A title in the series
Marine electronics

Storage batteries for boats

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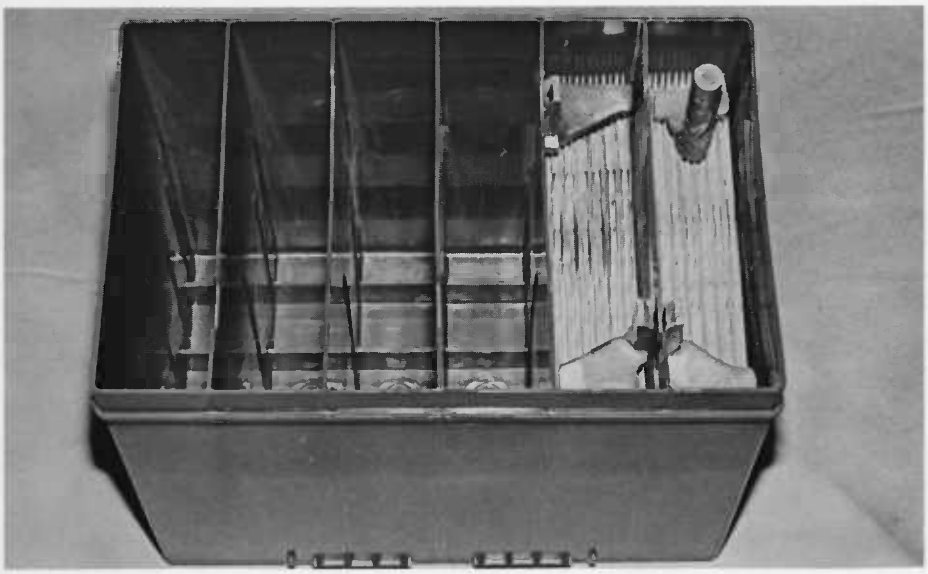


The wet cell is the basic building block of the lead-acid storage battery. Each wet cell develops 2.1 volts. Connecting two or more cells creates a battery. These views depict the beginning steps in the assembly of a typical 6-cell, 12-volt storage battery.

Don't repeat the mistake of the disgusted skipper who dumped his trouble-plagued old radar over the rail. When he replaced it (for $6,000), all the same problems showed up in the new set. His troubles were not electronic. As is often the case, they were electrical, caused by poor wiring connections in the boat's electrical system.

Properly installed batteries and electrical wiring should allow at least four to five years of electrical and electronic equipment operation without major repairs. One tugboat in Alaskan waters ran 12 years on the same batteries. Three fishing boats out of Ketchikan fished for four years without a single electrical breakdown.

Reliable electrical performance is not a fluke. It is what every skipper can get from ordinary lead-acid batteries and common wiring materials that are installed and maintained *properly*.

What is a battery?

Know your battery for what it is, and treat it properly. This is the *basic* component in your boat's electrical system. It starts the engines. It supplies the reserve power for motors and electronics while underway. The battery is your primary source of electricity at anchor or in an emergency. It means the difference between fishing and not fishing, and more than your income depends on its delivering electrical power when you need it. Taken care of, it will

Pacific Sea Grant Advisory Program

**Published for
Pacific Sea Grant Advisory Program
by Oregon State University
Extension Marine Advisory Program
A Land Grant / Sea Grant Cooperative
Corvallis, Oregon 97331
Printed in the U.S.A.
PASGAP 13 September 1977**

serve you for about 10 years. Mistreated, it may not last six months, and the manufacturer probably will not honor the warranty. In many instances, batteries on fishing boats have had their service lives cut 50 percent by mishandling before and during installation.

The lead-acid storage battery is a chemical generator. Its basic building block is the *wet cell*—named for the liquid in it. Each wet cell generates an electrical force of 2.1 volts. Two or more cells wired together make a *battery*. A so-called 12-volt battery, for example, has six cells and actually develops 12.6 volts when fully charged.

What are its uses?

The battery has four basic uses in the marine electrical system:

1. To start the engine. Starting usually draws power from the battery for no more than five seconds and should, if the engine is in good repair and well maintained, take only one second. Batteries of almost any type will satisfy this need. This use puts the heaviest drain on batteries, but only for seconds at a time.

2. To supply instant-current surges required by electric motors when they start. Once the engine is running, the generator or alternator supplies all the current needed except for these short-current pulses. Instant surges normally last only a portion of a second.

