

Report on Argo Float Batteries

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- **Increasing efficiency of batteries is easiest way to extend the average lifetime of an Argo Float**
- Report prepared after extensive discussion at Seattle Technical Workshop
http://www.argo.ucsd.edu/Argo_battery_report.pdf
- Battery configurations in APEX, NAVIS and SOLO2 floats
- Recommendations for diagnostic data and plots
- Analysis of battery performance in APEX, NAVIS, and Solo2 floats
- Recommendations for improved battery performance

Summary of battery usage in US Argo floats from Appendix 2

1. APEX floats
Low current demand (single stroke pump)
16 kJ per dive
12 Electrochem CSCDD93 primary cells, 5.3 MJ
2. NAVIS floats
Low current demand (reciprocal pump)
13 kJ per dive
12 Electrochem CSC93DD primary cells, 5.3 MJ
3. Solo2 floats
High current demand (1.5 amp reciprocal pump)
11 kJ per dive (McClune reports improvements to give 8 kJ)
8 or 12 Electrochem CSC93DD primary cells, 3.5 or 5.3 MJ
Float 8381(2 packs) 24 TL6930 D primary cells
+ 12 HLC1550A lithium ion cells, 3.8 MJ,
with 3 packs, 5.8 MJ

Electrochem battery pack versus Tadiran battery pack

- Electrochem battery packs provide current directly to float
 - Extended periods of no load, passivation occurs
 - Significant demand when float pumps to rise to profile (Solo2 as extreme)
 - Low current drain will burn off passivation with less damage than high current drain. Some degradation of battery still occurs.
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- Tadiran primary batteries are used to trickle charge the lithium ion batteries. Optimal use of primary batteries, with no passivation.
 - Lithium ion batteries provide low resistance, high current power
 - Efficient when lithium ion battery capacity exceeds energy for one cycle.

Recommendations for battery monitoring

- Battery voltages and currents to estimate internal battery resistance should be measured at
 1. Minimal load
 2. At initial use of hydraulic system (battery with passivation layer)
 3. At later time when passivation layer has been removed
- Useful for:
 1. Monitoring battery health and passivation
 2. Can identify when a single pack has failed
 3. Ruling out battery failure in post-mortem analysis

