APLUXOR MARINE ELECTRICAL LIBRARY · PART III. ENERGY: HOW MUCH YOU HAVE AND WHERE IT COMES FROM

Chapter 6. Batteries: What You Have and What Shape It’s In

Read the label, judge the battery by its maker’s numbers, and keep it secured, covered and vented

Every amp your boat uses with the engine off comes out of its batteries, and a battery holds enough energy to start a fire. This chapter shows you how to read your battery from its label, judge its condition by its maker’s numbers, and keep it installed so that it stays put, keeps metal off its live terminal and lets its gas out.

AFTER THIS CHAPTER YOU CAN

- tell a flooded, an AGM and a gel battery apart, and say what each changes for its charger and its care;
- read CCA, MCA, RC, Ah and the group size on a label, and match a start battery to its engine maker’s number;
- tell when a voltmeter on a battery says how full it is, and when it does not;
- see how your batteries are joined into banks, and where the cables of a parallel bank should leave it;
- check an installation by eye and hand: hold-down, terminal cover, box, vent and fuel parts;
- take a lead-acid battery out, put one in, and clean or tighten its terminals by the planned job on a battery;
- say why the card for a battery that smells, is hot or swells puts its actions in that order;
- read and top up the cells of a flooded battery, and judge by its makers’ criteria when a battery is due for replacement.

Read first: → 1.1, → 1.8, → 3.5, → 3.6

6.1 Lead-acid chemistries and the label
6.2 Resting voltage and state of charge
6.3 Start and house batteries
6.4 Banks: series, parallel, 24 V
6.5 Installation, and a battery that smells, is hot or swells
6.6 Checking condition
6.7 Marine-grade or not? A car battery on a boat
6.8 On board

6.1. Lead-acid chemistries and the label

What kind of battery do you have, and what does its label promise? This chapter is about lead-acid batteries: plates of lead in sulfuric acid, six cells in a 12 V battery. A lithium battery has its own chapter (→ 11.1). Lead-acid batteries come in three builds, and the build decides how the battery is charged and cared for. The label names the build and gives the ratings that say what the battery was made to do.

In a flooded battery the plates stand in free liquid electrolyte, and vent caps on top give you a way into each cell. In an AGM (absorbent glass mat) battery the electrolyte is held in mats of glass fiber between the plates; in a gel battery it is thickened into a gel with fine silica. AGM and gel batteries are both VRLA (valve-regulated lead-acid) batteries: sealed, with a one-way valve that lets gas out when the pressure inside rises. These are the definitions of the Battery Council International (BCI), the association of battery makers.

Sealed does not mean that the battery gives off no gas. One maker of thin-plate AGM batteries writes that charging above 15.0 V opens the pressure valves and lets hydrogen, oxygen and water out of the battery. Every lead-acid battery needs the vent of → 6.5 · p. 16. MFR

Vent caps on top mean a flooded battery; without them, the label decides, and with no type on the label the maker's data sheet does (→ 2.2). A lithium battery is marked LiFePO4, LFP or lithium. One maker's

lithium battery built for starting prints a CCA rating, so CCA on a label does not tell you the chemistry: the chemistry word does. MFR

Table 6.1. What the build of a lead-acid battery changes for you, from its makers' manuals MFR

	Flooded	AGM	Gel
Water	Added as its maker says (→ 6.6 · p. 34)	Never added (two makers)	Never added (one maker)
Equalizing charge	Only as its maker prescribes (→ 6.6 · p. 34)	Not done (two makers); not needed (a third); a conditioning charge, by its own method (a fourth)	Not done (one maker); not needed (a second)
Charger	Set for flooded	Voltage-limited, set for AGM (one maker)	Voltage-limited, set for gel (one maker)
Charge lost by itself	10–12 % a month at 77 °F (one maker)	1–3 % a month (one maker); under 2 % at 77 °F (a second)	Under 2 % a month at 68 °F (one maker)
Position	Upright (one maker)	As its model's manual says: upright for two makers' AGM lines; any position but upside down in typical starting uses for a third maker's thin-plate AGM	Upright for one maker's marine gel

The build comes first for the charger too: one battery maker requires a voltage-limited charger for its gel and AGM batteries (→ Table 6.1 · p. 3), and a charger set for flooded batteries can overcharge an AGM or a gel battery. The charger's setting is in → 9.3. MFR

The ratings on the label

The numbers on a label are ratings. Each is measured on a new, fully charged battery, under conditions that its definition fixes. They say what the battery was built to do, not what it does now: how it is now is the subject of → 6.6 · p. 34.

Cold cranking amps (CCA) is the current in amps that a new, fully charged battery at 0 °F can deliver for 30 seconds while its voltage

stays at 1.2 V per cell or higher — 7.2 V for a 12 V battery. Marine cranking amps (MCA) is the same test at 32 °F. Both are the definitions of ABYC's E-10 in its 2006 edition; BCI defines CCA the same way. ABYC BCI adds that European standards define a CCA rating somewhat differently, and that the two numbers are close but not always equal. One outboard maker's manual prints its battery requirement as "CCA/EN".

A battery delivers more current warm than cold, so on one battery the MCA is the larger number. The two do not turn into each other by a fixed factor: on one maker's four group 27 batteries in → Table 6.2 · p. 5, the MCA is from 1.22 to 1.55 times the CCA, and that maker calls its MCA ratings "approximations for comparison only". MFR

One maker's article even gives MCA at 80 °F. Read the temperature printed beside the number, and compare a rating only with the same rating at the same temperature. PRACTICE

Which rating counts for your start battery is the engine maker's: ABYC's E-11 of 2003 asks for the CCA the engine maker requires. ABYC Compare the label with the number in your engine's manual in the same rating: CCA with CCA, MCA with MCA. How long a battery carries the boat's loads is part of the energy budget (→ 7.1).

Reserve capacity (RC) is the number of minutes a new, fully charged battery at 80 °F can deliver 25 A until its voltage falls to 1.75 V per cell — 10.5 V for a 12 V battery. That is the definition of ABYC's E-10 (2006 edition) and of BCI. RC is a number of minutes, not of amp-hours, ABYC and → 6.6 · p. 34 compares a battery's measured minutes with it.

Amp-hours (Ah) are current multiplied by hours. BCI's example: a battery that delivers 5 A for 20 hours delivers 100 Ah. The Ah on a label belong to the rate printed beside them: "20 HR" or "C20" is a discharge that lasts 20 hours. A faster discharge gets fewer amp-hours out of the same battery: one maker rates its AGM battery 100 Ah at the 20-hour rate, 82 Ah at the 5-hour rate and 110 Ah at the 100-hour rate. MFR

The RC test draws 25 A, far more than the 20-hour current of a battery of this size — 80 ÷ 20 = 4 A for the second battery of → Table 6.2 · p. 5 —

so it gets fewer amp-hours out of it: 175 minutes at 25 A is 25 × 175 ÷ 60 = 72.9 Ah, against the 80 Ah on its label at the 20-hour rate. A battery built for starting may print no Ah at all: the maker of Table 6.2 leaves that column empty for its starting battery.

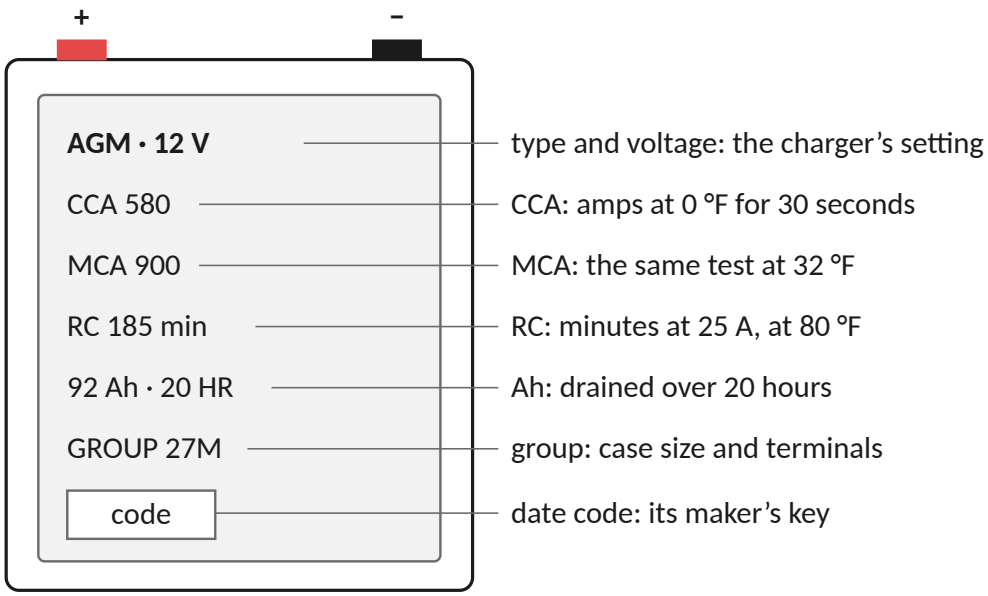
The group number — 24, 27, 31, 4D, 8D and others — is BCI's: it fixes a case's largest dimensions, its terminal layout and the special features that decide whether the battery fits. It does not tell you the capacity: BCI's own table lists group 24 batteries from 200 to 1,000 CCA, all in a case no larger than 10 1/4 × 6 13/16 × 8 7/8 in. A letter after the number is read in the maker's catalog.

The date code is the maker's coded date of manufacture, and each maker has its own key. One maker reads the first four digits of its code as the year and the day of production; another uses a letter for the month and a number for the year. The first of them writes that a round sticker on its battery is not the date it was made. The date the Boat Passport asks for (field 4, → 2.3) is the date you installed the battery: your own record. A code whose key you cannot find is written into field 4 as it is printed. MFR

Table 6.2. Four group 27 batteries of one maker's marine line, as its data sheet prints them MFR

Section of the maker's sheet	CCA	MCA	Ah, 20-hour rate	RC	Weight
Starting	840 A	1,050 A	—	182 min	53 lb
Deep cycle service	675 A	830 A	80 Ah	175 min	51 lb
Heavy-duty deep cycle service	625 A	765 A	90 Ah	180 min	53.5 lb
AGM heavy-duty deep cycle service (group 27M)	580 A	900 A	92 Ah	185 min	61.5 lb

Four batteries of one case size, from one maker: the battery built for starting has the most CCA and no Ah; the AGM battery has the most Ah and the least CCA. The group number fixes the box; the label tells you the battery.



CCA, MCA and RC are ratings of a new, fully charged battery.

Fig. 6.1. The ratings one maker's data sheet prints for its group 27 AGM battery, the last row of → Table 6.2 · p. 5, set out as a label. A real label puts them in its own order and may leave some out.

Where this book speaks of an AGM battery in an example, it means an ordinary AGM battery like the one in → Fig. 6.1 · p. 6. A thin-plate pure-lead (TPPL) AGM battery is a premium type with numbers of its own; its short-circuit current, which its maker publishes, belongs to that model only (→ 4.4).

WHY IT WORKS

A battery makes its current by a chemical reaction between the plates and the acid, and the acid has to reach the plates' surface to keep it going. Cold slows the reaction and thickens the electrolyte, so the same battery delivers less current at 0 °F than at 32 °F, and less at 32 °F than at 80 °F. That is why each cranking rating names its temperature, and why a start battery that cranks well in summer can fail the first cold morning. The ratings are also those of a new battery: as a battery ages, its plates lose active material and its current falls, while the label stays the same.

6.2. Resting voltage and state of charge

When does a voltmeter on a battery tell you how full it is? Only at rest. A lead-acid battery's voltage follows what the battery is doing: on charge it reads high, because the charger pushes current in; under a load it reads low, because the current drops voltage inside the battery. The voltage that says how full the battery is — its resting voltage — is read with no charge and no load, after the rest its maker names, and is compared with that maker's table, by the procedure of → 3.5.

Right after the charger stops, or right after the engine stops — the engine's alternator charges like a charger (→ 1.7) — the battery reads higher than its true voltage. One battery maker calls this surface charge: a battery just charged can show readings higher than its true voltage, and letting it sit lets the surface charge go away. A charger, a solar charge controller or a DC-DC charger still connected gives the same high reading (→ 3.5). PRACTICE

> **WHY IT WORKS**
>
> Charging turns the sulfate on the plates back into acid, and that acid forms at the plates first. Right after a charge, the electrolyte at the plates is stronger than the rest, and the voltage follows the acid at the plates: it reads high. With rest, the strong acid mixes into the rest of the electrolyte, and the voltage settles to the value the maker's table describes. A discharge does the opposite: it uses up the acid at the plates, the voltage reads low, and it rises again as fresh acid reaches them.

