Chapter 3

AIRCRAFT BATTERIES

INTRODUCTION

A battery is a device which stores energy in chemical form and this energy is easily recovered as electricity. A battery is made by interconnecting electrical cells. Cell plates are submersed in an electrolyte (usually a liquid) which by chemical action, causes electrons to accumulate on one plate. This plate becomes the negative terminal of the battery and the other is the positive terminal. The potential difference between the terminals of each set of plates is about 2.1 volts for a lead-acid cell and 1.25 volts for the nickel-cadmium type. The cells in a battery are connected in series to provide standard operating battery voltages of either 12 or 24 volts.

The functions of aircraft batteries are to provide DC electrical power for:-

a) engine and APU start.
b) a limited time in an emergency.
c) generator field excitation (at start-up)
d) a limited time during ground operations (before engine start)
e) damping or sustaining by providing extra current during high demand periods such as motor operations with starting surge.

DRY CELL BATTERIES

The dry cell battery is the common torch battery used in aircraft emergency beacons, portable lights and radios. They are important to abnormal aircraft operations and are maintained by servicing schedules and are not a day to day consideration for the pilot.

WET CELL BATTERIES

Wet cell batteries have been developed to provide a large amount of current for a reasonable period. However, this means the chemical processes involved are rapid and fairly violent and a gas, usually hydrogen is given off.

Some advantages of wet cell batteries when compared to dry cell batteries, are that they can supply a large amount of current and ***can be recharged***. By causing a current flow back into the battery, charging is effected by reversing the chemical action.

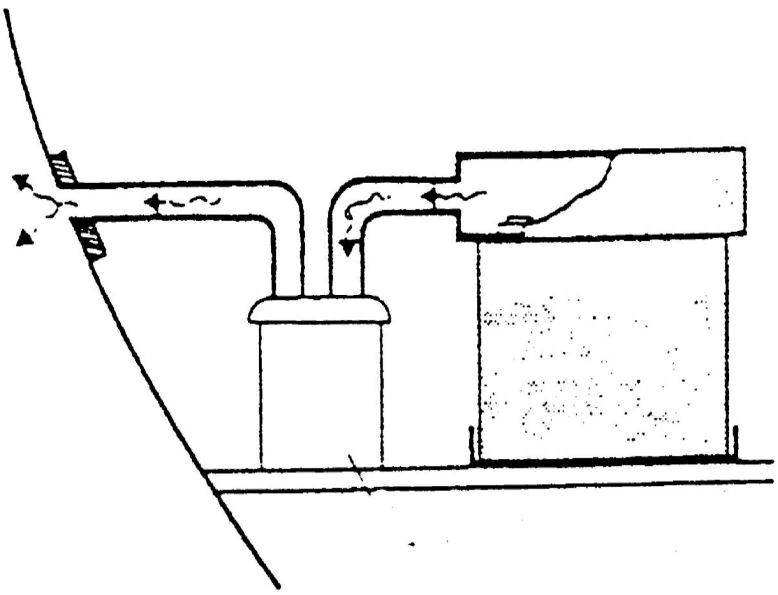
There are several types of wet cell batteries :-

- lead-acid
- nickel-cadmium
- nickel-ion
- silver zinc

Lead-acid batteries are the most common in light aircraft. An appreciation of operating considerations of both lead-acid and nickel-cadmium batteries is required.

The wet cell batteries used in aircraft are best considered to be electrical energy storage devices that are sometimes referred to as electrical accumulators.

Caution : Aircraft batteries use highly corrosive chemicals (acids or alkaline) and sometimes vent dangerous gases. These gases are often toxic and flammable (hydrogen). Consequently, the battery is mounted in a container which vents these gases external of the aircraft to the air stream. This container will also prevent any acid contacting the airframe in the unlikely event of leakage from the battery



SEALED AND VENTED BATTERY CONTAINER

THE CAPACITY OF A BATTERY

Batteries are ***rated*** on how much current they can provide for a specified time (discharge rate). A battery rated at 32 amp/hour, means it can technically provide 3.2 amps for 10 hours. Alternatively, it is said to provide 64 amps for 30 minutes or 16 amps for 2 hours. In reality batteries can sustain better low discharge rates than the rated capacity. However, battery's ability to sustain a discharge rate at its rated capacity is related to its:

a) state of charge,

b) condition, and

c) temperature.

