She's ELECTRIC

PART 1: **BATTERIES**

Do you know how to feed your marine battery through the winter? Do you know your CCAs from your VRLAs? Do you know that Dave McCabe does? In the first of a series on boat electrics, he explains the mysteries of amp-hours and life cycles

Our modern lives are inexorably bound up with electricity, a fact which our boats now mirror. They are equipped with heating, cooling, refrigeration, navigation and lights. They also present unique electrical difficulties. In most circumstances the boats' electrical systems must not only supply power to the various devices on board, it must generate it too.

BATTERIES, OR THE 'WHATSITS UNDER HERE SOMEWHERE'

The key to a sufficient, reliable and efficient electrical system is the battery pack. Typically in boats this will be a set of lead-acid batteries providing a 12 volt, or sometimes 24 volt, power source. Batteries on a boat lead a hard life – engine running time could be two – four hours per day. Yet we often expect our boats' batteries to keep the whole electrical show on the road for at least 24 hours (those of you who do rallies will understand this).

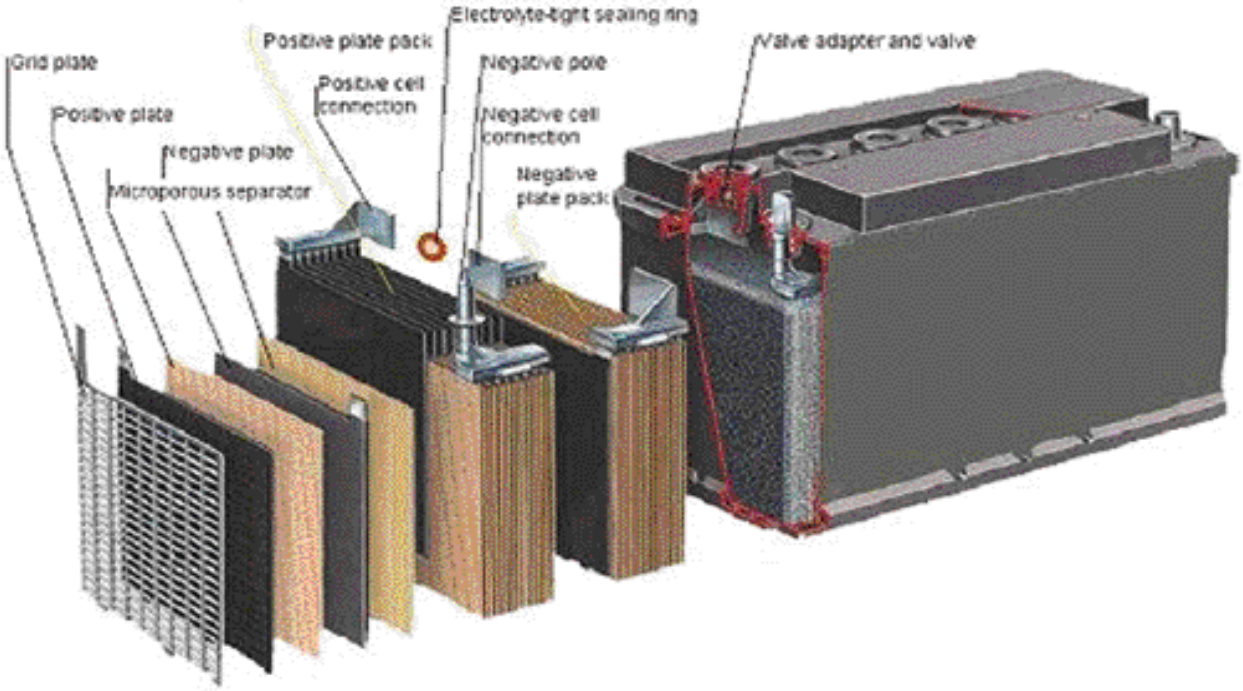
Lead-acid batteries make up the majority of battery banks on board. In recent years, enhanced lead-acid types have appeared. The basic flooded lead-acid battery is shown in **figure 1**. A lead-acid battery is an electrical storage device that uses a reversible chemical reaction to store energy. It uses a combination of lead plates or grids and an electrolyte consisting of a diluted sulphuric acid to convert electrical energy into potential chemical energy and back again.

Most car batteries and many 'marine' batteries are based on this type of construction, with alternating negative and positive plates, isolated by inert separator plates, making up a cell. Each cell produces approx 2.11 volts, so six cells form a typical 12 volt battery.

MARINE, LEISURE OR DEEP CYCLE, OR 'WHAT'S IN A NAME?'

Much confusion arises over the use of 'marine' or 'leisure' batteries, or the term 'deep-cycle'. A boat battery,

FIGURE 1
Basic flooded lead-acid battery



In the next part of this series, we look at on-board charging systems and ways to put back all those pesky amp hours.

Checking the battery state

There are three basic ways to check battery condition. A specific gravity test, an open-load voltage test and an on-load voltage test.

