Aircraft Battery Facts and Fallacies

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EAA Chapter 256

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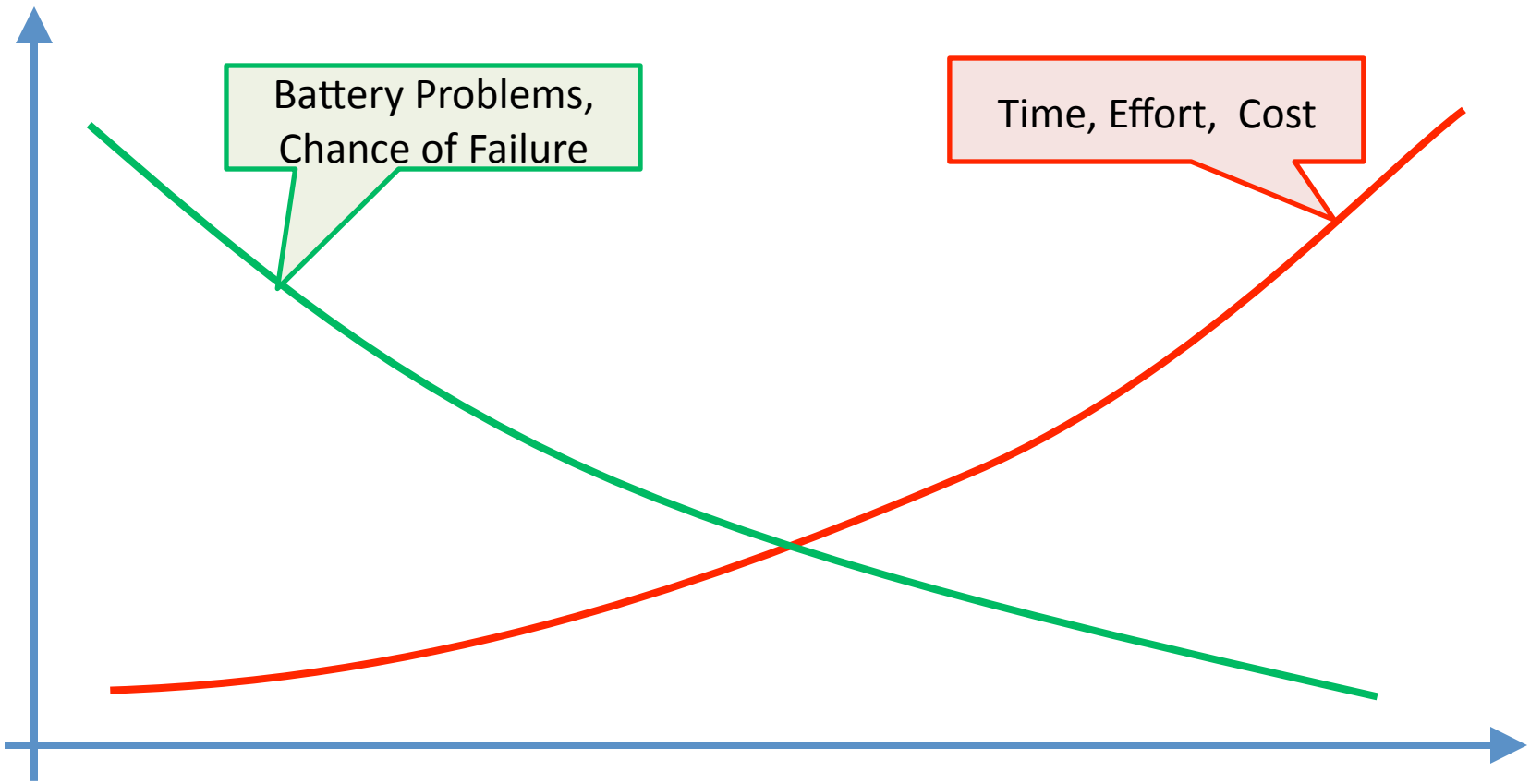
Level of Compliance/Belief



"All batteries, regulators, and chargers are the same and good enough. Recommendations are overkill."

"Do exactly what the FAA and manufacturers recommends."

