Aviation Battery Care and Longevity

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Abstract

Properly maintaining aircraft batteries to ensure maximum performance for engine starting, emergency reserves, and extended airworthy service life, enhances safety of flight and reduces operating costs.

Understanding the unique characteristics of aviation lead acid batteries will equip operators to optimize their engine starts (especially turbines), ensure dispatch reliability, provide maximum emergency electrical reserves, and extend battery service life.

Achieving all these objectives requires a specialized charging scheme that can precisely maintain the battery's state-of-charge, control sulfation, and monitor battery health and condition. This involves managing a number of variables that differ from one aircraft to another, the effects of which become increasingly important over time. Knowledge of these variables can help operators understand the reasons for significant differences in observed battery longevity, even within a fleet of similar aircraft, and develop informed strategies to preserve their aviation batteries.

Background

The information in this article is for owners, operators, licensed pilots and technicians of general aviation aircraft that incorporate batteries employing lead acid chemistry. Examples herein refer to aircraft batteries with nominal voltage of 24. Concepts are equally relevant for aircraft with 12-volt batteries if divided by 2.

Battery Maintenance Charging (BMC) involves low amperage charging of a healthy battery installed in the airframe to preserve its capacity and extend its service life. It is distinctly different than bench charging where a more deeply discharged battery is removed from the airframe for recovery and tested to ensure continued airworthiness.

BMC requires the installation of a simple wiring harness to easily connect the charger via the battery relay or contactor. This can be accomplished with standard aviation hardware and approved as a minor alteration by the installing mechanic's logbook entry. The BMC connection is not associated with the aircraft's external power receptacle.

Aviation Battery Distinctions

Weight – Designing starting batteries for aircraft involves unique tradeoffs and constraints compared to those for land-based vehicles. Top among these is weight. Lead acid batteries are by design heavy. While not an especially important constraint for most vehicles, weight is obviously a critical design parameter for aircraft. To minimize weight in aircraft batteries, the lead plates are thinner. It is an effective weight reduction scheme, but tends to reduce longevity. Besides thinner plates, the acid concentration in the electrolyte is typically higher, which also tends to reduce longevity.

Emergency Reserves – Besides the ability to deliver massive amounts of instantaneous current for engine starting, aviation batteries must also provide sufficient reserve capacity in an emergency for a safe return to the ground. Reserve capacity is not as important for automotive batteries. A car with a discharged battery can simply pull off the road, get a jump start, and drive away. In contrast, an aircraft should never take off without fully charging the battery because it may not have sufficient reserve power should an electrical failure occur.

Cost – There are many factors contributing to battery costs, but unique to aviation are very low economy of scale, certification/compliance, and product liability. Generally, aviation batteries cost about 5-10 times that of a comparable output car battery.

Capacity – The obvious utility of most starting batteries is their ability to spin the motor to start it. When it can no longer reliably operate the starter, it gets replaced. However, aviation battery service life is governed by regulation and usually defined by the ability to deliver 85% of its rated amp/hour capacity. This capacity test is required annually to determine continued airworthiness and return the battery to service. For piston aircraft, a battery with much less than 85% capacity may be able to start the engine, but lacks the required reserve capacity for an emergency.

All this is to say that cost, safety, and regulations create a compelling proposition to properly maintain aviation batteries and extend their airworthy service life.