CHARGING

During pre-flight and engine start, a large amount of current may be taken from the battery. The battery can be recharged by supplying a current in the reverse direction. To ensure the current will flow back into the battery the charging voltage must exceed the battery voltage. Typically, the electrical system supply voltage is significantly higher than the battery voltage, 28V and 24V respectively.
Batteries are quite inefficient and require approximately 40% more energy than their rated capacity to become fully charged. A 32 AH battery requires 42 AH of charge (6 amps for 7 hours).

Constant Voltage Charging

Initially, after engine start the potential difference between the charging voltage and the battery voltage is quite high so a fairly high charging current will flow to the battery. As the battery gains its charge the charging current progressively decreases because the battery voltage increases and the **potential difference between the charging supply and the battery decreases**. A battery is said to be fully charged when it draws less than 1 amp from its charging supply.

Constant voltage charging is common in light aircraft. When used in conjunction with a 'centre zero' ammeter, charging and discharging current ***to*** or ***from*** the battery can easily be interpreted.

Constant Current Charging

The charging voltage needs to be progressively increased to keep it above the battery voltage by the same amount (constant potential difference). As a battery is charged, its voltage rises considerably. Constant current charging therefore requires a dedicated battery charger which limits the charging current, initially, by reducing the charging voltage to a preset value. As the battery regains its charge, the charging voltage is increased to maintain that preset charging current for a longer period. This is a more acceptable way to recharge nickel cadmium batteries as these are temperature sensitive. However, nickel cadmium batteries should be matched with specific charging and monitoring equipment.

LEAD ACID BATTERIES

These common devices use cells containing positive plates of lead peroxide, negative plates of porous lead and an electrolyte that is a mixture of sulphuric acid and water. A fully charged 'lead acid' battery will support about 2.1 volts per cell at an electrolyte specific gravity of 1.275. Twelve cells are used to make a 24V Battery.

The greatest demand on a battery is made during the start cycle, perhaps 100amps of current will flow for 20-30 seconds. Some demand is made during the pre-flight phase, but during normal flight the battery is not used and should be completely recharged within the first hour of flight.

If the alternator was to fail or excessive current demands were made, the battery would provide all or some of the required current and some battery discharge would occur. If the load (current flow) was not reduced, the battery would continue to discharge, its voltage would decrease and it would become unusable.

As chemical action allows the electron flow from the battery, lead sulphate forms on the plates of each cell and the internal resistance of the battery increases. Eventually the current output and the voltage output decrease to an unusable level. The specific gravity of the electrolyte decreases to about 1.125 and the battery is considered completely discharged or FLAT. During recharging, the chemical action is reversed and the sulphate on the plates returns to solution. Some water is lost during this process, as the current causes some decomposition to hydrogen and oxygen.

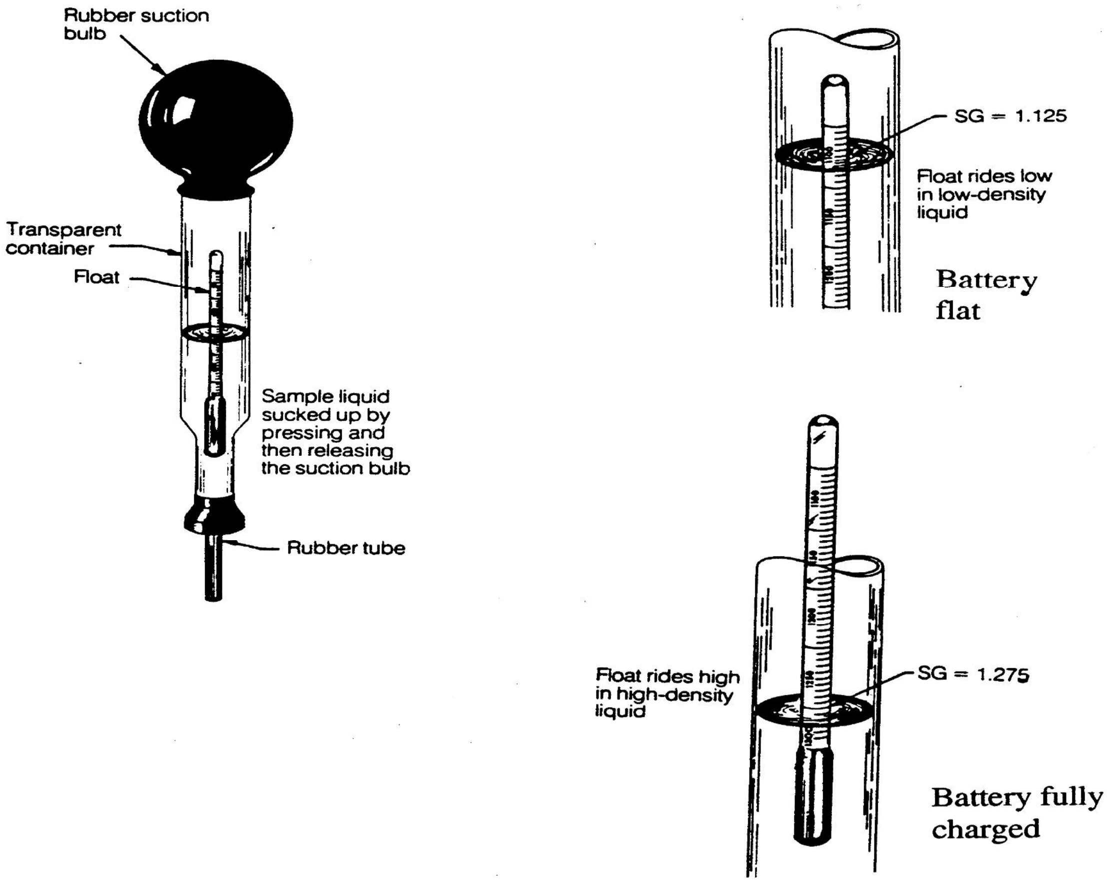
Hydrogen will always be vented from a charging battery and can form an explosive mixture as it mixes with the air. Every precaution must be taken to prevent a naked flame or a spark occurring near a battery. A battery should be kept fully charged as this reduces the risk of ‘sulphate hardening’ on the plates that will impair battery performance and shorten battery life. Gassing is also reduced if the battery is kept fully charged so the risk of an explosion or fire is reduced. During charging, electrons are returned to the battery, this reverses the chemical process and the specific gravity increases to about 1.275 when fully charged.

