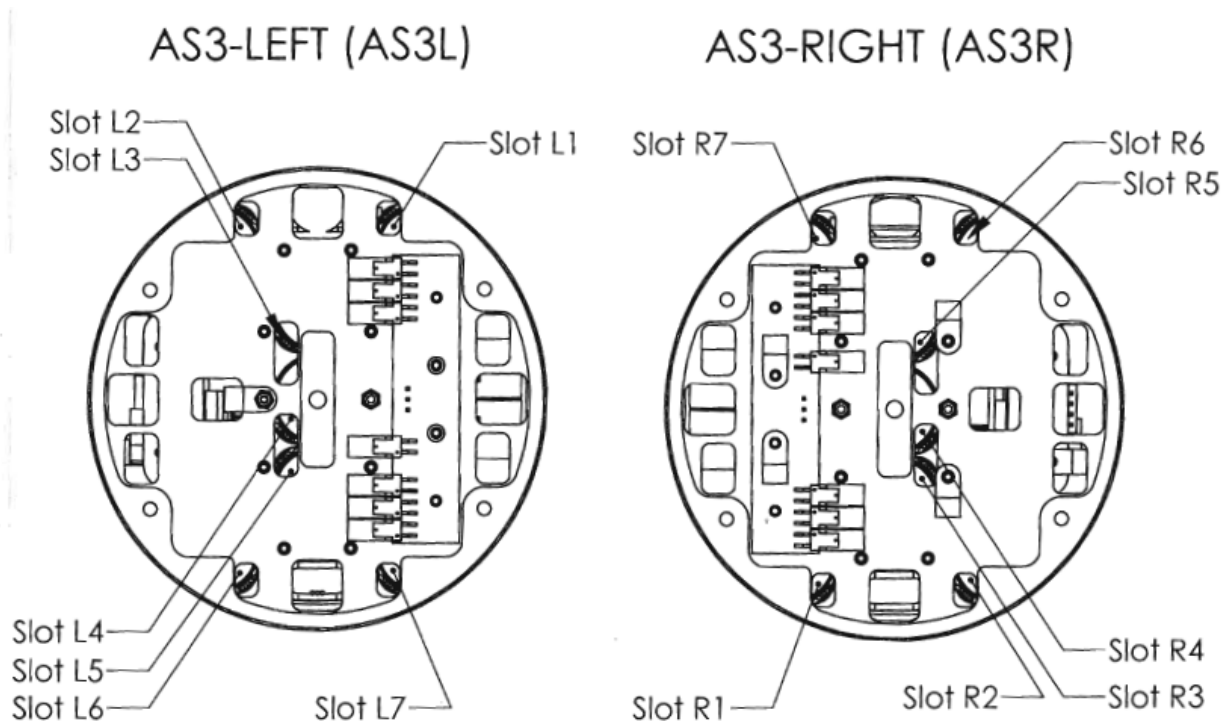


Coin cell on acoustic board stack has some surface corrosion/ discoloration. Cell removed for board cleaning, voltage measured at 2.997 V , model CVR1632; 3V nominal (= functional).



Inspection of battery sticks and cells. Table below indicates serial numbers of the cells installed in each slot as well as voltage of each cell measure at the time of the assembly and at the time of inspection after battery failure. Drawing below illustrates slots allocation per respective AS3-assembly.

Slot#	Model	Part#	Batch#	SN#	Voltage 11/26/2013	Voltage 5/9/2014	Note
Slot L1	CSC93DD	3B0036- XB	2334026	3027	3.886	3.859	positive wire missing; signs of corrosion under paper disk
Slot L2	same	same	same	7331	3.886	3.86	failed cell; 2 pitted areas on the edge on positive side; electrolyte leaked out, fuse blown
Slot L3	same	same	same	7305	3.886	3.344	
Slot L4	same	same	same	7306	3.885	3.85	severe connector corrosion
Slot L5	same	same	same	7339	3.885	3.061	
Slot L6	same	same	same	7340	3.885	3.739	
Slot L7	same	same	same	7334	3.885	3.852	
Slot R7	same	same	same	3026	3.885	3.856	
Slot R6	same	same	same	7332	3.885	3.856	other side of failed cell in slot L2
Slot R5	same	same	same	7325	3.885	3.856	
Slot R4	same	same	same	7336	3.885	3.856	
Slot R3	same	same	same	7335	3.886	3.856	
Slot R2	same	same	same	3029	3.886	3.857	
Slot R1	same	same	same	7327	3.886	3.856	



Affected “battery stick” from Slot L2, cell number SN 7331



Affected “battery stick” from Slot L2, SN 7331, heat shrinking material partially removed; light-green fluid present under the heat shrinking material



Light-green fluid present under the heat shrinking material to the middle of “battery stick” but not present of the other side of middle paper disk dividers



Plastic cap with protection elements of cell CSC93DD part# 3B0036-XB, batch 2334026, SN 7331. Fuse is blown (resistance measured at 51kOhm), reverse protective diode is functional (forward voltage measure at 0.133V; reverse 2.98V by Protek 506 multimeter)