How long is "at rest"? Each maker names its own time. One AGM maker asks for at least four hours with the battery shut off from its charging source and its load; a second AGM maker reads its batteries four hours after a charge ends and 30 minutes after a discharge ends; a third maker gives its flooded batteries 4 to 6 hours and its AGM batteries 24 hours; a fourth asks for at least six hours, with 24 hours its first choice. No one number fits every battery: wait the time your battery's maker gives. MFR

A full battery's resting voltage is its maker's number too. The makers in Table 3.3 (→ 3.5) put 100 % between 12.65 V and 12.9 V, and one more maker writes that its fully charged batteries of two AGM lines, all but one model, measure about 13.0 to 13.2 V; it names no rest for that reading. So 13.0 V on such a battery can mean a full battery, not a charger left on, and the same 12.24 V that is half full on one battery is more than half on another. With no table from your battery's maker, the voltage does not turn into a percentage. MFR

Temperature moves the resting voltage less than the makers' tables differ from each other. One AGM maker gives 0.10 mV per cell per °F: for a 12 V battery, 0.6 mV per °F, so a battery read at 40 °F instead of 77 °F reads about 0.02 V lower — less than one step of its table. Another maker prints a correction of its own for a cold reading. Where your maker's table gives a correction, use it; where it gives none, read the battery near the temperature its table names. MFR

Under charge the number that matters is the charger's, and temperature moves it the other way: makers raise the charge voltage when the battery is cold and lower it when the battery is warm, each by its own coefficient; a charger with a temperature sensor on the battery can apply that coefficient (→ 9.3). MFR

A flooded battery can also be read cell by cell, with a hydrometer: it shows a weak cell that the voltage of the whole battery hides (→ 6.6 · p. 34). A lithium battery is not read by its voltage at all: its voltage stays nearly flat through most of its charge (→ 3.5, → 11.4). Batteries joined together read together: the probes on one battery of a parallel bank read the whole bank, and a 24 V bank reads the sum of its batteries across its two ends (→ 6.4 · p. 11).

WORKED EXAMPLE: A READING RIGHT AFTER THE CHARGER

Suppose a flooded battery of the first maker of Table 3.3 reads 12.95 V half an hour after its charger stopped. What decides is the maker's rest, not the number: 12.95 V is above that maker's 100 % row of 12.73 V, and it says nothing yet, because the battery has not rested the six hours its maker asks for. Suppose the same battery reads 12.60 V the next morning, after its rest, with nothing charging it and nothing drawing from it. That is below 12.73 V: the battery is not full. What the number means: the high reading of the evening was the effect of the charge, not of a full battery, and the next question is why the charge stopped short — the charger and its setting (→ 9.3), or a battery that no longer takes a full charge (→ 6.6 · p. 34).

6.3. Start and house batteries

Why does a boat carry two kinds of battery, and what happens when one battery does both jobs? The two jobs differ. Starting an engine takes a large current for seconds, and the alternator then puts back the little that was used. Running the boat's loads at anchor takes a small current for hours, and takes much of the battery's charge out before the next charge. A battery is built for one of these jobs, or as a compromise between them, and the build is inside the case. The battery that starts your engine is the start battery; the batteries that run the loads are the house bank.

One battery maker's marine brochure describes the difference. A battery built for starting has thinner plates: more plate surface with less resistance delivers current faster, and an engine start uses only the power off the surface of the plates. A deep-cycle battery has heavier, thicker plates, special active material and heavy-duty separators, made for repeated deep discharge. A dual-purpose battery is a compromise between the two, for starting and for light to moderate cycling. MFR

Three makers agree on what deep discharge does to a battery built for starting. The brochure above: its thinner plates cannot handle constant

deep cycling. A second maker: it cannot withstand more than a few deep discharges before it fails. A third: it is not designed for regular discharges of more than 1 to 3 % of its capacity. PRACTICE

So one battery that both starts the engine and runs the house loads does both jobs badly. The loads take it down; if it is built for starting, each deep discharge wears its thin plates; and a battery the loads have discharged cannot start the engine — far from help, that can leave you without the engine (→ 1.2). One battery maker advises one battery for starting and a deep-cycle battery for the trolling motor and the accessories; for a boat with room for one battery, a dual-purpose battery for light to moderate cycling, or its deep-cycle battery for heavy cycling. A trolling-motor maker asks for separate deep-cycle batteries for its motor where a cranking battery starts a gasoline outboard. PRACTICE

A deep-cycle battery can be the start battery when its label meets the engine maker's cranking number, in the same rating (→ 6.1 · p. 2): deep-cycle batteries print CCA too (→ Table 6.2 · p. 5), and one maker recommends its AGM deep-cycle batteries for high-current uses such as engine starting. The same maker writes that its gel batteries have a lower effective capacity at high discharge currents; a gel battery as the start battery is compared with the engine maker's number like any other. Which battery an outboard's own alternator is allowed to charge is in → 9.1. MFR

Your boat has one of a few arrangements: one battery that does everything, on a small outboard boat; a start battery and a house bank; the two and a trolling-motor bank (→ 6.4 · p. 11); and on some boats a battery of its own for a windlass or a thruster (→ 8.4). A start battery and a house bank are two banks, each with its own cables to the battery switch, and no jumper joins them: a jumper would make them one bank, and the house loads would discharge the battery that starts the engine. Where two banks meet — at the battery switch, an automatic charging relay (ACR), a diode isolator or a DC-DC charger — is in → 8.1 and → 8.3. Which battery starts your engine you find by following the starter cable by eye from the starter to the battery it comes from (→ 4.2); which

feeds the panel, by the battery switch's positions (→ 2.1). Both go into the Boat Passport (fields 4 and 6, → 2.3).

6.4. Banks: series, parallel, 24 V

How are batteries joined into a bank, and where should the cables go? ABYC's E-10 (2006 edition) calls a battery bank two or more batteries connected in series to give a higher voltage, or in parallel to give more capacity. In parallel, positive is joined to positive and negative to negative: the voltage stays that of one battery, and the capacities add. In series, the positive of one battery is joined to the negative of the next: the voltages add, and the capacity stays that of one battery. ABYC

Suppose two 12 V batteries of 100 Ah each. In parallel they make a 12 V bank of 200 Ah; in series, a 24 V bank of 100 Ah. The energy is the same: 12 × 200 = 2,400 Wh, and 24 × 100 = 2,400 Wh. Amp-hours at two voltages do not add; watt-hours do (→ 7.1).

The short cables that join the batteries of one bank are battery jumpers. They are part of the bank, not positives that leave it (→ 4.2); whether your bank needs protection between its batteries — a lithium bank, a large bank, batteries standing in separate places — is a question for its battery maker and a pro, and the answer goes into the Boat Passport. The bank's own positive cable leaves the bank through its main protection (→ 4.2).

Batteries that belong in one bank

The batteries of one bank are matched. A trolling-motor maker asks for batteries of the same manufacture, type, size and age; one battery maker for the same size and condition, and never different models or sizes in one string; another for the same make, model and capacity. Two battery makers ask that the batteries be at the same state of charge before they are joined. MFR

The reason is what the batteries share. Batteries in series carry the same current. A smaller one among them is full first, and goes on being charged while the larger one fills; on discharge it is empty first and goes

on being discharged. One maker writes that the smaller battery is overcharged and can overheat, and that it never connects batteries of different capacity in series. PRACTICE

A bank also ages as a set. One battery maker writes that, unless the string is less than 12 months old, replacing only the bad battery leaves the others under-charged or over-discharged, and it replaces the whole set; it adds that the more batteries are joined in parallel, the larger the risk that one faulty battery affects the whole bank. Three battery makers set three parallel strings as their maximum. MFR

Where the cables leave a parallel bank

In a parallel bank, where the bank's two cables leave it matters. If both are taken from battery 1, the current of battery 3 has to cross both jumpers on its way out, while the current of battery 1 does not: one battery maker's note shows that the jumper next to the take-off then carries the current of two batteries, and the cable that leaves the bank the current of all three (→ Fig. 6.2 · p. 13, top). The battery nearest the take-off, with the shortest path, gives the most current and works hardest. MFR

Two makers give the remedy: take the load and charging connections from opposite ends of the bank — the diagonal connection — or from a positive and a negative bus bar, with cables of equal length to each battery (→ Fig. 6.2 · p. 13, bottom). Then the current of each battery runs the same length of cable, and the batteries share the work. PRACTICE

The jumpers of one bank are the same gauge and the same length, two makers write, and sized for the largest current the bank carries; one maker holds the drop on its cables to 0.2 V at the full output of the charger. One trolling-motor maker asks for jumpers one size larger than its motor's leads. MFR

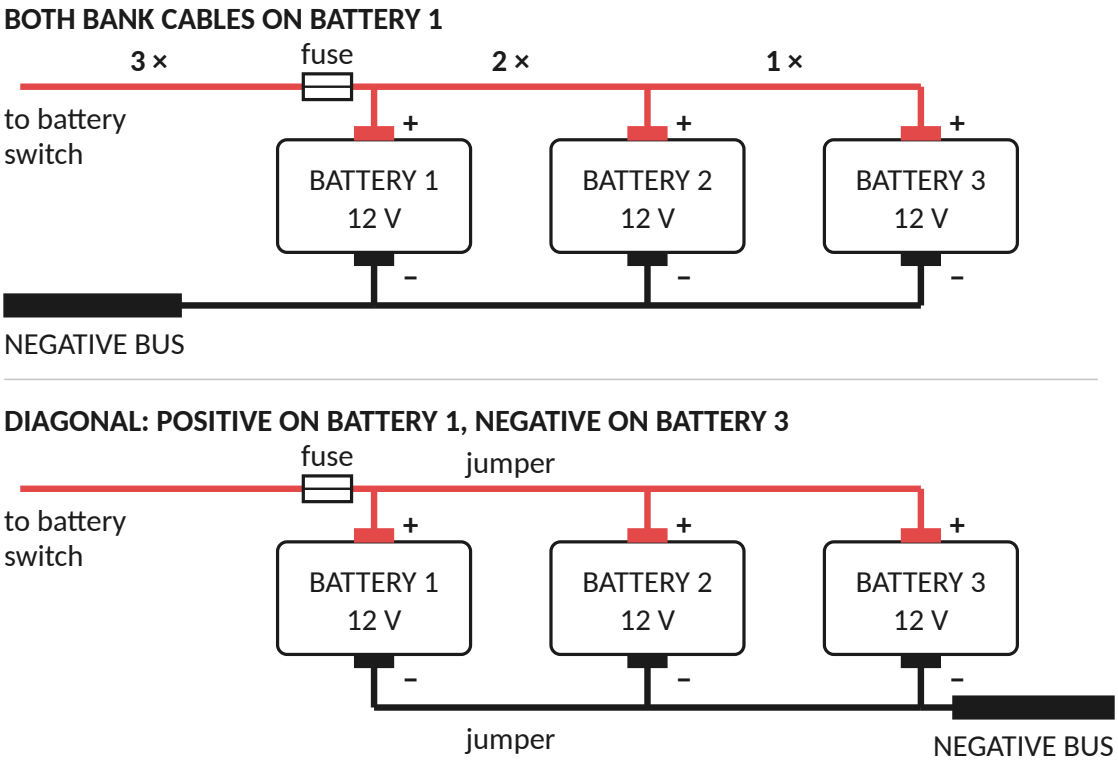


Fig. 6.2. A parallel bank of three batteries, two ways. Top: both bank cables on battery 1; the figures over the positive cables say how many batteries' current each one carries when each battery gives the same share. Bottom: the diagonal connection, positive on battery 1 and negative on battery 3, so that the current of each battery runs the same length of cable.

24 V: batteries in series

A 24 V bank is two 12 V batteries in series (→ Fig. 6.3 · p. 14, left): a jumper from the positive of battery 1 to the negative of battery 2, the bank's positive cable from battery 2 and its negative cable from battery 1. Across the bank's two ends a meter reads the sum, about 24 V; each battery is read on its own two terminals by the procedure "A battery's resting voltage" (→ 3.5), and the two readings, compared at rest, show whether the two batteries are at the same state of charge. Four batteries make a 24 V bank of twice the capacity as two series pairs joined in parallel, with the bank's cables taken from opposite ends (→ Fig. 6.3 · p. 14, right). On a bank in series — a 24 V bank, or a 12 V bank of two 6 V batteries — taking a battery out or putting one in, and cleaning or tightening its terminals, is a pro's job, and so is that job on a battery whose bank is tied on the positive side to a bank in series — by any of the ties that step 10 of the planned job names, a charger among them

unless it has an output for each bank and its manual says those outputs are isolated from one another (→ 6.5 · p. 16).

