WHAT IS THE BEST BATTERY TO BUY? —OR— HOW MANY BATTERIES DID YOU BUY THIS YEAR?

There are three basic kinds of batteries that are used on boats today. The first is the cranking battery like that found under the hood of our cars. The second is the deep cycle battery that should be used for our house (or cabin, or auxiliary, or spare, or what have you) battery. The last and far from the least are the new gel cell batteries. Much more about these later.

CRANKING BATTERIES have only one real purpose, and that is starting engines. They are made with thin lead plates that are doped with calcium. This allows them to put out high currents for short periods of time.

A good way to ruin cranking batteries is to deep cycle them about twenty times. An exception to this are most 8D batteries. 8D's were designed to start large diesel engines. Since some of these engines are cantankerous, they add a little antimony along with the calcium to allow the batteries to be deep cycled about 40 times. While I'm on the subject of 8D's, we had a customer come in the other day and tell us that a battery dealer claimed that all 8D's were the same. Now let me ask you, are all boats built the same? Neither are batteries! There are poorly built, cheap batteries and well built, expensive ones. It pays to shop wisely.

Like boats, there are many sizes of batteries, including BCI group sizes 8D, 4D, 27, 24, 2HT, etc. Inside these case sizes you can have all kinds of batteries including cranking, deep cycle and gel cell.

This brings us to our next subject -- DEEP CYCLE BATTERIES. Deep cycle batteries are intended to run equipment over a longer period of time without recharging. This would include refrigeration, cabin lights, anchor light, radios, head, inverter, etc. The kinds of things that leave you with dead batteries while on the hook in some wonderfully secluded bay.

Deep cycle batteries are built with thick, antimony doped plates. This allows them to be completely discharged without damage. This assumes that they are immediately recharged, of course. A good quality deep battery will survive about 200 deep cycles before significant loss of capacity is noticed. The "Rolls Royce" of conventional batteries, Rolls and Surette, typically see 800+ cycles.

Deep cycle batteries do not have the high current capacities of cranking batteries. However, large ones will start small engines. A battery expert should be consulted for your application.

Last but not least are the new GEL CELL BATTERIES. Actually, these are not so new. Technology has advanced to the point that these high tech batteries are now affordable for boaters. In fact, for many applications, they are by far a "best buy." A comparison will follow.

Gel cell batteries are constructed using many thin plates doped with calcium. The electrolyte is a gel rather than a liquid as in conventional batteries. The plates, separators, and gel are compressed before assembly resulting in a battery highly resistant to damage from shock and vibration. These batteries are truly sealed and may be mounted in any position.

Gel cell batteries have many other advantages. Because they are sealed they never need maintenance. They can survive being left discharged for several days, although I don't recommend treating them that way. Never do that to a conventional battery! You will have a new set of batteries and an empty pocket book. They are capable of putting out high currents for cranking and they can be deep cycled. Recent tests of some Prevailer (R) gel cells by Sonnenschein Batteries have exceeded 1,000 deep cycles an the batteries have not yet dropped to 80 percent capacity!

More advantages include a very low self discharge rate. These batteries can be left unused for as long as two years without need for recharging. Remember our article on batterycide? These batteries are harder than an opossum to kill! They do have one Achilles heel. Overcharging will force them to gas which can result in permanent damage. Have your charging system checked when you install them.

There is one more advantage I will mention here. While gel cell batteries are being discharged, they maintain a higher voltage than conventional batteries. This makes inverters much more efficient, engines crank faster, etc. Now, as I promised, a look at the following chart to see the cost advantages of gel cells:

8D Battery	Cost New	# Cycles	Reserve Capacity	Total Use	Cost/ Cycle
Conventional Cranking	$163.95	40	465	18,600	$4.10
Conventional Deep Cycle	$210.95	200	450	90,000	$1.05
Rolls Deep Cycle	$455.00	800	450	360,000	$.57
Prevailer Gel Cell	$496.61	1,000	450*	450,000	$.50

*Gel cell batteries increase their capacity by 15% after the first few cycles. Also note that the above conventional batteries are premium batteries.

This table is a bit of an unfair comparison for the conventional cranking battery because it is not intended for this kind of service. Unfortunately it is pressed into this kind of service perhaps because of its large size. "Wow, look at the size of that battery! It should take anything." Well, it won't. Some have survived as house batteries because they have not truly been deep cycled. In these applications a smaller deep cycle battery would have done the job for a lot less space, weight and money.

To summarize: cranking batteries are intended to start engines. Deep cycle batteries are intended to be used to run the electrics of your boat between charges. Batteries like Rolls and Surette are among the best batteries in the world and despite their higher cost are a better buy. However, they are just as susceptible to batterycide as any other conventional battery. Good gel cell batteries like the Prevailer make better cranking and deep cycle batteries. They are far more rugged than conventional batteries even when abused. They are the best buy.

Have you been buying new batteries every year or two? Now you know more reasons why. A tight budget may prevent you from buying the right choice now, but choosing the right battery for the job will greatly increase battery life and save you money. If you plan to keep your boat three years or more, gel cell batteries are the obvious choice.

The New Batteries: What They Are, How They Compare with the Old

By David Smead

If you think the new "sealed" deep-cycle marine batteries are merely a variation of your car's "no-maintenance" battery, think again. These new batteries represent a developing technology that may eliminate the use of the familiar, conventional "liquid-electrolyte" batteries on boats.

In the following article, engineer David Smead discusses the origins, the technology, the virtues, and the shortcomings of these new batteries.

