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Practical maintenance advice for owners and pilots

Shop Work Basics

Battery Basics

The AGM or sealed battery is now the most popular. They have lots of appeal, but do need more precise charging.

By LPM Staff

Aircraft starting batteries have a tough life; much more so than their automotive counterparts. They are left idle for days or even weeks at a time, then asked to start a 500 cubic-inch engine in cold weather with three gallons of oil (e.g. IO-520) the consistency of molasses in the sump. To make matters worse, aviation batteries are typically about one-third the capacity of an auto battery.

To a limited degree we can mitigate the demands on a starting battery by using multi-grade oils, but this is only a small help. The real issues in general aviation are marginal battery capacity for the ever increasing electrical demands, relatively primitive aircraft charging systems not entirely suitable for modern batteries, and long periods of sitting idle due to the extraordinary costs of flying.

THE BASICS

First, let's look at volts and amps, two often-confused terms. We will use the common (but imperfect) water analogy.

The rate of flow through a pipe (amps) is governed by two things: the pressure (voltage) and the size of the pipe (wire diameter). A third factor also has influence— pipe length. The longer the pipe the more resistance (ohms) and pressure (voltage) drop.

Increasing pressure or pipe size

increases the potential flow. More flow, more work. Greater pressure or voltage allows delivery of more fluid (amps) in a given diameter pipe (wire).

Excessive pressure and flow can cause a pipe too small for the

equal the same power, given the wire size is appropriate for the application. That's why lighter wiring works in 24 volt systems—more pressure for any given application, lowering the amps required.

Unfortunately, the 24-volt system has a number of basic shortcomings, such as much higher costs for batteries and components, as well as shorter lives based on our experience and feedback by hundreds of reader questionnaires.

BATTERY TYPES—SEALED AND THE WET CELL

We will expand on terms as the article progresses, but a *wet cell* battery is the term we typically use for a battery in which you periodically remove the caps to visually check the electrolyte level and occasionally add distilled water. Another term for a wet cell battery is a “flooded” battery since the electrolyte “floods” the plates.

A second type of battery, which has become very popular, and now far outsells wet cell batteries in general aviation, is the sealed battery (at least outsells in the Concorde brand by nine to one). There are a few versions of sealed batteries, but the one of primary concern to us is the AGM type sealed battery. The AGM battery is also called a VRLA or valve regulated lead acid type battery.

The chemical actions are the same as for the wet cell battery, but improved design and internal structure as well as a positive internal pressure maintained by a valve significantly



BatteryMINDER Model 12248-AA-S2* Aviation specific charger from VDC Electronics - the only way to go for AGM batteries.

application to burst or a wire to overheat and melt. Thus, there must be a balance of pipe (wire) size for a given flow (amps) and length combination.

That's why starting batteries need such large wires leading to the starting motor. There are hundreds of amps required at 12 or even 24 volts to deliver the large quantity of amps to spin the starter. The product of volts times amps equals watts, or, power in a properly sized circuit for DC electricity. (Note that motor circuits have other considerations.)

You can have more volts and fewer amps or fewer amps and more volts to

improve the AGM performance over a wet cell battery.

The term AGM means absorbed glass mat, referring to internal construction. The caps are sealed on this battery—no water can be added. Forcing open a cap will ruin an AGM battery, as the contents are actually under a slight pressure. If you broke open an AGM battery you would not find any liquid electrolyte, only a moist paste, sometimes also called a starved electrolyte design. The *gel cell* battery is another type of sealed battery, but seldom found in GA applications, as neither Concorde nor Gill sells such a type for general aviation.

Yet another type of sealed battery is the *nicad*, and they have been around for many years, but are generally only found in biz jets and turbo props since they are capable of extreme current drains for starting. We will not be discussing nicads.

IDLE HANDS

When left idle, flooded batteries self-discharge internally about one percent or so a day due to the side effects of internal components (antimony) used to keep battery grid structures from shedding and damage during use. This self-discharge process has a long-term deleterious effect on the battery if not corrected by frequent and prompt recharging.

The term is *sulfation*, and when left unchecked it means the gradual self destruction of the battery. Recharging and the replacement of lost electrolyte, a natural process in wet cell batteries, staves off permanent sulfation. AGM batteries are more resistant to sulfation, but to stave off sulfation they still need to be periodically recharged and never left in a deeply discharged state—even overnight.

