EO 40-5A-2

ROYAL CANADIAN AIR FORCE

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

AIRCRAFT STORAGE BATTERIES

LEAD ACID

(This EO replaces EO 40-5A-2 dated 24 Mar 50)

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

14 JAN 52

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PART 1

INTRODUCTION

1 These instructions are issued as the basic Engineering Order for the Equipment involved.

2 Instructions contained in this EO apply to all Lead Acid Storage Batteries used in RCAF Equipment.

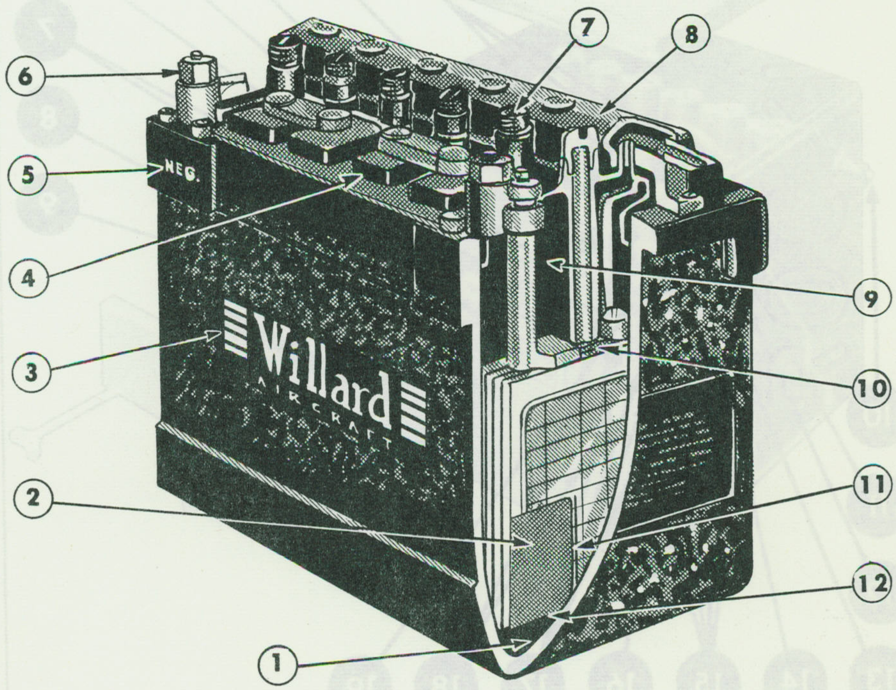

Figure 1-1 - Unshielded Aircraft Storage Battery

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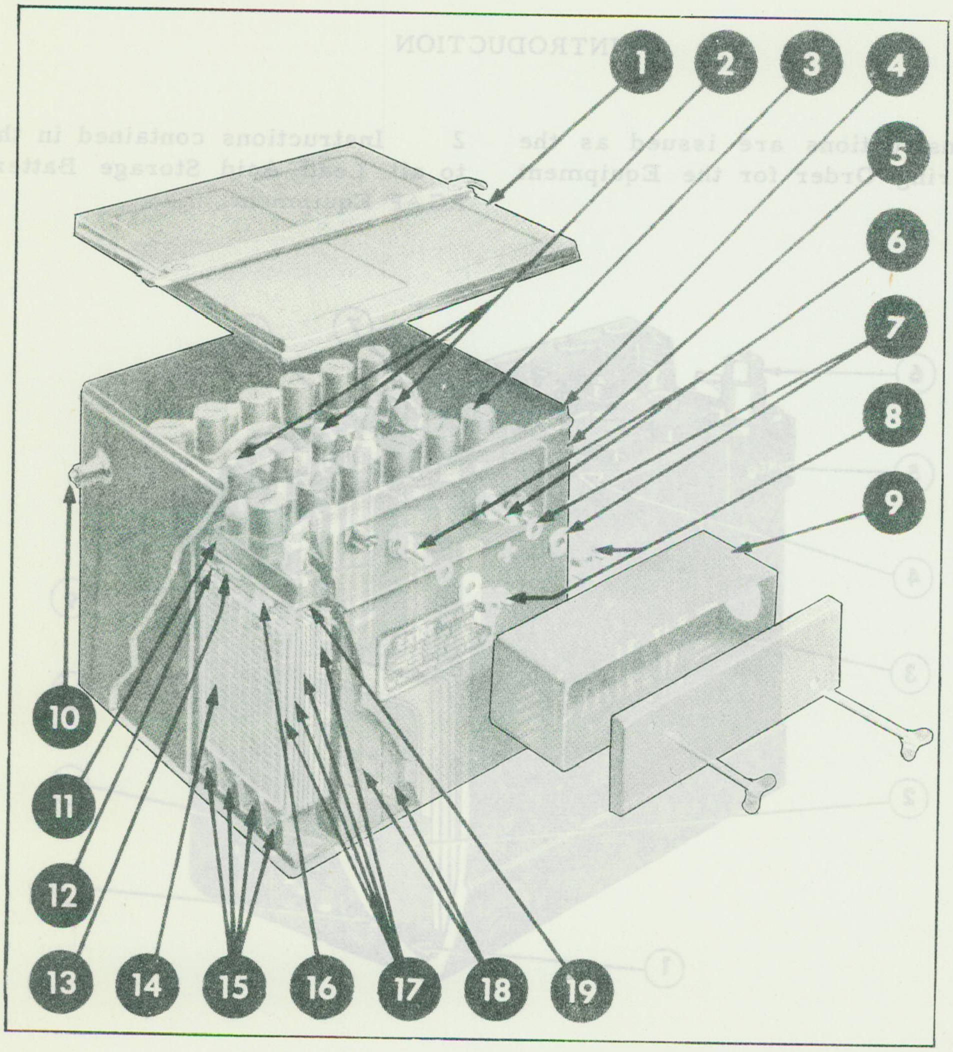