Estimating battery internal resistance

$$R_b = (V_{ocv} - V) / (I - I_{ocv})$$

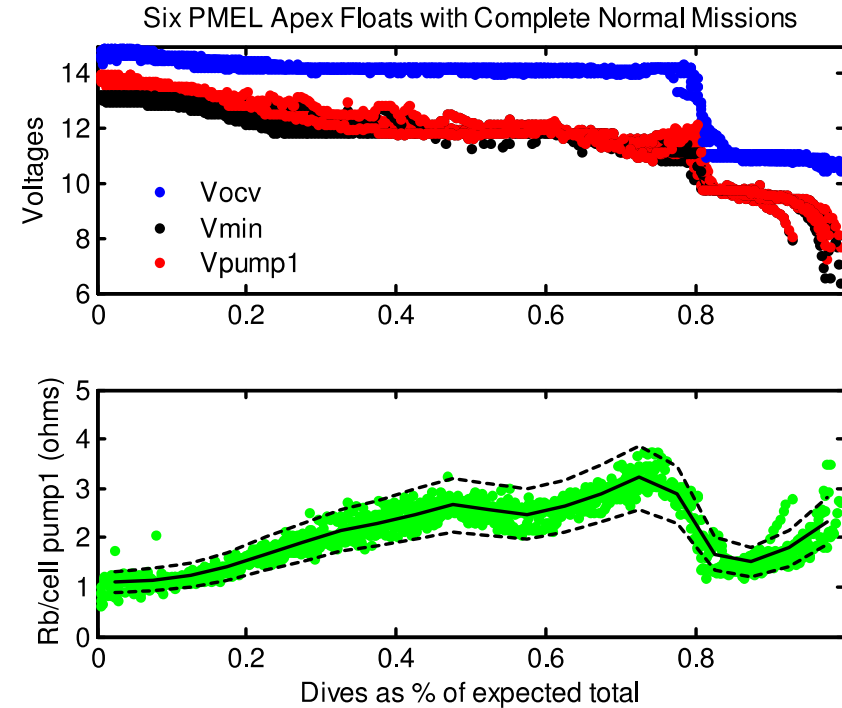
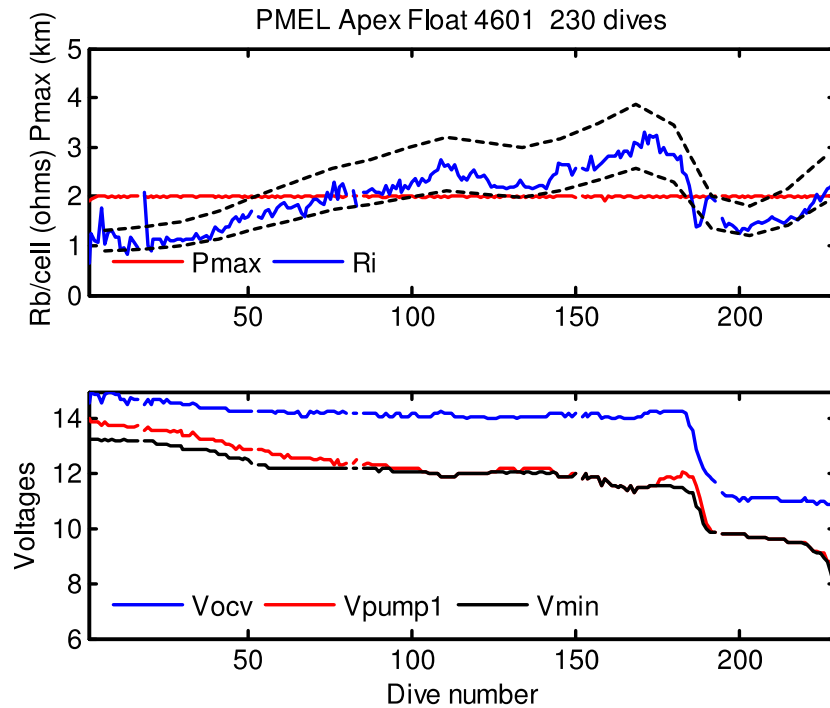
where

