Lead Acid Batteries in marine applications demystified

Non-technical article for boat owners regarding battery options.
[Released for Pacific Motor Yacht Magazine - October 2009]

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Abstract: Today, there is a range of Lead Acid batteries on the market with variation on a theme to accommodate a raft of applications. Because the chemistry is specific so to deliver the energy in a usable format for that application, it is important to ensure correct selection. Where it is now possible to select the correct battery, it is also possible to select an inappropriate model and experience poor performance. An understanding of the variations will assist the user to select the correct chemistry and maximise life expectancy.

Index Terms: Variation, appropriate charge algorithm, cost

The lead acid battery was invented 150 years ago by Gaston Plante in 1859 and today we still have no cost effective alternative. We use them in cars, mobility vehicles, wheel chairs, golf buggies, UPS systems and yes, boats - the list goes on.

With the age of the electric vehicles upon us, governments around the world are funding development to break our reliance on fossil fuels. The success of the plug in vehicle is wholly dependant on the announcement of an affordable light weight power storage battery.
We are well accustomed to lead acid technology and let's face it, globally it is a multi billion dollar industry.
However, the objectives and challenges of battery design is attempting to steer us away from Lead Acid but perhaps the driving factor to keep us on the well worn track is cost.
So, can lead acid compete in this mobile world? a resounding yes and even though we are still relying on the basic technology, we are spoilt with choice as the chemists develop variations on the theme.
The variations lend themselves to specialised applications so where it is possible to get exactly the right battery for the job, it is also possible to get the wrong one or at best, a compromise.
No longer is a battery a battery but having a little understanding may keep us out of trouble.

Essentially there are five variations on that theme, each with its advantage and disadvantage for any given application.

The flooded or wet battery, sometimes called a vented battery would be the most common battery used for starting purposes. The commercial units designated 'N' series, N120, N150, N200 etc are big robust batteries and commonly used in launches where high current is demanded for starting big diesels, powering anchor winches and bow thrusters. They are cost effective and heavy.

Maintenance Free or Calcium Lead Acid batteries are also available for start duty and generally used for the smaller motor used in yachts or trailer boats. These batteries are still vented but it is not possible to service the electrolyte. They often come with a 'magic eye' which changes colour telling us something about the specific gravity of the electrolyte. Perhaps a criticism of this system is the magic eye measures one cell only and of course does not tell the complete story. However, the up side of the maintenance free calcium is low self discharge and when charged correctly does not gas. This has been achieved by adjusting the chemistry to elevate the gassing voltage to around 14.8volts, subject to temperature, in contradiction to the 14.1volts of the normal flooded version.

The 50's produced the first modern Gel battery and the 70's saw the development of the AGM. Absorbed Glass Matting applies to the separator between the electrode plates in each cell and made of felt where micro-fine glass fibres absorbe and immobilise the acid.
The use of matting as a separator is considered the ideal method to immobilise the electrolyte necessary to create a sealed battery. The term Dry Cell Battery often applied to this technology comes from the 95% starvation saturation of the matting of the aqueous solution - the electrolyte. The separators are assembled under a compressive load to enhance the electrolyte / electrode interfacial conductivity. This compression loading against the plates improves the cyclic life of the AGM battery. It is also assembled maintaining a variable 3psi internal pressure to assist with the oxygen recombination cycle necessary in a sealed battery. For safety purposes, the case has pressure relief valves to release pressure in the event of excessive build up from over charging or high ambient temperatures. Hence the term VRLA, Valve Regulated Lead Acid.

Initially AGM batteries were designed as stand-by batteries as used in UPS applications, a roll they are well suited. However, in later years, with design variations, they are also available for start and deep cycle applications.

The limitation of the AGM battery is an inability to cope with high ambient temperatures as experienced in the tropics. Often you will find in the small print of warrant terms and conditions – ‘Warrant period is halved if this battery is used in temperatures exceeding 25ºC for more that 10 consecutive days’ – or similar.
This is due to dry-out of the mat separator reducing that electrolyte / electrode interfacial conductivity which reduces cyclic life.
A word of caution, you will often find battery banks housed in engine rooms mounted adjacent to hot engines. This is not a good place for any battery and in particular, sealed batteries.

The Gel battery was introduced and utilises a Gel electrolyte. The otherwise free acid is immobilised with a fine silica powder and forms a gel substance. The German Exide company, Sonnenschien has promoted gel technology for many years and have been very successful in cyclic applications out performing many rivals.
On the other hand, the immobilised gel electrolyte suffers shrinkage over time due to loss of water and dry out or sulphating of the negative electrode.
The gelled electrolyte inherently has a lower recombination efficiency compared with AGM. And further, the gel will not tolerate gassing brought on by excessive voltage while charging. However, this issue is manageable with appropriate regulation of alternators and mains-powered chargers preventing voltages from exceeding the 14.1 gassing voltage.