Summary of Differences

		Nominal Voltage	Cost
Automotive Battery	Spec. Grav. = 1.265	12.6-12.7	
Aircraft Battery	Spec. Grav. = 1.270-1.30	12.9-13.1 Damaged if charged over 14.7 or trickle over 13.2	$160-$250
Auto. Regulator		13.8 (on @ 13.5, off @14.5)	
Aircraft Regulator		14.2	
Auto. Charger	**Not temp. compensated**	14.8, some 13.8-14.4	
Aircraft Charger	**Fully temp. compensated**	Varies per schedule	
Auto. Minder	**Not temp. compensated**	Up to 13.2	$30-90
Aircraft Minder	**Fully temp. compensated**	Varies per schedule	$140
Cold Cranking Amps	Down to 7.2 V in 30 sec @0degF		
C1 rating	AmpHr rating, Down to 10V in 1 hr		

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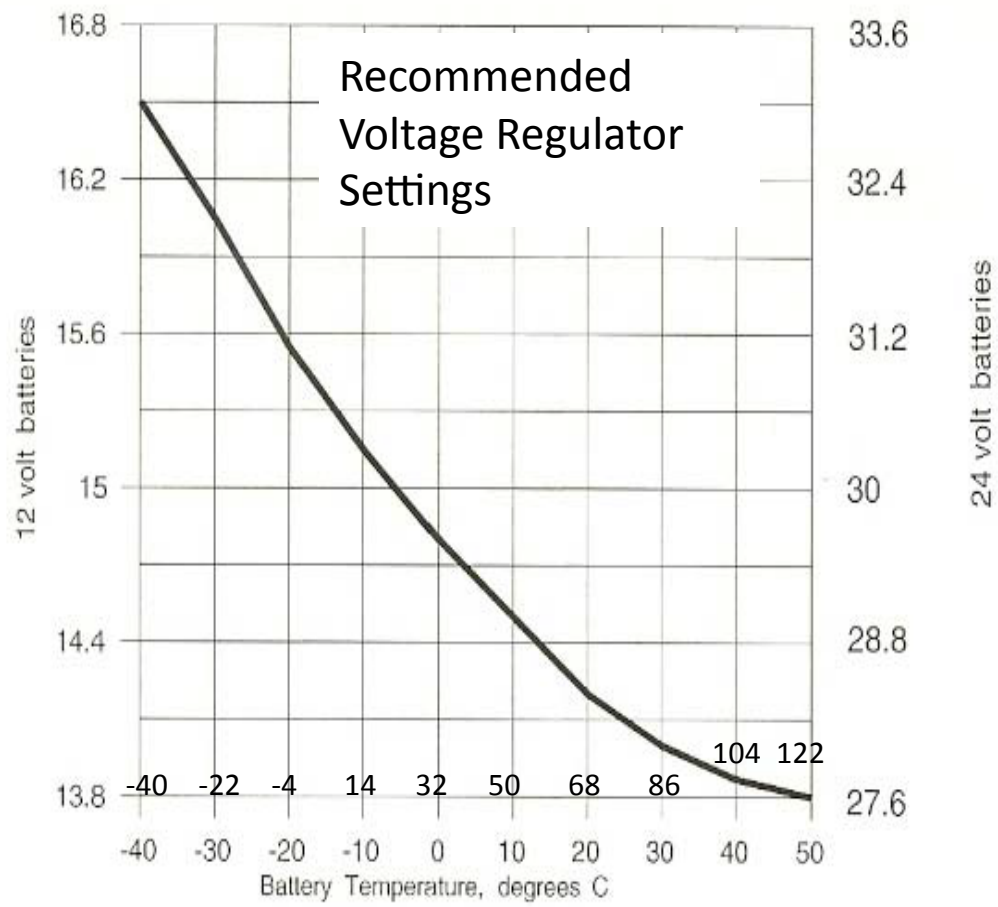
Temperature Effects

	Fully Charged-->	1.285	+-.005
Electrolyte Temp. degF	Points to be subtracted or added to specific gravity readings	Reading for Nominal	
140	24	1.309	
130	20	1.305	
120	16	1.301	
110	12	1.297	
100	8	1.293	
90	4	1.289	
80	0	1.285	
70	-4	1.281	
60	-8	1.277	
50	-12	1.273	
40	-16	1.269	
30	-20	1.265	
20	-24	1.261	
10	-28	1.257	
0	-32	1.253	
-10	-36	1.249	
-20	-40	1.245	
-30	-44	1.241	