V_{ocv} and I_{ocv} are voltage and current at low load

V and I are voltage and current under load

R_b is the internal battery resistance

APEX Floats



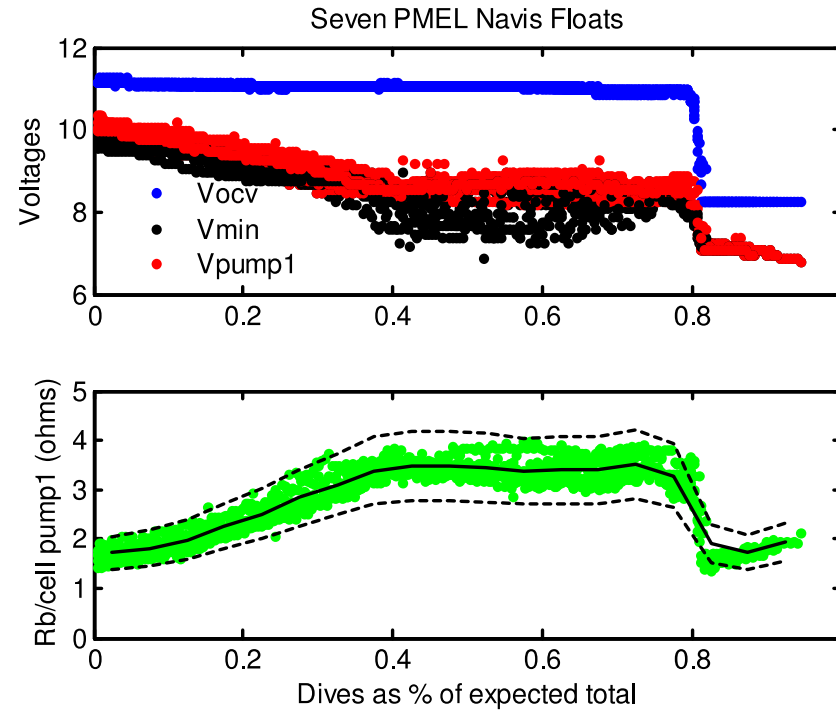
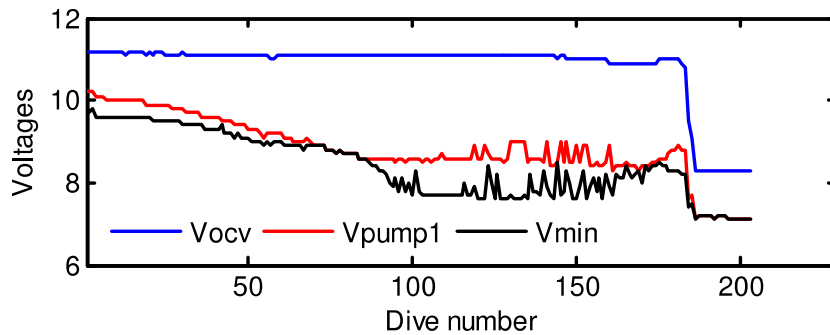
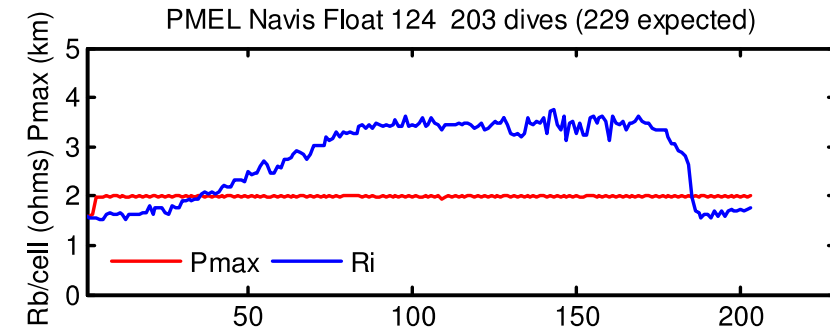
Retracting piston burns off passivation.

Battery performs the same through pumping.

Increase in internal battery resistance over time result of passivation and aging of battery.

APEX floats extract roughly 65-70% of available battery energy.