In 1790, Luigi Galvani discovered that electrical current would flow between two dissimilar metals placed in a conductive liquid. At the time, he was probing a frog with a copper pin and noticed that the frog's muscles reacted convulsively. The frog was hung from an iron hook, and there was electrical current between the copper and the iron. Even though Galvani didn't understand his discovery, the reaction of the two metals in an electrolyte has become known as galvanic action.

Ten years later, Alessandro Volta correctly deduced that the frog's muscle twitches were the interaction of copper and iron, acted upon by the electrolytic action of the frog's blood. And battery chemistry was begun, first as an art and later as a scientific technology.

In the early 1830s, the great scientist Michael Faraday performed the quantitative analysis of the electrochemical reactions in a battery. In the process, he developed the terms *electrolyte, electrode, anode,* and *cathode.*

The first practical battery was developed in 1836, but it could not be recharged. The rechargeable battery has been with us since 1859, but at that time, the only way to recharge the batteries was by discharging non-rechargeable batteries into them—the generator hadn't been perfected yet. Later, around 1880, Thomas Edison was selling electrical energy by day and recharging his batteries with a generator at night when power demand was lowest. Today, considerable money is spent on research for a better means of using batteries as *load leveling* storage for large power plants, as first practiced by Edison.

In 1895, the land-speed record of 59.5 knots was held by an electric car powered by a lead-acid battery. Charles Kettering, founder of Delco, invented the electric starter in 1911 and installed it in the 1912 Cadillac, displacing the hand crank then used to start engines. Since then, batteries have become civilization's biggest consumer of lead.

Conventional "Wet" Batteries

The conventional lead-acid batteries of today are made essentially the same way they were in 1912 when Kettering first started his Cadillac with one. Two dissimilar metals are placed in a conductive liquid.

The two "metals"—lead and lead-dioxide plates—are submerged in sulphuric acid to form a "cell" which will produce about two volts. A cell may have as many as a dozen pairs of lead and lead-dioxide plates, though most don't have this many. The 12-volt batteries we use are made by connecting six of these two-volt cells in series.

To prevent short circuits within the cell, the individual lead and lead-dioxide plates must be separated from each other. The quality of the separator is very important, since it prevents short circuits by inhibiting migration of the active material between the positive and negative plates, yet allows a free flow of electrolyte. Nowadays, quality separators are made of fiberglass or microporous rubber as opposed to the original paper separator.

Battery construction details vary according to the quality and the life expectancy of the battery. Deep-cycle batteries for marine use have thicker plates, and the plates are better supported with thicker grids and separators than those of automotive batteries. Whereas an automotive battery may only withstand several complete discharges, the deep-cycle battery will tolerate several hundred.

The Gel Battery

About 25 years ago, a sealed thixotropic gel lead-acid battery was developed. We should note that this sealed "gel" battery is totally different from the "sealed" or "no-maintenance" batteries now found in automobiles. The "sealed" automotive batteries are nothing more than conventional lead-acid technology, partially sealed, with enough liquid electrolyte to last for the short life of the other materials in the battery.

The new thixotropic gel batteries do not have a liquid electrolyte. Instead, the acid is captivated in a gel. More recent methods coat thin, closely separated plates and the separators, made of fiberglass and felt mat, with just enough electrolyte to dampen them. This second variety of sealed batteries are known as absorbed-electrolyte batteries. Sometimes they are called starved-electrolyte batteries.

In both kinds, special micro-porous fiberglass separators are used. The plates and separators are compressed when assembled, giving the sealed battery great resistance to vibration. Compression also reduces the electrical resistance of the battery, allowing it to generate large amounts of current, such as required when starting big diesels.

Of the two competing technologies, the gelled unit appears to support faster charges than the absorbed-electrolyte version. For absolute performance, the gelled unit should be chosen since it stands up to faster discharges and may be left for short periods in a discharged state without permanent damage. The absorbed-electrolyte battery, in contrast, needs to be treated with about the same care as a conventional wet battery.

Patents covering the first sealed lead-acid battery were issued to Adolf Dassler, of Germany, in 1933, and in 1951 US patents were issued. Continual improvements have been made since then, and the use of sealed batteries has risen accordingly. Even though they have been around for a while, only recently have these sealed batteries become economically feasible for use on boats.

Early users of sealed lead-acid batteries took advantage of the "position-independent" characteristics of the batteries. They could be mounted any way—even upside down—with no problems, an advantage previously held only by Ni-Cad batteries. (Nickel-cadmium batteries have been made commercially in the United States since 1909.)

While small Ni-Cad batteries are still common, sealed lead-acid batteries offer more capacity less expensively than Ni-Cad. In particular, the sealed units have almost totally replaced Ni-Cads in Uninterruptible Power Supplies (UPS) that protect sensitive and critical electronic systems from catastrophic power outages.

Emergency lighting systems also now use sealed batteries almost exclusively. In addition, sealed batteries can be used in the home and office environment where the gases and acid fumes from a conventional battery would be objectionable and unsafe.

In recent years, as many as 60 manufacturers have joined the battle for market share; consequently, performance has grown while prices have actually decreased. Most of the activity has been in small sizes unsuitable for marine use, but development has also occurred in larger units.

When well maintained, wet batteries offer more deep discharge cycles, but the sealed battery stands up better when abused

Sealed technology most likely will not be economical enough in the near future that it finds widespread use under the hood of automobiles, but anybody seriously thinking about a performance electrical system must strongly consider the many advantages offered by today's sealed lead-acid batteries.