Charge time for battery at 80 degF = 1 hr

Charge time for battery at 0 degF = 5 hr



If the automotive charger output is 12 volts:

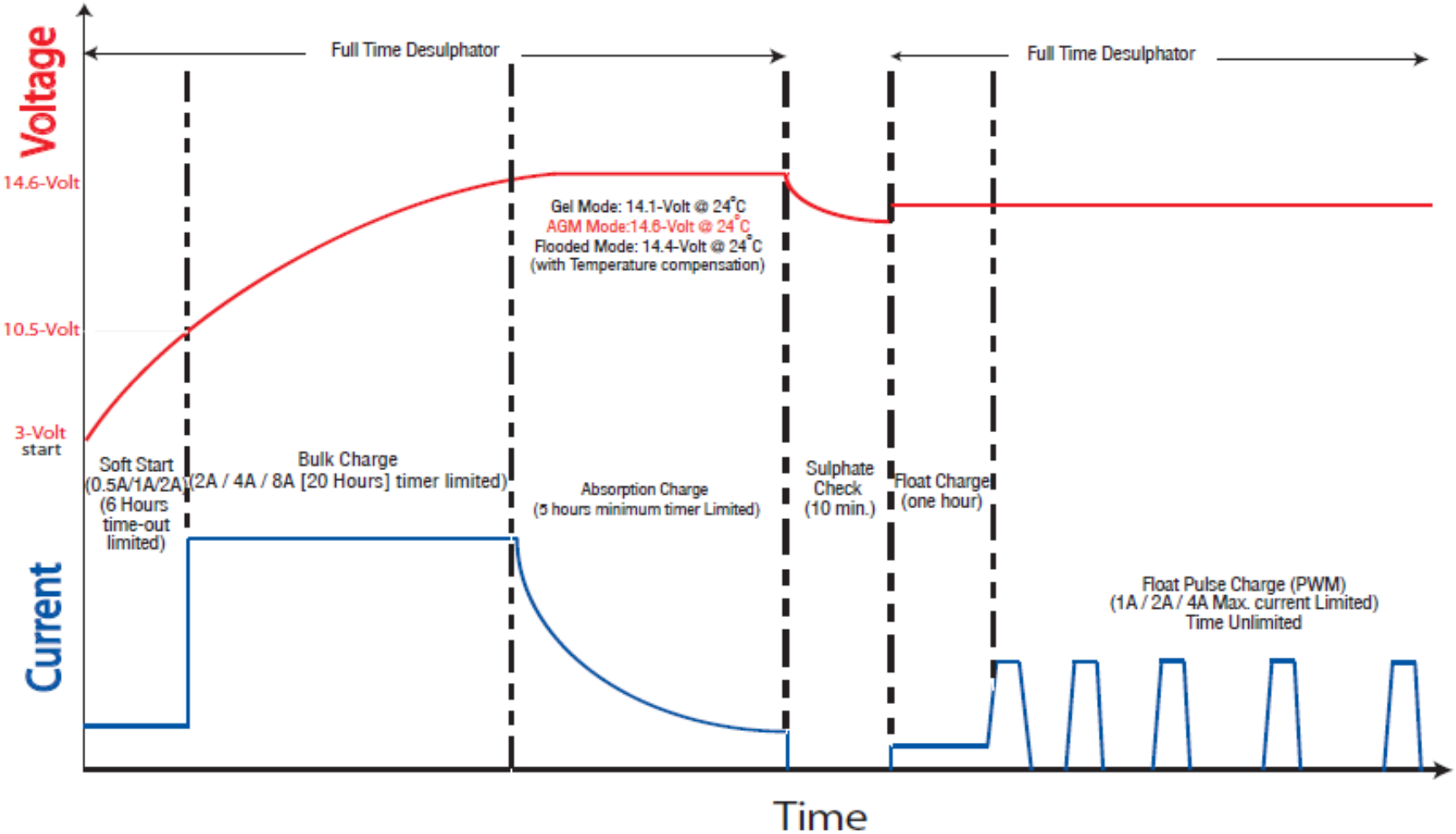
State of Charge	Open Circuit Voltage	Specific Gravity
100%	12.9	1.300
75%	12.7	1.270
50%	12.4	1.220
25%	12.0	1.140
0%	11.7	1.090

Question to Gill:
On initial charging, my battery charger charges at 2 amps, 6 amps, and 8 amps. You recommend charging at 3 amps for initial charging. Can I use my charger?

