B1 BATTERY BANK ANALYSIS

March 1, 2013

Charging Equipment

- Prosine AC/DC 2500 watt inverter/charger (1998-2004, 100A DC) with temperature compensation, replaced by Prosine AC/DC 3000 watt inverter/charger (2004, 120A DC) with temperature compensation.
- Ample Power Next Step regulator (1998 & 2005) with temperature compensation.
- Ample Power EMON monitoring system (2000) including shunts to measure battery bank input/output and high output alternator performance (in addition to many other factors).
- Ample Power #4060 high output large frame alternator (1998 & 2001, 190A).

Battery Bank Management (based on 90% anchor/10% marina voyaging)

- When at anchor, the B1 battery bank state-of-charge (SOC) is usually no lower than 70%. Operating the generator in the morning and evening brings the SOC to at least 80%. The 80% state of charge is determined by observing the amp hour output of the AC powered 120A charger at 60A/77F for the Second Battery Bank.
- When underway, B1 usually becomes fully charged by the main engine high output alternator after 3 hours or so.
- When on shore power, full charge float is maintained using the backup AC powered 40A regulated taper charger.

The First Battery Bank

- First Battery Bank (1998 to 2004): (10) 2GCb wet cell 6V golf cart batteries (Dyno) wired in series/parallel to provide 12VDC and 1100Ah. For this bank, the high output alternator (190A) represented 17.3% of capacity, the AC charger (100A) represented 9.1%.
- The First Battery Bank was sized to accommodate a daily consumption of 250A which included a relatively large furnace and refrigeration system, all later downsized.
- The First Battery Bank of medium duty wet cell batteries provided around 180,000 Ah over 6 years equating to around 327 cycles at 50% DOD with a battery only ($55 each) expense of **$.003055 per amp hour or $1.68 per 50% DOD cycle (550Ah) or $.25 per calendar day.**
- The First Battery Bank required significant maintenance time in monitoring, measuring specific gravity, cleaning connections constantly immersed in acid, and equalizing. If you consider the $55 (each battery) price of acquisition only, this is by far the best possible amp hour value possible as long as you don't assign too much hourly pay to the maintenance time involved.

The Second Battery Bank

- Second Battery Bank (2004 to 2013): (10) GGC2 gel cell 6V golf cart batteries (Gel-Tech) wired in series/parallel to provide 12VDC and 900 Ah. For this bank, the high output alternator represented 21.1% of capacity, the AC charger (120A) represented 13.3%.

- When it became time for new batteries in 2004, a new 120VAC inverter/charger was installed having a charger rated at 120Ah and a charging profile for gel cell batteries. The daily consumption prediction was reduced to around 200Ah, and a more hands-off system was desired that also did not leave battery gas in a bilge area with limited ventilation.
- The Second Battery Bank of gel cell batteries provided around 216,000 Ah over 9 years equating to 480 cycles at 50% DOD with a battery only ($165 each) expense of **$.007639 per amp hour or $3.44 per 50% DOD cycle (450Ah) or $.51 per calendar day**.
- The Second Battery Bank did not require much maintenance/management time, primarily only monitoring charge rates and battery temperature when underway. There was no battery gas produced in the bilge area, which was a great improvement over wet cell batteries.
- It was also observed that the voltage discharge profile of the gel cell batteries was significantly different that the wet cells of The First Battery Bank: The wet cells' voltage would drop fairly fast down to around 12.4, then hang there for a long time; while the gel cells would drop very slowing from the full charged voltage. On average, the gel cell battery voltage appeared to be about .2 volt higher than the wet cells until 12.3 volts when they tended to match.

Priorities and Considerations for the Third Battery Bank

- Priorities include keeping a sealed (non-gassing) battery, so only gel and AGM batteries are considered (No lithium ion).
- The Third Battery Bank should, so far as possible, utilize existing chargers, regulators and monitors in addition to requiring a similar level of system management.
- Strong marketing efforts by AGM manufacturers and retailers coupled with gel cell charging restrictions, has produced a situation where (according to one battery retailer) AGM's currently outsell gel's about 100-1. One manufacturer (Concorde Lifeline) no longer makes gel batteries, only AGM's.
- Internet searches for various AGM battery suppliers/retailers and forum reports by real-world users indicate that AGM's tend to have less cycle life than gels, sometimes contrary to AGM makers support information.
- One web site (http://www.morganscloud.com/2010/08/02/agm-battery-test-part-1/) has verified this to some extent by reporting in detail on their AGM failures and the need for very specific charging and management procedures. Their report includes battery factory input and life cycle extension solutions.
- Only Concorde Lifeline manufactures AGM batteries that recommend a conditioning (equalization) charge to help control plate sulfation which reduces battery cycle life.

Third Battery Bank Options

- **Option 1:** Install another bank of (10) 6V gel golf cart batteries (900Ah) for about $330 each. Assume 216,000 Ah over 9 years equating to around 480 cycles at a 50% DOD with a battery only ($330 each) expense of **$.01528 per amp hour or $6.88 per 50% DOD cycle (450Ah) or $1.02 per calendar day**. **Pros:** No change in charging/monitoring equipment. Expect the same level of service and battery

maintenance/management requirements as The Second Battery Bank. **Cons:** Heaviest option.

- **Option 2:** Install a bank of (8) AGM 6V golf cart batteries (880Ah) for about $290 each. Assume 144,000 Ah over 6 years equating to around 327 cycles at a 50% DOD with a battery only ($290 each) expense of **$.01611 per amp hour or $7.09 per 50% DOD cycle or $1.06 per calendar day**. **Pros:** Can utilize existing charging equipment except for possible conditioning exercise. Recharging is enhanced by increased acceptance rate, therefore somewhat lower recharging times. Total 156 lbs less weight than present bank. **Cons:** If Lifeline batteries, may need to condition several times per year (at least beginning/ending of cruising season). AC chargers are unable to condition/equalize at recommended Lifeline voltage (15.5V vs 16.5V equalizing voltage for flooded batteries), consider varying temp sensor input to produce the recommended 15.5V (or similar) conditioning charge. If Lifeline, have read that 6 hours at 16V or 8 hours at 15.5V are both acceptable.

- **Option 3:** Install a bank of (8) 6V gel golf cart batteries (720Ah) for about $330 each. Assume 168,000 Ah over 7 years equating to around 467 cycles at 50% DOD with a battery only ($330 each) expense of **$.01571 per amp hour or $5.65 per 50% DOD cycle (360Ah) or $1.03 per calendar day**. **Pros:** No change in charging/monitoring equipment. Expect a similar level of service and battery management requirements as the Second Battery Bank. Total 138 lbs less weight than present bank. **Cons:** Expect a slightly lower cycle life due to deeper depth of discharge.