Be advised, however, that not all of today's sealed batteries are appropriate for a deep-cycling application. Many units are designed for standby float service, as in UPS or emergency lighting systems, and they will not perform well if cycled through the deep discharges that occur in ordinary sailboat applications.

Shortcomings of the Old

Regular maintenance is required on wet lead-acid batteries. Acid level has to be checked frequently, and topped off with distilled water. When batteries are not in service, self-discharge rates are high enough that batteries must be frequently charged or they would suffer permanent sulfation.

Conventional batteries have to be kept in an upright position. In a sailboat, long upwind passages on the same tack can expose part of the battery plates to air, with permanent loss in capacity the consequence. A capsize in a sailboat could mean dangerous battery acid throughout the boat.

Extremely deep discharges have to be avoided, and recharge is required immediately to prevent sulfation. Overcharging is such a problem that users put up with time-consuming low-voltage chargers. Even the technically mindful, using fast charging methods, have modest performance as a goal.

Old Technology vs New

An old-fashioned battery requires thick plates to provide deep-cycle performance. The principal reason for this is the fact that the supporting plate grids must be made thick to provide mechanical strength, and to tolerate the corrosion which occurs on overcharges.

Plates in a conventional battery are suspended in fluid, not compressed with the separators. Conventional grids use a lead/antimony alloy to gain strength even though the antimony contributes to self-discharge, internal corrosion, and hydrogen generation before full charge can occur.

The thicker plates of conventional batteries cause problems with acid diffusion—fast discharges and charges are ruled out by design. Using a thick plate, conventional deep-cycle battery for large starter currents can result in poor engine cranking. Larger boats that use electric windlasses or electric winches are forced to buy extra battery capacity to get enough high current capability to operate properly.

Sealed units, on the other hand, are constructed with thin, pure lead or lead-calcium grids which are supported by fiberglass separators and tough, strong (usually polypropylene) cases. Some manufacturers use a lead-calcium-tin alloy for the plate grids.

Although the chemical reactions inside a sealed battery are the same as that of a conventional unit, the high purity of the material minimizes hydrogen generation during overcharge conditions. The active materials in the battery are balanced so that the positive plate will become fully charged and begin evolving oxygen before the negative plate is fully charged. To achieve this, more active material than strictly necessary is put into the negative plate. Under normal operation the negative plate is never fully charged and consequently no hydrogen gas is generated.

Because the plates are closely spaced and not separated by liquid electrolyte, homogeneous gas transfer occurs, resulting in recombination of oxygen inside the cell. Internal pressures of 1 to 4 pounds per square inch contribute to oxygen recombination. Efficient recombination occurs at 1 to 2 pounds per square inch. As a safety measure, pressure release valves (Bunsen type) are fitted so that continuous high overcharges do not cause the case to rupture. These valves are set to release gas in the range of 5 to 10 pounds per square inch.

While the principles of sealed batteries are easy enough to understand, developing ways to immobilize the electrolyte and allow gas transfer to occur required much effort

Sealed Advantages

Besides being sealed, and never needing maintenance, the sealed battery can be operated in any position. If operated upside down, precautions should be taken to leave clearance around the safety release valves. Overcharges are not required to fully charge, and the natural absorption rate under a combination charge, absorb, and float voltage (13.8 volts) is about twice that of a wet battery.

Many thin plates, with a correspondingly large surface area, support rapid discharges and charges, since acid diffusion through the thin plates is more rapid. Because the batteries are designed for high current, no current limiting is required for charging. Under properly controlled conditions some sealed batteries can be fully charged in about half an hour. To accomplish this on a 100-amp-hour unit, you will need a source capable of delivering 600 amps while maintaining an output voltage of 14.1 volts (plus or minus 1%). This puts those 200-amp alternators in the wimpy class!

With high purity lead grids, corrosion at the positive plate—the usual battery killer—is practically eliminated, assuring a long life. At 80% depth of discharge on a daily basis, with proper charge control, you might expect 200 to 600 cycles. At the optimum 50% discharge level, 400 to 1000 cycles are possible. With 25% depth of discharge, life may exceed 2000 cycles. At a 10% depth of discharge, expect 20,000 cycles.

These numbers compare favorably with even the best of conventional deep-cycle batteries. In practice, while the conventional battery may offer more deep discharge cycles if treated carefully, the sealed battery stands up better under tough conditions such as fast charges and very deep discharges. Therefore, you may achieve both higher performance and more cycles than with a conventional battery.

The sealed battery is not as sensitive to depth of discharge as its predecessor. While 50% discharge will still result in the most power for your money, it isn't always convenient to recharge at the 50% point. A high quality sealed unit, meeting the European standard DIN 43539, must withstand 100% discharge followed by 30 days connection to the load, and suffer no permanent damage. After such abuse, it must reach full charge at 13.8 volts within 48 hours. While it may lose 25% capacity on the first charge, it is expected to regain full capacity, as well as its naturally high absorption rate, on subsequent cycles. No wet battery made can stand up to this kind of torture.

It should be pointed out that not many sealed batteries will withstand the torture test of the DIN 43539 standard. Even those that do may require some special treatment to bring them back. Later on, we'll report on our own experience with this subject.

Some sealed units have very low self-discharge rates. Units not in service should be charged every 16 months. In cold climates the battery needs attention only every couple of years. Here's a battery that can be left uncared for over the winter as long as it is fully charged prior to storage.

Old fash[illegible]

suffer this problem, more capacity is available under heavy loads such as those encountered when operating inverters to power microwave ovens or electric winches. The output voltage under such heavy current stays higher, keeping the efficiency of the inverter higher, resulting in more usable power for your money.