Answer: **Yes**. First determine type charger…Constant Current or Constant Voltage. If Constant Current, follow the recommended Charge Rate and Time in Gill Service Manual available on the Gill website; make sure that you have a reliable **timer** to terminate charge. If Constant Voltage, you could set the initial current at any of the settings you indicate. The charge would be complete **when current drops below ½ ampere**.

Complex Charging Schedule for Aircraft Battery Minder

BatteryMINDer® **Model 12248**



From "The Aviation Consumer" October 2011

Automotive type chargers that we have repeatedly tested have either too high a peak voltage or too high a trickle voltage or excess current for optimal life of aviation batteries—or all three.

According to our recent AVWeb reader survey of 723 owners, only 37 percent of owners use chargers, and of those 37 percent, only six percent use an aviation-specific charger. Such low charger utilization helps account for the alarming failure rates (failed in under 24 months) that were reported with Gill batteries (29.6 percent) and Concorde (7.6 percent). *Gill has discontinued the worst one – the G35S*

Unfortunately, even well-intentioned owners can do as much harm as good when they place their battery on some automotive-type chargers. The harm starts with the battery being charged initially with a high current (10 amps or greater) automotive charger, overheating the plates and permanently warping them. But even a low current automotive charger can do harm if the float voltage is set too high. Batteries have an optimal charge rate based on their amp-hour capacity, and 2 to 4 amps is more than adequate for most GA lead-acid batteries of 24 or 12 volts, but the voltage must be correct also.

Both the primitive or multi-stage automotive chargers (at least every one of the dozen we have ever tested) slowly **cook the battery and boil away the electrolyte** while it sits plugged in during the so-called "float" or trickle charge. The reason is that automotive "float" or trickle charge **voltage is nearly universally set too high** for aircraft batteries and **does not adjust adequately or at all to temperature** changes as it must to do a proper job. In one case, a very popular automotive multi-stage charger, the **Batter Tender brand, recommends against it use for aircraft batteries**, as does Concorde on their Web site.

AGM sealed batteries are now the majority installed in the fleet, and these batteries cannot recover from an overvoltage and loss of electrolyte. One big advantage of AGM batteries is that their lower self-discharge rate is more resistant to sulfation when ignored and left sitting. The downside is their **vulnerability to overcharging**. AGMs can take huge charging currents like a sponge without damage as long as the voltage is not excessive. For the same reason (ultra-low internal resistance) they can put out higher cranking current than a flooded counterpart.

True or False?

1. Storing a battery on a concrete floor is bad for the battery life? (or better)
2. If the liquid level goes below the top of the plates, it is best to add 50/50 mix of acid/water? (or water only)
3. One good battery minder can be used to maintain any little used 12 volt Concorde and Gill aircraft batteries (also automotive 12 volt batteries)? (or must be specific for type)
4. No aircraft voltage regulators should be adjusted to compensate for temperature? (or theoretically should be adjusted)
5. Ground power units (with high charging voltages) can be safely used by decreasing charging time? (or is this likely to cause damage)
6. To check the state of charge of a battery after charging, wait for 15 minutes? (or 1hr, or 6 hrs., or 72 hrs.)
7. A fully charged 12 volt aircraft battery should read at least 12.3 volts? (or 12.8, or 13, or 14.7)

True or False?

8. The state of charge (open circuit voltage) is the best and easiest way to determine the health of a battery? (or a significant power drain test)
9. Sulfating (build up on the plates) on a 12 volt battery is prevented if the battery voltage is not allowed to go below 12V? (or 13, or 13.5)
10. Allowing a battery to run down (low voltage) causes heating and evaporation of fluid, but does not usually cause sulfating? (or always does)
11. Even a fully charged battery can freeze at very low temperatures (below -22 deg. F)? (or -40, or -60)
12. Engines are harder to start in cold weather because of the extra power required, not because the battery has less power? (or battery loss also)
13. When starting an engine in freezing temperatures, it is recommended to use a GPU to prevent the battery from shock heating suddenly? (or use the aircraft battery)

True or False?