3. To furnish power while anchored, moored, drifting with a set, or in any of the multitude of normal work or harbor situations when the engine is not running. This is a major working time for the batteries, lasting hours and sometimes days at a stretch.

4. To supply power in an emergency. When the engine is down and flooding or other disabling conditions exist, the batteries must operate all pumps, lights, tools, radios, or whatever other electrical gear is needed until the situation is corrected. This is the time when good battery performance is a must.

How does it work?

Electrical charge, or *voltage*, is created as the liquid—*electrolyte*—in the wet cell reacts chemically with two sets of rectangular metal plates. Electrolyte is sulfuric acid mixed with pure water; the *plates* are lead-antimony grids filled with sponge lead (for negative plates) and with lead peroxide (for positive plates).

The electrolyte chemically attacks these two metals, converting both to a third substance, lead sulfate. In the process, the acid of the electrolyte is changed to water. The chemical reaction causes negatively charged particles, *electrons*, to leave the atoms of metal of the positive plates and to collect on the negative plates. The negative and positive plates, although close together, are held apart by separators and do not touch. The strength of the electrical force created by this unequal buildup of electrons is measured in *volts*.

When a wire or load (such as a motor or a light bulb) is connected between the two sets of plates, the voltage forces the extra electrons that collect on the negative plates to flow through whatever was connected. They flow back to the positive plates, through the load, until electrical balance is restored. Balance is reached only when all the acid of the electrolyte has reacted with the plates. Then there is no voltage difference between the two sets of plates, no current can flow, and the chemically exhausted battery has been fully *discharged*.

The current supplied by a battery decreases as the battery discharges, as less and less sulfuric acid remains to react with the plates. As the acid is exhausted, fewer and fewer electrons collect on the negative plates. Therefore, the current available from the battery becomes smaller. Eventually, the supply of current is too small to be useful, and the battery needs recharging.

Lead-acid batteries can be recharged because their chemical reaction can be reversed. They are recharged by running a direct current back through them in the opposite direction to normal electron flow from the battery. The electrical energy from the charging unit (a generator or alternator) reverses the chemical reaction in the battery from that which takes place during the discharge, or power-producing, phase. Charging gradually restores the electrolyte to a solution of acid and water and turns the plates back into their original materials. (See the formula at the top of page 3).

There is a practical limit to how many times you can run a battery through the discharge-recharge cycle. Each time you draw it down and recharge it, tiny amounts of unwanted material build up on the plates—a process called *sulfation*. Some of it flakes off and drops to the bottom of the battery case. Eventually, either so little lead is left in the plates that a small discharge current will exhaust them, or sulfation flakes pile up on the bottom until they connect negative and positive plates in a short circuit. At this point, you need to rebuild or replace the battery.

Photo credits:

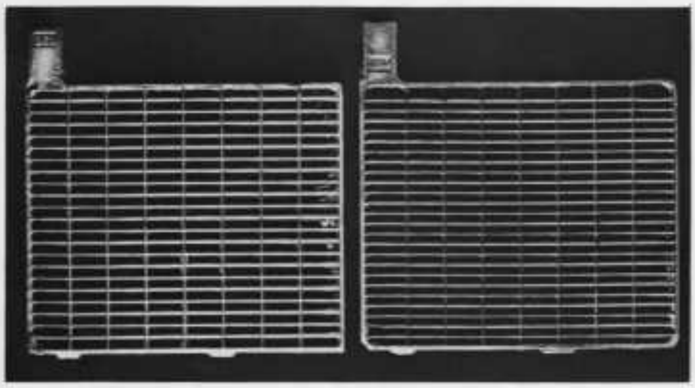
Delco-Remy Division of General Motors, 3 bottom, 5 bottom, 6 bottom, 7 top right.

Exide Power Systems Division, ESB Incorporated, 6 center.