1. Specific gravity
This uses a battery hydrometer, but this only works where you can access the individual cells. You can get a battery hydrometer in any motor factors and it's simple to use. First protect around the battery case against acid spill and wear gloves and eye protection. Then using the hydrometer, draw off a sample from the cell. Check against the table below.

BATTERY STATE USING HYDROMETER

Specific gravity (15°C)	Specific gravity (26°C)	Percent charged
1.273	1.265	100%
1.233	1.225	75%
1.198	1.190	50%
1.163	1.155	25%
1.128	1.128	0%

Check each cell in turn. There should be no significant difference from cell to cell. If there is subject the bank to a good long recharge and check again. A recurring low cell indicates that the battery is in poor condition and needs replacing.

2. Open voltage test
This is a simple test that simply requires any digital multimeter. The battery must be rested for at least an hour (24 hours for gels). That means no discharge or recharge activity. Measure the voltage at the battery terminals.

BATTERY STATE USING OPEN VOLTAGE

Open circuit volts	Percent charged
> 12.6	100%
12.4 - 12.6	75% - 100%
12.2 - 12.4	50%- 75%
12.0 - 12.2	25% - 50%
11.7 - 12.0	0% - 25%
< 11.7	0%

Remember this test only works on a battery fully in rest state. For good results leave any battery disconnected from any sources and test after 24 hours.

3. On-load
This is a method often seen in garages and motor factors. It requires that a big load be placed across the battery. This is typically in the form of a large resistor position between two test prongs. The test prongs are placed on the battery and the voltage is read. A good battery should hold a steady voltage reading for 10 secs. A failing or partly-charged battery will show a gradual fall off in voltage. This test is a crude but fast way to determine an approximate state of the battery.

unlike a car battery, often needs to withstand multiple deep discharges to 50% of its capacity or below and then can be subjected to rapid recharging from the boat's alternator or battery charger. This is a deep-cycle battery. It may spend considerable amounts of its time partially charged and may be subjected to many partial recharges and discharges before being fully recharged. Proper deep-cycle batteries have significantly stronger internal construction, larger, thicker plates and denser active materials. The heavier construction allows the battery to withstand the rigours of the discharge and recharge cycles that no car battery could cope with.

For a boat's domestic 12 volt system, the only way you can evaluate batteries marked 'marine', or 'leisure' is to get the specifications and gen up on battery comparisons. Alternatively ensure that you buy from an established battery company with a record of providing technical information. Be wary of no-name batteries marked 'marine' as they could be car batteries in disguise.

AMP-HOURS, LIFE CYCLES AND MORE
There are several key specifications for lead-acid batteries.

- **Amp-hours:** the number of amps the battery will theoretically provide in one hour of use. So for example a 100 amp-hour battery can in theory provide 10 amps for one hour or one amp for 100 hours. However things are not that simple. The amp-hour capacity is not linear – capacity falls with the increasing discharge currents. Typically amp-hour rating is given for a rating period, usually 10 hours. Hence a 100 amp hour battery is dead after 10 hours, that is, discharging at 10 amps per hour. Double this discharge and the battery will die in less then five hours. So, pulling large currents out of a battery will provide you with less capacity then you might other wise expect. So drawing large currents from battery banks can result in woefully underperforming systems, even though theoretically they should be all right.
- **Life cycle:** the typical number of times the battery can survive a discharge to 50% of capacity and recharge. Car batteries will have anything from 50-100 cycles, while top of the line deep-cycle batteries may have life cycles in the thousands. Sometimes life cycles are given as a graph against degree of discharge – usually the less cycles the greater the discharge
- **Cold cranking amps (CCA):** sometimes known as cranking amps (CA), a specification associated with starter batteries. CCA gives an indication of the starting current the battery can deliver to the starter motor – CCAs of 600-1000 are typical. If you want to use your deep-cycle batteries to also start your engine, then it may be useful to look for CCA figures. However CCAs are not a measure of how the battery will perform in a deep-discharge environment. Good marine batteries suitable for domestic applications on board may have a lower CCA then the equivalent starter battery.

FIGURE 2
100A/h 10 hour rated battery

Discharge amps	Capacity hours	Effective amp-hours
2	81	162
6.0	13	107
10	10	100
20	4	81
30	2.5	71
40	1.6	65
80	1	54
100	0.5	50

'If your batteries are approaching the 50% discharge point, recharge as soon as possible'

Types of lead-acid batteries

The most common lead-acid battery is the open cell, flooded lead-acid battery. Each cell is accessible via a plug or cover and the cell electrolyte can be examined and replenished. Most alternatives come under the general title or VRLA or valve regulated lead-acid.

Sealed low maintenance or no-maintenance types
These are typically found in cars and are basically a wet acid battery with excess electrolyte contained in partially sealed cases. During service the excess electrolyte is used up and the battery fails. They really have no place in a marine environment.

Gel types
Gel cells use a thickening agent like fumed silica to immobilise the electrolyte. Thus if the battery container cracks or is breached the cell will continue to function. Furthermore, the thickening agent prevents stratification by preventing the movement of electrolyte.