Figure 1-2 - Typical Aircraft Storage Battery (Shielded Type)

1. Container Cover
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PART 2

DESCRIPTION

GENERAL DESCRIPTION

1 A lead acid storage battery is an electrochemical device for storing energy in chemical form so that it can be released as electricity.

DETAILED DESCRIPTION

2 Fundamentally, there is no difference in the operation of aircraft and automobile batteries. Both have the same type of lead plates immersed in a solution of sulphuric acid and water and operate on the same basic principles. The aircraft battery, however requires a great deal more care because of the unusual conditions under which it operates.

3 Aircraft batteries are specially built so that they will not leak when the aircraft is flying upside down or during aerobatic manoeuvres.

4 The complete battery is usually shielded by enclosing in a grounded, metal covered housing (see fig. 1-2). This completely shields the battery and its terminal connections, preventing radio interference from the electrical system being radiated by the battery or any unshielded wiring. Some aircraft batteries however are of the unshielded type as shown in Figure 1-1.

5 Because of increasing requirements for electrical power in aircraft, higher voltages are being used than on automobiles, usually 12 or 24 volts. This permits the use of smaller wires for transmitting a given amount of power.

6 To save weight, aircraft batteries have exceedingly small capacity, being only about one-third that of the average automobile battery. Consequently, they must be used and serviced with much greater care. For example if connected to a charging source, only a fraction of a volt above normal, an aircraft battery will overcharge considerably in a short time. This overcharging causes the formation of more hydrogen and oxygen gas than can enter into chemical reaction with the plates. As the excess gas is liberated at the surface of the plates, it causes the solution to appear as though it was boiling. The mixture of gases given off during overcharging is highly explosive, so that open flames or sparks should be kept away from the battery at such times. The gases liberated during overcharging are formed by the breaking down of water in the electrolyte. This action causes an excessive loss of water which makes frequent addition necessary. The sulphuric acid is not affected in any way by this process.

7 The battery must be kept fully charged at all times in order to retain sufficient energy to function properly after starting the engine.

CONSTRUCTION
(see fig. 1-1 and 1-2)

Chemicals Used

8 There are four essential chemicals in a battery:-

Essential Chemicals	Where found in Cells
Lead peroxide	Positive Plates
Sulphuric Acid	Electrolyte
Water	Electrolyte
Lead	Negative Plates

Plates

9 The plates used in aircraft storage batteries consist of an electrically conducting grid framework in the meshes of which the active materials are incorporated by electrochemical processes. These grids serve to conduct the current to and from the active materials of the positive and negative plates. An alloy consisting of lead and antimony is used for the grids which have a heavy outside border with substantial vertical bars and light weight horizontal bars. These serve as an interlocking arrangement to hold the active material firmly in place (see fig. 2-1). The small percentage of antimony (about 10%) is to harden the lead, in much the same manner that a small percentage of carbon or nickel