A 12 V load taken from one battery of a 24 V bank discharges that battery alone, and a charger that sees only the whole bank cannot put the difference back. One inverter maker's wiring guide writes that loads on the midpoint of a bank create a large imbalance, larger than a battery balancer can correct, and that the battery used for the lower voltage fails early; the same maker's battery balancer manual describes the imbalance as one battery undercharged and the other overcharged.

PRACTICE

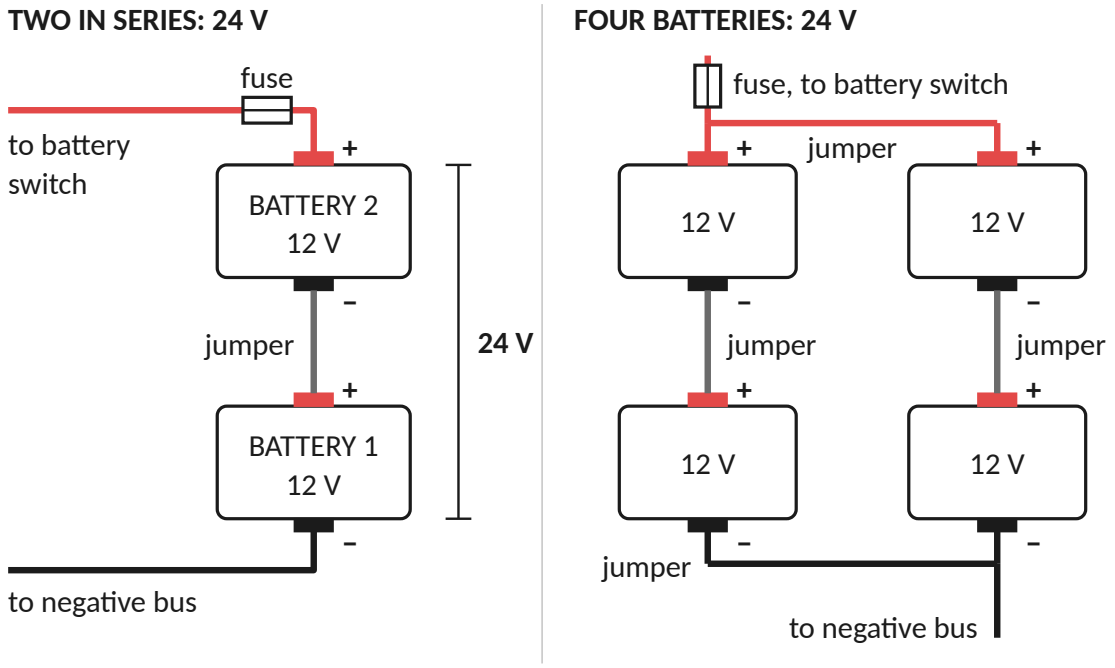


Fig. 6.3. Left: two 12 V batteries in series make a 24 V bank. Right: four make a 24 V bank of twice the capacity, as two series pairs joined in parallel, with the bank's cables taken from opposite ends.

The trolling-motor bank

A 24 V or 36 V trolling-motor bank is a separate circuit, with its own rules: one connection with the rest of the boat's system, or none where the motor's or the charger's manual keeps it apart — never two (→ 14.3). A second connection — a second negative wire, the motor's bracket or an aluminum hull — gives the current a path that nobody planned (→

1.4). If you cannot tell how your trolling bank is connected, leave it as you found it and add no connection to it.

ABYC's E-11 of 2003 asks for a battery switch in the positive conductor from each battery or bank whose CCA rating is greater than 800 A, and lets the conductors of dedicated trolling-motor batteries go without one when they have overcurrent protection at the battery and a manual means of disconnect apart from the motor's controls. ABYC

WALK-AROUND CHECK: HOW YOUR BATTERIES ARE JOINED

 HOT BATTERY  SHORT CIRCUIT

Lift off the lid of each battery box that lifts off by hand, and before any hand goes nearer, look, listen and smell: a battery that smells of gas or of rotten eggs, hisses, or whose case swells, or one that gives off heat you feel with your hand held near its case, is a case for the card "Battery smells, is swollen, or is hot" (→ emergency card), and the check stops there. Otherwise, by eye and with your hands off the terminals: count the batteries, and follow each jumper from terminal to terminal. Note which batteries are joined positive to positive and negative to negative — in parallel — and which positive to negative — in series. Find the battery each bank cable leaves from: one end of the bank, opposite ends, or bus bars; a battery that no jumper joins to another and that has its own cables to the battery switch is a bank of its own (→ 6.3 · p. 9). Read each label: the same type and size, and about the same age? Read the gauge printed on each jumper and on the bank's own cables: a jumper of another gauge or length than the others, or one thinner than the bank's own cables, is written on the first line of the Boat Passport, and a new jumper is a pro's (→ 6.8 · p. 46). Write each bank into the Boat Passport (field 4, → 2.3) with its batteries; where you could not see both ends of a jumper, write "banks not traced" (→ 2.1). Put back each lid you lifted.

6.5. Installation, and a battery that smells, is hot or swells

HOT BATTERY

Does a battery smell of gas or of rotten eggs, is it hot, does it hiss, or is its case swelling? Then the first move is on the card “Battery smells, is swollen, or is hot” (→ emergency card), now: its actions come before anything in this section, and “Why the card’s actions come in this order”, below, explains them. Otherwise this section answers how a battery is installed so that it stays put, keeps metal off its live terminal and lets its gas out; what goes on a terminal; how you take a battery out, put one in, and clean or tighten its terminals; and how you tell a battery in trouble from one that only looks like one.

Hold-down, cover, box and vent

A battery is a heavy box of acid with a terminal that is live all the time. Its installation answers four questions (→ Fig. 6.4 · p. 18): does it stay put, can metal reach its positive terminal, does a spill stay where it is, and does its gas leave the boat? The federal regulation for boat builders puts the first in numbers. For a boat within its scope (→ 1.9), 33 CFR 183.420 asks that each installed battery move no more than one inch in any direction when a pulling force of 90 pounds, or twice the battery’s weight, whichever is less, is applied through its center of gravity: vertically for one minute, fore and aft for one minute each, and to each side for one minute each. CFR

Suppose a battery weighs 44 lb. Twice its weight is 88 lb, less than 90 lb: the test pulls with 88 lb. Suppose a battery of 62 lb: twice its weight is 124 lb, more than 90 lb, so the test pulls with 90 lb. Either way the battery moves no more than one inch.

The pull test is the builder’s. Your check is by eye and hand: a strap or a clamp over the battery, fastened, and a battery that does not shift when you push it. PRACTICE

One maker asks that a hold-down be tightened firmly but not over-tightened, which damages the battery. PRACTICE

Metal must not reach the positive terminal. The regulation asks that each battery be installed so that metallic objects cannot come in contact with its ungrounded terminals — the positive ones. CFR

One parts maker publishes a summary of ABYC's battery standard E-10 in its text dated 12/96, which ABYC recommends for boats built after July 31, 2001; the summary is not the standard's full text. It names three ways to keep metal off the positive terminal: a boot or non-conductive shield over the terminal, a covered battery box, or a compartment made only for the batteries. VERIFY

ABYC's E-11 of 2003 asks that boots or other protection cover all energized surfaces of a positive battery terminal: a cover that leaves the nut or the lug bare is not the cover. ABYC

Why the positive: the negative terminal is tied to the engine block and the negative bus, so metal from the positive terminal to the engine, to the negative bus or to anything joined to them closes a short whose current only the battery limits (→ 1.8).

The same summary asks that a leak or a spill of electrolyte be contained, and that a battery box whose cover forms a pocket over the battery be vented at the uppermost portion of the cover. VERIFY Hydrogen is the lightest of gases: it rises and gathers at the top of a closed space, and a vent at the top lets it out.

The regulation asks for a vent system or other means that lets the hydrogen a battery gives off leave the boat. CFR

A sealed battery is no exception: two battery makers write never to install a battery in a sealed or airtight container (→ 6.1 · p. 2). MFR

A battery is kept away from fuel. The regulation: no battery directly above or below a fuel tank, a fuel filter or a fitting in a fuel line, and each metallic fuel line and fuel system component within 12 inches and above the plane of the battery's top shielded with dielectric material. CFR

The parts maker's summary of E-10 measures the 12 inches from a battery terminal, and adds that a battery is not installed directly below a battery charger or an inverter. A dropped tool or a loose cable VERIFY

that bridges the positive terminal and a metal fuel line makes its spark at the fuel; a fuel leak above a battery drips onto it.

These are the builder's requirements. On your boat they become things to look at, by the check below; what you find goes into the Boat Passport, and a positive terminal that metal can reach is written on its first line.

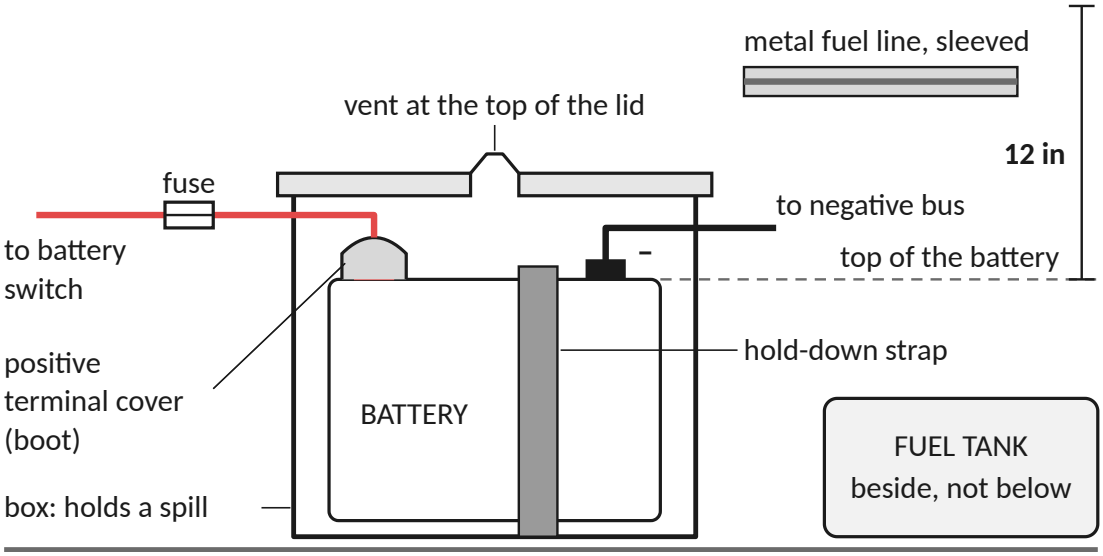


Fig. 6.4. A battery installation: a box that holds a spill, a hold-down strap, a cover on the positive terminal, a lid vented at its top, a metal fuel line above the plane of the battery's top and within 12 in of it, in a sleeve, and the fuel tank beside the battery, not above or below it. Not to scale.

WALK-AROUND CHECK: THE BATTERY INSTALLATION

HOT BATTERY **SHORT CIRCUIT** **BATTERY ACID**

Open the battery compartment, and lift off the lid of each battery box that lifts off by hand. Before any hand goes nearer, look, listen and smell: a battery that smells of gas or of rotten eggs, hisses, or whose case swells, or one that gives off heat you feel with your hand held near its case, is a case for the card "Battery smells, is swollen, or is hot" (→ emergency card), and the check stops there. Otherwise, without touching the terminals, push each battery by

> hand at its case: a battery that shifts, or a strap that is loose, broken or missing, needs its hold-down fastened or replaced, and a battery that has to be moved for that is moved by the planned job on a battery below. Look at each positive terminal: a boot, a box lid or a compartment only for the batteries keeps metal off it; bare metal of a positive terminal, or of a lug or a nut on it, with none of these over it, is written on the first line of the Boat Passport. Look for a crack in a case, a wet or crusted battery top, liquid in the box, and a case that bulges slightly (→ "Swollen, or only its shape?" below). Look above and below each battery: an unsleeved metal fuel line above the plane of its top and within 12 in of it, a fuel tank, a fuel filter or a fitting in a fuel line directly above or below it, a charger or an inverter right over it. Put back each lid you lifted, and write down what you found.

What goes on a battery terminal

A battery terminal is a tapered post — the SAE post of car batteries — that takes a clamp tightened by a bolt; a threaded stud that takes a nut; both on one battery; or a flag or a side terminal. Some of one maker's marine batteries carry an SAE post and a stainless steel stud with a wing nut for each terminal. MFR

The regulation bans a connection held by a spring: for a boat within its scope, it asks that no battery terminal connector depend on spring tension for its mechanical connection to the terminal. CFR

A spring holds the connection only as hard as it pushes; vibration and heat work against it, and a loose connection heats under current (→ 3.1).

