Selene Rendezvous 13

Roche Harbor, WA

Lithium Ion Batteries for Boats

Fact or Flame?

Dean Klein

SaltHeart (5319)

- Originally named “Outward Bound”.
- SaltHeart is a 12V boat, with a ProSine 3.0/12 inverter/charger, Balmar 320A alternator and MC612 regulator.
- Batteries were in the engine room, aft on the port side in a nicely-made rack.
- 12 telecom-style batteries, 90lbs each, in Selene boxes.
- We bought S5319 in 4/2011 and renamed her SaltHeart.

The Genesis of an Idea

- Initial battery woes
  - Battery system had been re-done, but the replacement batteries proved insufficient.
    - Capacity was allowing only 1 day on the hook
    - Windlass performance was inadequate
    - Thrusters were good, but had separate 24V banks each.
- Telecom batteries are not good for marine deep-cycle application: Designed for infrequent discharge cycles
- Noticed a slow charge rate, cause???

- Upgraded to 4 FullRiver DC260-12 8D AGM batteries. (260Ah*4=1040Ah…) Painfully…

The Death of a Battery

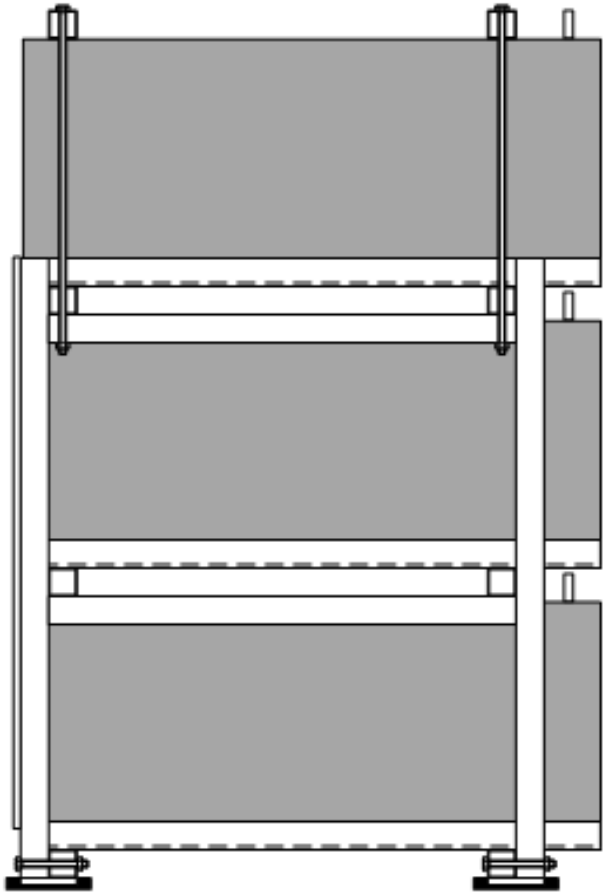
- Noticed 2 things:
  - Charging by the Balmar alternator was slow and slower.
- Discovered two things:
  - Only one output from the Balmar alternator was connected. Only 160A, not 320A
  - Battery and alternator temp sensors were swapped to regulator.

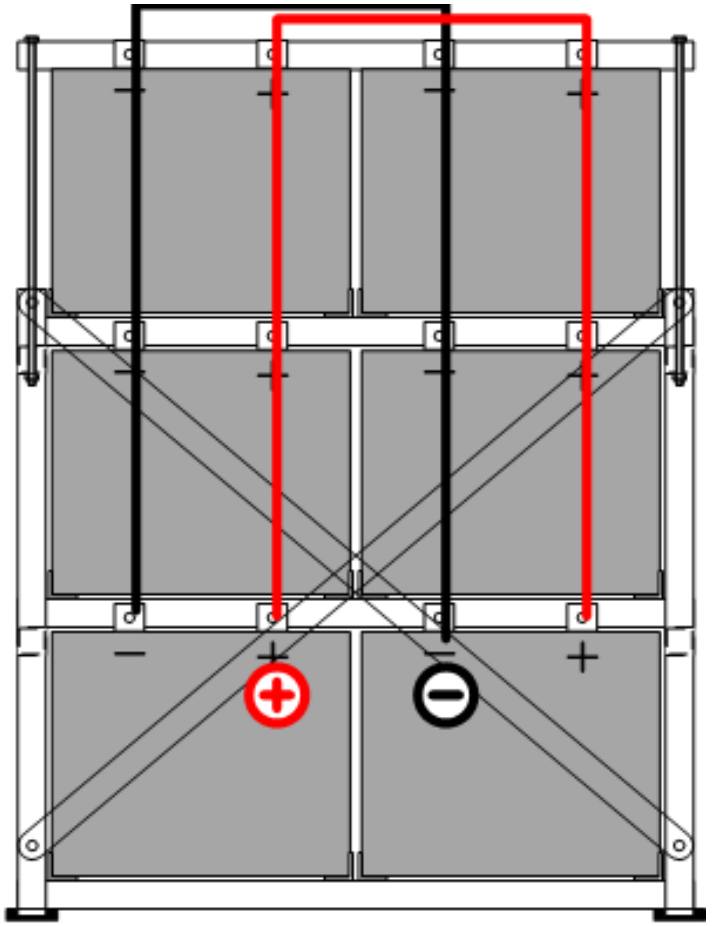
- Regulator would prematurely reduce bulk charge voltage (and thus current), never getting the batteries to a full charge.
- Fixed this before the batteries were damaged.