14. When starting an engine in cold weather, it is recommended to put the pre-heat on both the engine and battery? (or not the battery)
15. A battery minder should be used especially if the aircraft is stored outdoors? (or especially indoors)
16. If a battery is frozen, charge at below 1 amp rate to slowly thaw it out? (or don't charge until thawed)
17. When connecting/disconnecting a charger that is plugged in, do the negative terminal first? (or don't connect/disconnect either)
18. When making the connections to the battery, always watch the battery to look for vapors or excessive sparks? (or don't look at it)
19. An analog (needle type) or digital voltmeter can be used for automotive or aircraft battery testing? (or use only digital)
20. It usually takes 24-36 hours to recover a sulfated battery? (or 48, or 72)
21. A battery minder can not be used on more than one battery at a time? (or 2, or 6 are OK)

True or False?

22. Positive plates are made of lead (Pb) and negative plates are made of copper (Cu)? (or both copper, or both lead)
23. The traditional flooded (vented) type have slightly more starting power than the more convenient RG (sealed) type? (or same, or less)
24. When charging multiple batteries with a constant current battery charger, connect them in parallel so that the total potential is 12V? (or in series)
25. An aircraft battery has significantly more power than an automotive battery? (or significantly less)
26. To replace acid (in the event some is spilled), you can purchase appropriate acid from auto parts suppliers? (or auto and aircraft acid is different)

Answers to True/False Questions

All true/false questions are FALSE
Correct answer is found to the right in parentheses

- Aviation batteries have **significantly** lower capacity than an auto battery.
- In automotive use, "maintenance free" generally means a wet-cell battery with simply more electrolyte and different chemical additive.
- Aviation-type maintenance-free batteries for certified airplanes -- available from Gill and Concorde -- are also called sealed, valve-regulated batteries and are truly maintenance free from adding liquids. They can be damaged by **overcharging** with excess voltage (over 14.7 volts for a long time).
- In an "alternator-out" situation, you will get much more than double the battery time if you cut the current drain on the battery in half when running electronics.
- Capacity Testing is a greatly ignored annual requirement, because most shops don't have the proper equipment. You must have an annual capacity test performed on your starting battery. It's part of the Instructions for Continued Airworthiness that should come with any new battery.
- The FAA indicates that they interpret the rules that the capacity test is mandatory for Part 23 certified airplanes and recommended for CAR 3 certified airplanes.
- The test must show that your battery is capable of sustaining 80 or 85 percent of the amp-hour rating of your battery (depending on the type of test protocol performed). See each maker's ICA for the specifics -- they do differ.
- If you want the best chance of passing this test (and longest-lived battery), then the best bet is to use a multi-stage battery charger that reaches up to 14.5 volts, **but not more**, at the conclusion of the charging cycle.

- If you try to charge a 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. Some will also break down the water portion of the sulfuric acid electrolyte into gaseous hydrogen and oxygen and vent out the caps.
- One of the best ways to charge a battery is at a constant current rate in amps equal to 20 to 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 charging device should 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 1 percent of its capacity (e.g., a 25-Ah aircraft battery accepting 0.25 amps), it can be considered fully charged. A current of 5 percent of 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 (13.1 volts nominal for a 12-volt battery). This float voltage doesn't really charge the battery but helps maintain a charge to compensate for internal losses in the battery. If your charger is trickle charging at more than 13.2 volts, it is slowly cooking the battery -- don't leave it on all the time.

- Phase charging is what a "smart" charger does. A typical alternator/regulator charging system is not as sophisticated in recharging a battery, nor is the typical automotive battery charger.
- A quick start takes very little charge out of a battery, so sophisticated charging is not critical. Batteries that sit idle, though, need more capable battery chargers for long life to reverse any sulfation that always take place when a battery sits.
- Never recharge a battery that's low on electrolyte (plates showing to air). Add distilled water before starting the charging cycle, not after. Only fill it to the bottom (or a bit below) 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, and usually kills the battery in a matter of days.
- If you buy an aviation battery in a dry-charged state via mail order and plan to buy automotive acid locally, don't. Auto acid is not the same specific gravity and will reduce battery life.
- Overfilling beyond the bottom of the split ring promotes the gassing out of the excess electrolyte, which forms conductive bridges on the surface of the battery. Also, when initially placing in service, fill to a little below the split rings or you can boil away electrolyte, making a mess. Fill to split ring after the initial charge is complete.