When a battery is allowed to remain in a state of sulfation, either from lack of use or from lack of recharge or long-term incomplete recharge, it tends to lose both capacity and life. Repeated deep discharge of starting batteries also dramatically shortens their life.

Initially reversible, sulfation hardens with time and becomes less

and less reversible. As sulfation flakes off and falls to the base of the case, it can also short out the cells. Some battery chargers allege they can reverse sulfation, but very few can actually do this in our testing, except at the very earliest stages of sulfation. It is virtually impossible to reverse a badly sulfated battery to be suitable for aircraft use.

BASIC DESIGNS

Starting batteries have many thin plates (deep cycle batteries have thicker, more rugged plates) with fiberglass separators to provide the maximum active surface area for the greatest burst of current. It's also why a short rest (20 minutes is better) may allow an apparently dead battery to spontaneously recover a bit, sometimes for one last shot to start.

What is happening during the rest period is the remaining unsulfated lead is being contacted by the electrolyte through diffusion. Wet cell batteries are the least efficient when you demand maximum discharge currents.

When a wet cell battery is charged, and especially when excess voltage is applied, some of the water in the electrolyte is converted to gaseous hydrogen and oxygen and vents out. As this condition continues electrolyte is lost to the atmosphere, thus the normal requirement to replenish the water in the cells, preferably with distilled water. Proper charging voltages minimize the electrolyte loss.

Aircraft caps also have internal stoppers to help prevent loss of electrolyte in unusual attitudes. But battery surfaces and boxes still manage to become coated with gaseous forms of electrolyte over time, and cause several problems.

Alternatively, an AGM battery does not normally vent to the atmosphere because there is a positive internal case pressure. If subjected to excess charging voltage an AGM battery will vent through its valve, but this chemical loss cannot be recovered and results in capacity loss.

CAPACITIES

Being chemical beasts, the ability to supply current is not linear. The greater the draw in amps, the less efficient the

typical wet cell battery. Therefore, a battery that has a 25 amp-hour rating of 60 minutes will not sustain a 50 amp load for 30 minutes, but substantially less time due to the inefficiencies of the plates, internal resistance and chemistry.

A battery has an internal resistance of fractions of an ohm, but it's meaningful. The greater the amp drain per unit of time, the more energy is lost as internal battery heat due to that small resistance.

Bottom line, the discharge curve is very sharply sloped rather than linear, and every battery has an optimal maximum rate for current draw. (Note that AGM batteries do have a more efficient discharge curve than wet cells due to lower internal resistance.)

The concept of load shedding is important for pilots to understand because in an "alternator-out" situation, you will get much more than double the battery drain time if you can cut the current drain on the battery in half when running electronics.

CAPACITY TESTING

Aircraft batteries should be capacity tested with the proper equipment at each annual inspection. Testing is supposed to be a requirement for part 23 certified aircraft, but it is often ignored due to a lack of proper equipment by the shop. It's a bad idea to skip capacity tests, no matter what the certification source of your plane—CAR or FAR.

Many batteries are woefully inadequate to provide meaningful backup power in case of a lost alternator because people are skipping this important test.

RECHARGING

Once you've discharged a storage battery, promptly recharge it. You reverse the chemical action that produced the electricity. This converts the lead sulfate and water back to lead, lead dioxide and sulfuric acid.

As a rule of thumb, you have to supply about 120 percent of the electrical energy you've taken from the battery to recharge it. It should be supplied in a controlled manner

specific to the battery if you are to achieve maximum battery life.

If you try to charge a wet cell battery faster than it can accept a charge, some of the electrical energy goes to producing additional lead dioxide that will flake off and fall uselessly to the bottom of the cell and accelerate aging. Some will also break down the water portion of the sulfuric acid electrolyte into gaseous hydrogen and oxygen and vent out the caps.

Flooded batteries are more susceptible to damage from excess current during charging. Anything over 10 amps from a charger is way too much for a 12 volt flooded aircraft battery—four amps is about right. On the other hand, sealed batteries

are less susceptible to damage from a high charge current, but they are very susceptible to permanent damage from excess voltage e.g. anything over 14.6 (29.2) volts is pushing your luck.

That's why the battery makers recommend against AGMs for electrical systems that are not well regulated and capable of producing at least 35 amps. The AGM might overheat your generator with its high acceptance current and low internal resistance.