The Death of a Battery, Part 2

- After 18 months of use, capacity was not satisfactory. (<300Ah usable)
- Noticed something else:
  - Several times I came to the boat to find the batteries dead and the charger off.
- Discovered something else:
  - The ProSine charger would not start charging after a power interruption. This, as it turns out, is a setup menu option.
  - Recommendation: Don't do this!!!
- Designed a new battery rack for 6 FullRiver 8D batteries, but then…

6x8D Battery Rack





Battery: 8D AGM by Full River

Lithium Ion Batteries

- I had been using Lithium Ion batteries for 10+ years:
  - Computers
  - Power tools
  - RC planes, helicopters and cars
  - High powered rocketry
- Never a failure
- Superior energy density
- Lighter weight
- In use by Coastal Craft

Lithium Ion Battery Chemistries

Type	Chemistry	Short Form	Notes
Lithium Cobalt Oxide	$LiCoO_2$	Li-Cobalt	High capacity: Cell phones, laptop, camera
Lithium Manganese Oxide	$LiMn_2O_4$	Li-Manganese	Most safe. Lower energy density than Li-cobalt, but high specific power and long life
Lithium Iron Phosphate	$LiFePO_4$	Li-phosphate	
Lithium Nickel Manganese Cobalt Oxide	$LiNiMnCoO_2$	NMC	
Lithium Nickel Cobalt Aluminum Oxide	$LiNiCoAlO_2$	NCA	Gaining importance in EV, grid storage
Lithium Titanate	$Li_4Ti_5O_{12}$	Li-titanate	

Chemical Soup

- Lithium + water = fire!
  - (Don't douse your Tesla!)
- Lithium Ion + failure = runaway!
  - (Dreamliner nightmare!)
  - Must detect a failure before it happens, or very early after the failure. Lithium Ion batteries need battery management systems.

- Lead-Acid + seawater = chlorine gas!