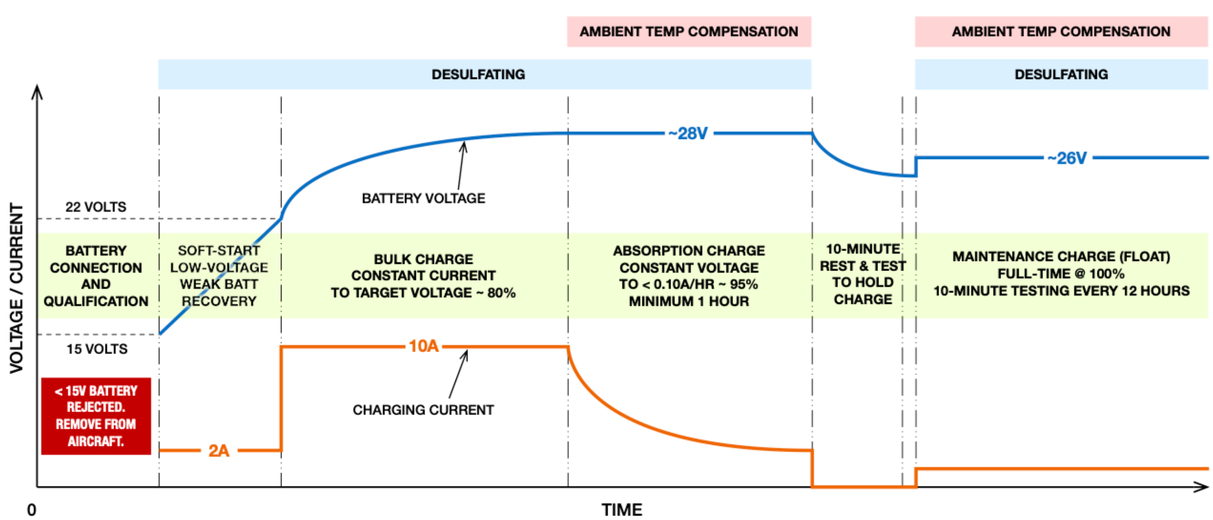
Battery Characteristics

Stages of Charging – Battery charging generally operates in at least 2 stages. The first is termed "bulk" charging and is achieved by supplying a constant current (amps) to the battery. As the battery's level of charge increases, the battery voltage also increases until it reaches the battery's temperature-compensated target charging voltage. This will bring the battery to about 80% of a full charge.

The second stage, absorption, begins with the charging voltage held constant and current gradually decreasing until only a fraction of an amp is required to hold the target voltage. For 24-volt aviation batteries, this is approximately 28 volts. The exact voltage varies inversely with temperature. Simple battery chargers should be disconnected after the absorption stage is completed.

If the charger is to be left connected to the battery, it should have a 3rd stage called float, or maintenance, where the objective is to supply whatever small amount of charge is required to keep the battery fully-charged without damaging it from overcharging. This is slightly more than 26 volts and ideally delivered only as needed to compensate from any parasitic loads and/or self-discharge.

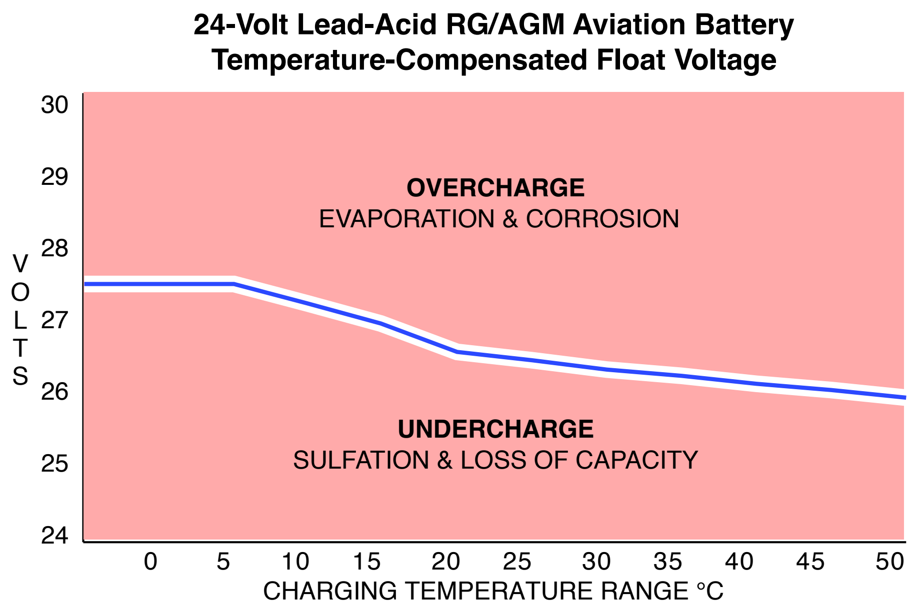
More elaborate "smart chargers" vary their charge voltages to compensate for temperature variations and incorporate more stages to test a battery's condition and assess its ability to safely charge based on feedback measurements. But the bulk and absorption stages are common to all.