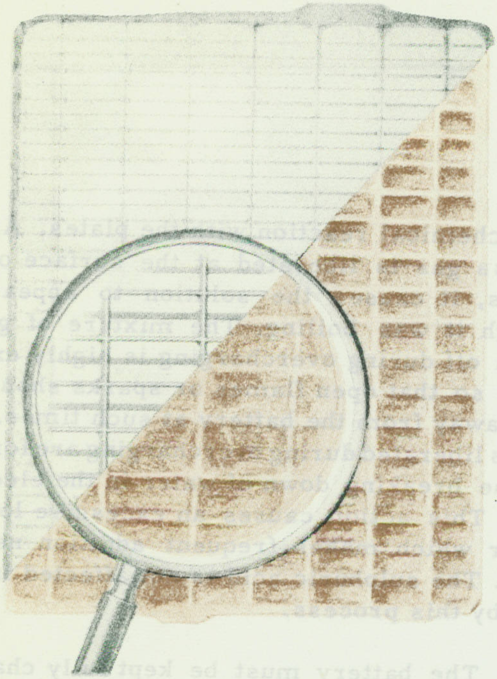


Figure 2-1 - Grid with Half Active Material Removed to Show Grid Construction

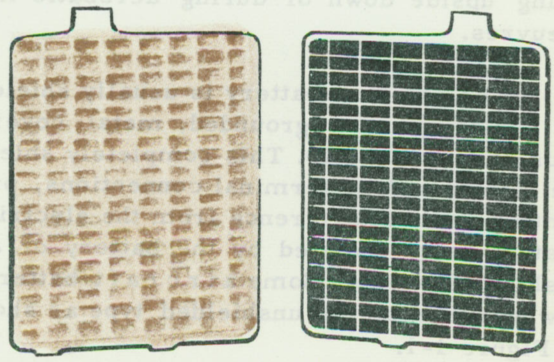
hardens steel. This makes the grids stronger and harder and less susceptible to chemical action during normal charge and discharge as the antimony in the lead prevents rapid oxidation of the grid. The presence of antimony in the lead also facilitates casting the fine detail of the wire structure of the grids so that the battery weight can be kept to a minimum. However, when subjected to continued overcharging the positive grids are attacked chemically by the continued formation of oxygen on them. They then gradually change into active material, lose their strength, and the plates crumble and fall apart, which quickly ends the useful life of the battery.

10 Positive plates are filled with lead peroxide active material. This is dark brown chrystalline material which consists of very small grains or particles, disposed so as to provide a high degree of porosity in order to allow the electrolyte to penetrate the plate freely. The lead peroxide is a paste made up of a mixture of commercial red lead and diluted sulphuric acid (see fig. 2-2).

(a) Negative plates are of basically the same construction as positive plates but are filled with porous lead paste made up of yellow lead oxide and diluted sulphuric acid and are a light grey in colour (see fig. 2-2).

(b) The active material also contains so-called "expanders" included to prevent the sponge lead from contracting and reverting to the solid inactive state during the life of the battery.

11 The plates are dried after pasting by a special process which hardens the mixture. They are then given an electrochemical treatment or forming process, consisting of a number of cycles of charge and discharge. The treatment converts the lead compounds into active material. In this forming process, a large number of positive plates are connected to the positive terminal of a charger and an equal number of negative plates are connected to the negative terminal. These two groups are then immersed in a diluted solution of sulphuric acid and water and charged slowly for a long period. After charging, the plates are separated, washed and dried by a special process, and assembled into groups.



POSITIVE PLATE NEGATIVE PLATE

Figure 2-2 - Normal Storage Battery Plates

Separators

12 The positive and negative plates must be electrically insulated or separated from each other so they cannot touch. Thin porous sheets of insulating material called "separators" are inserted between each positive and negative plate for this purpose (see fig. 2-3). Separators are usually made of micro porous rubber or wood to permit easy flow of electrolyte through them. They have a grooved face next to the positive plate which permits free circulation of the electrolyte between the plates. This also allows for the normal shedding of active material from the positive plates, to fall to the

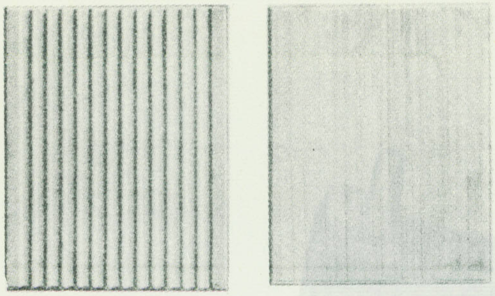


Figure 2-3 - Plate Separators

sediment chamber at the bottom of the cell where it accumulates. This shedding takes place much more rapidly on the positive plates which wear out much faster than the negative plates. The ribs also minimize the area of contact with the positive plate which has a highly oxidizing effect on wood separators.