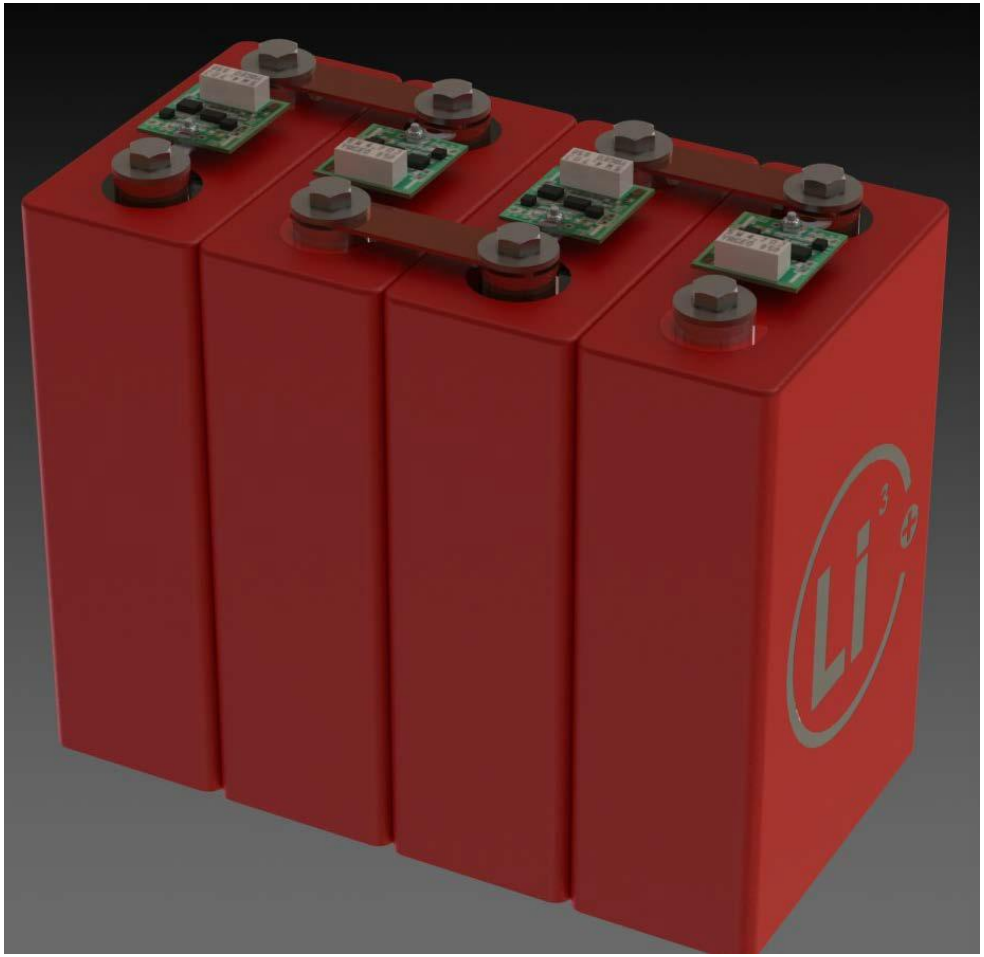
Other Lithium Ion No-No's

- No overvoltage
  - No equalization cycles
  - No thermal compensation
  - Pay careful attention to charger profiles
- No deep discharges!
  - Take care to balance cells
- Very flat voltage until ~95% discharged
  - Deep discharge sneaks up on you.
  - Voltage detection methods not useful
- Watch Temperature:
  - -4° to 140°F (-20° to -60°C)

The Lithionics Solution

- Monitor each battery cell at the cell.
  - Distributed vs. centralized management
  - Slightly more expensive
  - Monitor temperature, voltage, balance
- Protect the bank from overvoltage and undervoltage.
  - Use the “Never-Die” box
  - Check for cell balance and correct as needed using a precision charger
- Balance the loads between parallel cells
  - Equal length cables
  - Heavy bus bars