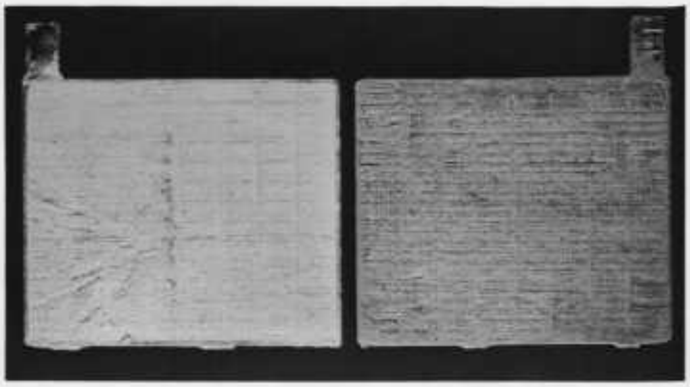
Oregon State University: courtesy of Western Batteries, Inc., 1, 3 top and center pair, 4, 5 top and center, 6 top, 7 top left and the two below; courtesy of Harbor Battery, Inc., 8.

$$\underbrace{\text{Lead (Pb)} + \text{lead peroxide } (PbO_2) + \text{sulfuric acid } (2H_2SO_4)}_{\text{Current produced}} \underset{\text{recharge}}{\overset{\text{discharge}}{\rightleftharpoons}} \underbrace{\text{lead sulfate } (2PbSO_4) + \text{water } (2H_2O)}_{\text{Current supplied}}$$

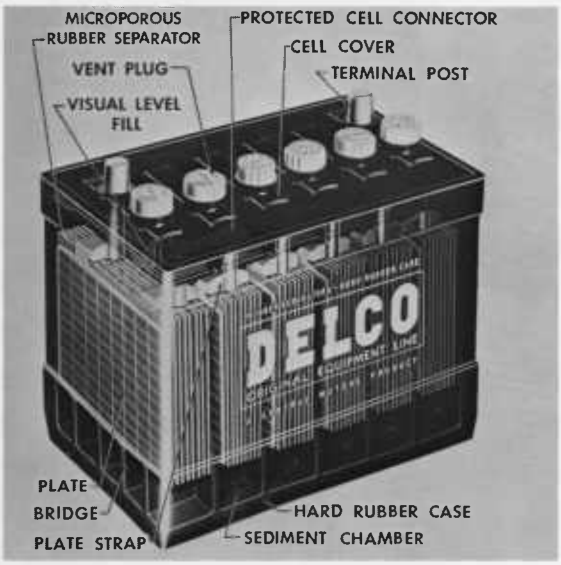
A heavy-gage lead strap connects adjacent cells across the cell wall. Cells are connected in series—from the positive side of one to the negative side of the second to the positive side of the third, and so on. The first and last connectors serve to install the battery in the circuit it powers.



Voltage develops between the negative and positive plates in each cell. The plates are metal grids, such as the two samples illustrated here, that are filled with compounds of lead.



Positive plates (left) are filled with lead oxide, which is yellow. Negative plates (right) are filled with lead oxide and expander, and are gray. During the formation process, positive plates are converted to lead peroxide, which is brown. Negative plates are converted to sponge lead.



The arrangement of plates in the cell, and of cells in the battery, is illustrated in this ghost view of an assembled storage battery.

How is it made?

A battery is an assembly of wet cells, wired together in a durable case. The case is hard rubber or plastic. It supports the hardware inside and contains the corrosive electrolyte. Each cell is inside a separate, sealed chamber in the case. The cell chambers are deeper than the plates. Ribs of plastic or hard rubber stick up from the bottom of each chamber to support the bottom edges of the heavy plates. The extra space under the plates provides a receptacle for sulfation products from the plates.

The rectangular plates are of two types: negative plates are sponge lead, and the positive plates are lead peroxide (lead combined with oxygen). Negative plates are gray. Positive plates are dark brown. In a wet cell, the two types of plates are stacked alternately, starting and ending with negative plates. They hang down into the cell chamber but are kept from touching each other by thin separators that are electrical insulators. The separators are made of wood, rubber, plastic, fiberglass, or combinations of these, and have vertical corrugations or ribs to allow the electrolyte to flow over the plate surfaces.

Each plate is attached to a heavy-duty conductor, called a *bus bar* or *post strap*, that runs across the top of the individual cell. Every cell has two bus bars, one for the positive plates and another for the negative plates. In some types of batteries, a lead rod extends up through the top of the battery case from each bus bar. Usually the rod from the positive bus bar is at one side of the cell, and the negative rod is at the opposite side. In batteries built this way, one cell is linked to the next by another short bus bar across the top of the battery. In other types, the cells are connected through the chamber walls. These connections are made just above the tops of the lead plates but beneath the battery cover. The electrical principle is the same, no matter how the electrical plates are supported in the chambers and connected between cells.