13 Glass fibre retaining mats are sometimes provided between the positive plate and separator to retard the loss of active material from the plate and to protect the separator from oxidation.

Elements

14 Since the capacity of a single plate is relatively small, a number of plates are grouped together to give the required capacity, (see fig. 2-4). Each plate has an extension, or lug with which it is connected to a strap (or bridge) by lead burning. Positive plates connected to a strap form a positive group and negative plates with a connecting strap form a negative group. These groups assembled with separators inserted between the positive and negative plates are called an "Element" of which one is used per cell.

(a) The plates are arranged alternately positive and negative with all the positive plates connected through a strap to a post at one side of cell and all the negative plates are connected through a strap to the negative post on the opposite side of the cell.

(b) Figure 2-5 shows an exploded view which shows the relationship of the various elements. A negative group always has one more plate than the associated positive group. Thus each positive plate has a negative plate on each side. This is to equalize the effect of expansion of the active material on the positive plates during discharge. It minimizes the buckling which would occur if expansion took place on only one side of a positive plate. It also provides the excess negative plate area and material required for good battery performance. The corner of the plates are rounded and the edges beveled to prevent damage to the separators.

15 There may be any desired number or size of plates used in an element, depending upon how much energy is to be stored. The greater the number of plates used per element the higher will be the voltage during discharge at high rates and low temperatures. However the open circuit voltage of a fully charged cell, no matter what the size of the cell or the number of plates in the element, is only a little over 2 volts. The battery voltage is the sum of the voltage of its cells.

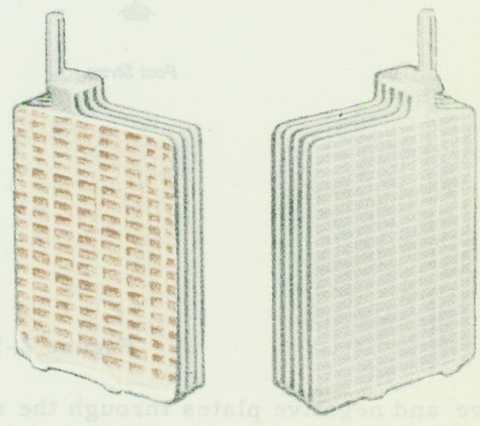


Figure 2-4 - Plate Groups

Cells

16 A cell is an assembly consisting of a positive and negative group of plates immersed in a solution of sulphuric acid and water.

Electrolyte

17 The sponge lead and lead peroxide which fill the respective plates are referred to as the "active" materials of the battery. These materials cannot become active until they are covered by a water solution of sulphuric acid called "electrolyte". The sulphuric acid of the electrolyte supplies the sulphate which combines with each of the plate materials and releases the electrical energy. The sulphuric acid electrolyte is also the carrier for the electric current inside the battery between the