- The flaking and separation of lead sulfate -- and, to a lesser extent, lead dioxide -- from the plates that occurs even in normal operation can eventually cause a sludge in the bottom of the battery that actually short-circuits the plates. That can't be helped, but this process (flaking) is exacerbated by overcharging and by excessively high charging rates. Even worse is when a battery is left badly discharged (more about this in a minute).
- Gassing and subsequent loss of electrolyte is another possible failure mode. It's caused largely by overcharging the battery and by neglecting to check electrolyte levels from time to time. Check the vent caps once a month for electrolyte level. If you find that every couple of months you need to add water to the battery, have the airplane's charging system checked. It shouldn't be gassing that much, and the charging voltage may be set too high -- i.e., over 14.3 or 28.6 volts -- or the regulator is malfunctioning. If the charge voltage is too low, it can sulfate the battery.
- The most common cause of battery failure is sulfation. It occurs when a battery is left in a discharged state, in which much of the plate area is covered with a fine deposit of lead sulfate. This deposit grows into larger, harder crystals of lead sulfate that clog the spongy surface of the lead plates, acting as insulators. The crystals don't readily break up, and so the battery loses effective plate area, and therefore capacity.
- It's a very poor idea, in terms of longevity, to discharge a battery down to less than 50 percent of its capacity. In fact, a battery that remains in a low or discharged condition for a long period of time will be permanently damaged.

- During periods of disuse, the battery will gradually lose its charge. The rate of such self-discharge is highly dependent on temperature. At an ambient temperature of 77°F, a fully-charged battery will lose approximately 1/4 of its charge every 30 days. For every 18°F increase in temperature, the self-discharge rate doubles! At 95°F the battery will lose 1/4 of its charge every two weeks, and at 113°F it will lose 1/4 of its charge every week.
- Consequently, any time the airplane will be inactive for more than a couple of weeks, it's a good idea to put the battery on a trickle charger to maintain it at a fully charged state. This is especially important during hot weather. If the battery is ever allowed to discharge deeply (to 11.4 volts or 22.8 volts), it can sustain permanent damage.
- A battery's state of health must be determined by verifying its ability to provide sufficient stored energy for essential power requirements. The amount of stored energy (battery capacity) required to start a reciprocating engine is generally less than 3%, while a turbine engine start requires approximately 10% of the rated capacity. Good starting performance is not necessarily a safe indication of the battery's state of health. An airworthy battery must be able to provide essential power in the event of a failure of the generating system. Therefore, a periodic capacity check of the battery at the C1 rate (one hour) is recommended.
- Flooded (vented) batteries have a higher rate of self discharge than the Valve Regulated Batteries (VRB) (RG® Series). To minimize the extent of self discharge, store charged batteries in a cool place.

- Some owners use an ordinary, automotive battery charger to charge their aircraft battery. This may or may not be a mistake, depending on the charger used. Many automotive chargers will charge at a rate that can be damaging to an aircraft battery.
- Aircraft batteries should never, ever be charged at more than a 10-amp rate, and even that is pushing things. A 3-amp charge rate is just about ideal. Naturally, this means that the charging process will take some time. If your aircraft battery is rated at 35 ampere-hours and it is fully discharged, it will take about 12 hours to charge it to full capacity at a 3-amp charge rate. Patience is a virtue here: Charging the battery at a substantially faster rate may be hazardous to its health.
- Most automotive chargers are "constant-voltage chargers" that apply a fixed voltage to the battery as it charges, similar to what the aircraft electrical system does in flight. With a constant-voltage charger, the charging current starts out relatively high and gradually tapers down toward zero as the battery becomes fully charged.
- For initial charging, however, both Teledyne/Gill and Concorde recommend that their aircraft batteries be charged using a "constant-current" charger that gradually increases its charging voltage as necessary to maintain a constant charging current. A constant-current charger will charge the battery faster and more completely than a constant-voltage charger. The downside is that such a charger can easily overcharge and damage a battery if it is left connected for too long, so it's essential to monitor the battery's charge state (either with a hygrometer or a voltmeter) and disconnect the charger once the battery reaches full charge.