Cell SN 7331; plastic cap and labels removed; 2 “cavities” are visible on the edge of pressure vessel; “left one” about 2x3 mm; and “right one” about 2x5mm



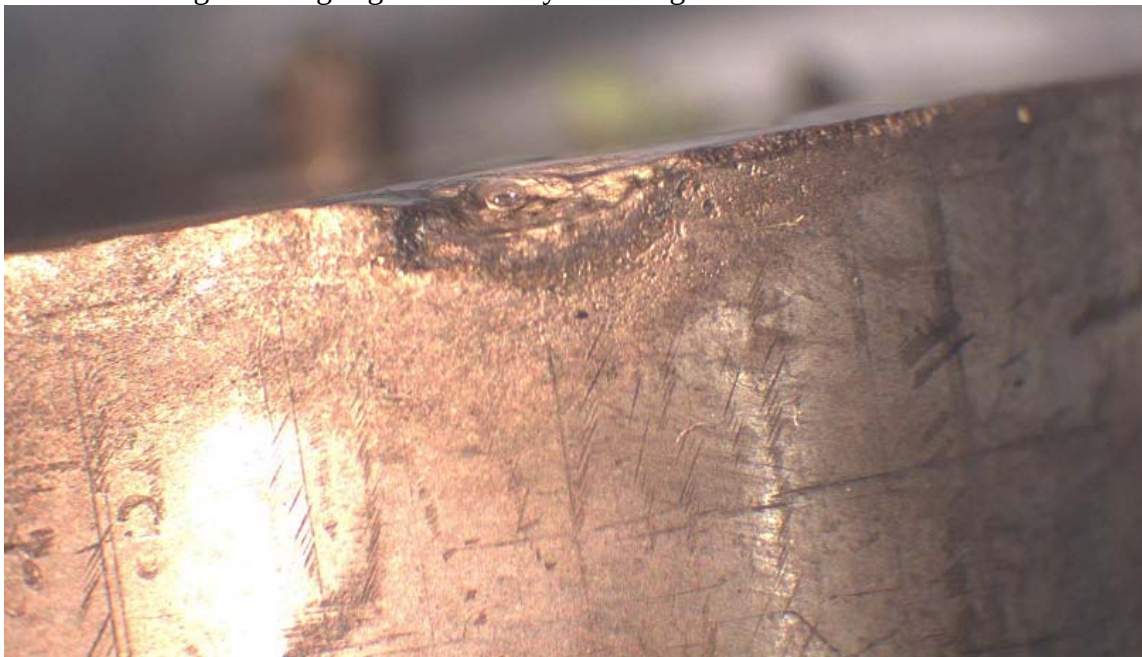
Those 2 cavities proven to be leaking electrolyte which was confirmed by holding a cell against a tissue upside-down with some shaking; resulting in 2 light-green spots forming on a tissue



“Right cavity” under microscope. There is a small opening in the middle of the cavity where bubbles of the gas and light-green electrolyte coming out are visible which prevents accurate measurement of a size of the opening.



“Left cavity” under microscope. There is a small opening in the middle of the cavity where bubbles of the gas and light-green electrolyte coming out are visible



Geometry of the Cell SN 7331 pressure vessel, with protective plastic cap and labels removed to bare metal, measured by 6" digital Mitutoyo calipers. Please refer to the diagram below.

Length, inches at 4 quadrants: L1=4.247"; L2=4.249"; L3=4.247"; L4=4.247"

Diameter range, inches, MIN-MAX, at top edge: 1.314"-1.315"

Diameter range, inches, MIN-MAX, 1/8" below top edge: 1.313"-1.313"

Diameter range, inches, MIN-MAX, 1/4" below top edge: 1.312"-1.314"

Diameter range, inches, MIN-MAX, 1/2" below top edge: 1.312"-1.315"

Diameter range, inches, MIN-MAX, 1" below top edge: 1.311"-1.315"