The torque for a nut on a battery terminal is a number of the battery's maker, on its label or in its data sheet, and the makers' numbers differ with the terminal: at most 200 in-lb for one maker's heavy-duty 3/8 in stud on some of its batteries, and at most 100 in-lb for a stud of the same size on another; 35 in-lb for another maker's M6 terminal and 70 in-lb for its M8 and M10 terminals; 100 to 120 in-lb for a third maker's terminal; 95 to 105 in-lb for a fourth's. Each number MFR

belongs to its own terminal; for a clamp on an SAE post, the first of these makers gives no number of its own. Two of these makers warn that over-tightening breaks a terminal and that a loose connection can melt a terminal or start a fire; what is done where the maker gives no number is in step 16 of the procedure below.

On the terminal the lug lies flat, with nothing between it and the terminal. One maker asks that no washer and no other material sit between the cable lug and the lead terminal, other than a light film of the grease it names; another never puts the lock washer between the cable and the terminal, and puts a protective coating on only after the cables, because a coating between the terminal and the cable can cause resistance. The washers and the nut go on top of the lug as on any stud, and no more than four conductors go on one stud (→ 5.6). A terminal fuse made to sit on the positive post under the lug (an MRBF) is its maker's design, not a washer, and a battery that carries one is not part of the planned job below (→ 4.4, → 1.8). MFR

The planned job on a battery

Most work at a battery terminal is a pro's (→ 1.8): a battery terminal is live all the time, and nothing on the boat switches it off. One job at the terminals is yours: taking a 12 V lead-acid battery out — one on its own, or one of a bank joined in parallel — and putting it or a new one back in during the same session — before you leave the boat, or, on a boat out of the water, later by the same job from its first step, before the boat goes back in the water — and cleaning or tightening its terminals. It is yours because its order takes the path for a short away, and a reading proves that the path is gone, before a tool goes near the positive terminal. Three battery makers give owners this job; the procedure below adds the reading that proves it. PRACTICE

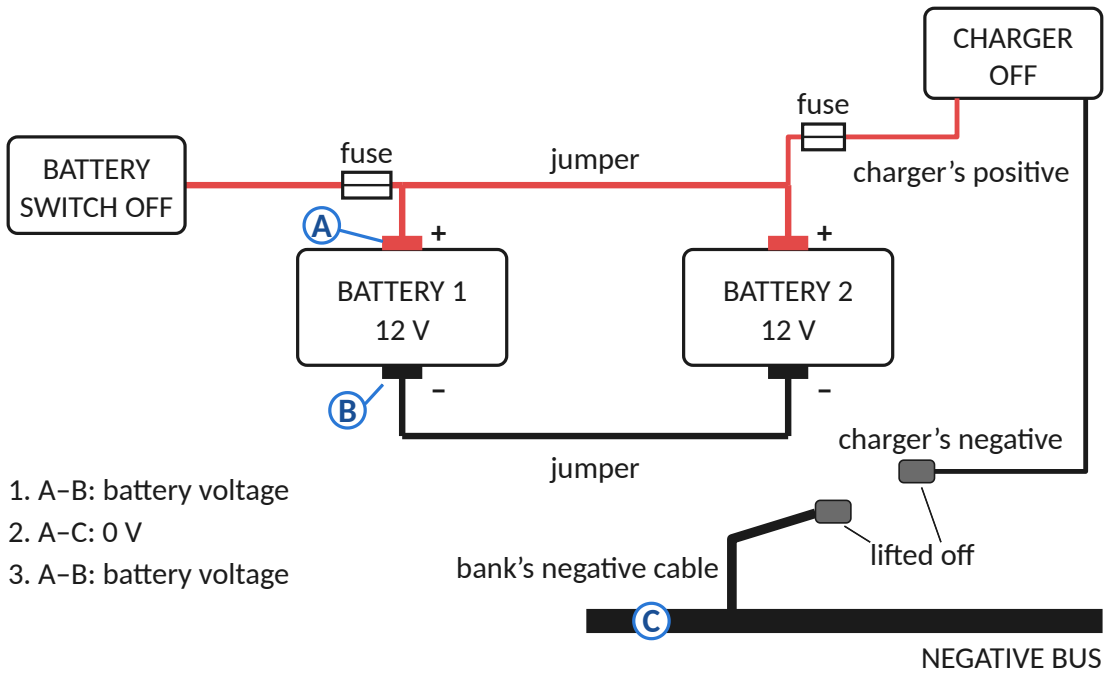


Fig. 6.5. The reading points of the planned job on a battery, on a house bank of two batteries in parallel, with every negative lead that leaves the bank lifted off, the jumpers on, and the battery switch and the charger OFF. A: the bank's positive terminal, which its positive cable leaves from; B: the same battery's negative terminal; C: the negative bus.

Procedure: A planned job on a battery

For a 12 V flooded, AGM or gel battery — one on its own, or one of a bank of 12 V batteries joined in parallel (→ 6.4 · p. 11) — that is not hot, swollen or gassing (→ "Swollen, or only its shape?" below), whose terminals water in the boat has not reached, and whose positive terminal carries no fuse bolted to it: taking it out and putting it or a new one back in, both in one session — before you leave the boat, or, on a boat out of the water, later by this procedure from step 1, before the boat goes back in the water (step 15) — or cleaning or tightening its terminals. A battery in trouble goes to the card "Battery smells, is swollen, or is hot" (→ emergency card); a battery whose terminals water in the boat reached, to the card "Water in the boat — the pump can't keep up or is silent" (→ emergency card); a lithium battery, to its maker's manual (→ 11.4). A fuse holder bolted to the positive terminal (an MRBF), a battery cable replaced, a new lug crimped on a cable, a battery of a bank in series — a 24 V bank, or a 12 V bank of two 6 V

batteries (→ 6.4 · p. 11) — and a battery whose bank is tied on the positive side to a bank in series are a pro's (→ 1.8). On someone else's boat this job is not yours: tools — no (→ 2.6).

You need: the wrench, the gloves and the eye protection that the entries of the SHORT CIRCUIT and BATTERY ACID signs name; the torque your battery's maker gives on its label or in its data sheet, and a torque wrench with insulated handles that covers it, if you have one; your meter; tape, a marker and cable ties; insulating tape or boots for the lugs you lift off; a terminal brush, clean water and a clean cloth for cleaning; the battery's own handles or a lifting strap. A new battery for a bank matches the batteries it joins (→ 6.4 · p. 11). The points A, B and C are those of → Fig. 6.5 · p. 21.



1. If the boat needs its engine running, or its navigation or anchor lights, its radio or its electronics, from this bank or from a bank tied to it (step 10) — under way, or at anchor after dark — while the job lasts, or before a pro could come if the battery cannot go back in (step 15), stop here until it does not. Nothing the boat needs before then runs from this bank, from a bank tied to it or from the engine.
2. If a new battery goes in, it is on board before the job starts: the battery that comes out, or the new one, goes back in during this session, before you leave the boat, or — on a boat out of the water — later, as step 15 says. If a battery will join others in a bank, charge each battery of the bank on a charger before the day of the job, and a new battery as well, until its charger shows the charge complete. That goes for the battery that comes out, too, when it is charged ashore before it goes back (→ 6.6 · p. 34); it goes back in only once its charger has shown the charge complete. Any new battery is on board, and each charger has shown the charge complete.
3. Read the battery's label, and follow each jumper on its terminals by eye to the terminal at its other end (→ 6.4 · p. 11); do the same on every bank tied to its bank, by the ties step 10 names. Look, listen

and smell first, without touching the battery; then lay the back of your hand on the side of its case, away from the terminals. A 12 V flooded, AGM or gel battery, on its own or joined to the others of its bank only positive to positive and negative to negative, whose bank is tied to no bank in series, cool, not swollen, with no hiss and no smell of gas, no water in the boat at its terminals and no fuse holder bolted to its positive terminal: continue. A top that is only damp, or crusted, is not water in the boat: step 15 cleans it. Anything else: this procedure stops here, and the paragraph above says where the battery goes.

4. With the engine stopped, open the battery compartment to the air. In a compartment with a gasoline engine or tank, the entry of the GASOLINE VAPOR sign says what comes first; nothing is switched off yet, so the blower still has power. Leave the compartment open for the time the entry of the SHORT CIRCUIT sign gives for this job before you continue. The time has passed on your watch.
5. Stop every other source that can charge the battery: the charger and any inverter/charger at its own switch or at its breaker on the AC panel; a DC-DC charger at its own switch, or at the DC breaker or isolation switch that feeds it; the solar panels at their disconnect switch, or covered; a wind generator stopped as its manual says; a generator stopped, with its automatic start OFF. The charger's light or display shows no charging.
6. Switch every load off: each at its own switch or at its breaker on the DC panel, and the inverter at its own switch. Nothing you switched runs.
7. With the engine stopped, turn the battery switch of this bank OFF; a selector that joins two banks — BOTH, ALL, 1+2 or COMBINE — goes to OFF. On a boat with no battery switch, step 6 has already switched every load off. What this switch fed is dark. What still works now is wired around the battery switch (→ 1.7): a bilge pump's automatic switch, a CO alarm or an electronics memory loses its power when the negatives of its bank come off in step 10 — this bank's, or those of a bank tied to it — and the restore below gives it back.

8. Get ready as the entries of the SHORT CIRCUIT and BATTERY ACID signs say for this job: what comes off your hands, wrists, neck and belt, what you put on, and the wrench you use — the torque wrench of the list above, where you have one. Nothing on those lists is missing.
9. Mark each cable before anything comes off: a piece of tape on each lead and each jumper, with the battery it is on and + or −, and a photograph of the whole bank. Every lead and jumper carries its tape.
10. Take off the negative leads one at a time, starting with the bank's main negative cable — to the negative bus or to the shunt: loosen its nut — or the bolt of its clamp — with the wrench and lift its lug or clamp off the battery's negative terminal; cover the lug or clamp at once with insulating tape or a boot, and tie the lead back so that it cannot touch a terminal, another lead or other metal. Then, the same way, every other negative lead on every battery of the bank — the charger's, and those of circuits wired around the battery switch. The jumpers that join positive to positive and negative to negative stay; a jumper's lug under the same nut stays on the terminal. Then the same on every bank tied to this one on the positive side, its main negative cable first, then its other negative leads: a bank tied by a battery switch at BOTH, ALL, 1+2 or COMBINE, a parallel switch ON, a charging relay (ACR) whether or not it seems closed, a DC-DC charger, or a charger — a charger with an output for each bank whose manual says those outputs are isolated from one another is no such tie (→ 1.8). No lead is left on a negative terminal of these banks but a jumper that joins two negatives, and every lug you lifted is covered and tied back.
11. Set the meter as the entry of the METER LEADS sign says, and put the probes on A and B: A, the bank's positive terminal — the one its positive cable leaves from — and B, the same battery's negative terminal. The meter reads that battery's voltage — about 12 V. This proves the meter and its leads on a known live source. A battery that reads far less — a flat or failed one — proves nothing: prove the meter on a known live source instead, across the two terminals of a charged battery of another bank or of a charged spare battery, and

use the same source in steps 13 and 14. With no such source, the job waits: put back what step 10 took off, as step 18 says, then the restore below.

12. Keep the red probe on A and move the black probe to C: bare metal of the negative bus — for a bank kept apart from the boat's other negatives (→ 6.4 · p. 11), of that bank's own negative cable at the lug you took off, its tape opened for the probe and closed after it. It reads 0 V: nothing joins this bank's positive to a battery any more — continue. Any voltage: something still does — a negative lead still on, a charging source still on, a bank tied to this one — and the job is a pro's. No tool touches a positive lug or terminal: take step 5 again, then put back what step 10 took off, as step 18 says, then the restore below.
13. Put the probes back where step 11 proved the meter. The meter reads that voltage again: it was working through the 0 V reading. If it does not, the 0 V proved nothing: find why the meter failed (→ 3.7) and take steps 11 to 13 again; with no working meter today, put back what step 10 took off, as step 18 says, then the restore below.
14. Read each positive terminal you will work on that is not A: the red probe on it, the black probe on C as in step 12, and then both probes back on the source of step 11. It reads 0 V, and the source its voltage again: continue. Any voltage on the terminal: the job is a pro's, and no tool touches a positive lug or terminal — take step 5 again, then put back what step 10 took off, as step 18 says, then the restore below. A source that no longer reads its voltage: the 0 V proved nothing — find why the meter failed (→ 3.7) and take steps 11 to 14 again; with no working meter today, put back what step 10 took off, as step 18 says, then the restore below. Each positive terminal you will work on has read 0 V.
15. Do the job:
    - to take the battery out: loosen every positive lead and every jumper still on its terminals, one at a time — each nut, or the bolt of each clamp — and lift their lugs or clamps off; cover each one and tie it back as step 10 does, the free end of a jumper whose other end stays on a battery of the bank as well; unfasten

the hold-down; and lift the battery out by its handles, or by a strap under it — never by its terminals;

- to put a battery in: set it in its tray or box with its terminals the way the photograph of step 9 shows, and fasten the hold-down until the battery does not move when you push it;
- to clean a terminal: loosen its lead and lift the lug or clamp off the battery's terminal, then clean the terminal and the inside of the lug with the terminal brush until both are bright metal. One maker neutralizes a crust of corrosion with a paste of baking soda and water, brushes it off and rinses the place with clean water; another, cleaning a battery, first checks that every vent cap is tight, lets no cleaning solution or anything else get into the battery, and dries it with a clean cloth after the rinse;
- to tighten a loose lug: it goes back on, tightened, in step 16 for a positive lead or a jumper, step 18 for a negative lead.