- Both manufacturers require a four-step maintenance cycle:

1. Check the electrolyte level and add distilled water as necessary to bring each cell up to the bottom of the split ring;
2. Charge the battery to full capacity;
3. Perform a capacity test; and
4. Charge the battery once again to full capacity and return it to service.

- Virtually every mechanic performs steps 1 and 2 at every annual, but few do steps 3 and 4. The reason for this is that not many shops have access to a capacity tester, and the ones for 24-volt batteries are rather pricey.
- The capacity test simply consists of placing a specified load on the fully-charged battery and then measuring the time it takes for the battery to be drawn down to a specified voltage (10 volts for a 12-volt battery, 20 volts for a 24-volt battery).
- Because of the compressed construction, the RG® (sealed) batteries have a much lower internal resistance and thus provide greater starting power and faster recharging, particularly at cold temperatures, than comparable flooded batteries.
- When adding water to a battery in extremely cold weather, the battery must be charged at once. If this is not done, the water will not mix with the acid and will freeze.

- **When flooded (vented) batteries** are on charge, the oxygen generated at the positive plates escapes from the cell. Concurrently, at the negative plates, hydrogen is generated from water and escapes from the cell. The overall result is the gassing of the cells and water loss. Therefore, flooded cells require periodic water replenishment.
- **When valve regulated Recombinant Gas (RG®) batteries** are on charge, oxygen combines chemically with the lead at the negative plates in the presence of H2SO4 to form lead sulfate and water. This oxygen recombination suppresses the generation of hydrogen at the negative plates. Overall, there is no water loss during charging. A very small quantity of water may be lost as a result of self discharge reactions, however, such loss is so small that no provision need be made for water replenishment. The battery cells have a pressure relief safety valve that may vent if the battery is overcharged.
- The lead, acid cell used in aircraft batteries consists of positive plates made of lead dioxide (PbO2); negative plates of pure spongy lead (Pb); and a liquid known as electrolyte, consisting of a mixture of sulfuric acid (H2SO4) and water (H2O). The sulfuric acid and water are mixed so the solution has a specific gravity (S.G.) of 1.275 to 1.300 in a fully charged battery.
- Caution: Aircraft are certified with batteries that have reserve or essential capacity for emergency operation. Never “jump start” an aircraft that has a “dead” or discharged battery. It takes approximately three hours to fully recharge a discharged battery with the aircraft generating system.

- Valve regulated lead-acid (VRLA) battery - A lead-acid battery in which there is no free electrolyte and the internal pressure is regulated by a pressure relief valve. This battery requires no maintenance of the liquid level and recombines the gases formed on charge within the battery to reform water. The battery may be used in any attitude without danger of leakage or spilling of electrolyte.
- Rated C1 capacity - The nominal capacity, expressed in Ampere-hours (Ah), obtained from a fully charged battery when discharged at the one hour rate to the specified end point voltage at a temperature of 21 - 25C (70 - 77F).
- C1 rate – The rate, in amperes, equal to the battery's rated C1 capacity. For example, the C1 rate of a battery rated at 3.5Ah is 3.5 amperes.
- End Point Voltage (EPV) - The voltage at which the discharge current is terminated when measuring battery capacity. Unless otherwise stated, the EPV is equal to 20.0 volts (10.0 volts for 12 volt batteries).
- Open Circuit Voltage (OCV) – The voltage of the battery at rest (no charging or discharging current present). A stable OCV requires a rest of at least four hours.
- **WARNING: LOW CAPACITY HAZARD.** Aircraft batteries are certified to have a certain minimum capacity for emergency operations in the event of a electrical generator system failure. Never use a battery that has less than 80% of rated capacity.

Capacity Test Procedure – Part I

A. If the battery is cold, warm it up to at least 20C (68F) before testing.

B. Charge the battery at constant potential per Paragraph 8.

C. Connect the battery to the discharge equipment and discharge at the C1 rate on the label (i.e., 42 Amps for a 42 AH battery).

D. Discharge the battery to an EPV of 20 volts (10 volts for 12 Volt batteries) or other EPV specified by the airframe or equipment manufacturer.

E. Record the time to the EPV. The battery passes the capacity test if the time to the EPV is 51 minutes or greater (85% of rated C1 capacity or greater).