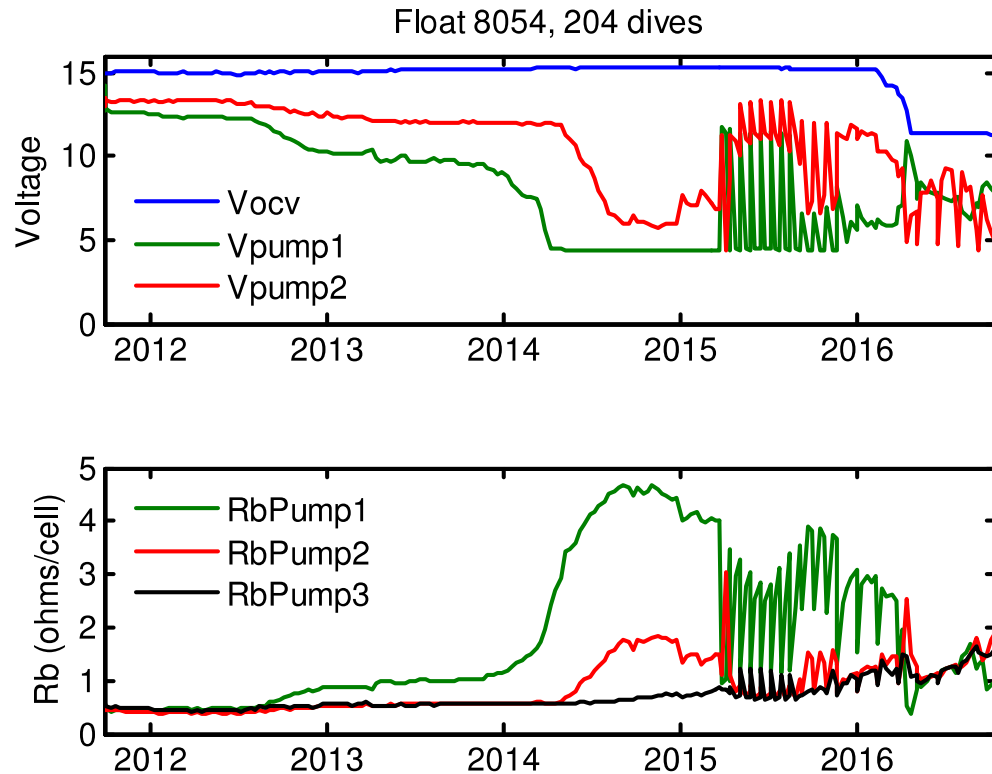
Navis Floats



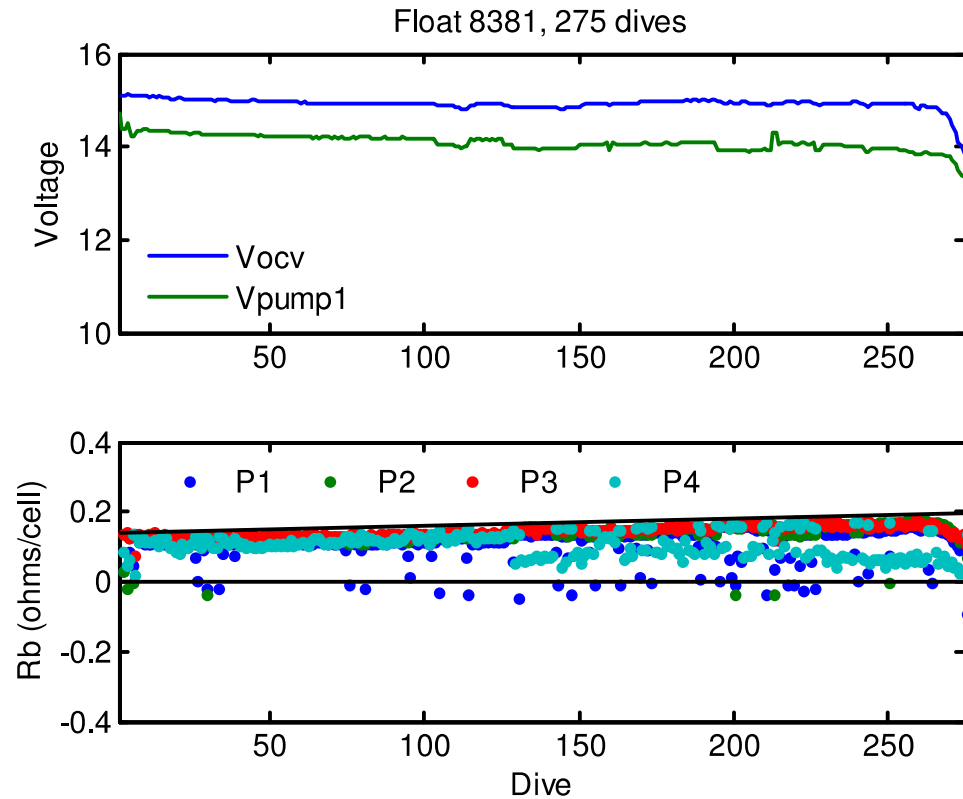
Slightly degraded performance compared to APEX floats, due to reciprocal pump, but still has low current drain.

Navis floats extract ~60% of their battery energy

Solo2 Floats



Float with 2 Electrochem battery packs
 Passivation layer causes high resistance at start of pumping
 Significant battery degradation over time.
 Solo2/Electrochem floats only extract 50% of battery energy.



Float with 2 Tadiran battery packs
 No passivation or degradation of batteries
 Low internal battery resistance
 Presently completed 320 cycles.
 Solo2/Tadiran floats extract 75% of available battery energy.

Summary

- Plots of battery voltage (or internal battery resistance, if possible) with no load and during pumping are excellent diagnostics for evaluating battery performance.
- Improving battery performance is the easiest way to increase the Argo fleet.
- All Electrochem batteries show some effects of passivation. Degradation is most profound when high demand occurs before passivation has been burned off.
- Tadiran batteries avoid passivation and have a much lower effective internal battery resistance.
- Expect to extract 75% of energy from Tadiran primary lithium/lithium ion battery packs.
- Decreasing energy per cycle and increasing battery capacity should enable Solo2 floats to make 500 cycles.