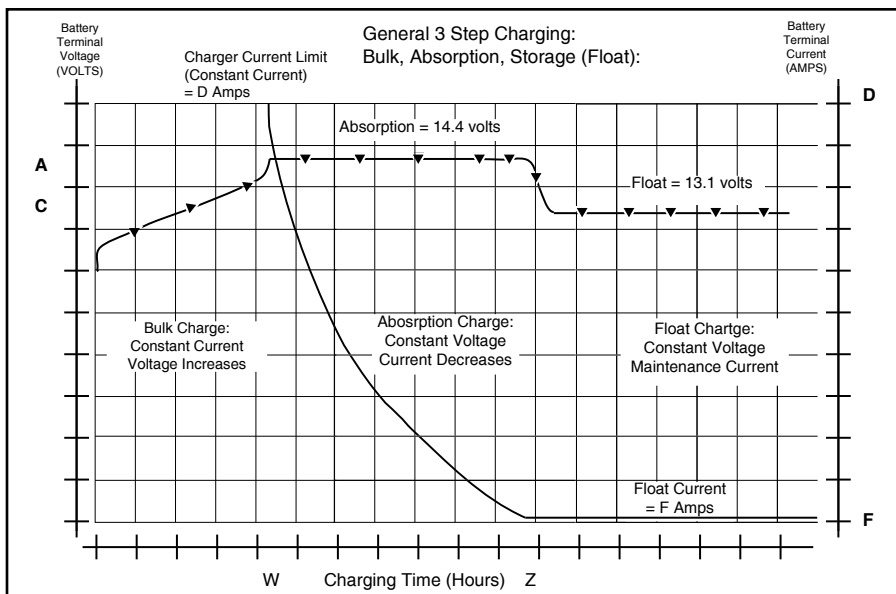
IDEAL MULTI-STAGE CHARGING

One of the best ways to charge a battery is with a computer chip controlled charger. Typically, a quality charger will start at a constant current rate in amps equal to 20-40 percent of the battery's capacity in amp-hours (Ah) until the battery reaches an optimal voltage for its type.

The level of charge at this point is equivalent to about 75 percent of the battery's capacity. This first phase of charging is called bulk charging.

Once the bulk charging is complete, the charger should shift programs and maintain the charging voltage at a constant value and allow the charging rate in amps to drop steadily.

When the battery accepts current at only about one percent of its capacity, (a 35 Ah battery accepting 0.35 amps, for example) it can be considered fully charged. A current of five percent of battery capacity



represents about an 85 percent charge. This phase, which can take several hours, is called the acceptance phase of the charge cycle.

Once a battery is charged, a float cycle helps to hold it in that condition. A float cycle is simply a voltage maintained slightly above the battery's rested, open circuit voltage. This float voltage (13.1 volts nominal) helps maintain a charge despite internal losses in the battery.

This phase charging is what a "smart" charger does. (As for these and all the other chargers currently available, we'll have more in an upcoming issue; stay tuned.) In our experience several automotive smart chargers have an excessive float charge of 13.3 volts or higher.

These chargers need to be placed on timers rather than left on all the time for aircraft battery use. Some of these chargers also have excessively high bulk charging voltages as well. Moreover, the optimum charging profiles for AGM and wet cell batteries of the same capacity will generally be different.

It's obvious that smart chargers have become more and more complicated over the years to keep up with the varied charging regimens now required. It's the price we pay for more battery capacity in relatively light weight packages, as well as the increased demands on batteries from greater periods of sitting idle than in past years when we could better afford

Example of charging algorithm for a multistage "smart" charger—essential for top AGM performance and long battery life. They help extend wet cell life as well.

to fly.

The typical automotive battery charger is not the right choice for an AGM battery. Batteries that sit idle need more capable battery chargers for long life to reverse any sulfation that always takes place when a battery sits idle.

By the way, never recharge a wet cell battery that's low on electrolyte. Add distilled water before starting the charging cycle, not after. Only fill it to the bottom of the split rings, not to the top, or else the electrolyte will overflow during the charging cycle. Tap water is not good since it contains minerals that tend to accelerate adverse reactions. Adding more battery acid is even worse for the battery.

CHECKING THE CHARGE

A hydrometer is a simple instrument used to measure the state of charge of a wet cell battery only. It does this by measuring the specific gravity—the weight as compared with water—of the electrolyte.

You can get a suitable hydrometer at a local auto parts store, but be sure that it only requires an ounce or two of electrolyte for a reading. That's about all you'll get from an aircraft battery. Also, get a numerically calibrated one; do not buy a pith-ball type.