It is easy to note that mixing these technologies within the same charging regime is not possible.

Having briefly discussed the two SLA units above introduces the Hybrid technology being a hybrid of AGM and Gel.

It is reported that the Hybrid came about through co-operation between the American and British Telecommunication Industries. As a supporting power source, UPS, it was in their interest to provide an answer to the short fall of the batteries we have discussed above. It was

necessary to overcome the gel dry-out and AGM glass matting shrinkage reducing the interfacial conductivity to achieve reliable batteries with a reasonable life span.
It is considered AGM has the preferred method of immobilising the electrolyte and a material was developed with an improved memory.
The cell cavity was filled with a reservoir of electrolyte to prevent dry-out eliminating the gel issue. It was then up to the LA Battery Industry to produce the revised technology and so the Hybrid was announced onto the market.

Other technologies are immerging such as Silicon and Carbon for the production of electricity from chemistry.

A subsidiary of Caterpillar, Firefly, has produced a Carbon Foam technology, offering cost effective and improved Kilowatt/ Kilogram efficiencies. They introduced their first model into the truck market about a year ago and are very excited about its advantages.

In the world of Lithium, LifeBatt of Canada and MasterVolt of Holland have introduced a Lithium Ferrous Phosphate or otherwise known as Lithium Iron Phosphate battery. $LiFePO_4$ technology emerges as a 24 Volt cyclic and start battery. The manufacturers boast one third the weight of Lead Acid, non toxic with a 3000 cycle warranty. That's four times the life of a good quality Lead Acid battery and I understand is about 3 times the price but at this time price is 'on application'. One could reason price equivalence based on longevity but of course you would need to own them long enough to enjoy the advantage. That advantage, as serious race yacht owners know, is the lack of weight.
The battery is made up of individual cells connected in series. As lithium can be unstable under undesirable conditions, this battery has Bidirectional Cell balancing electronics inside the case and has facility to be connected to a computer for management purposes.
The British Marine Electronics Association headline the Lithium Iron as being lighter and better value than Lead Acid. Watch this space….

You will appreciate that all of the batteries discussed here are rechargeable, or to put it clinically, the chemistry is reversible. However not all potential power stored is available to us and not all power taken from the charger is accepted by the battery's chemistry. We talk about Peukerts exponent and charge efficiency but perhaps this is a subject for another discussion. However, I would like to point out the importance of recharging your battery bank correctly.

All the batteries discussed above have an appropriate charge algorithm. This should not be taken lightly if you expect a reasonable life span. My experience of battery complaints is dominated by one common theme. "The house batteries don't last as long as they did when new". The reason is also common, they have not been correctly recharged or have been reliant on the alternator for recharging. The alternator was not designed to recharge a house bank. It is designed to replenish the start battery and carry the electrical loads of the running engine. If you need to rely on the alternator, the capacity of such needs to be balanced with the bank size and voltage algorithm be controlled by an appropriate external regulator.

In conclusion:-
Don't look at any part of the battery bank or power management system in isolation as all must be congruent to operate efficiently.

<u>Bank size</u>:
You should start with the expected electrical load analysis which should not be your budget and if that is a factor, perhaps the whole system be scaled to suit a budget.
The load analysis is the amperage requirement between recharge interval's. If you recharge daily, the load requirement is twenty four hours.

To expect a reasonable life span from your chosen battery, the depth of discharge should not exceed 50% therefore once the load is known in amphours, double it to find the battery bank Amphour capacity.

Battery Technology:
Choose a technology to suit the environment categorised by ambient temperature and perhaps existing charge voltages from the alternator and shore power charger. The chosen technology will also determine the battery maintenance needed.

Alternator capacity:
The amphour capacity of the bank is the main determinant of alternator size and a good rule of thumb is 25% of the bank. ie. 500AH bank requires 125A alternator.
The internal resistance of the battery will also in part, determine the current draw during recharge and is a consideration with sealed batteries. In general, they will draw more than the wet battery counterpart.

Shore powered charger.
Again the capacity of a charger is determined by the bank being charged and again, a rule of thumb is 10% of bank size. However, if consumers are drawing current while charging, the fridge for instance, the current draw will need to be added. Another rule of thumb takes us to 20% of bank capacity.

Where I cannot attempt to specify any given power management requirement in this article, my hope is for the reader to have a good enough feel for the need to discuss the subject appreciating the complexities of onboard electrical systems. A good deal of thought is required to get it right or as close to it as reasonably possible so your batteries perform and you enjoy your boating.