Parallel Connections in Battery



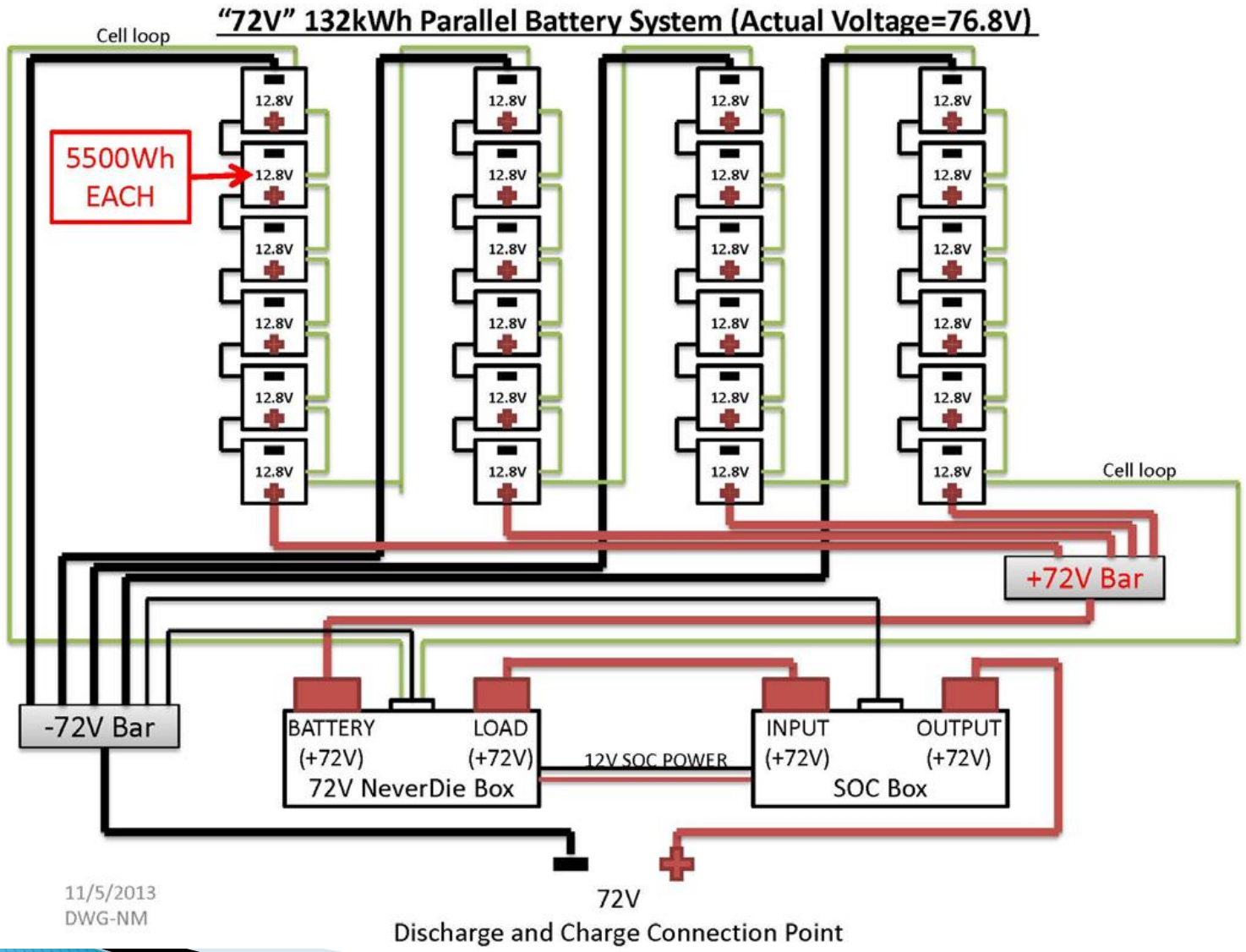
At Cell Monitoring, Shutdown