Neutralizing Agent

The acid in Lead Acid batteries is Sulphuric Acid (H_2SO_4), and is extremely corrosive. Should an acid spill occur on or near an aircraft the risk of serious damage to the aircraft is high. Considerable risk to skin and clothing of personnel is also likely. Diluting the acid with water is not always the best option as it might just spread the damage over a larger area. The immediate application of **Sodium Bicarbonate** (Bicarbonate of Soda or common Baking Powder) $NaHCO_3$, will neutralize the acid and minimize the adverse affects. The area should then be washed down thoroughly with clean water and dried.

SPECIFIC GRAVITY AND LOAD TESTS

Specific gravity tests using an 'hydrometer' measure the chemical condition of the battery. For a lead acid battery this is also a fair indication of the state of charge of the battery.



HYDROMETER

The LOAD TEST is probably the best performance related test on a battery. The no load voltage of a 24 volt lead acid battery may be as high as 26 volts. A voltmeter with a shunt resistor (load resistor) can be used to cause a high current flow for a few seconds. If the battery is fully charged and in good condition its voltage should not drop below 21 volts. A similar check can be carried out during pre-flight using the aircraft voltmeter and the landing lights as the load. If the voltage drops to less than twenty one volts it is unlikely the battery will be able to supply the amount of current required for starting.

Initial Charge after Start

Current flow to the battery is usually quite high for a period of 5 to 10 minutes after start after which it reduces. The pilot must be aware that this is normal, but that it is possible, if the battery is faulty or over heated, to accept a high charge for a longer period causing overheating and battery failure. Should this high charging current persist for more than ten minutes, the battery should be disconnected.

NICKEL CADMIUM BATTERIES (NICAD)

Nickel Cadmium batteries have cells where the positive plate is coated with nickel hydroxide, the negative plate is primarily of cadmium and the electrolyte is potassium hydroxide and distilled water.

The specific gravity of a NICAD is about 1.30 at 25°C and unlike the lead acid battery, the specific gravity does **not** change with the state of charge of the cell.

The chemistry and performance of the nickel cadmium battery is different from lead acid batteries. The operation and precautions have many similarities. Hydrogen is given off during the charging process, so the risk of fire or explosion is still a possibility, hence battery compartment venting is again important. The chemical action causes the plates to absorb electrolyte during discharge and release it during charge and consequently the liquid level change (decrease during discharge) is noticeable. As with lead acid batteries NICADS lose their charge fairly quickly in hot conditions.

An advantage of a NICAD when compared to a lead acid battery is that during use, and discharging, its voltage for any given load is more constant for a much longer time. Unfortunately, the NICAD is more expensive and is far more susceptible to overheating problems, known as thermal runaway, than lead acid types.