Sealed Battery Maintenance

Because you can't measure the specific gravity (SG) of a sealed battery, you must rely on an accurate voltage measurement to determine the capacity remaining. The electrolyte in the sealed battery takes longer to stabilize after a charge or discharge—in some cases twice as long as a conventional battery. Whereas we recommended alternating between conventional batteries on a daily basis aboard a boat, a user of sealed batteries should alternate every other day, for best accuracy in measuring the capacity remaining. Before switching from one bank to the other, measure the rested battery voltage. Given in Table 1 is the state of charge for various voltage readings for a sealed battery sold by Ample Power Company. While all sealed batteries are not the same, Table 1 can be used as a general guideline.

State of Charge (%)	Rested Voltage (after 48 hours)
100	12.80
75	12.60
50	12.40
25	12.20
0	12.00

Table 1: Capacity Remaining vs Voltage

Charging

As noted earlier, sealed batteries can be charged rapidly. At a constant voltage of 13.8 volts, natural absorption rate is about 50% of capacity. This rate decreases as the battery approaches the full charge condition, but full charge on a flat dead unit can be accomplished in about 3 to 4 hours, by applying a constant 13.8 volts. Diagram 1 demonstrates the time required to reach a 90% charge with different initial charge currents. At the start of charging, the battery is 100% discharged. As shown, an initial charge current of 50% capacity will charge the battery in about 3.5 hours.

To develop the diagram, a fixed voltage of 13.8 volts was applied to the battery, but limited in current delivery. The numbers 0 to 12 along the bottom are multiples of the 20-hour capacity. A unit rated at 100 Ah for 20 hours will have a rate of 5A. At two times that rate, about 13 hours will be required to recharge. At 10 times the 20-hour rate, a full charge can be attained in about 3.5 hours.

Perhaps 3.5 hours is acceptable, but faster charges can be obtained by a higher charge voltage. Raising the voltage to 14.1 volts permits initial charging as fast as current can be delivered. Because of the highly [illegible]

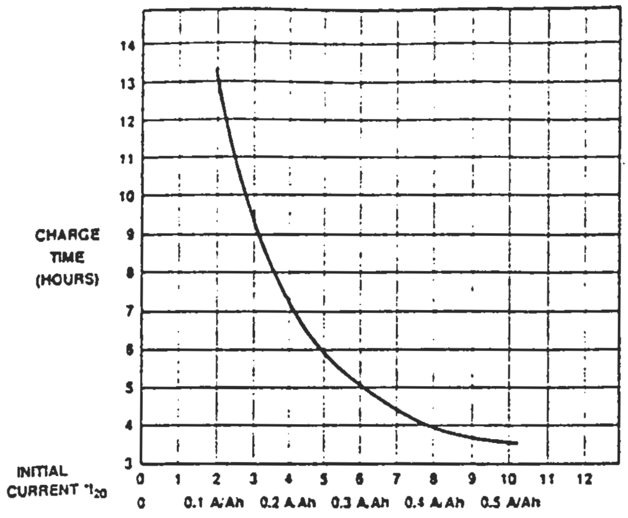

Diagram 1: Time to Charge

recommended that fully charged batteries be floated at 13.2 to 13.8 volts.

Diagram 2 shows the proper range of float voltage versus temperature for sealed batteries. For the longest life, always use the lower of the values. Diagram 3 shows the float current of a 100-amp-hour battery at three different float voltages. The effect of high voltage and high temperature is dramatic, indicating the necessity of a properly adjusted charger. Note that between 13.2 and 13.5 volts, there is little difference in current as temperature rises to the upper limit of allowable battery operation. With just 0.3 volts more on the battery, the current rises rapidly. At this excessive current, the positive plate will shortly be oxidized and turned to lead dioxide. Ultimately the continuity between the positive terminal and the active material in the positive plate will be lost, and total failure will occur.

Conventional wet batteries should be floated toward the high end of the range, while sealed units should generally be floated closer to the lower range. Note that the voltage doesn't continue to decrease as temperature rises above 50° F (10° C). This is because the self-discharge current rises as the temperature increases, and to make up for the self-discharge current, an over-voltage is necessary.

Excessively high voltages for long periods will generate internal pressures which will eventually vent through the safety valves. Repeated venting will lead to drying out of the electrolyte and eventual failure. To prevent excessive charging, the charging must be accomplished with precisely adjusted regulators for the temperature of the battery.

Since the electrolyte of a conventional wet battery stratifies into heavy and light layers, periodic equalization is necessary. The immobilized gel electrolyte does not stratify, so no equalization is necessary. In practice, it is found that cell voltages in some sealed batteries tend to equalize during float, rather than diverge as happens in the wet battery. With no need to equalize the sealed battery, which usually involves manual operation, fully automatic regulators are more applicable.

We are sometimes asked about using the typical voltage regulator that is standard equipment with engine alternators. Generally, the answer is that they will work about as well with sealed batteries as with wet deep-cycle batteries—which is to say, not very well. Unfortunately, these ordinary regulators have the voltage set all over the place, and most cannot be adjusted in any practical way. The sensible answer is, if you are spending the money for quality deep-cycle batteries, you should also invest in an efficient alternator regulator that will charge them properly. This is true of both wet and sealed batteries.