On each cell install a microcontroller & Sensor

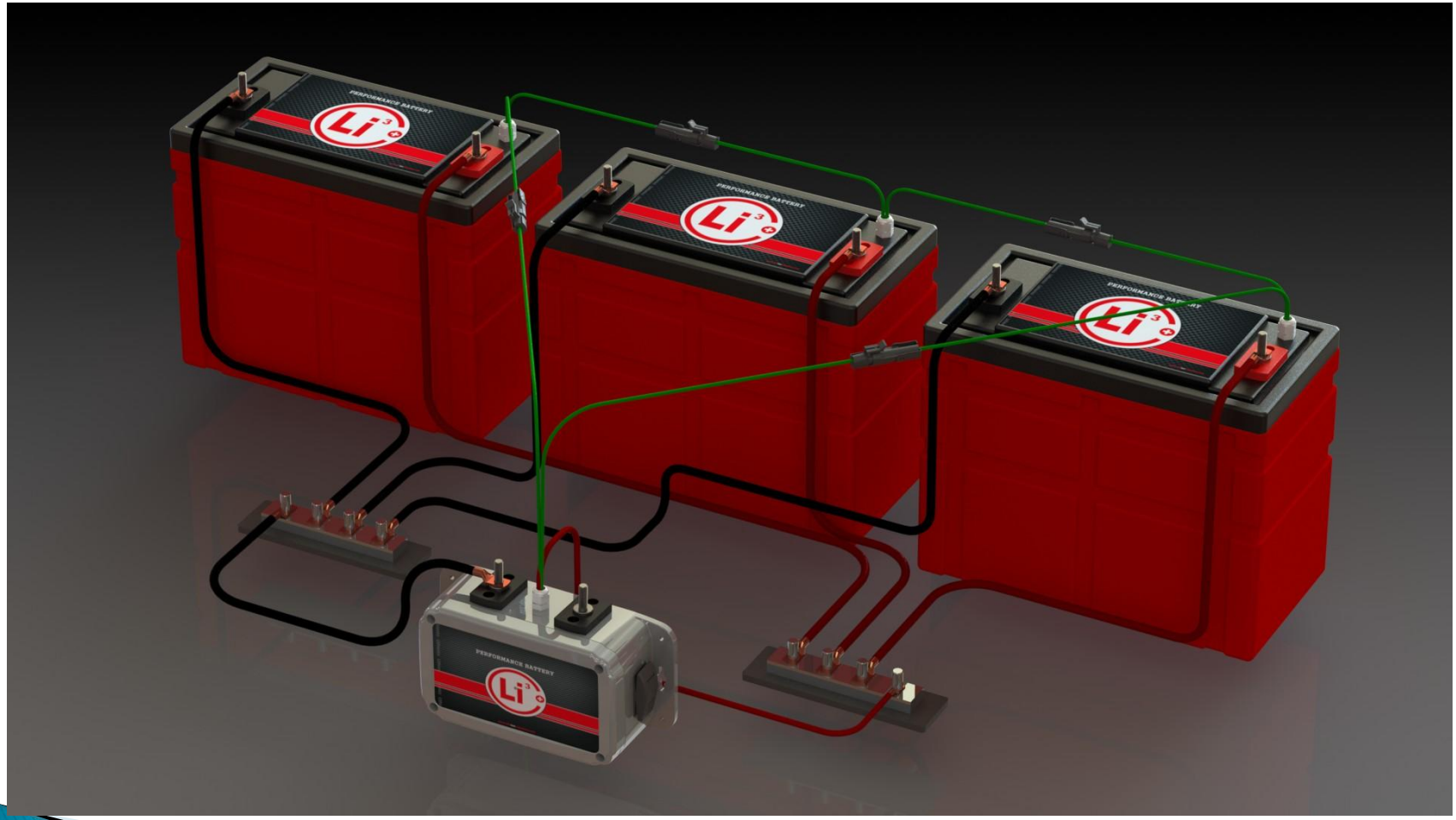
ADVANTAGES:

- ON-CELL Data Collection is Instantly Processed and Compared to EPROM Values of That Cell's Control Standards
- GOOD-BAD (State-of-Health) Decisions Continuously Broadcast Via Proprietary Single-Wire OPTO-ELECTRIC Communication Protocol that Features ZERO Data Distortion to Main Computer
- ON-CELL Balancing is CRITICAL: More Accurate, Free from Connector-Wire Induced Voltage Drops and Resistance
- Each Per-Cell Microprocessor has the Capability to Judge and Shut-Down the Entire Battery: Example….a 48 Volt Battery Has 17 Series-Connected Computers Using GO/NO-GO Logic

Example


"72V" 132kWh Parallel Battery System (Actual Voltage=76.8V)
Cell loop
5500Wh EACH
12.8V
Cell loop
+72V Bar
-72V Bar
BATTERY (+72V)
LOAD (+72V)
72V NeverDie Box
12V SOC POWER
INPUT (+72V)
OUTPUT (+72V)
SOC Box
11/5/2013
DWG-NM
72V
Discharge and Charge Connection Point

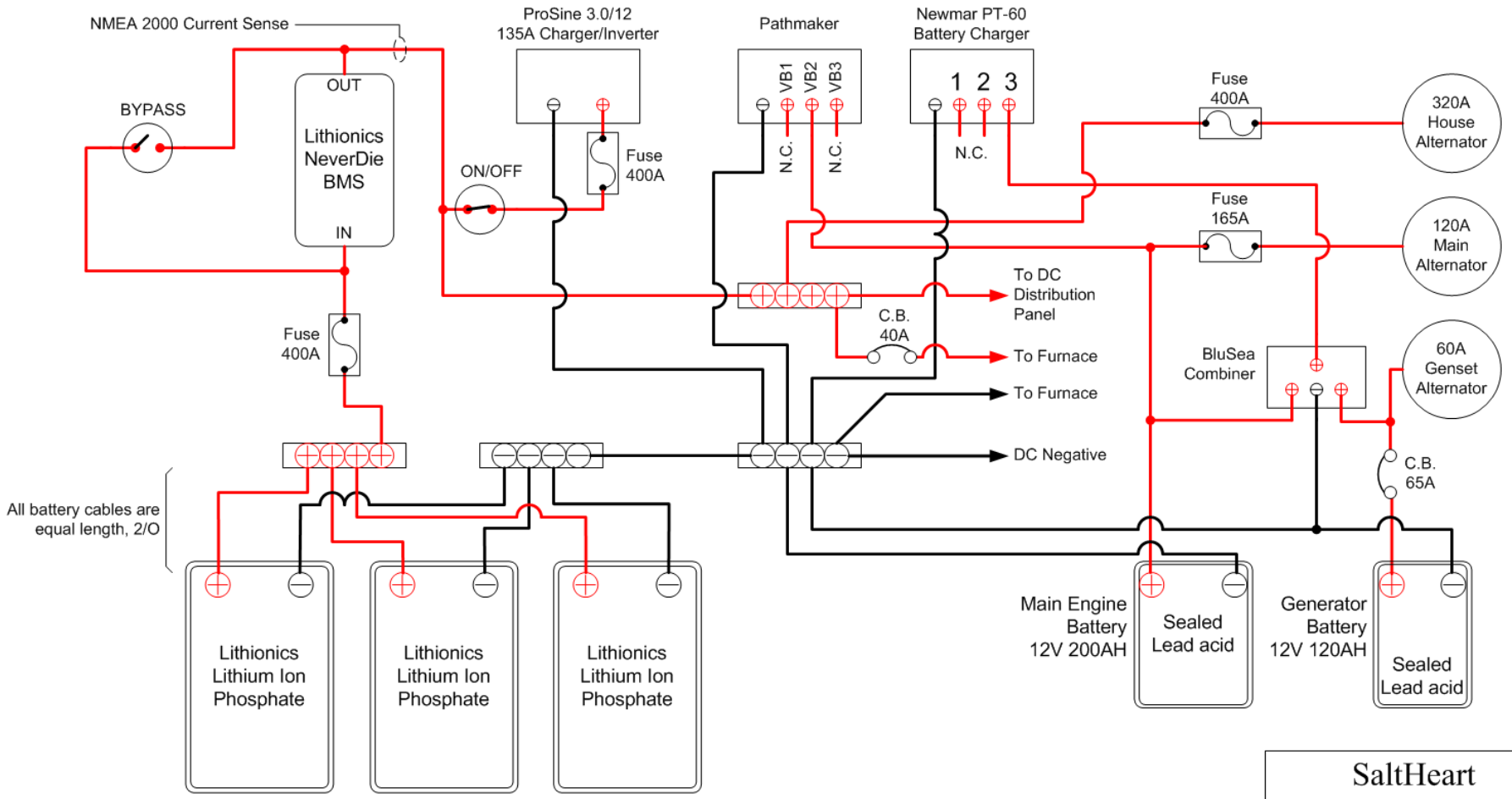
As Done on SaltHeart



Dean's Improvements

- Moved batteries out of engine room to commissary.
  - Lower, more consistent temperature
  - Side benefits:
    - Closer to Inverter/charger
    - The biggie:
- Removed measurement shunts in favor of Hall-effect current sensors. (Using Maretron DCM-100 NMEA2000 System)