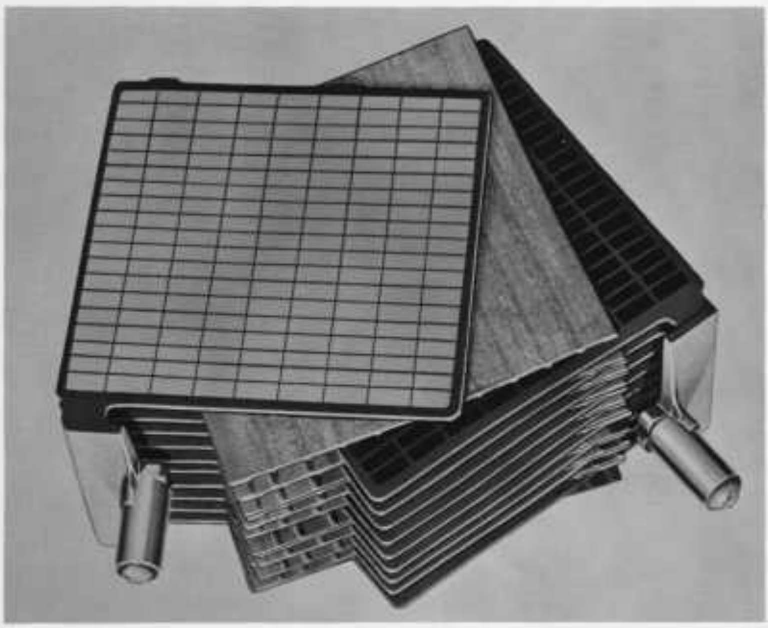
Raised ribs run across the cells along the bottom of the battery case. They support the weight of the plates and provide space at the bottom of the case. This space allows byproducts, that form as the battery works, to fall clear of the plates and not short-circuit the cell.

Lead sulfation occurs in any lead-acid battery. It can shorten battery life if a battery is allowed to sit discharged. The white at the bottom of these plates is lead sulfate. This cell sat discharged for a long time, with low electrolyte level. Lead sulfate built up prematurely, short-circuiting the plates and cutting the useful life of this battery.

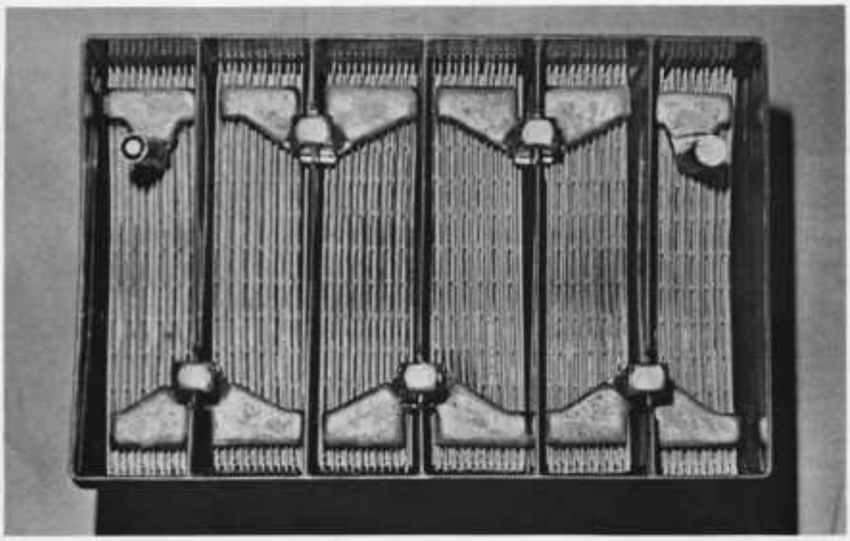
Sulfation can do mechanical as well as chemical damage. When batteries are allowed to sit discharged for long periods, sulfation attacks the grid structure of the plates. The positive plates of this cell were broken by sulfation expansion. The damage to this battery occurred as it sat on a boat in the discharged state for 1½ years.

Failing to keep each cell filled with electrolyte can do permanent damage. The dark gray lower portion of this cell shows that electrolyte was allowed to drop and remain low for an extended time. Refilling and recharging could not restore the sulfated, damaged plates.

The plates are separated by ribbed, electrically insulating separators. Separator ribs create space for electrolyte to reach all of the plate surfaces. Note that the connector posts at the ends of the battery are fastened to the plates. The posts are not very strong; never use them to lift a battery..