As in the case of conventional batteries, floating at a constant current is better than floating at a constant voltage. This is not possible if the battery is also being used as it is being charged. If a battery is to be floated for a long time, a trickle current of 0.04% to 0.2% of amp-hour capacity is appropriate. At higher temperatures, more trickle current is necessary to maintain the charge. For temperatures below 100° F, a current of 0.04 to 0.1% is adequate. For a 100-amp-hour battery, this translates to 40 to 100 milliamperes. As noted above, some sealed batteries have a low rate of self-discharge and, once fully charged, can be left unattended for many months.

Finally, it should be noted that, because of the differences between sealed and conventional wet batteries, it is generally not a good idea to use them together in a system. The main problem comes in charging them in parallel. Because of the different charge rates, the sealed battery will almost always be fully charged long before the wet battery. Consequently, if your system keeps the sealed battery fully charged, the wet battery will be chronically undercharged. If you fully charge the wet battery, the sealed battery will be chronically overcharged. Neither condition is conducive to efficient service or long battery life.

Cost of Ownership

The true cost of any battery is made up of original invoice price and the additional expenses which are incurred over the life of the battery. The invoice price of a sealed lead-acid battery will be 10% to 20% more than a top-of-the-line old-fashioned battery with equal amp-hour capacity. If you

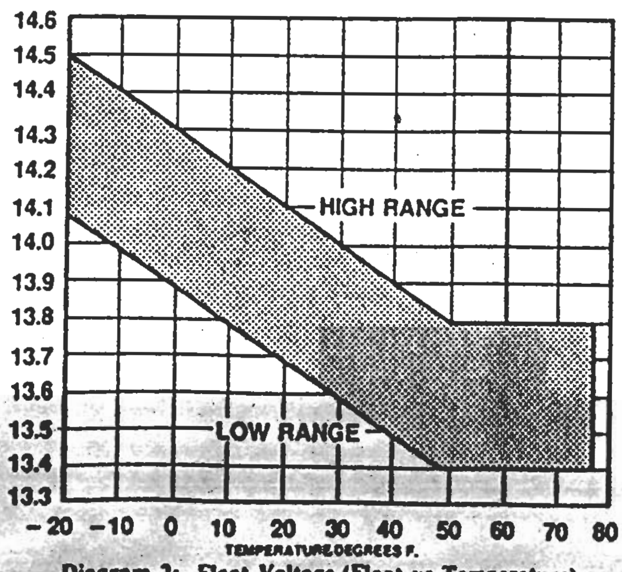

Diagram 2: Float Voltage (Float vs Temperature)

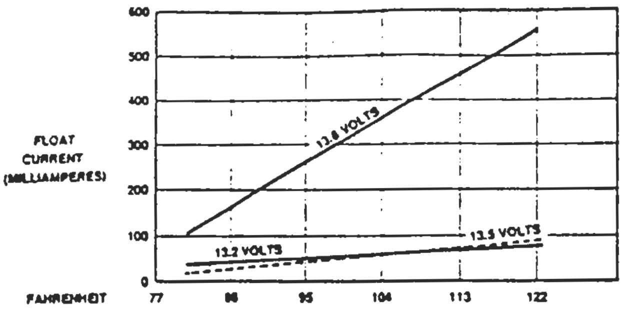

Diagram 3: Float Current vs Temperature

add gas-recombinant caps, such as the Hydro-Caps, to the conventional battery, the invoice price may be nearly identical. If you include charging costs over the life of the battery, the sealed battery is actually less expensive to own due to its inherently higher charge rate.

The other intangible benefits might be considered as insurance. You won't spill acid in the bilge on a knockdown. You won't have to buy a new battery when you accidently leave your running lights on for a week. You won't be constantly checking water. You have the freedom to use some out of the way space for your batteries. You won't be spending valuable time equalizing. If you should flood your battery compartment, the battery itself will survive, though it will discharge through salt water.

Sealed Battery Problems

If you do discharge one of the DIN rated units down around the 8-volt region or lower, you may have to completely discharge the battery before charging. In this regard, the sealed battery acts more like a Ni-Cad battery. Our first experience with this phenomenon occurred when an instrument with an LED display was left on for about three weeks while we were away. On return, the battery had discharged to about 2.5 volts.

Instead of immediately charging the battery full, we applied a charge for a few hours and then had to leave for another few days before we could finally attend to the battery. When we did return to fully charge the battery, the absorption rate was severely low. As the charge progressed, the battery got warm. The voltage returned to normal, but when we removed the charger, the voltage fell to about 11 volts in a few hours. We left the charger attached for over 48 hours, hoping that the battery would recover. It didn't.

However, the battery would sustain a load at about 11 volts, indicating that perhaps the problem lay in a single cell. This was reminiscent of problems we had witnessed with Ni-Cad batteries which can have cell reversals under some over-discharge conditions.

We treated the sealed battery to the same cure that we had used for Ni-Cads. First we applied a 10-amp load on the battery for 24 hours. The load reduced the battery voltage to less than one volt. Next we put a short circuit on the battery for another 24 hours, using a #12 wire. After that, we put the unit back on the charger with a constant current of about 10% (10 amps) of the battery's amp-hour rating. Initially, the internal resistance of the battery was high and the charger voltage rose to about 12.5 volts. Shortly, however, the resistance declined and to maintain a 10% current, the charger voltage fell to less than 11 volts. Battery temperature barely rose above ambient after several hours of charging, indicative of charge acceptance.

We left the charger on constant current but set the upper voltage limit at 13.8 volts and left the charger running for a full 72 hours. At the end of the charge, we began a discharge to measure the actual capacity. The unit only had about 60% of its former capacity. Again, we charged the battery at 13.8 volts for another 72 hours, and measured the capacity again by discharging. Capacity had risen to 85% of rating. After a third 72-hour charge, capacity had recovered to about 95%. Despite the torture applied to the battery, it fully recovered.