Example of 7-Stage Smart Charger Operating Diagram

Charging Profile – The electrical values that specify the optimal charging characteristics for a particular battery design determine its charging "profile." Smart chargers can optimize precision by selecting a profile specific to the particular battery type.

Maintenance Charging – The objective of maintenance charging is to precisely hold the battery at its temperature-compensated fully-charged state, without overcharging it. This prevents sulfation while simultaneously electrically pulsing the battery to dissolve sulfate crystals into the electrolyte solution. Properly done, maintenance charging can effectively reverse the battery sulfation aging process.



Absorption charge voltage is approximately 2 volts higher than float stage and follows a similar temperature compensation curve.

Variables Affecting Maintenance Charging

Battery Decay – A fully-charged battery will discharge over time for two reasons. Batteries have an inherent rate of decay or self-discharge over time. At room temperature, this rate is relatively small, about 4% per month but rises sharply as temperature increases.

Parasitic Load – The other source of discharge for an installed battery is any parasitic load from the airframe to power systems from the battery bus when the battery master switch is off. The parasitic load on the battery will vary from one aircraft to another, but it can be measured and calculated to determine the load, ideally less than 1mA (0.001A). This load is added to the normal battery decay to determine the expected rate of battery discharge when in not in operation. Concorde Battery Corporation's Technical Bulletin 10 is a good reference for measuring and calculating the parasitic load of a specific aircraft.

Sulfation – When less than fully-charged, lead acid batteries react to form sulfate crystals on the lead plates. The accumulation increases with decreases in battery voltage and time of exposure. Sulfate crystals impede the charge/discharge chemical reactions thereby reducing the battery's capacity and load response.

Exposure Duration – The adverse effects from imprecise and improper battery charging are cumulative over time. In the short term (hours, a couple of days), relatively low amperage maintenance chargers will not damage a battery. However, over long periods of time, cumulatively, even minor errors in charging can have significant impact on battery longevity and capacity. So, continuous maintenance charging over a period of weeks or months requires a level of monitoring and precision that are far beyond that provided by a normal battery charger or a “trickle” charger. The longer the time of exposure, the more essential the need for dynamic charge precision. Floating a battery at full charge without overcharging it, under all temperature conditions, is a delicate balancing act.

Temperature – Ideally, charging temperature would be measured and monitored at the battery, but in certified aircraft the sensor would have to be FAA certified for permanent installation for the specific aircraft type, so ambient temperature is normally substituted. Test data has shown this to work well because heat gain from low current charging is negligible. But it does not account for any heat gain or loss in flight. The absence of battery temperature data makes a compelling argument for allowing a period of time prior to initial charging for the battery temperature to acclimate to ambient.

Aircraft Bus Voltage – It is generally accepted logic that an aircraft flown frequently for sufficient duration would have little need for maintenance charging since the opportunity for natural charge decay would be minimized. However, a closer examination of this variable may suggest otherwise. This assumes negligible parasitic loads which is often not the case.

In a typical flight sequence, engine start (especially turbine engines) presents a brief but intense load and drain on the battery. After a successful start, the generator or alternator rapidly recharges the battery at the ship’s bus voltage, ideally about 28.2 volts. However, once the battery is fully charged, the bus voltage does not step down to a lower, float level. Also, the bus voltage is not normally temperature compensated, which will result in overcharging at higher than standard temperatures. If the aircraft bus voltage is regulated higher than necessary or specified, this would exacerbate overcharging.