SELENE-5319 DC 12V BATTERY CHARGE AND DISTRIBUTION SYSTEM



REVISION HISTORY		
1.0	6/2/13	Following Li Ion Phosphate battery installation
2.0	7/26/13	Following NeverDie bypass installation

SaltHeart	
PROJECT:	SELENE 5319
TITLE:	DC WIRING
DRAWN BY:	D. Klein
DATE:	July 26, 2013
REVISION:	2.0

The Economics…

	AGM	Lithium-Ion	
Maker	Lifeline	Lithionics	
Part number	GPL-8DL	GT12V450A-8D	
Raw Capacity	255	450	Ah
Depth of Discharge	50%	90%	
Useable Capacity	127.5	405	Ah
Batteries Required for a 1200Ah useable bank	10	3	Batteries
Lifetime Cycles	1000	5000	Cycles
Weight/Battery	156	110	lbs
Total Weight	1560	330	lbs
Cost/Battery	$600.00	$5,000.00	Each
Total Price	$6,000.00	$15,000.00	Total
Expected Cycles/Year	150	150	Cycles
Expected Lifetime	6.7	33.3	Years
Cost/Cycle	$6.00	$3.00	per cycle

Experiences

- 3-4 days at anchor without charging.
- Improved windlass and davit performance.
- Fast charging

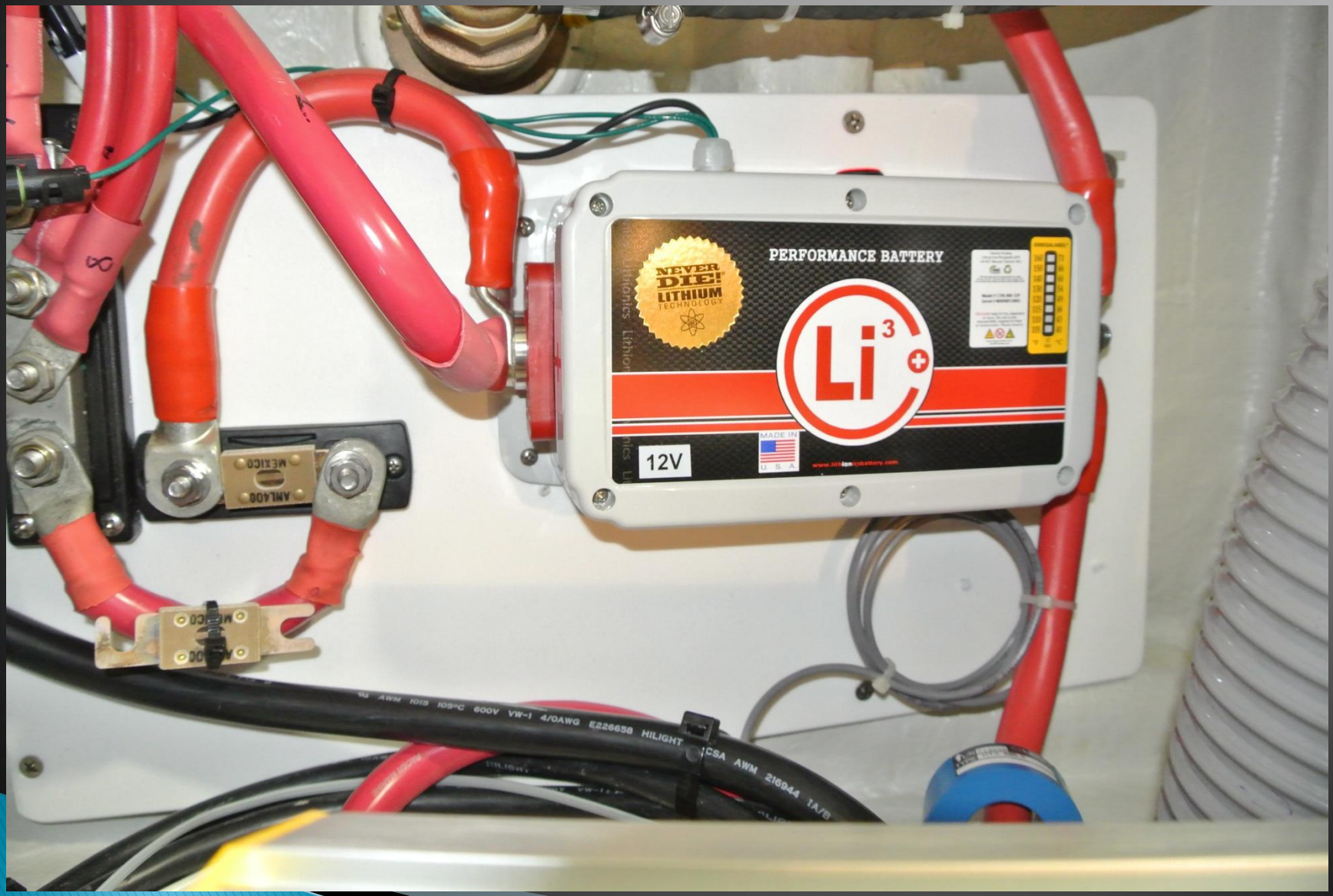
- Alternator heat – due to higher charge current. Have upgraded regulator, but have not yet programmed this.
- Never-Die trips – fixed by tricking the ProSine charger.