Thermal runaway is an uncontrolled rise in battery temperature which permits an increased current flow during charging. The increased current flow causes further heating which again causes a further increase in current flow. Eventually, after 5 to 10 minutes, it leads to electrolyte boiling, violent gassing and possibly a fire, as hydrogen is also given off. When NICADS are fitted, a constant current charging device and a battery temperature gauge are usually provided.

Neutralizing Agent

Nickel Cadmium batteries contain the alkaline Potassium Hydroxide (KOH) which is a very corrosive chemical. Should a spill occur, Boric Acid Solution (H_3BO_3) is an effective neutralizing agent. The area of the spill should be covered with Boric Acid solution as soon as possible. This done, the area should be cleaned up then washed down with generous amounts of clean water. If a boric acid solution was not available, vinegar or lemon juice may be used to neutralize the alkaline.

NICAD Batteries Operation

On large aircraft the NICAD batteries are computer monitored to reduce the risk and manage the potential thermal problems. In small and medium aircraft which are fitted with NICAD, the monitoring and management is usually the duty of the pilot.

Sensing systems include temperature sensing, where the pilot can see the battery temperature and is alerted by a 'BATT TEMP' light at about 80°C. Current monitoring alerts the pilot, should the charge exceed a preset level. Voltage sensing, compares the potential of each cell and alerts the pilot should differences exceed preset acceptable tolerances.

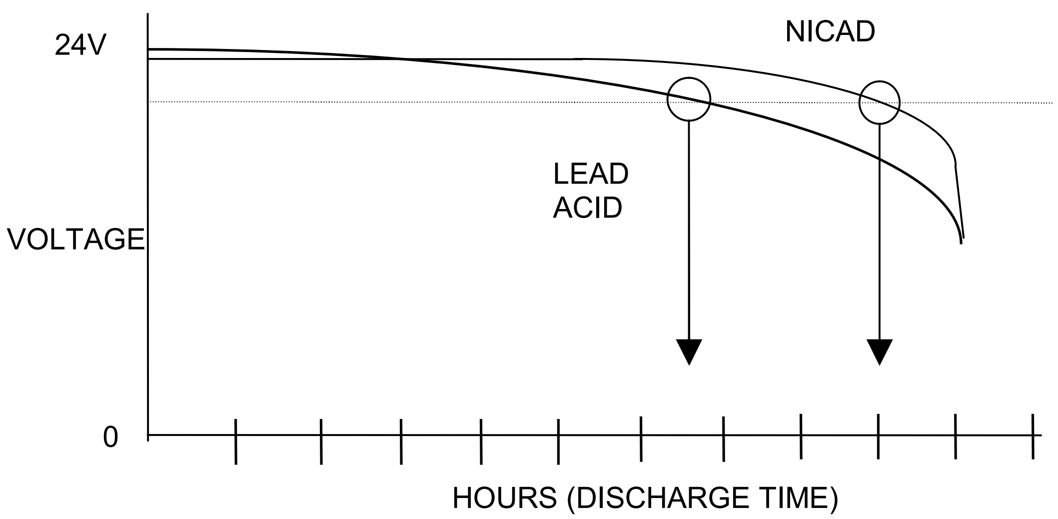
Charging

The constant voltage charging principle is a poor option for NICADS. Constant current is acceptable, but a purpose built NICAD Charging Control Unit (CRU) is preferred. NICAD performance is improved, should significant discharge occur before recharging is initiated.

The state of charge of a NICAD is difficult to determine because the specific gravity does not change and the output voltage remains remarkably constant during use. The only sure way to know the state of charge is to record how many ampere-hours of charge have been applied.

LEAD ACID verses NICKEL CADMIUM

Comparing batteries of similar capacity, the nickel cadmium battery is more expensive than the lead acid type and also has an increased risk of thermal overheating problems. The NICAD will maintain a constant output voltage and is smaller and much lighter than a similar capacity lead acid battery.



DISCHARGE PERFORMANCES

BATTERIES in GENERAL

Over Charging

All batteries vent gasses during their charging cycle. If a battery is overcharged, a large amount of moisture is carried away in the venting and cooling process. This loss through gassing and normal evaporation depletes the electrolyte level in the battery, reducing surface contact area with the plates. Eventually the ability of the battery to supply current will be reduced to such an extent that the normal operation of the battery will no longer be possible.