Battery Maintenance Strategies and Recommendations

Verify Airframe Voltage Regulation – Ensure that the aircraft electrical system is adjusted to the voltage recommended by the aircraft manufacturer.

Delay Initial Charge – Some strategies for battery care involve trade-offs based on the variables above. One strategy that appears to have no downside is to delay the initial maintenance charging for several hours after shutdown to allow the ship’s battery adequate time to acclimate to ambient temperature. A delay of at least 4-8 hours is adequate for temperature equalization and assures that charge voltage compensation based on ambient temperature will accurately represent the battery’s condition.

Allow a Full Charge Cycle – A charge cycle is defined as completing the bulk, absorption, rest & test, and initiation of float charging at 100% state-of-charge. For reasonably well-charged battery this typically takes about 12 hours, so 2 cycles would require about 24 hours. A more deeply discharged battery will require even more time in the bulk charge stage.

Continuous (24/7) vs Scheduled Charging – Battery maintenance using a fulltime, continuous charger offers the convenience of walk-away, unattended operation for an indefinite period of time. But as discussed above, the longer the duration of maintenance charging, the more critical its precision to simultaneously prevent sulfation and not overcharge. Some battery manufacturers do not recommend continuous maintenance charging due to the possibility of water loss and corrosion of the grids, which over a long period of time could shorten the life of the battery. However, there are many operators who have used continuous maintenance charging for years and extended their battery life by 2-3 times. So, benefit vs risk is debatable and there are conflicting reports on this tradeoff.

For those concerned about continuous charging, a solution is to operate the charger on a schedule instead of continuously. This would involve an initial charge cycle, then pausing for a period of several days. The number of days is determined by the operator and would depend on discharge rate – a combination of the aircraft’s parasitic electrical load and the natural decay rate of the battery. A schedule example would be the initial charge, resting for 14 days, 24 hours of maintenance charging, resting 14 days, etc. This would avoid concerns about possible continuous charge effects on battery longevity but not allow any significant loss of battery state-of-charge and sulfation.

On-Condition (Monitored) Charging – A charger offering scheduled charging should also employ an on-condition protection scheme for monitoring the battery's condition during its resting time and automatically initiate the charge cycle anytime the battery's open circuit voltage drops below a discharge limit to prevent unexpected discharge between charging schedules.

Preflight Charging – Scheduled charging may not always align with unexpected flights. The ability to remotely initiate a charge cycle to assure flight readiness is an important feature for those who elect scheduled over continuous charging.

Conclusions

There are two ways to achieve the above battery care recommendations.

An aviation-specific battery maintenance charger (BMC) with temperature compensation and battery specific profile, such as the BatteryMINDer Model 244CEC2-AA-S5 can be used for continuous 24/7 charging. It has a 4A maximum output and operates on 115V AC only. This type of BMC simply plugs into an AC outlet (no on/off switch) and connects to the ship's battery via the installed harness described earlier.

WhiteLightningGPU.com/products/244CEC2-AA-S5

Delayed and scheduled charging, if desired, can be accomplished with other devices, such as programmable timers, controlling power input to the charger.

The required harness kit, Model BM-AIK2A Airframe Interface Kit, is not included and can be sourced from White Lightning for installation by a licensed mechanic.

WhiteLightningGPU.com/products/BM-AIK2A

Second, a "smart" BMC can automate and remotely control the options for selectable battery profiles, initial charge delay, charging schedules, remote battery monitoring, preflight charging, and of course temperature compensation. White Lightning offers the Model BMC24, a 10-amp maintenance charger with these advanced features. It is available in their Smart Ground Power Units (SmartGPUs) and feature universal AC inputs (90-250V) for worldwide operation, a simple user interface, and USB ports for accessory charging and data transfer and firmware updates. The BMC24 includes the required Airframe Interface Kit to install a wiring harness for battery maintenance charging.

WhiteLightningGPU.com/products/products/SmartGPU

References

White Lightning SmartGPU BMC24 Operator's Manual

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