Every terminal and lug you cleaned is bright metal and dry; every lug that is off is covered and tied back; a battery that came out stands outside the compartment, and the battery that goes back in stands in its tray or box with its hold-down fastened. If neither the battery that came out nor a new one goes in during this session — it does not fit, a terminal is broken, or, on a boat out of the water, it goes ashore to be charged or tested — this bank stays as it is, every lug covered and tied back: on a boat out of the water until a battery goes back by this procedure from step 1, before the boat goes back in the water; elsewhere the job is a pro's. A bank tied to this one comes back only where every tie between it and this bank is set apart, with the engine still stopped: a selector set to that bank alone, or a dual-circuit switch set to ON, where each bank feeds only its own circuit; a parallel switch OFF; a charging relay (ACR) with its own fuse at one of the two banks taken out, where that fuse sits in a holder that opens by hand — its hold-open position alone is not enough, because contacts that have welded keep the banks joined there; a DC-DC charger between the two banks, either way, stopped at the DC breaker or isolation switch that feeds it; a charger whose manual says its outputs, one for each bank, are

isolated from one another is no tie (step 10) and needs nothing here, and any other charger that reaches both banks is a tie you cannot set apart. Then put back that bank's negative leads, each the same way as in step 18. A bank whose tie you cannot set apart, or cannot tell, stays down with this one; the restore below says what then.

16. Put each positive lead back on its terminal: the lug flat on the terminal — or the clamp on its post — with nothing between them, the washer and the nut on top, and the nut or the clamp's bolt tightened to the torque the battery's maker gives on its label or in its data sheet, with a torque wrench with insulated handles. Where the maker gives no torque, or you have no such wrench, it is tightened as the entry of the SHORT CIRCUIT sign says. A loose lug is tightened the same way. Then put back each jumper that joins positive to positive or negative to negative, the same way. Pushed by hand, no lug turns on its terminal.
17. Put the positive terminal's cover (boot) back over the terminal and its lug. No metal of the positive terminal or of its lug shows; where the lid of a battery box is the only cover, it goes on at the end of step 18.
18. Put back every negative lead step 10 took off, each the same way as in step 16, the tape that covered it taken off: first those of a bank tied to this one; then this bank's other negative leads — the charger's, and those of circuits wired around the battery switch — and, last of all, this bank's main negative cable. Every lead is where its tape and the photograph of step 9 put it, none turns when you push it, and a battery box's lid is closed.

PUT THE BOAT BACK IN SERVICE

- After step 18, or after a stop at step 11, 12, 13 or 14 with the leads of step 10 put back as step 18 says: with the engine still stopped, the battery switch of this bank back to its working position.
- After a stop at step 15, this bank stays as that step left it until a pro has finished the job, or, on a boat out of the water, until a battery goes back by this procedure from step 1, before the boat goes back in the water: every lug covered and tied back, no tool touches its lugs or terminals, its battery switch stays OFF — or a selector on another bank alone, or a dual-circuit switch at ON — and every charging source you stopped stays stopped, unless — on a boat in the water — it charges only a bank that step 15 put back: with this bank's negatives off, a charger whose manual calls its outputs isolated is such a source. A bank tied to it that step 15 did not put back stays down with it. Until then, no charge reaches the banks left down, and what they feed has no power — the bilge pump's automatic switch, the high-water alarm and the CO alarm among them, where they are wired that way: the entries of the CARBON MONOXIDE and BILGE PUMP signs say what you do meanwhile. The items below go only to a bank that step 15 put back, to what it feeds and — on a boat in the water — to a source that charges it alone; where no source charges it alone, how long it lasts on its own charge is worked out by → 7.4.
- Every charging source you stopped, back as you found it — the charger and any inverter/charger, the DC-DC charger and the breaker or switch that feeds it, the solar disconnect switch or the cover, the wind generator, the generator and its automatic start — each set for the battery now in place: a battery of another type than the one that came out gets its maker's charging settings on every source that has a setting (→ 9.3) before that source charges it.
- Every load you switched off, and the inverter, back as you found them.
- A CO alarm wired to this bank or to a bank tied to it lost its power with the negatives; the entry of the CARBON MONOXIDE sign says how you see that it is working again.

- Electronics that lost their clock or settings are set again by their manuals; the meter's dial goes to OFF.
- Check that every bilge pump's automatic switch has power, by the procedure "The check that the automatic switch has power" (→ 12.2).

WHY IT WORKS

A short needs a closed path: from the battery's positive, through the tool, and back to the negative of a battery. With every negative lead of the bank off, the path back is open, and a wrench that touches the positive and the boat's metal at the same time carries no current. A bank tied to this one on the positive side is a second path back — through this bank's positive, the tie and that bank's negatives on the boat's metal — so its negatives come off too; they come off before any reading could show the tie, so those of a bank tied by a charging relay come off whether or not the relay seems closed. The 0 V from A to C shows that every path is open; the readings on a known live source before and after it — the battery itself, when it is charged — show that the meter could have shown a voltage there. A lug lifted off is covered and tied back because the lead behind it can still be joined to a battery: a jumper whose other end stays on a battery carries that battery's voltage to its free end. Any voltage on a reading means a path that nobody has found, so no tool goes on a positive until a pro has found it; the negatives still go back, in the order of the way back, so that what the banks feed — the pump and the alarms among them — has its return again while the pro is awaited. A bank tied to this one comes back without this battery only with its tie set apart: through a tie, its battery would put this bank's positive, and every lead lifted from it, back at its own voltage, with a path back through its negatives on the boat's metal. On the way back, the order keeps the path open as long as it can: the positive goes on while the negatives are still off, the positive's cover goes back before the first negative, and the last connections made are negatives, last of all the bank's main negative cable: with the battery switch OFF, a wrench that slips from a negative terminal onto the boat's metal can carry no more than the current of a load wired around the switch — and, where a relay ties two banks, the current their difference in voltage pushes from one into the other, or, after a voltage on a reading, the current of a charging source that nobody found — not the battery's short-circuit current. What the order cannot prevent is a short across one battery's own two terminals, or across two batteries joined by a jumper: those are what the entry of the SHORT CIRCUIT sign covers.

A new battery and the batteries it joins are each charged full before they are joined. The last jumper closes the circuit between them: two batteries at different states of charge, joined, push a current from one

> into the other, limited only by their own resistance and the jumper's. The battery goes back in the session it came out — before you leave the boat — because, while it is out, its bank and any bank tied to it stay down with their pump and alarms, and nothing on the boat shows how long that lasts.

Why the card's actions come in this order

The card "Battery smells, is swollen, or is hot" (→ emergency card) puts its actions in an order that follows from what happens inside a battery in trouble. This part takes them in the card's order and gives the reason for each; the actions themselves stand on the card.

First on the card is a lithium battery that hisses, vents or swells fast. A lithium cell that fails inside heats itself, and the cells vent gases that burn and are toxic (→ 1.1). Nothing you can do at the battery cools a cell that heats itself, so the card's protection is distance and a call for help. A lithium battery that is hot or swollen but does not hiss or vent has its own branch on the card; a lithium battery with nothing wrong is in → 11.4.

For any other battery the card first stops the engine before any battery switch is turned: a battery switch turned with the engine running takes the battery away from a running alternator (→ 1.7). Where the switch sits with a gasoline engine or tank, the card's gasoline lines come before the switch, because a switch is a spark in gasoline vapor (→ 1.1).

Then every charging source stops. A lead-acid battery gives off hydrogen and oxygen when it is charged, and the heat of a battery on charge can feed on itself. BCI calls this thermal runaway: on a charge held at a set voltage, a rising temperature lets the battery take more current, and the larger current heats it more, until its electrolyte boils away. One battery maker writes that it happens only with a high temperature around the battery, a charge voltage set too high, or both, and that after the electrolyte has boiled away the temperature can climb until the plastic melts and the battery can catch fire. MFR

That is why the card names every source that can charge the battery: the charger and any inverter/charger; a DC-DC charger, which on one

maker's units keeps charging from the start battery with the engine off when its forced charging is set; the solar panels; a wind generator; and the engine's alternator. A source left out keeps charging. Under way, the engine is the source that is hardest to stop: its alternator's regulator is one of the things that can overcharge a battery, and a boat whose engine stops in a narrow channel is in danger too. The card weighs the two. Shore power comes off in the card's order, until the plug is out of the pedestal and out of the boat's inlet (→ 17.2), so that no charger on the boat can start again. MFR

Then the people leave the battery compartment and any cabin it opens into, and both are aired. Hydrogen burns in air from 4 % to 75 % (→ 1.1), and a small spark lights it; it rises and gathers at the top of a closed space — under a hatch, under a cabin sole, in the cabin above. A rotten-egg smell is hydrogen sulfide: one battery maker writes that hydrogen sulfide from a battery can cause poisoning and death, and sends people to a well-ventilated place away from the vehicle, the equipment or the battery. Under way, the person at the helm stays at it only while the boat needs steering. MFR

Only then does the card turn to the battery switches, with the engine stopped, and first to a switch that joins the banks — at a position printed BOTH, ALL, 1+2 or COMBINE, a parallel switch ON, or a charging relay's own combine control ON: two banks joined let a healthy bank feed a battery that may have a cell shorted inside, at anchor and under way as much as at the dock. A bank that feeds the lights, the radio or what steers and navigates the boat comes next, and at anchor or under way the card leaves it on: losing them is the greater danger. Otherwise, the card turns the gassing bank's own switch OFF: it takes every load wired after it off in one move, so nobody goes back into the aired spaces to switch loads off one by one.

The card makes a switch inside those spaces wait, and not one outside them, because a switch's contacts spark each time they open or close (→ 1.1) and the gas is inside those spaces. A switch marked ignition protected does not change that: the regulation tests ignition protection in a mixture of propane and air, 4.25 to 5.25 percent propane by volume, and hydrogen is not propane. CFR

The wait the card gives is the time two makers give a closed battery compartment to air out before a connection is made or a charger is started in it, for ordinary work; one battery maker writes, for a battery that gives off an odor or vents, to disconnect it only after the area has been ventilated. MFR

The card keeps every hand and every tool off the battery's terminals. Lifting a lug draws a spark right at the terminal, where the gas is; and with every source stopped and the bank's switch OFF, nothing at the battery needs your hand. The card calls for help when the battery smokes, hisses, makes noises, changes shape or keeps getting hotter: then it is failing faster than airing and cooling can follow.

A lead-acid battery that was hot, swelling or gassing waits for a pro, who finds the cause before it is charged again. Makers name several causes: overcharging, high temperature and too little electrolyte (one maker, for a rotten-egg smell); a charge voltage set too high or a high temperature around the battery (a second, for thermal runaway); a blocked valve (a third, for a battery that bulges on charge); a recharge after a severe discharge (a fourth, for swelling). MFR

> **NUMBERS · HOW HOT IS TOO HOT**
>
> Each maker sets its own limits. One maker's flooded industrial line is never charged above 122 °F; one maker of thin-plate AGM batteries does not charge them above 104 °F; another maker's marine AGM and gel line keeps its average cell operating temperature at or below 95 °F, and never above 105 °F for more than eight hours; one AGM maker counts its battery as hot above 130 °F during a recovery charge, and stops the current. MFR The inside of a battery is hard to measure on board; the case is not: a case hot to the touch is a case for the card "Battery smells, is swollen, or is hot" (→ emergency card).

Swollen, or only its shape?