However, you can kill even the best of sealed batteries. The best way to do so is to discharge it about 80% and then leave it that way for a few months.

Brand Tests

Initially, we tested two sealed batteries. One of them was the Absolyte 12-5000. This unit is now sold as the Stowaway. The GNB battery is of the absorbed-electrolyte type rather than the gel. While rated at 100 amp-hours, that rating is for a 100-hour discharge. Its 20-hour rating is 80 amp-hours. Our tests yielded no more than 65 amp-hours.

After a complete discharge, the GNB battery was sometimes slow to start accepting a charge. Once charging, its acceptance rate was no better than that of a conventional wet battery.

Given the wide disparity between the claimed capacity and our measurements, and the unspectacular charging performance, we concluded that the battery had no merit in a performance deep-cycle system. If you are convinced that you need a separate starter battery, then the GNB may have an application. It is sealed, after all, and quite inexpensive.

Price of a sealed battery will be 10% to 20% more than a premium wet battery of equal amp-hour capacity

The second battery tested was the A212/110A made by Sonnenschein. Since our tests, Sonnenschein has begun mass marketing their line of batteries under the Prevailer label. They hold the original patents on sealed batteries, including the one that protects their use of phosphoric acid as an additive.

We ran several discharge tests on the Sonnenschein. Its rated capacity is 110 amp-hours. Out of the carton, we obtained 93 amp-hours; after a full charge, we were able to squeak out 101 amp-hours. Since capacity increases during the first 25 to 30 discharge cycles, we expect the unit to eventually produce the rated 110 amp-hours.

We couldn't begin to charge it too fast, even with a 100-amp alternator running at capacity.

show signs of heating, we concluded that charge acceptance was extremely high—perhaps three to five times better than the Surrette batteries which we have tested and used as a standard among high-quality wet batteries.

Later, we completely discharged the Sonnenschein unit; then shorted it out for 30 days. It did in fact take a full charge, and several cycles later we were able to get 103 amp-hours from it.

Sonnenschein is a large West German company, with a long history of battery manufacturing. Their batteries are qualified by NATO for use in tanks. Given these circumstances, and the fact that their battery stood up to our tests, we felt that we had found a battery good enough for us.

The unit which we had tortured was put into service as an active display. It eventually failed, but only after a prolonged period at about the 50% discharge level. In the past year, we have also seen four other units fail. The circumstances surrounding the failures seem to indicate that the batteries were allowed to remain partially charged for extended periods.

When a conventional battery is maintained at partial charge, the battery doesn't usually fail outright. That is, the battery will recharge to a normal voltage and current. It will suffer from permanent sulfation, but this loss of capacity may go unnoticed by the user.

All the Sonnenschein failures which we have seen are characterized by an inability to accept a full charge. While the voltage will rise to the expected 13.8 to 14.2 volts, the battery overheats. Almost as soon as the charger is removed, the battery voltage drops to about 11 volts.

Sonnenschein batteries carry a full replacement warranty for 18 months, followed by a pro-rated warranty for another 42 months. We are convinced the presence of Sonnenschein in the marketplace will lead to improved power systems for boaters. On the other hand, marine batteries are regularly murdered by ignorant users and poor charging equipment. If the Sonnenschein batteries have a more obvious failure under mistreatment than do wet batteries, only users who carefully monitor and control their electrical system will fully enjoy the benefits of the technology.

The list price of Sonnenschein batteries is not appreciably more than the list price of a Surrette. However, dealer discounts can be as high as 60% on a Surrette or Rolls battery, and retail dealers may pass some of this along to their customers. The margin on Sonnenschein batteries is not as great—in the range of 30% to 40%. You can expect to pay more for the Sonnenschein.

Useful Life

When a battery will wear out is a complex function of the frequency and depth of discharge, the amount and duration of overcharge, and the length of time between a deep discharge and recharge. Time spent at elevated temperature is also a factor in eventual failure. In Diagram 4, daily capacity loss is plotted against battery temperature. This loss occurs whether the battery is used or unused. It demonstrates quite clearly that batteries should not be hot. While we include this particular chart in an article on

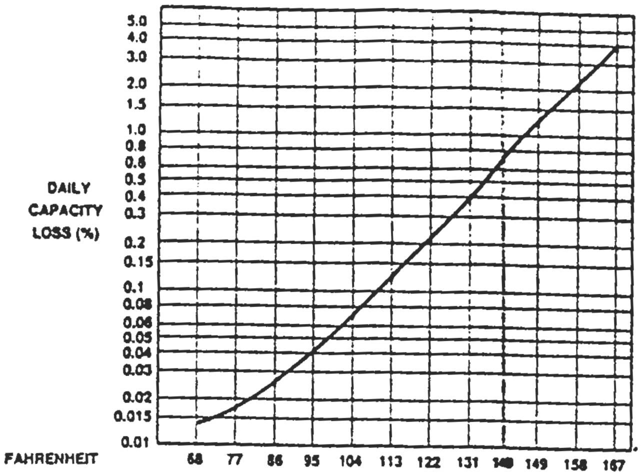

Diagram 4: Capacity Loss vs Temperature

sealed batteries, the same phenomenon occurs with conventional batteries—perhaps even worse. The capacity loss shown is permanent, so keep your batteries cool.

Summary

The sealed lead-acid battery is position independent, can be charged fast, requires no equalization, can be left unattended for many months, stands up to high current loads, never needs maintenance, is easily charged and floated, provides a great number of deep discharge cycles, and survives up to 30 days in a completely discharged condition.