Normal aircraft servicing schedules should preclude this type of problem. Lead acid cells can be topped up with clean distilled or de-mineralized water. Extra care must be taken with a NICAD because the electrolyte level decreases with discharge. Should the battery be topped up above the recommended level while discharged, electrolyte overflow and spillage is likely to occur during recharging.

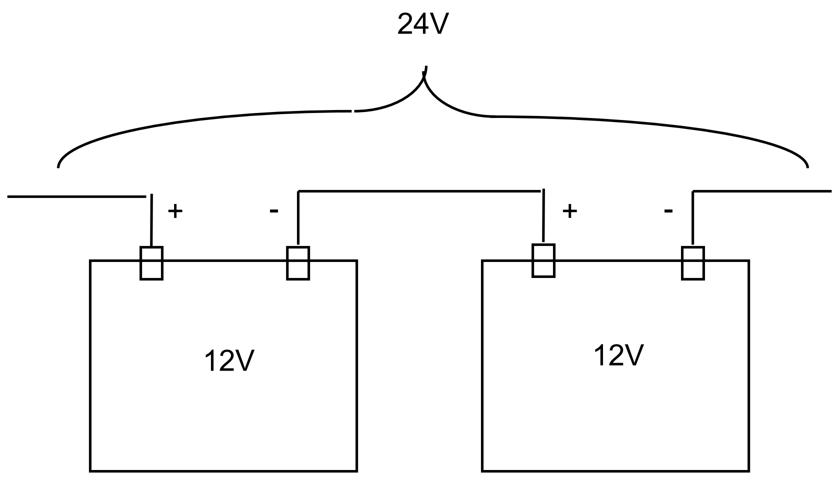
Storage of Batteries

Batteries that are correctly serviced and used regularly within their normal operating range, will have a long and useful life. Should a battery not be required for a month or so, it should be serviced, and fully charged. It should be checked and recharged periodically. In the case of a NICAD it should be fully discharged before recharging.

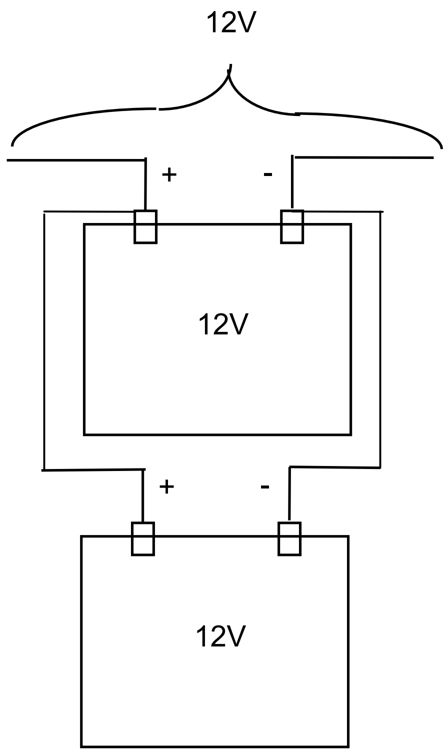
Storing a battery will reduce its useful operational life. Correct storage will keep this life reduction to a minimum. A battery must never be left discharged or in a low state of charge for more than a few days or the adverse affects on the battery's ability to then accept a charge are great. The chemical compound transfer to the plates of each cell during discharge tends to harden. Any attempt now to recharge to battery is met with increased resistance and the complete reversal of the chemical reaction will not be possible.

Interconnecting Batteries

Batteries are direct current power sources (storage devices) which can be connected in series or parallel to suit particular circuits.



SERIES CONNECTED 24V (capacity, same as smallest capacity battery)



PARALLEL CONNECTED 12V (capacity, sum of both batteries).

There are two important conditions which must be met to effectively connect batteries in parallel. Each battery's **voltage** and **internal resistance** must be the same. Should these conditions not be met, the voltage output and current available will be lower than expected, perhaps even to the point of being unusable.

Caution *:* *(1)* *Acid and alkaline electrolytes are dangerous to your eyes and skin. Any contact should be immediately washed off with water. A sulphuric acid spill can be quickly neutralized by applying bicarbonate of soda (common Baking Soda). The alkaline (potassium hydroxide) from a NICAD can be neutralized with a boric acid solution.*

(2) *All aircraft batteries release hydrogen and oxygen gasses during the charging process. Hydrogen is highly flammable. Do not use naked flames or cause sparks anywhere near charging batteries.*

(3) *When installing a battery, connect the negative terminal last. When removing a battery, disconnect the negative terminal first. This reduces the chance of causing a short to the frame which would result in arcing.*