A lead-acid battery's case is not perfectly flat, and makers describe shapes that are normal. One AGM maker: a slight outward bulge of the end walls can appear when the pressure inside is above that of the air but not high enough to open the valve, and it does not affect the

battery's operation. A second maker of sealed batteries: each cell holds about 1.6 psi before its valve vents, so a large battery with large cells bulges somewhat as that normal pressure builds, more when it is warm, because its polypropylene case gives; a sucked-in look is normal too — that maker charges such a battery and ignores a look that stays after the charge, but counts a load test prudent where only one cell has that look, or only one lacks it (→ 3.6). A third maker counts slight impressions of the cell dividers in its case as normal. MFR

What the makers do not count as normal: a battery that bulges severely on a charge, which one maker reads as a blocked valve or an overcharge and takes out of service; and significant deformation, which another maker counts as a battery to replace. So a cool battery with a slight bulge of its end walls, its maker's normal, is no emergency. A battery whose case bulges more, keeps changing shape, is hot or vents is a case for the card, and so is a battery you cannot judge. MFR

A battery whose terminals water in the boat has reached is another case: the card "Water in the boat — the pump can't keep up or is silent" (→ emergency card) and the entry of the HOT BATTERY sign say what happens to it (→ 12.1).

6.6. Checking condition

Is your battery still good, and when is it due for replacement? Three numbers describe its condition, and each takes its own test: how full it is — its resting voltage (→ 3.5) or, in a flooded battery, its specific gravity; whether it can still deliver a heavy current — a load test (→ 3.6); and how much it still holds — its capacity, by a timed discharge. A charged battery can pass the first two and fail the third: a starting current for 15 seconds and a night of house loads are different questions. The makers' criteria in → Table 6.3 · p. 42 judge a battery by its tests and by what you see, not by its years; its date code says how long it has served (→ 6.1 · p. 2).

The load test of → 3.6 answers whether a charged battery can deliver a heavy current now; a test of seconds does not measure how much the

battery holds. Whether it is a test for a deep-cycle battery at all, the battery's maker says. Two makers of deep-cycle batteries write that CCA testers, which judge a battery by its internal resistance, and carbon-pile testers are not suitable testing methods for deep-cycle batteries, and a third that carbon-pile testers, impedance meters, conductance meters and others are not reliable in determining a battery's actual capacity; two other battery makers give their load test with no type of lead-acid battery left out. A deep-cycle battery MFR prints CCA too (→ Table 6.2 · p. 5), so a CCA on its label does not make the load test its test; its maker's manual names the test.

Capacity: the timed discharge

Capacity is measured by a timed discharge. Two battery makers give it this form: the battery fully charged first, every charging source and every load disconnected, a constant 25 A drawn until the battery falls to 10.5 V — 5.25 V for a 6 V battery — and the minutes recorded and compared with the battery's reserve capacity, its rated minutes at 25 A (→ 6.1 · p. 2); two others discharge at the rate the tester is set to and compare the result with the battery's rating at that rate. Minutes MFR are compared with minutes, never with the amp-hours on the label: 25 A is a faster discharge than the 20-hour rate and gets fewer amp-hours out of the battery.

Temperature changes the result, and the makers handle it two ways. One holds the battery at 68 to 86 °F for at least 24 hours before the test. Another corrects the minutes by a formula valid only between 75 and 90 °F: the corrected minutes are the recorded minutes × (1 − 0.005 × (T − 80)), with T the battery's temperature in °F at the end of the discharge. MFR

The pass mark is the maker's share of the rated minutes: 50 % for two makers of flooded deep-cycle batteries; 80 % for one maker of thin-plate AGM batteries; and for one AGM maker, below 80 % its conditioning charge first, below 50 % replacement, a line that maker lets the owner move to the capacity the boat needs. No share fits MFR every battery: read your battery's maker.

WORKED EXAMPLE: A TIMED DISCHARGE READ AGAINST RESERVE CAPACITY

Suppose a flooded deep-cycle battery rated 200 minutes at 25 A and 115 Ah at the 20-hour rate runs 118 minutes at 25 A down to 10.5 V, and ends the test at 86 °F. What decides is its maker's correction and its maker's share. Corrected: 118 × (1 − 0.005 × (86 − 80)) = 118 × 0.97 = 114.5 minutes, and 86 °F lies inside the formula's 75 to 90 °F. Then 114.5 ÷ 200 = 57 % of its rated minutes, above that maker's 50 %: the battery passes by its maker's line. The same run delivered 114.5 × 25 ÷ 60 = 47.7 Ah, a number never compared with the 115 Ah on the label. What the number means: the battery runs a load a little over half as long as its rating says.

The test needs a load that holds 25 A steady for hours while the voltage falls, a record of the end point, and the battery's temperature: a discharge tester, not a load tester. The makers above describe it with such a tester, and a full discharge of a bank aboard leaves everything on that bank — the bilge pump's automatic switch, the high-water alarm and the CO alarm among them — without power at its end. The test is a pro's or a battery shop's, done with a discharge tester; you order it in the words of "What to tell the pro" (→ 6.8 · p. 46) and read the result against your maker's share. From a boat out of the water you can take the battery to the shop yourself: out, and back later, by the planned job on a battery (→ 6.5 · p. 16).

What you see, and the cells of a flooded battery

What you see counts too. Makers list a cracked or broken case or cover, a leaking seal between case and cover, and damaged or leaking terminals; one writes that a battery with visible external damage is not to be used, another that a damaged battery or cable is replaced right away. A swollen case is in → 6.5 · p. 16; a crust on a terminal is PRACTICE cleaned by the planned job on a battery (→ 6.5 · p. 16), and its drop under load judges the connection afterwards (→ 3.4).

In a flooded battery each cell can be read by itself. Specific gravity is the density of a cell's electrolyte compared with water: as a cell discharges, acid leaves the electrolyte for the plates, and the number

falls. A hydrometer draws a sample from the cell and reads it. One maker's table, for a reading corrected to 80 °F: 1.265 full, 1.225 at 75 %, 1.190 at 50 %, 1.155 at 25 % and 1.120 discharged. Three makers correct a reading the same way: add 0.004 for every 10 °F above 80 °F, and subtract 0.004 for every 10 °F below. MFR

The cells are compared with each other, and the makers draw the line in different places. One asks for an equalizing charge when the cells differ by more than 0.015, and reads a cell more than 0.050 off the others as a bad cell; another equalizes above 0.030; a third above 0.025 to 0.030. The third also asks that the readings after a charge stay the same for three hours or more before they count as full. An MFR equalizing charge is a controlled charge at a higher voltage that a battery's maker prescribes to even out its cells; it is done only as the battery's maker says, by its method, with a charger that can give it (→ 9.3). Most AGM and gel makers in → Table 6.1 · p. 3 do not do it; one AGM maker prescribes a conditioning charge at a higher voltage, which a charger's equalize setting may give, by that maker's own method.

Suppose a cell reads 1.240 at 50 °F. 50 °F is three steps of 10 °F below 80 °F, so the corrected reading is 1.240 − 3 × 0.004 = 1.228: in the table above, a little over 75 %.

A flooded battery loses water as hydrogen and oxygen while it charges, and the water has to be replaced. Three makers add it after a full charge; before a charge only where the plates already show above the electrolyte, and then only enough to cover them. One maker asks for a level 1/4 to 1/2 in below the vent tube; another writes that a well filled up to the cap is likely to make the battery overflow acid, and checks a new battery every few weeks to learn how often it needs water.

That gas has a look of its own. While it charges, a flooded PRACTICE battery gives off hydrogen and oxygen, and more on an equalizing charge. Two battery makers describe where normal ends: one writes that flooded batteries gas, or bubble, toward the end of the charge and during equalization; the other reduces or halts a charge when the gassing turns violent, electrolyte spews, or the case feels hot to the touch. Bubbles in the open cells of a cool battery near the end of its

charge, or on an equalizing charge, are that charge at work, and the water they take is what the procedure below puts back. A battery on charge that gasses violently, spews electrolyte, is hot, swells, hisses or smells is past the makers' line: it is a case for the card "Battery smells, is swollen, or is hot" (→ emergency card). PRACTICE

Procedure: The cells of a flooded battery

For a flooded battery whose vent caps come off; a sealed battery is never opened (→ Table 6.1 · p. 3). You need: a hydrometer with a thermometer, or a hydrometer and a thermometer; the water the entry of the BATTERY ACID sign names; a flashlight; clean rags; baking soda and water for a spill; a pencil and the Boat Passport.



1. Wipe the top of the battery clean and dry, and open the vent cap of every cell. Each fill well is open, and no dirt has fallen in.
2. Look into each cell with the flashlight. The electrolyte covers the tops of the plates in every cell: continue with step 4. The tops of the plates show in a cell: step 3.
3. Into each cell whose plates show, add water only until the plates are just covered. The plates are covered in every cell; the rest of the water goes in at step 7, after the charge.
4. Close the caps, charge the battery fully, and let it rest for the time its maker names (→ 3.5). The charger shows the charge complete, and the rest time has passed.
5. Open the caps again. In each cell in turn, read the specific gravity and the temperature as the hydrometer's instructions say, and return the sample to the cell it came from. You have one reading and one temperature for each cell, written down in cell order.
6. Correct each reading to 80 °F and compare the cells, as the text above shows, by your maker's figures; where it gives none, by those of the text: a spread of more than 0.030 (two makers), and a cell more than 0.050 off the rest (one maker). Every cell at the full row of your maker's table — or of the table above, where you have none — and the cells within the spread: the battery is full and its cells are

even. Every cell below the full row, the cells within the spread: the battery did not come up to full charge — check the charger's setting for a flooded battery (→ 9.3) and charge it again; one maker equalizes a battery whose cells read low after a full charge, by its method; still low: → Table 6.3 · p. 42. Cells that differ by more than the spread: an equalizing charge only as the battery's maker says, by its method (→ 9.3), and the readings again after it; with no method from its maker, write the readings into the Boat Passport and read the cells again after the next full charge. Cells still apart after an equalizing charge, or one cell off the rest by more than the line for a bad cell: → Table 6.3 · p. 42. You have written down which of these the cells show.

7. Add water to each cell up to the level the battery's maker gives. Every cell stands at that level.
8. Close every vent cap, wipe the top dry, and, if you added water, charge for 30 minutes more to mix it in, as one maker asks. Every cap is tight.

PUT THE BOAT BACK IN SERVICE

- The charger back to the setting and the state you found it in; every load you switched off for the rest back as you found it; a battery box's lid or a terminal cover you lifted back on; the hydrometer rinsed with clean water and stored.

Procedure: A battery on a portable charger

For a lead-acid battery out of the boat — taken out by the planned job on a battery, for example for the load test of one battery of a bank (→ 3.6), and put back in by that job the same session, before you leave the boat, or — from a boat out of the water — later, by that job from its first step, before the boat goes back in the water (→ 6.5 · p. 16) — or one in the boat where the charger's own manual allows charging aboard and the battery is not in a compartment with a gasoline engine or tank: two makers of portable chargers ask that a marine battery be removed and charged on shore, and charged aboard only with equipment made for marine use. The charger is one its maker allows for the battery's type

and that stops by itself at the end of the charge: a charger with a setting for flooded, AGM or gel batteries is set to the battery's type, and one battery maker requires a voltage-limited charger for its gel and AGM batteries. A charger with no setting for the battery's type, or one that does not stop by itself, is not the charger for this procedure. A battery that may have frozen is first judged as "Charge lost on its own, and a battery that froze" below says. MFR

 BATTERY ACID  SHORT CIRCUIT  HOT BATTERY

1. A battery out of the boat: carry it to a flat, dry place that a spill does not damage, away from the boat, and set it there upright. A battery in the boat stays in its place, as the charger's manual says for charging aboard. Check the charger's setting for the battery's type and voltage. The charger's setting and the label agree.
2. With the charger switched off and its plug out of the outlet, put its red clamp on the battery's positive terminal and its black clamp on the negative terminal. Each clamp bites clean metal, the red one on the terminal marked +.
3. Put the charger's plug into the outlet and switch the charger on to charge the battery. Its light or display shows that it charges.
4. From time to time, look at the battery and touch its case with the back of your hand. Cool or warm, no smell, no hiss, no change of shape: let it charge. Hot to the touch, a smell of gas or of rotten eggs, a hiss or a swelling case: the card "Battery smells, is swollen, or is hot" (→ emergency card).
5. When the charger shows the charge complete and has stopped by itself, switch it off and pull its plug out of the outlet; then take off the black clamp, then the red one. Both clamps are off and apart.
6. A battery out of the boat: carry it back aboard, and put it back in by the planned job on a battery that took it out (→ 6.5 · p. 16), before you leave the boat — from a boat out of the water, later, by that job from its first step, before the boat goes back in the water; a battery that cannot go back in by then is in step 15 of that job. A battery charged in the boat stays in its place. The battery stands in its place — one that came out, with that job's restore done.