As gel cells are sealed and cannot be re-filled with electrolyte, controlling the rate of charge is very important or the battery will be ruined. Furthermore, gel cells use slightly lower charging voltages than flooded cells and thus charging voltages will have to be adjusted. Standard alternators will also have to be modified.

Gels have the advantage that they are generally leak proof and can be used in any orientation. However, they can be prone to failure if left partially charged for long periods.

Absorbed glass mat batteries
Absorbed glass mat (AGM) batteries are the latest step in the evolution of lead-acid batteries. Instead of using a gel an AGM uses a fibreglass-like separator to hold the electrolyte in place. AGMs are the most spill-proof and the most vibration- and impact-resistant lead-acid batteries available today. AGMs use almost the same voltage set-points as flooded cells and thus can be used as drop-in replacements for flooded cells.

Basically, an AGM can do anything a gel cell can, only better. However, since they are also sealed, charging has to be controlled carefully or they too can be ruined.

Gel and AGM batteries can dispense charge at a higher rate than flooded cells. Deep-cycle flooded cells cannot deliver more than 25% of their rated amp-hour capacity in amps. Deep-cycle flooded cell battery manufacturers recommend a 4:1 ratio between battery bank size and the largest load encountered on board. AGM and gel cell manufacturers recommend a ratio of at least 3:1.

AGMs and to some extent gels can accept recharge currents much higher then normal flooded cells. So if you can afford it, you can recharge them significantly faster.

Simple tips

Maintenance
Your battery bank is expensive, so mind it. If you can access the cells, then ensure you top up with distilled water (available from any motor factors). Only top up to the level marked on the battery case, but in all cases ensure the tops of the cells are covered. Letting the cells dry out is not a good thing. Ensure the cable connectors are tight, and grease the battery terminals with a bit of Vaseline. If you have sealed cells then ensure you have a battery charger that can handle sealed cells properly.

Series and parallel batteries
Batteries can be connected in series to get higher voltages or in parallel to get higher current. Always use batteries of the same age, amp-hour, and technology type in battery banks. Avoid mixing types unless absolutely unavoidable (emergency starting, etc).

Checking the battery state
If you can access the cells, use a hydrometer (see panel, page 11) or use the rest state voltage graph to regularly determine battery status. If your batteries are approaching the 50% discharge point, recharge as soon as possible.

Keep it ventilated and temperate
The best batteries are housed in a dedicated acid-resistant battery box that has a cover. It should be vented to the outside and away from any extreme sources of heat or cold. The charging process releases hydrogen. In winter ensure they do not freeze. Make sure your batteries are secured well and cannot move.

If in doubt, recharge
Don't leave discharged or partially discharged batteries in that state for long. Recharge them to full as soon as possible. Discharged batteries undergo a process called sulphation where the plates prove resistant to reaccepting and holding charge.

Buy the best you can afford
Don't skimp, read the specs, ask around, and avoid cheapo stuff.

Lay-up
Over the winter, if you have a good three-stage battery charger, then leave it connected to the bank and powered on permanently. This will ensure the batteries stay topped up and will do no harm. Alternatively ensure you charge them fully at least every month.

SIZING YOUR BATTERY BANK, OR HOW TO DETERMINE HOW LONG THE WATER PUMP WILL RUN

To do this properly you need to establish what each electrical item on board draws and for how long in a typical 24 hours it draws it over. This can be done by looking at the rating of each 12 volt device or measuring the current drawn under load. The rating method is usually sufficient. Most ratings are given as watts. Divide the watts by the voltage (usually 12) and you have the current. Figure out the rough time the device is on (in hours) over a 24 hour period. Multiply the two together and that gives you the amp hours over a 24 hour period. So a 20watt Halogen light will draw 1.6 amps and you figure you'll use about 4 hours a day of such a lamp, giving 6.4 amp hours of capacity over 24 hours. I use 24 hours because it's typically the minimum time you want the battery bank to cope without any recharge cycle.

Do this energy audit for all devices on board, then add up all the amp-hours. This gives you a reasonably accurate figure for the boat's requirements. Now here's the kicker.

For a reliable battery bank that will last through many cycles, you typically need four times that total capacity in your battery bank. So if you have a 100 amp-hour requirement, the battery bank needs four times that figure (a little less for top-quality batteries). This is to ensure that at peak demand the batteries don't discharge faster then expected (see **figure 2**, page 11). Remember the calculation above is only for 24 hour standby. If you want several days (remember those rallies again) multiply everything by the desired number of days. This can be a sobering and expensive calculation to convert into actual batteries!
Note: lead-acid batteries cannot generally cope with being discharged by more then 50% or their life cycles are severally reduced. The way to ruin a good battery is to completely flatten it and leave it sit for days in a discharged condition. ■

Dave McCabe boats whenever and wherever he can, is a member of the IWAI executive, contributes to the IWAI chat line now and again and occasionally remembers to go home and see his family.