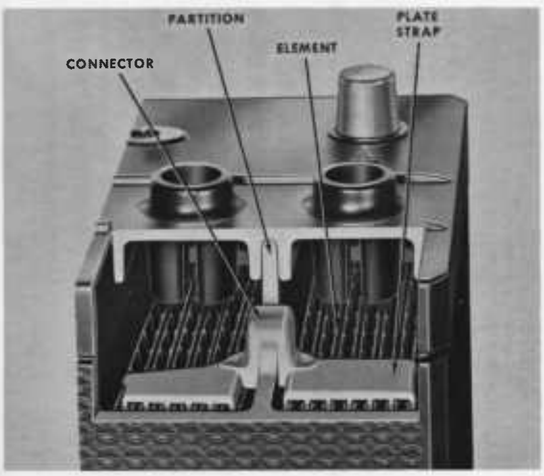


Negative plates are soldered to one bus bar; positive plates, to a second bus bar. The plates are spaced to allow interleaving them, with a separator between each pair of negative and positive plates, to prevent short-circuiting.



As a battery supplies electrical current, the plates generate gases. The ribs on the insulating separators minimize separator contact with the positive plates, to reduce oxidation of the separators. They also allow better circulation of the electrolyte.

Regardless of the type of case used, each cell is sealed by the cover plate. Industrial batteries commonly locate the heavy-gage connectors between cells on the top. Smaller batteries usually have the connectors inside, beneath the cover plate.



The cover plate seals each cell but provides a filler hole. The hole allows gases to escape and provide access for testing the condition of the electrolyte and for adding distilled water to keep the level of electrolyte above the top of the plates.

The tops of all the cells are closed over with a protective cover plate that has a filler hole with a vented cap. The filler holes are necessary for refilling the cells with water or new electrolyte. The hole in the vent cap must be kept open to allow air and gasses to pass in and out of the cell chamber. During charging and discharging and as the battery heats and cools, the plates and electrolyte expand and contract, requiring free movement of gasses in and out of the top of the cell chamber. The number of caps is normally the same as the number of cells in the battery. Count the caps, multiply by 2.1 volts, and you have the voltage rating of the battery.

In batteries where connecting posts protrude from every cell, the first and last posts—often at opposite ends of the battery—are used as external connection posts for installing the battery in the circuit it powers. In batteries with cells that connect through the chamber walls, only the two external posts stick up above the cover plate. In both types, one external post is attached to the first cell's negative bus bar and the other post is connected to the last cell's positive bus bar. Between the external connecting posts, all the cells of the battery are wired in *series*: the positive post of the first cell linked to the negative post of the second cell; the positive post of the second cell connected to the negative post of the third; and so on, for the number of series connections needed to get the voltage wanted from that battery. On rubber-case batteries, tar is used to seal the cover plate, and pressed-on hard rubber seals are used around all connection posts. Plastic cases are sealed together with heat or solvent glues.

What do you look for in a battery?

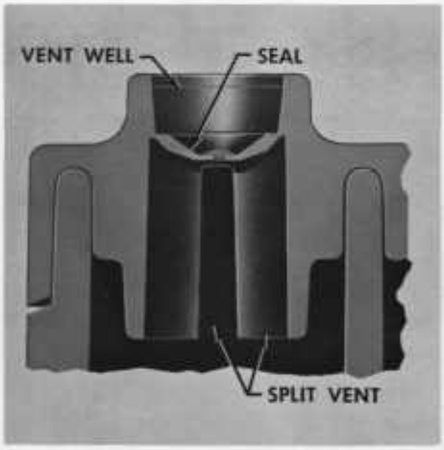
All lead-acid batteries work the same way. There are only about a half-dozen major manufacturers of batteries. Two or three firms supply all the lead plates. Often the biggest difference between competing brands is in the paint and labels on the cases.

How do you tell what is a good buy and what is not? Look for two things: long service life and high current capacity.

Service life is how long the battery lasts under constant usage; it is determined by the amount of lead in the plates. Because lead is porous, the electrolyte works over the surfaces and through the pores of the plates. The more lead that each cell contains, the longer the service life. More lead can be put into the limited space of the cell by using a few thick plates than by using many thin plates. Also, for every two plates, there must be a separator. Thus, the more plates, the more room that separators take up and the less room there is for lead. The greater the number of plates, the greater the plate surface area and the faster surface sulfation will shorten the service life. Generally, batteries built with thin plates do not last more than two to three years. Batteries made with thick plates last up to ten years.