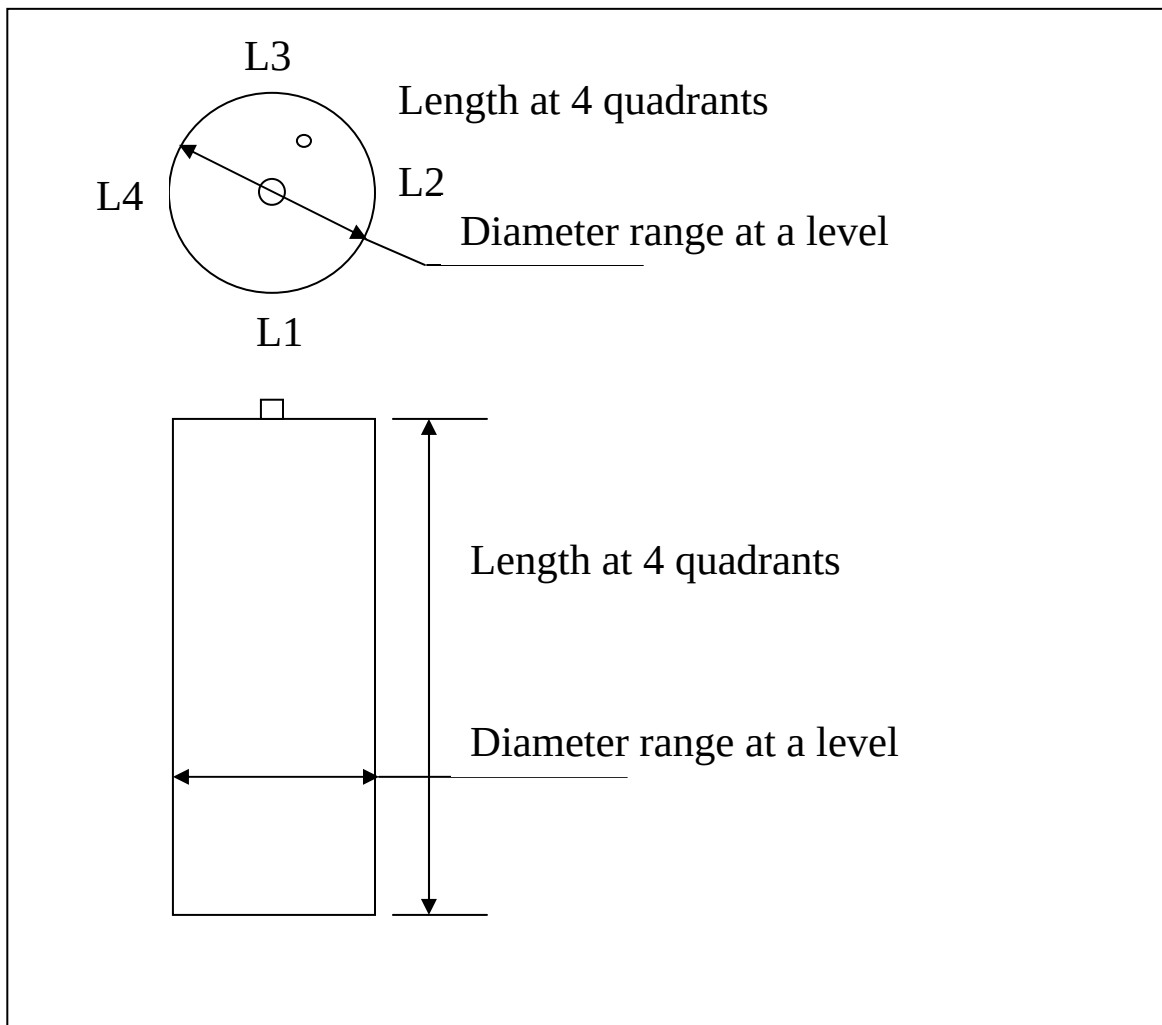
Diameter range, inches, MIN-MAX, middle of battery: 1.310"-1.315"

Diameter range, inches, MIN-MAX, 1" above bottom: 1.311"-1.314"

Diameter range, inches, MIN-MAX, 1/2" above bottom: 1.311"-1.314"

Diameter range, inches, MIN-MAX, 1/4" above bottom: 1.311"-1.314"

Diameter range, inches, MIN-MAX, at bottom edge: 1.311"-1.313"



Conclusions:

1. Damage to the electrical system of the BEDS assembly is caused by a presence of corrosive light-green liquid with strong chlorine smell inside the housing. Source of the liquid:
 - a. Battery cell SN 7331 located in a Slot L2 of the LEFT half-pack
 - b. Possibly, presence of seawater inside of the housing.
2. Battery pack:
 - a. LEFT half-pack failed due to corrosion of copper traces on Battery Pack Board
 - i. Channel milled in a Black Delrin endplate under Battery Pack Board negatively affected reliability allowing liquid to be trapped under the board and electrochemical corrosion to occur.
 - ii. Due to damage to the battery pack board, other cells in the same LEFT half-pack were affected (partially discharged compare to unaffected cells) as indicated by their voltage at the time of the inspection.
 - b. RIGHT half-pack retained full functionality and continued supplying power to Mother Board.
3. Battery cell failure (SN 7331):
 - a. Protective fuse is blown presumably due to corrosion and electrical short circuit on Battery Pack Board.
 - b. No change in pressure vessel geometry
 - i. Reason for a cell failure with subsequent electrolyte leak is unknown.
 - c. No signs of thermal damage or thermal run-away (by condition of heat shrinking material and polymer labels).
4. Other system level effects
 - a. In general, higher voltage and always-energized components degraded the most, including:
 - i. 3V coin cell on Acoustic Modem board stack.
 - ii. 3V coin cell on Mother Board
 - iii. Battery pack boards
 - iv. Homer power harness

Suggestions and action items:

1. Check if collected light-green liquid contains sea water, to rule out leaking pressure housing.
 - a. Compare optical absorption spectra of collected liquid to pure CSC93 series electrolyte?
 - b. Compare refractive index of collected liquid to pure CSC93 series electrolyte?