Trick your charger

- Most chargers (and alternator regulators) will run just fine without battery temperature sensing. Many allow manual setting of battery temperature. By adjusting the charger's battery temp setting to output voltage can be tweaked.
- It may also be possible to replace the battery temp sensor with a resistor or potentiometer – but I have not tried this.
- For the ProSine 3.0 I set the battery temp to "warm" and the voltage is perfect.

Commissary View

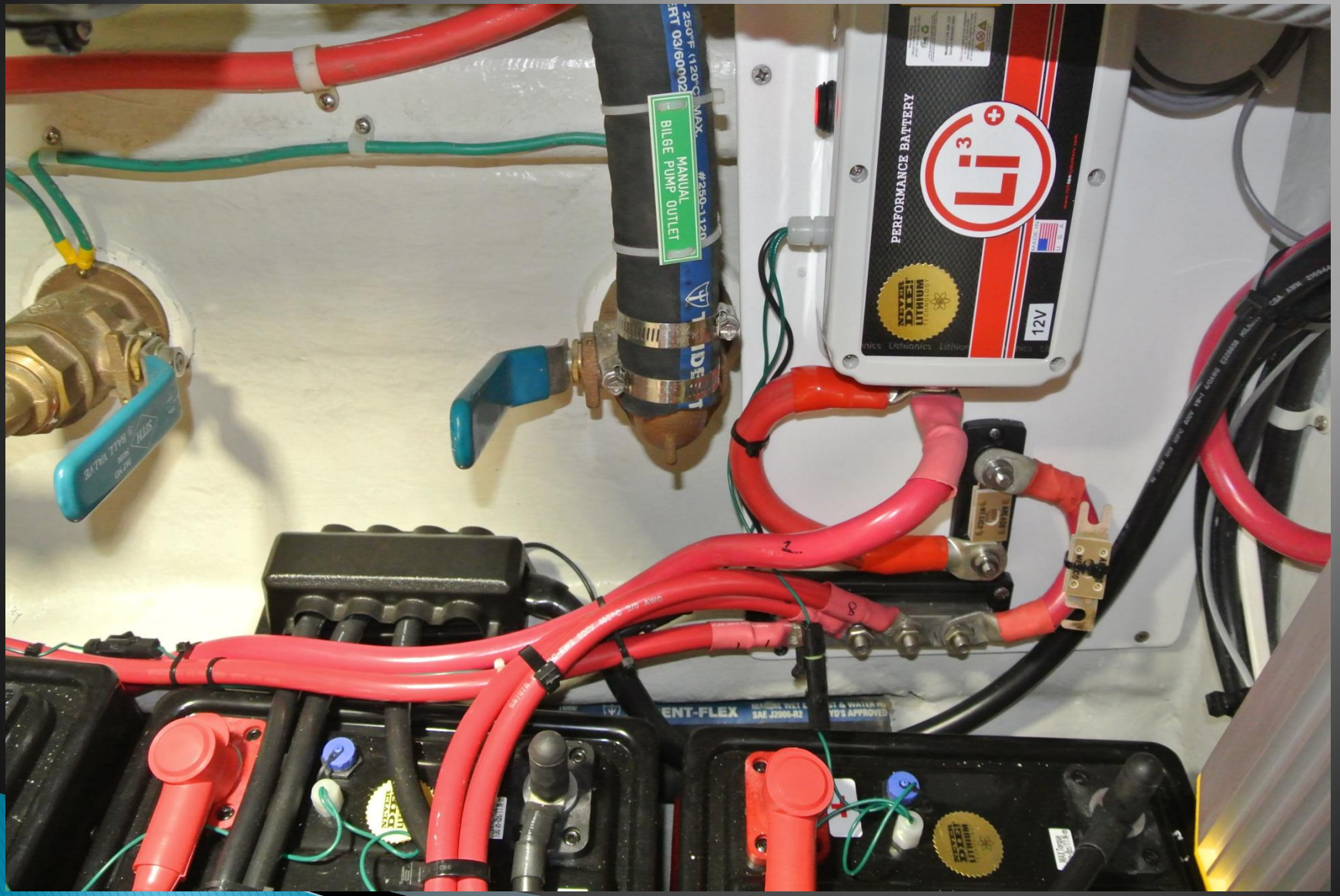
NeverDie BMS



Balancing Charger

NeverDie Bypass

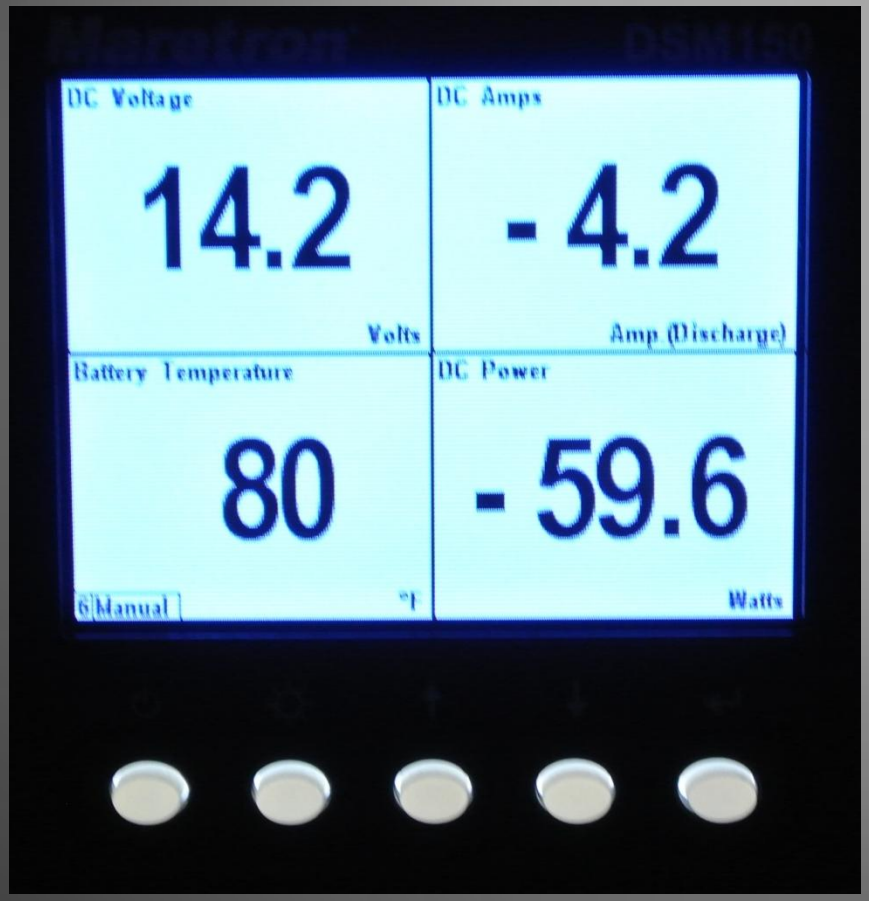
Done!



The Bonus


COOLANT SERVICE
COOLANT FILTER
RAW WATER IMPELLER
HEAT EXCHANGER
INTERCOOLER
ZINCS
VALVE ADJUST
EXHAUST ELBOW
OIL CHANGE
OIL FILTER
FUEL FILTER
RACOR LEFT
RIGHT

Maretron DCM-100 System



Lithionics Contact Info

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Clearwater, FL 33759

Group: “DK Selene” should get you a discount.

Questions?

April 21, 2014