F. The battery is at least 90% of rated capacity if the time to the EPV is 54 minutes or greater. For other discharge times, the percent capacity can be calculated using this formula: Percent Capacity = Discharge minutes x 1.667.

NOTE: AIRFRAME OR ACCESSORY EQUIPMENT MANUFACTURERS MAY SPECIFY A DIFFERENT CAPACITY TEST REQUIREMENT, WHICH SHOULD TAKE PRECEDENCE.

Capacity Test Procedure – Part II

G. If the battery passes the capacity test, charge at constant potential per Paragraph 8 and return battery to full state of charge. The battery is acceptable for installation.

H. If the battery fails the capacity test, perform the conditioning procedure given in Paragraph 9. After the battery has been conditioned repeat the capacity test.

I. If the battery passes the second capacity test, charge at constant potential per Paragraph 8 and return battery to full state of charge. The battery is acceptable for installation.

J. If the battery fails the second capacity test, repeat the conditioning charge per Paragraph 9 and repeat the capacity test.

K. If the battery passes the third capacity test, charge at constant potential per Paragraph 8 and return battery to full state of charge. The battery is acceptable for installation.

L. If the battery fails the third capacity test, the battery should be replaced.

M. If the battery gets very hot (greater than 55C/130F) during constant potential charging, the battery should be replaced

- **C1 rate -** The one hour discharge or current rate in amperes that is numerically equal to rated capacity of a cell or battery in ampere hours.

CB-35A Premium Concorde Aircraft Battery Specifications: Primary Aircraft
Purpose General Aviation Aircraft Battery
Voltage 12v
Rated Capacity C1 = 1 hr.
rate in ampere hours 29.00
Cold Cranking Amps 325.0
Max Weight 28.50 lb / 13.0 kg

CB-25 Premium Concorde Aircraft Battery Specifications: Primary Aircraft
Purpose General Aviation Aircraft Battery
Voltage 12v
Rated Capacity C1 = 1 hr.
rate in ampere hours 20.00
Max Weight 22.00 lb / 10.0 kg

Specifications | Drawings

- 12
- Type: Dry
- Weight: 21
- 1 hr (C1) 18
  30 min (2C) 30
  60 sec/0 deg F (CCA) 225
- Electrolyte: 2 Qts./1.285 s.g

BatteryMINDer® Aviation Models Comparison Chart

All Aviation-Calibrated BatteryMINDers are for Sealed or Wet (Filler Caps) Lead-Acid GA Batteries Only - NOT for NiCad

Click on any model no. to go to the website link

MODELS / FEATURES	12248-AA-S2	12248-AA-S3	12248-AA-S5	24041-AA-S2	24041-AA-S3	24041-AA-S5	28252-AA[1]
Battery Voltage	12	12	12	24	24	24	24
Battery Brand(s)	• Gill • Concorde CB Only	• Odyssey - Hawker	• Concorde RG® or Flooded CB	• Gill • Concorde CB Only	• Gill LT/7000 Series • Odyssey - Hawker	• Concorde RG® or Flooded CB	• Gill • Concorde • Hawker, Odyssey • Non-Aviation
Battery Type (Sealed or Wet)	• Gill - Both • Concorde - Wet	Sealed	Both	• Gill - Both • Concorde - Wet	Sealed	Both	Both
Input Voltage (VAC)	120	120	120	120	120	120	110 - 240
Auto-restart after a power failure	✓	✓	✓	✓	✓	✓	✓
Desulfation - Automatic	Full-time	Full-time	Full-time	Full-time	Full-time	Full-time	On Demand[2]
Maintains from 1 - 6 batteries at a time (parallel connected)	✓	✓	✓	✓	✓	✓	✓
At-the-Battery Temperature Sensor (included)	✓	✓	✓	✓	✓	✓	✓
Weather-proof	✓	✓	✓	✓	✓	✓	
Power Supply Function							✓

[1] Dip switch can be reset for Gill LT (7000's Series) and Odyssey - Hawker

[2] Aggressively performs 6x faster than our other models

[3] Applies to 2 - 12 Volt series-connected (= to 24V) batteries

[4] 5.5 (L) x 5.5 (W) x 2.25 (H)

[5] 9.45 (L) x 8.46 (W) x 3.8 (H)