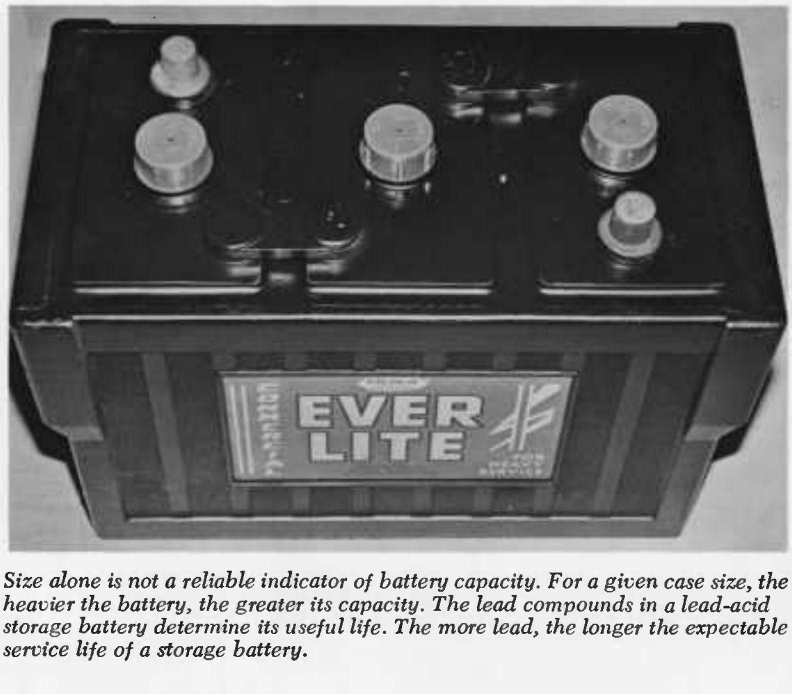
Brand-name products are pictured in this bulletin for purposes of illustration only; their depiction does not in any way constitute an endorsement of these products.

To get best performance and longest service, keep the electrolyte in each cell filled to the bottom rim of the filler hole. Never overfill a cell so that liquid reaches the bottom of the vented cap. Keep the vent hole through the cap clear and dry to allow gases to move between the cell and the outside atmosphere.

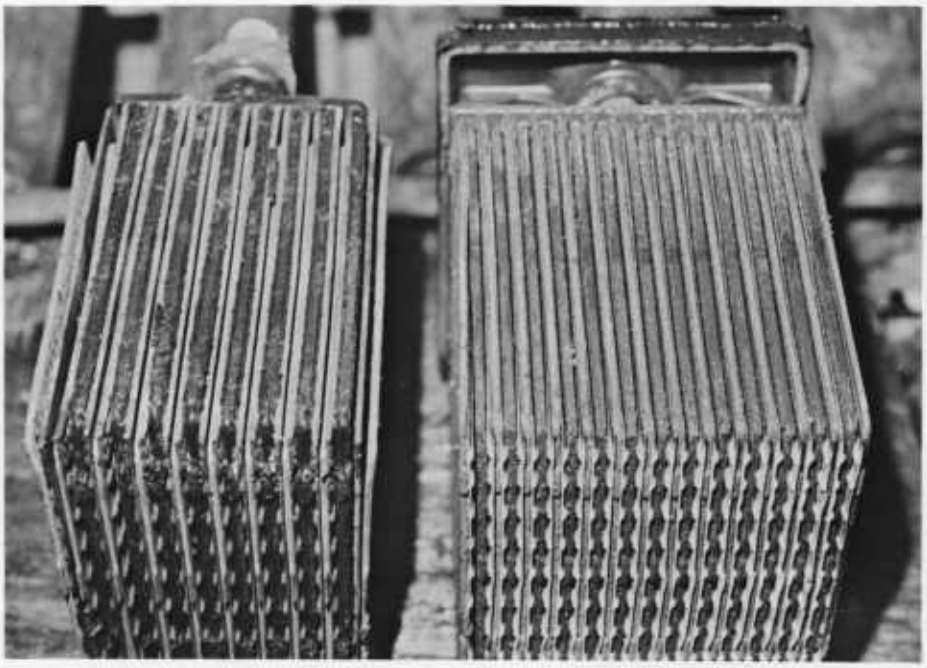


The filler cap seats tightly in the filler hole (or vent well). The slots (split vents) at the sides are for escape of gases. The cap seals the filler hole and serves to keep unwanted substances from contaminating the cell or short-circuiting plates, while allowing gases to move freely.