Checking the charge is simply a matter of taking a sample of electrolyte from a cell and reading the value where the fluid line meets the hydrometer's floating scale. Write the number down.

A specific gravity reading between 1.300 and 1.275 indicates a high state of charge; between 1.275 and 1.240 is a medium state of charge, and between 1.240 and 1.200 is a low state of charge.

A battery in a low state of charge has only 50 percent or less of its capacity left and needs recharging. Check all the cells; then compare the readings. Usually, if there's a spread of more than 0.050 between the worst cell and the average of the others, the battery is on its way out.

When testing a battery with a hydrometer, observe temperature factors; the temperature of the battery can make a big difference in the readings. When its temperature is between 70 and 90 degrees F, the readings can be used as is.

Outside of this range a correction chart is needed. Some hydrometers have this chart printed on floating scales; others have the chart on or in the packaging.

Also, hydrometer readings are taken after the battery has been off the charger for a couple of hours; overnight is even better for accuracy.

The same time and temperature factors hold for AGM batteries, only you check them by a voltage test with a multimeter. Hydrometers cannot be used—you must never open the case. A voltage reading only gives a state of charge, not condition or capacity. A capacity check will tell the condition of the battery.

A battery can fool you and temporarily show nearly a full charge voltage with no load, but be completely unacceptable for service—even if it can sustain, say, one or two easy starts. That's why periodic capacity tests are needed.

HOW BATTERIES FAIL

A battery should last a minimum of three years before it fails the capacity test. Reader feedback indicates two years is more of a real world result, with Concorde AGMs having the

BATTERY STATE OF CHARGE (S.O.C.)

State of Charge	12 Volt Open Circuit Volts	24 Volt	Specific Gravity
100%	12.9	25.8	1.300
75%	12.7	25.4	1.270
50%	12.4	24.8	1.220
25%	12.0	24.0	1.140
0%	11.7	23.4	1.090

Chart determines 12 or 24 volt battery state of charge. You probably never thought at 12.4 volts a battery is 50 percent discharged.

longevity edge.

A good aviation specific charger could add at least a year to these numbers, especially with AGMs, which pays for the charger the first year. We recommend the VDC Electronics brand, 12 volt series 12248-AA or 24 volt series 24041-AA. [VDC has upgraded to a "Plug 'n Run" version, the -AA-S2 series.] Go to www.batteryminders.com, ph (800) 379-5579 x208 ET as it's specifically designed for aircraft batteries, and we have tested it. It's well worth the price.

For any type of battery, sitting idle and uncharged is slow death from sulfation. For AGMs it lasts longer between recharges since they stay charged much longer than flooded batteries due to their design. Nevertheless they will eventually sulfate if left in an uncharged state and not periodically recharged.

Once either an AGM or wet cell battery drops below, say, a 50 percent charge level they are being damaged by sulfation as they sit—the lower the battery voltage the greater the damage from sitting. (See the voltage and state of charge diagram.)

They should stay above 75 percent at all times to prevent premature aging, meaning a battery charger permanently plugged in (or on a timer if the trickle charge is over 13.1 (26.2) volts, or the battery brought home periodically for a recharge). We arrived at these percentages and voltages from years of constant testing of both aircraft and marine AGM and wet cell batteries.

With AGM batteries a major cause of premature failure is excess charging voltage, either by an automotive

type charger or an aircraft charging system set at too high a charge voltage (and sometimes too low, leading to the battery never being completely charged, which also promotes sulfation). Excess charging voltage causes the AGM battery to vent gas, and it's only a one-way valve—once it vents, capacity is permanently lost.

Excess or insufficient voltage can harm flooded batteries as well, but on the high voltage side the flooded battery can take 14.8 volts or more, as long as you keep adding water to make up for boiled away electrolyte. An AGM cannot take this.

The output of charging systems varies with the temperature, so in a four season climate a voltage regulator set for 14.4 volts in the winter will be putting out excess voltage for an AGM battery when the weather warms up unless voltage is adjusted for the warmer conditions. A wet cell battery, on the other hand will show its displeasure with excess voltage by needing constant replenishment of distilled water, or it, too, will cook.

**NOTE: The BatteryMINDER 12248-AA-S2, VDC's latest "Plug 'n Run" version, supersedes the model shown in the original article.*

All highlighting emphasis placed by VDC Electronics