7. Let the battery rest, and read it in its place by the procedure "A battery's resting voltage" (→ 3.5). It reads its maker's 100 % row; a battery that does not is in → 3.5 and in the route below.

> **PUT THE BOAT BACK IN SERVICE**
>
> - The charger stored with its clamps apart.

Charge lost on its own, and a battery that froze

A battery left alone loses charge by itself. One maker gives its flooded batteries 10 to 12 % a month at 77 °F and its AGM batteries 2 %; another gives its AGM batteries 1 to 3 % a month; two makers write that each rise of 18 °F halves the time a battery keeps its charge. A battery found flat after a layup has lost its charge this way, or to a load that stayed connected (→ 7.3), or it no longer holds a charge (the route below). The layup itself is in → 19.2. MFR

Charge also keeps a battery from freezing. One maker's table: its electrolyte freezes at −75 °F in a full battery, at −34 °F at half charge and at −10 °F in a discharged battery. A second maker writes that a battery can freeze only when it is left partly or fully discharged, and that freezing damages its plates and its container for good; a third, that a battery that is frozen or has been frozen is not to be used. PRACTICE

 **HOT BATTERY** A battery that may have frozen is looked at first: one maker writes that a battery whose container shows any evidence of cracking is no longer serviceable and is not to be used. Makers differ on one whose case is whole: one charges it once it has thawed, another does not use a battery that is frozen or has been frozen. Whether it is used again, and how it goes on charge, the entry of this sign says, by its own maker's manual. PRACTICE

Table 6.3. What makers do with a battery, by what you find MFR

What you find	What the maker does
The battery fails its maker's load test, is recharged, and fails it again (→ 3.6)	Replaces it (two makers)
It does not come up to full charge	Replaces it (one maker)
A timed discharge below the maker's share of its rated minutes	Counts it acceptable above 50 % (two makers of flooded deep-cycle batteries), and replaces it below (one of them); counts it failed below 80 % (one maker of thin-plate AGM batteries); conditions it below 80 % and replaces it below 50 % (one AGM maker)
One cell's specific gravity more than 0.050 off the others, or cells still apart after an equalizing charge	Reads it as a bad cell (one maker), or as a battery that may have failed (two makers); the test its type takes decides (step 4 of the route below)
A cracked case or cover, a leaking seal, a damaged terminal	Replaces it right away (one maker); does not use a battery with visible damage (another)
A severe bulge on charge, or significant deformation (→ 6.5 · p. 16)	Takes it out of service (one maker); replaces it (another). On board: the card "Battery smells, is swollen, or is hot" (→ emergency card), and a pro takes it out (→ 6.8 · p. 46)
The battery is frozen or has been frozen	Does not use it (one maker); does not use it if its container shows any cracking (another)
One battery of a bank fails	Replaces the whole set unless it is less than 12 months old (one maker)

LOOKS LIKE THE FIX	FIND OUT FIRST	WHAT FIXES IT
A new battery, because the old one goes flat.	Its resting voltage after a full charge and its maker's rest (→ 3.5); the test its maker names — a load test where it gives one (→ 3.6), and for the capacity of a	What the checks point to: a battery that fails its own maker's test; a charge that never reaches full; a load that discharges the battery; or a second

	deep-cycle battery a timed discharge; whether one battery does two jobs (→ 6.3 · p. 9); whether the charger is set for its type (→ 9.3) and the engine's charging output reaches it (→ 9.1, → 9.2); what the boat draws with everything off (→ 7.3).	battery for the second job. A new battery on a boat with one of the other three goes flat like the old one.

Route: the battery seems weak, or goes flat

WHAT CHANGED BEFORE THE PROBLEM?

- after you installed or changed a device → what it draws with everything off: step 3
- after charging → whether the charge reached this battery, and the charger's setting for its type: step 1
- after rain or washing the boat → the terminals and the case, by the walk-around check of → 6.5 · p. 16; then step 1
- after the boat sat unused → the charge it lost by itself: step 1
- still low after a run with the engine → whether the engine's charging output reaches it: step 3
- after switching sources (shore power, generator, inverter) → which bank the charger reaches now (→ 8.1): step 1
- nothing you noticed → step 1

ROUTE: THE BATTERY SEEMS WEAK, OR GOES FLAT

1. Its resting voltage after a full charge, by the procedure "A battery's resting voltage" (→ 3.5).
   You will see: A reading taken before its maker's rest says nothing yet (→ 6.2 · p. 7). At or above its maker's 100 % row: step 2. Below it after a full charge and its rest: the battery does not hold its charge, or the charge stopped short —

write the reading into the Boat Passport and continue with step 2. A charger that will not start on it, or will not bring it up: the charger's setting (→ 9.3) and the battery maker's manual.

2. Its type and its job: its label (→ 6.1 · p. 2) and what it feeds (→ 6.3 · p. 9).
   You will see: A battery built for starting that also carries the house loads: the job wears it out, and a deep-cycle battery for the loads is part of the fix whatever step 3 shows. Otherwise: step 3.

3. What takes its charge, and what puts it back.
   You will see: What the boat draws with everything off, by the route of → 7.3; whether the charge reaches it — the charger (→ 9.3), the engine's charging output (→ 9.1, → 9.2) and the sources that charge together (→ 9.4). A draw that stays on, or a charge that does not reach the battery: its fix first, then step 1 again. Neither: step 4.

4. The test its type takes.
   You will see: A starting or dual-purpose lead-acid battery: the procedure "A load test of one lead-acid battery" (→ 3.6). A deep-cycle battery: the test its maker's manual names — that maker's load test, where it gives one; for its capacity, a timed discharge ordered from a pro (→ 6.6 · p. 34); a flooded one also by the procedure "The cells of a flooded battery" in this section. A lithium battery: its maker's manual (→ 11.4). Fails its maker's test: → Table 6.3 · p. 42. Passes: step 5.

5. Write the readings, the test and its date into the Boat Passport (field 4).
   You will see: The record a pro needs, and your baseline for next season.

PUT THE BOAT BACK IN SERVICE

- The procedures of steps 1 and 4 end with their own restore blocks.

6.7. Marine-grade or not? A car battery on a boat

A car battery costs less and is sold everywhere. May it be used on your boat? No rule against an automotive battery on a boat stands in 33 CFR 183.420, in ABYC's E-11 of 2003 or E-9 of 1990, in the opening sections of

ABYC's E-10 of 2006 (through 10.5), or in a parts maker's summary of E-10's text dated 12/96. What they ask concerns the battery's numbers and its installation: a cranking rating at least the engine maker's, a battery that stays put, a positive terminal that metal cannot reach, and no connector held by a spring (→ 6.1 · p. 2, → 6.5 · p. 16). ABYC

E-10 of 2006 also asks makers and suppliers of batteries for marine use to meet the construction and performance specifications of BCI's Battery Technical Manual: it asks this of the battery's maker, not of the boat's owner, and the verdicts below rest on the battery's numbers and its installation. What that manual asks of a battery, and what E-10 says after its opening sections, in that edition or a later one, is not in the texts above. VERIFY

MARINE-GRADE OR NOT? · A CAR BATTERY AS THE START BATTERY

A car battery as the start battery. It is built for starting, and it can start a boat's engine when its label meets the engine maker's cranking number in the same rating (→ 6.1 · p. 2) and it is installed as → 6.5 · p. 16 asks. One battery maker writes that car batteries most often come with SAE posts, made for clamps: a clamp tightened by a bolt holds without a spring, and a spring clip is what the regulation bans (→ 6.5 · p. 16). Another maker's marine FAQ writes that vibration or jolting can lead to electrical shorts or a loss of storage capacity; the first maker writes that the fine print of many car-battery warranties excludes use in a boat. PRACTICE

Verdict: Starting only, if its numbers match

MARINE-GRADE OR NOT? · A CAR BATTERY FOR THE HOUSE LOADS

A car battery for the house loads. Its plates are built for short, heavy currents, and three makers write that a battery built for starting does not survive repeated deep discharge (→ 6.3 · p. 9). Discharged by the house loads night after night, it wears out early, and a battery the loads have discharged cannot start the engine. PRACTICE

Verdict: Not for the house bank

MARINE-GRADE OR NOT? · "MARINE" ON THE LABEL

"Marine" on the label. The word is not a type. One maker's marine line holds batteries built for starting and for deep cycle service, flooded, AGM and gel (→ Table 6.2 · p. 5). The type, the ratings and the date code on the label decide, on a marine battery as on a car battery. MFR

Verdict: Read the type, not the word

MARINE-GRADE OR NOT? · A NEW BATTERY OFF THE SHELF

A new battery off the shelf. A battery loses charge by itself while it waits to be sold (→ 6.6 · p. 34), and its date code tells you how long it has waited (→ 6.1 · p. 2). One battery maker asks that a battery always be tested and charged if necessary before installation. A battery that joins a bank is charged full before it is joined, and so are the batteries it joins (→ 6.5 · p. 16). PRACTICE

Verdict: Charge it before it goes in

6.8. On board

Your batteries tell you what they are on their labels and how they are on your meter, and the installation shows by eye whether they are secured. This section turns what you see into a first check, says which battery jobs are yours, gives you the words for a pro, and says what changes on someone else's boat.

ON BOARD: GOLDEN RULE

Judge a battery by its own maker's numbers: its label for what it was built to do, its resting voltage after its maker's rest for how full it is, and the test its maker names for what it still holds. Keep it still, keep metal off its positive terminal, and let its gas out.

What it means

Each first check below names the procedure or route that carries it out; the signs at the start of that procedure go with it.

Table 6.4. What it means

What you notice	What is happening	First check	Yourself or a pro
The voltmeter reads about 13 V or more right after the engine or the charger stops	Surface charge, or a charger or a controller still connected; one maker's full AGM reads about 13.0–13.2 V	The resting voltage after the maker's rest, with nothing charging and nothing drawing (→ 3.5, → 6.2 · p. 7)	**Do it yourself, if… you can do that procedure, with its signs**
The battery reads below its maker's 100 % row at rest	It needs a charge, or it no longer takes a full charge	A full charge with a charger set for its type, its rest, and the reading again (→ 3.5)	**Do it yourself, if… you can do that procedure, with its signs**
A new battery goes flat within weeks	One battery doing two jobs; a charger set for another type; a load that stays on; a charge that never reaches full	The route "The battery seems weak, or goes flat" (→ 6.6 · p. 34)	**Do it yourself, if… you can do its procedures, with their signs**
The engine cranks slowly or only clicks	A discharged or worn start battery, or volts lost in the starter circuit	The route "the engine cranks slowly or only clicks" (→ 3.8)	**Do it yourself, if… you can do its procedures, with their signs**
A battery smells of gas or of rotten eggs, is hot, hisses, or its case swells	Overcharging, high heat, too little electrolyte, a blocked valve or a recharge after a severe discharge: makers name several causes	The card "Battery smells, is swollen, or is hot" (→ emergency card); why its order: → 6.5 · p. 16	**STOP**

What you notice	What is happening	First check	Yourself or a pro
The end walls of a cool AGM battery bulge slightly	For one maker, the normal pressure inside a sealed battery	Its maker's description of normal (→ 6.5 · p. 16)	**Do it yourself: the look**
A white or green crust on a battery terminal	Corrosion; the connection may heat under load already, or not yet	The drop across the connection under load (→ 3.4)	**Do it yourself, if... by the planned job on a battery, with its signs (→ 6.5 · p. 16)**
The battery shifts when you push it, or its strap is loose or missing	A hold-down that does not hold	The walk-around check of the installation (→ 6.5 · p. 16)	**Do it yourself, if... the strap is fastened without moving the battery; a battery to be moved, by the planned job on a battery (→ 6.5 · p. 16)**
Bare metal on the positive terminal, or on the lug or the nut on it, with no boot, box lid or battery-only compartment over it	Nothing keeps metal off a terminal that is live all the time	Write it on the first line of the Boat Passport (→ 2.3)	**Do it yourself, if...** ⚠ **SHORT CIRCUIT the cover snaps or hinges shut over the terminal by hand; a boot that goes on with the positive lead, by the planned job on a battery (→ 6.5 · p. 16)**
A spring clip on a battery terminal	A connection held only by a spring	The Boat Passport, first line (→ 6.5 · p. 16)	**Hire a pro: a new lug on the cable (→ 1.8)**
The plates show in a cell of a flooded battery	Water lost on charge and not yet replaced	The procedure "The cells of a flooded battery" (→ 6.6 · p. 34)	**Do it yourself, if... you can do that procedure, with its signs**
One cell's specific gravity stands apart from the others	Cells that need an equalizing charge, or a bad cell	The procedure "The cells of a flooded battery" (→ 6.6 · p. 34); your maker's lines (→ Table 6.3 · p. 42)	**Do it yourself, if... you can do that procedure, with its signs: the hydrometer readings, and an equalizing charge only as the battery's maker says, with a charger that can give it (→ 9.3)**

What you notice	What is happening	First check	Yourself or a pro
Both bank cables leave from one battery of a parallel bank	The battery nearest the take-off works hardest	→ Fig. 6.2 · p. 13; the Boat Passport (field 4)	**Hire a pro: a bank cable moved to another battery (→ 1.8)**
Batteries of different ages or sizes in one bank	The weaker battery is overcharged and over-discharged	Their labels and date codes (→ 6.1 · p. 2, → 6.4 · p. 11)	**Do it yourself, if… the set is replaced by the planned job on a battery (→ 6.5 · p. 16)**
A car battery in the boat	A battery built for starting	Its cranking rating against the engine maker's, and its job (→ 6.7 · p. 44)	**Do it yourself: reading its label**

ON SOMEONE ELSE'S BOAT

1. **Find:** the batteries and their labels, and which bank each position of the battery switch connects; the boat's papers or the base can tell you.
2. **Check:** the battery switch positions and the panel's voltmeter or the battery monitor; and by eye only, a battery that moves, a bare positive terminal, a crust on a terminal, a case that bulges.
3. **Don't touch:** the terminals, the cables, the vent caps and the charger's settings. A meter and a wrench are tools.
4. **What to tell the base or the owner:** what the panel's voltmeter or the monitor read, and when; what you saw at the batteries, and where.