The appearance of a battery reveals little about its serviceability. It does, however, reveal the voltage. Multiply the number of cells (there is one filler hole for each cell) by 2.1, and you have the voltage of the battery: 8 volts in this case.



Size alone is not a reliable indicator of battery capacity. For a given case size, the heavier the battery, the greater its capacity. The lead compounds in a lead-acid storage battery determine its useful life. The more lead, the longer the expectable service life of a storage battery.



Thickness of plates in a cell affects service life and current capacity of a battery. Thick plates can deliver longer service between chargings and longer service life. Thin plates require more separators and may mean less productive cells. (However, an equivalent amount of lead used in a greater number of thinner plates produces higher voltage and current for starting purposes.)

Current capacity is one useful measure of battery performance. It tells how much current a battery can deliver steadily for how long before needing charging. (This capacity is related to the amount of lead in the cells.) Current capacity is measured in ampere-hours. The manufacturer's ampere-hour rating for a battery is based on how many amperes of current that battery can deliver steadily for 8 hours. The *ampere,* a unit of electrical current, is a quantity of electricity flowing through a conductor for one second. If you think of electricity as a fluid, like water, the ampere corresponds to the number of gallons flowing through a pipe in one second.

Say your boat draws 10 amperes when the engines are shut down but necessary lights, the blower in the gallery, and a few other electrical devices are on. In this situation, a fully charged battery rated at 120 ampere-hours will power these items continuously for 12 hours before needing recharging.

To determine current capacity (ampere-hours), multiply average current (amps) by time (hours of use).

Example 1: The average current powering a bank of equipment measures 10 amps. The length of time that the battery will have to power this equipment is 24 hours. What capacity battery is needed?

$$\text{Current capacity} = \text{current} \times \text{time}$$
$$X = 10 \text{ amps} \times 24 \text{ hrs}$$
$$= 240 \text{ amp-hrs}$$

Example 2: The average current drawn by a load measures 15 amps. The battery powering this load is rated at 120 ampere-hours by the manufacturer. How long can the battery power the load before it needs charging?

$$\text{Current capacity} = 120 \text{ amp-hrs}$$
$$120 \text{ amp-hrs} = 15 \text{ amps} \times X \text{ hrs}$$
$$X \text{ hrs} = \frac{120 \text{ amp-hrs}}{15 \text{ amps}}$$
$$= \frac{120 \text{ hrs}}{15} = 8 \text{ hrs}$$

To figure how many ampere-hours you need, add up the currents (in amps) drawn by the items that will be on while you lie at anchor or drift with your set: mast light, stern lights, strobe light, cabin light, galley stove blower, automatic bilge pump, CB radio, VHF radio, depth sounder, SSB HF radio, etc. If you take this current and multiply it by 24 (for the hours in one day), you get the minimum ampere-hours you need.

To cover possible emergencies, you should have a battery capacity that at least allows for four days of heavy pumping or repeated attempts to start the engine. A 750- to 800-ampere-hour capacity is the minimum recommendable for the smaller vessel, and larger battery capacities for proportionately larger vessels with more crew and larger engines.

Beware of advertising claims for "quick-charge" batteries. These have many thin plates per cell. They charge quickly, but they discharge even more quickly. When industrial-quality batteries (with thick plates) and "quick-charge" batteries of the same ampere-hour ratings were compared on Alaskan fishing boats, the thick-plate industrial batteries supplied current for almost 24 hours after the quick-charge batteries had been fully discharged.

As a rule, when you shop for batteries, look for the highest ampere-hour rating with the fewest plates per cell and thickest plates that you can find. You may be surprised to find that industrial batteries are generally less expensive than the shorter-lived, thin-plate batteries of comparable ampere-hour ratings. Compare the length, width, and height of the same ampere-hour batteries, along with price. Sometimes a little larger battery with the same number of plates has nearly twice as much lead in it for only a few dollars more. That is the buy to look for.

For further reading

A very useful publication is the *Battery Service Manual* published by Battery Council International. It is available, at $2.00 a copy, from: Western Batteries, Inc., 11155 S. W. Denny Rd., Beaverton, Oregon 97005.

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