Besides all these advantages, the cost of ownership may actually be less than that of high quality, old-fashioned batteries. Is nostalgia for old-fashioned, familiar technology worth the inconvenience? For a 1912 Cadillac, perhaps, but not for a battery built with 1912 methodology. This was demonstrated to us quite effectively when we were pooped by a rogue wave and knocked down in a North Pacific storm. The smell of battery acid in the bilge screamed a simple imperative: get sealed batteries!

As mentioned earlier, however, not all sealed batteries are equivalent. The sealed battery is a newcomer to the retail market. As the traditional battery manufacturers begin to develop sealed technology, expect a plethora of sealed units which do not perform even as well as conventional batteries. •

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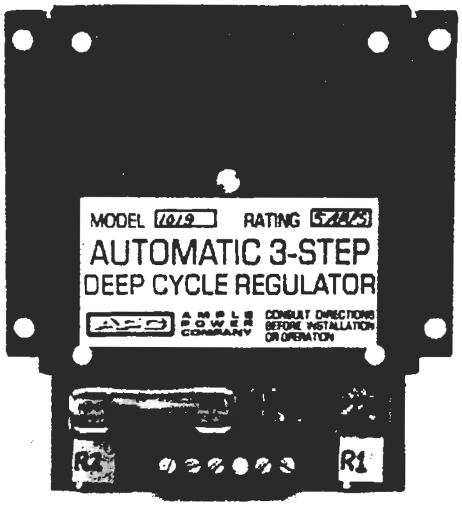
3-Step Deep Cycle Regulator:



- Completely Automatic Operation; no user interaction required.
- Provides Charge, Absorption and Float Cycles for a Correct, Full Charge.
- Automatically Compensates for Battery Temperature
- Senses Volts and Temperature for Multiple Batteries, at the Batteries.
- Two internal Timers and Sense Circuits for Correct and Safe Charging.
- Regulates Alternators, Solar Panels or Battery Chargers.
- Two Models for P or N Type Alternators.
- Both P and N Models are available in Normal or Heavy Duty Versions.
- Over Voltage Protected, and Low/High Temperature Rated.
- Precision Laser Trimmed Reference for Long-Term Stability.

The 3-Step Deep Cycle Regulator has been designed to charge deep cycle batteries the way they should be charged. It provides the bulk charge cycle, followed by the absorption cycle and finally the float cycle. The regulator operates completely automatically, with no need of user interface, making it ideal for RV owners and charter boats. (Absorption and float voltage can be adjusted at the regulator.)

Battery voltage and temperature for multiple batteries is sensed by Battery Sensors and the 3-Step Deep Cycle Regulator automatically adjusts. Should the battery sensing wires open circuit, the regulator automatically shuts off. Two internal timers operating with sensor circuits protect from overcharging batteries which are already fully charged.

Wide temperature range parts are used throughout, and each regulator is temperature cycled during test and quality control procedures; you don't need to worry about cold winter, or hot desert. Units are epoxy sealed to survive life under the hood or in a hot engine room.

Use them to regulate alternators; Catalog Numbers 1019 and 1020 will work with alternators up to and including 130 Amps. Use Catalog Numbers 1021 and 1022 for larger alternators.

Use Catalog Number 1021 to regulate solar panels. It is rated for a continuous 10 Amps. This regulator can also be used to regulate inexpensive battery chargers.

Use as many Battery Sensors as necessary to sense all the batteries being charged. All regulators include one Battery Sensor. Additional sensors may be purchased separately for multiple battery sensing. By sensing both voltage and temperature at each battery, rest easy knowing that charging is correct.

Catalog Number 1018 – Battery Sensor: Volts and Temperature
***Catalog Number 1019* – For P Type Alternators to 130 Amps**
***Catalog Number 1021* – For P Type Alternators to 200 Amps**

Application Note 114: Over Voltage Protection and the 3-Step Regulator

We have all been warned about turning the battery selector switch when the engine is running. The reason is simple. When a charging alternator is suddenly disconnected from the battery, a large voltage transient called `load dump' occurs. This large transient can/will destroy the diodes in the alternator, the alternator regulator and any electronic equipment connected to the alternator output; in short, total electrical system failure.

The load dump transient is caused by the fact that a charging alternator has magnetic energy stored in its field winding. The amount of energy stored is proportional to the rate of charge. When the alternator is suddenly disconnected from the battery, the alternator is no longer loaded. The stored field energy must be dissipated, however, before the alternator output can be cut off. Since current can no longer flow to the battery, the alternator output voltage rises to 200 to 300 Volts. Recall that Power is equal to the product of Volts times Amps, ($P = E * I$). The energy store in the field winding attempts to keep power constant. With current interrupted, voltage must rise to maintain power. Once voltage rises to a high enough level, diodes and other devices fail, allowing current to flow and the energy in the field winding to be dissipated.

The battery selector switch is a time bomb, waiting for the uninformed to light the fuse. It doesn't need to be this way.

Much of the electronic equipment aboard will survive very short transients, and can sustain long-term voltages in excess of 20 Volts. The 3-Step Regulator has been designed to survive transients to 50 Volts and sustained over voltages to 30 Volts. Despite its hardy nature, load dump transients of 200 to 300 Volts will destroy the 3-Step. These transients can be avoided by connecting a `snubber' across the alternator output and ground.