On someone else's boat there are three levels, not four: switches and buttons — yes; tools — no; the gray zone — only with the permission of the charter base or the owner, by phone (→ 2.6).

Do it yourself or hire a pro

DO IT YOURSELF OR HIRE A PRO · BATTERIES

STOP ·  **HOT BATTERY** A battery that smells of gas or of rotten eggs, is hot, hisses, or whose case swells: its gas can explode, and a lithium cell that fails heats itself. A battery whose terminals water in the boat has reached.

What to do this minute: The card "Battery smells, is swollen, or is hot" (→ emergency card); water at the terminals: the card "Water in the boat — the pump can't keep up or is silent" (→ emergency card).

HIRE A PRO · A battery whose positive terminal carries a fuse bolted to it (an MRBF); a battery cable replaced, a new lug crimped, or a bank cable moved to another battery; a lithium battery's terminals (→ 11.4); a battery of a bank in series, or of a bank tied to one on the positive side, taken out or put in, or its terminals cleaned or tightened (→ 6.4 · p. 11, → 6.5 · p. 16); protection between the batteries of a bank, and a bank's main protection after it blew (→ 4.2); the cause of a battery that ran hot, swelled or gassed; a timed discharge of a deep-cycle battery; and a planned job on a battery that stops at a voltage on one of its readings, or, on a boat in the water, with a battery out that cannot go back in during that session. Order the work in the words of "What to tell the pro" below, and accept it by the checks there.

If no pro is available:  **SHORT CIRCUIT** Work at a battery terminal that cannot wait: the entry of the SHORT CIRCUIT sign gives the one way without a pro. A battery that ran hot, swelled or gassed stays as the card left it. The timed discharge waits; meanwhile the battery's resting voltage (→ 3.5) and, on a flooded battery, its cells (→ 6.6 · p. 34) are yours.

When a pro may do it differently: A pro may test a battery's capacity with a discharge tester at another current or by the battery maker's own procedure, or judge it with a tester its maker accepts: you see it in the instrument named and the numbers in the pro's report. A pro may add protection between the batteries of a bank where its maker asks for it: you see it in the Boat Passport.

DO IT YOURSELF, IF…

-  **SHORT CIRCUIT**  **GASOLINE VAPOR**  **METER LEADS**  **BATTERY ACID**  **HOT BATTERY**  **BILGE PUMP**  **CARBON MONOXIDE** The planned job on a 12 V lead-acid battery, on its own or in a bank joined in parallel, whose bank is tied to no bank in series: taking it out and putting it or a new one back in, both in one session, or — on a boat out of the water — later, by the same job from its first step, before the boat goes back in the water; cleaning or tightening its terminals (→ 6.5 · p. 16).
- The procedures “The cells of a flooded battery” and “A battery on a portable charger” (→ 6.6 · p. 34), “A battery’s resting voltage” (→ 3.5) and “A load test of one lead-acid battery” (→ 3.6), and the two walk-around checks (→ 6.4 · p. 11, → 6.5 · p. 16), each with the signs at its start.

DO IT YOURSELF · Read a label and a date code; compare a battery’s ratings with the engine maker’s number; follow a bank’s jumpers by eye; fill in field 4 of the Boat Passport.

What to tell the pro

WHAT TO TELL THE PRO

For the capacity of a deep-cycle battery, ask for this: “A capacity test of this battery: fully charged and rested as its maker asks, a constant 25 A discharge to 10.5 V — 5.25 V for a 6 V battery — with the minutes recorded and the battery’s temperature at the end, corrected as the battery maker’s manual says and compared with this model’s reserve capacity at 25 A.” For a battery that ran hot, swelled or gassed: “Find why this battery ran hot before anything charges it again: the charger’s setting for its type and its output voltage at the battery’s terminals, the alternator’s charging voltage, the temperature around the battery, and the battery itself.” For a battery with a fuse on its post: “Replace this battery and put the terminal fuse back on its positive post as the fuse maker shows, with its cover.” Accept the work by three checks. The minutes, the temperature and the maker’s share are written down, and the result is read against that share. Each voltage the pro measured is written down beside the battery maker’s charge voltage for its type. The

torque the pro used on each nut is the one on the battery's label or data sheet, the positive terminal is covered, and the Boat Passport (field 4) is updated the same day.

REMEMBER

- A label gives ratings of a new, fully charged battery: CCA at 0 °F, MCA at 32 °F, RC in minutes at 25 A, and Ah at the rate printed beside them.
- A start battery meets its engine maker's cranking number in the same rating: CCA with CCA, MCA with MCA.
- A battery's voltage says how full it is only at rest, after its maker's rest, by its maker's table.
- A battery built for starting does not survive repeated deep discharge; one battery that does both jobs does both badly.
- The batteries of one bank are matched in type, size and age, and the bank's cables leave from opposite ends or from bus bars.
- A deep-cycle battery's capacity is read by a timed discharge against its rating at the same current — for two makers, minutes at 25 A against its reserve capacity — never against its amp-hours at another rate, and its maker's share decides.
- A slight bulge of a cool AGM's end walls can be its maker's normal (→ 6.5 · p. 16).

Self-check

1. **Before you measure.** Suppose your flooded battery reads 12.95 V twenty minutes after the charger stopped, with nothing connected to it. Will it read more, less or the same tomorrow morning, after its maker's rest?

   Answer: less: the reading right after a charge is raised by the charge itself, and it settles with rest; only the reading after the rest is compared with the maker's table (→ 6.2 · p. 7).

2. **Two ratings.** Suppose your engine's manual asks for 600 CCA, and the battery you are offered is labeled 750 MCA, with no CCA. Does it meet the number?

   Answer: the label cannot tell you. MCA is measured at 32 °F and CCA at 0 °F, and on one maker's batteries the MCA is from 1.22 to 1.55 times the CCA: 750 MCA can be from about 480 to about 615 CCA. Ask for the battery's CCA (→ 6.1 · p. 2).

3. **A capacity test.** Suppose a deep-cycle battery rated 160 minutes at 25 A runs 100 minutes in a timed discharge, corrected for temperature. Does it pass for a maker whose line is 50 %, and for one whose line is 80 %?

   Answer: 100 ÷ 160 = 62.5 %: it passes the first maker's line and fails the second's. The line is its own maker's (→ 6.6 · p. 34).

4. **A bank.** Suppose two 12 V batteries of 100 Ah each are joined in series. What are the bank's voltage, its amp-hours and its watt-hours?

   Answer: 24 V, 100 Ah and 2,400 Wh — the same energy as the two joined in parallel, 12 V and 200 Ah (→ 6.4 · p. 11).

5. **A cell.** A cell of a flooded battery reads 1.205 at 60 °F. What is its corrected reading, and about how full is it by the maker's table of → 6.6 · p. 34?

   Answer: 60 °F is two steps of 10 °F below 80 °F: 1.205 − 2 × 0.004 = 1.197, a little over half full by that table (1.190 is 50 %).

6. **On your boat.** Read the label of each battery and write into the Boat Passport (field 4): its type, its voltage, its CCA or MCA, its RC, its Ah at the rate printed, its group and its date code.

   Answer: a start battery whose cranking rating is below the number in your engine's manual, in the same rating, is smaller than the engine maker asks for (→ 6.1 · p. 2); a battery with CCA and no Ah is, on one maker's line, a battery built for starting (→ Table 6.2 · p. 5).

7. **On your boat.** Do the walk-around check of → 6.4 · p. 11 and the one of → 6.5 · p. 16, and write down how your batteries are joined, which battery each bank cable leaves, and how each positive terminal is covered.

   Answer: a parallel bank with both cables on one battery works that battery

hardest (→ Fig. 6.2 · p. 13); a positive terminal that metal can reach is written on the first line of the Boat Passport (→ 6.5 · p. 16).

Terms

flooded lead-acid
A lead-acid battery whose plates stand in free liquid electrolyte, with vent caps over its cells.

AGM
A lead-acid battery whose electrolyte is held in mats of glass fiber between its plates; a VRLA battery.

gel
A lead-acid battery whose electrolyte is thickened into a gel with silica; a VRLA battery.

VRLA (valve-regulated lead-acid)
A sealed lead-acid battery whose gas can escape only through a one-way valve: AGM and gel batteries.

cold cranking amps (CCA)
The current in amps that a new, fully charged battery at 0 °F can deliver for 30 seconds while its voltage stays at 1.2 V per cell or higher — 7.2 V for a 12 V battery.

marine cranking amps (MCA)
The current in amps that a new, fully charged battery at 32 °F can deliver for 30 seconds while its voltage stays at 1.2 V per cell or higher.

reserve capacity (RC)
The minutes a new, fully charged 12 V battery at 80 °F can carry 25 A before its voltage falls to 10.5 V.

20-hour rate (Ah rating)
The amp-hours a battery delivers in a discharge that lasts 20 hours; a faster discharge delivers fewer.

group size
BCI's number for a battery's case size and terminal layout, such as group 24 or 27; it does not tell the battery's capacity.

date code
The maker's coded date of manufacture on the battery; each maker has its own key.

resting voltage (battery)
A battery's voltage after it has rested with no charge and no load for the time its maker names.

surface charge
The extra voltage a lead-acid battery shows just after charging, which goes away as it rests.

start battery
The battery that starts the engine: a role, whatever the battery's build.

deep-cycle battery
A lead-acid battery with thicker plates, built for repeated deep discharge.

dual-purpose battery
A lead-acid battery built as a compromise between a battery built for starting and a deep-cycle battery, for starting and light to moderate cycling.

battery bank
Two or more batteries joined in series for a higher voltage, or in parallel for more capacity, that work as one.

battery jumper
A short cable that joins two batteries of one bank.

series / parallel
Batteries joined positive to negative, so that their voltages add; or positive to positive and negative to negative, so that their capacities add.

battery balancer
A device that evens out small differences of charge between the batteries of a series bank.

positive terminal cover (boot)
An insulating cover over a battery's positive terminal and the lug on it, so that metal cannot touch them.

hold-down
A strap or a clamp that keeps a battery from moving.

thermal runaway
In a lead-acid battery on charge, a rise in temperature that makes the battery take more current, which heats it further, until the electrolyte boils away.

specific gravity
The density of a flooded cell's electrolyte compared with water, read with a hydrometer and corrected to 80 °F; it shows the cell's state of charge.

hydrometer
The instrument that reads the specific gravity of the electrolyte drawn from a flooded cell.

equalizing charge
A controlled charge at a higher voltage that a battery's maker prescribes to even out its cells; done only as that maker says.

self-discharge
The charge a battery loses by itself with nothing connected; it grows with temperature.

timed discharge (capacity test)
A constant 25 A discharge of a fully charged battery to 10.5 V, its minutes compared with the battery's reserve capacity.

load test
A test that loads a charged lead-acid battery at half its CCA for 15 seconds and reads the voltage at the end, with the load on.

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