The snubber (Catalog #1030), is a reverse avalanche silicon diode. It begins to conduct at 23 Volts, and can pass up to 110 Amps for a short duration (10 milliseconds). Current must decay to about 30 Amps in 100 mS. This is long enough to dissipate the energy stored in the field winding of the alternator of 100 Amp rating. Two snubbers can be used in parallel for large alternators.

A snubber will only absorb the load dump for a short duration. If the regulator does not sense the over voltage and shut down, then eventually the snubber will cook. Automotive regulators are usually attached to the alternator output, and thus will sense the high voltage. Sensing at the alternator output is not without its drawbacks. If a Fail/Safe or isolator diode is used between the alternator and the battery, then sensing at the alternator will result in a serious undercharge at the battery. To charge batteries properly, the voltage at the batteries must be sensed.

The 3-Step Regulator senses both battery voltage and temperature at the batteries. Multiple sensors can be used for multiple batteries. In addition, the 3-Step Regulator senses the alternator output. Under normal operation, the 3-Step regulates according to the needs sensed at the batteries. Should the alternator be disconnected from the batteries, then the 3-Step regulates according to the alternator output. The sense point for alternator output is set high enough so that it doesn't interfere with normal battery sensing, but low enough so that the snubber is not conducting. Typically, the 3-Step will regulate a disconnected alternator to about 21 Volts. This is 2 Volts below the cut-in point of the snubber, and well within the voltage range that the 3-Step can sustain.

While direct sensing of battery voltage and temperature is required for correct charging, a potential danger lurks in the system. The regulator will typically be mounted some distance from the batteries. What happens if the wires from the batteries to the regulator are severed by accident or by corrosion? Most regulators would see the open circuit as a need to pump more charge into the batteries to bring their voltage up. Such action would eventually destroy the batteries, the alternator, or both. A serious fire might even result. The 3-Step Regulator contains an additional sensing circuit that `senses the sense input'. If the sense input from the batteries is abnormally low such as would be caused by an open line or excessive corrosion, the 3-Step Regulator completely shuts down. The trip voltage for the sense line is about 4 Volts.

Synopsis: The 3-Step Regulator has been designed to operate in conjunction with a snubber to survive load dump transients should the battery selector switch be turned off. It has also been designed to shut down completely, should the input sense line become open circuited.

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Application Note 113: Voltage, Temperature and the 3-Step Regulator

The 3-Step Deep Cycle Regulator has many features which are not fully described in the promotional literature. This application note serves to illuminate those features which make the 3-Step Regulator an exceptional value.

As stated, the 3-Step performs the bulk charge cycle, the absorption cycle and then the float cycle. The bulk charge is delivered by operating the alternator at its maximum rating. When the voltage on the battery reaches the absorption voltage setpoint, then the 3-Step enters a timed absorption cycle. The length of the absorption cycle is 25 to 45 minutes, depending on how fast the absorption voltage was reached. Typically, the absorption cycle will be about 30 minutes.

At the end of the absorption cycle, the 3-Step switches regulation to the float voltage setpoint. This voltage will be maintained until the regulator is turned off. When turned back on again, the cycle repeats itself.

Problems have occurred with other products which use two different voltage setpoints. When a small charge source (alternator or battery charger) is charging a big battery, there is a danger that the battery voltage will not reach the higher setpoint and thus trip to the lower setpoint. When this happens, the battery voltage is held abnormally high and may go into destructive thermal runaway. The 3-Step prevents this from occurring by limiting bulk charge to 6 hours maximum. At the end of 6 hours, the float cycle is actuated, independent of the battery voltage.

Both the absorption voltage and float voltage are adjustable at the regulator itself. Adjustment is usually only done at the time of installation. As noted, the 3-Step automatically compensates for temperature. Supplied with each 3-Step is a voltage/temperature sensor which attaches to the positive post of the battery. For multiple batteries, multiple sensors are used. The voltage/temperature sensor operates in an inverse fashion; that is to say, as temperature goes up, voltage goes down. This action is a function of the voltage/temperature sensor and is set to compensate the voltage/ temperature characteristics of a lead-acid battery.

Additional temperature sensing is done on the 3-Step regulator itself which decreases the absorption time when the temperature is higher. The temperature at the regulator is dependent on the average amount of alternator field current. Thus absorption time is less when the alternator has been run hard to drive the battery to the absorption voltage. Similiarly, absorption time is less when ambient temperature is high.

Voltage/temperature sensing operates continuously, as opposed to a snap action limit. The absorption setpoint and the float setpoint must be made against a known battery temperature. Each 3-Step is shipped with installation procedures which include a voltage/temperature table for the two setpoints. The values given in the table for the float setpoint are higher than desirable for a long-term float. An alternator is never used for long-term float (weeks), and using a higher setpoint allows the 3-Step to be utilized over a wider range of alternator and battery sizes. For instance, a large alternator driving a small battery will pop up to the absorption setpoint faster than the actual state of charge would indicate. Nevertheless, the small battery will receive a full charge, since charging does occur at the float potential. In this case, however, the intended goal of acquiring a fast charge is not met. For best results, the alternator rating should be 25 to 40% of the Amp-hour capacity of the batteries.

It should be noted that all alternators generate electrical noise during charge. The bigger the alternator, the more the noise. The 3-Step regulator has slope compensation on the field drive which limits the high frequency noise associated with typical alternator regulators. This will not prevent normal rectification noise attributable to the alternator itself, but does reduce the overall noise level. To reduce rectification noise, a filter is required in series with the alternator.

It can be seen that the 3-Step Deep Cycle Regulator has many features which are not immediately apparent. Because of these features, the 3-Step Regulator is a valuable addition to the electrical system.

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