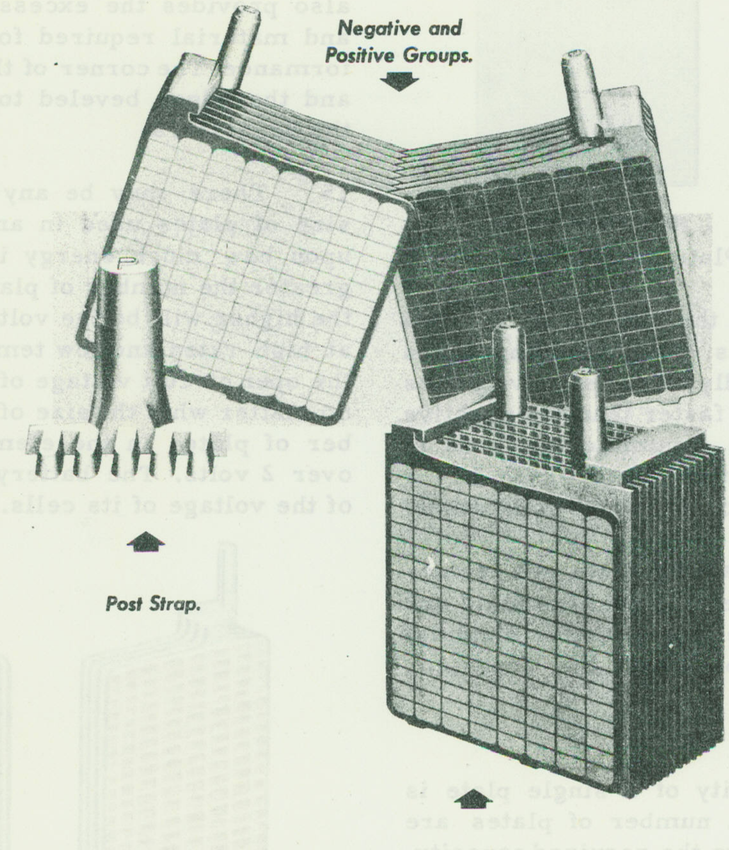


Figure 2-5 - Assembled Element

positive and negative plates through the separators. The antimony-lead alloy of the grid framework of the plates carries the electric current to and from the active materials to the outside terminals. The electrolyte of a fully charged battery usually contains about 38% sulphuric acid by weight or about 27% by volume. This corresponds to a specific gravity of 1.285.

Containers

18 The containers for aircraft batteries are of the one piece molded type and are usually made of hard rubber or bituminous composition. These must withstand extremes of heat and cold as well as mechanical shock and must be resistant to the absorption of acid. Integrally shielded batteries have the containers moulded in a metal case with gasketed metal cover. A hole is usually provided at each end for attaching rubber tubing for ventilation and drainage. In the bottom of each cell compartment are molded narrow element rests or "bridges" on which the element sits. The plates are usually provided with stub feet on their bottom edges which sit on alternative rests for positive and negative plates. This minimizes the danger of short circuits due to sediment which falls from the plates onto the bridges where the plates sit and provides a reservoir for sediment between the bridges, (see fig. 2-6).

Cell Covers and Vent Plugs

19 The covers are usually molded hard rubber and provide an acid tight seal for the two terminal posts which protrude through the cover, (see fig. 2-7). Covers also provide a vent opening in which various constructions and devices are provided to prevent overfilling when rewatering the battery. Vent plugs of special design co-operate with the cover vent opening to baffle the gases and electrolyte splashed and sprayed against the under side of the cover, to prevent loss of acid from the

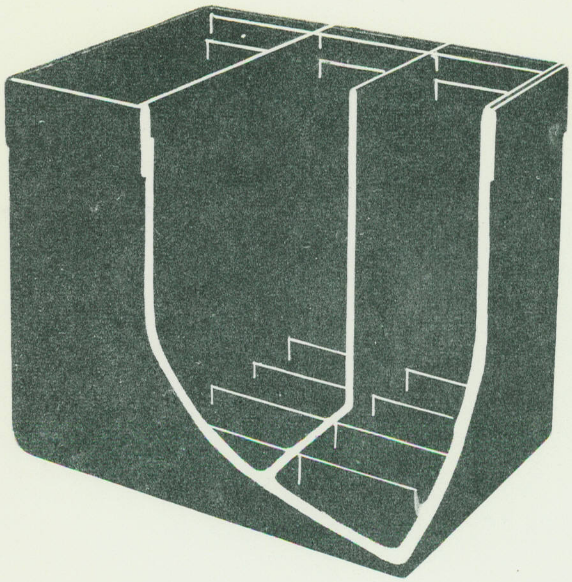


Figure 2-6 - Container Cut Away to Show Partitions and Element Rests

cell, one type is shown in Figure 2-8. Spillage and leakage of electrolyte when manoeuvring or flying upside down is prevented by the design of the vent cap or opening and deep design containers. Some batteries are provided with solid plugs and are vented through a separate vent hole into a vent manifold.

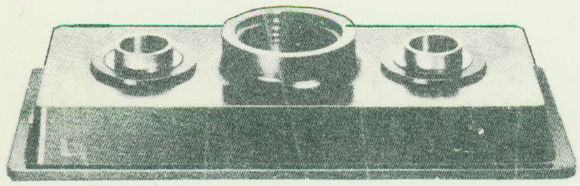


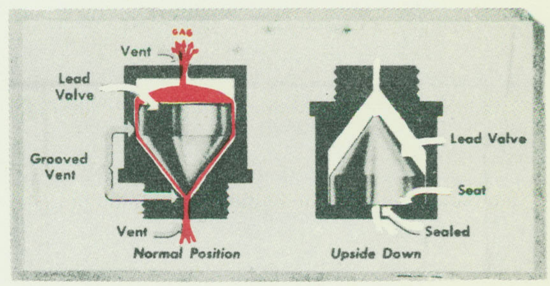
Figure 2-7 - Cell Cover

Cell Connectors

20 In order to connect the cells of a battery in series to give the required voltage, the elements are placed in each cell so that the negative terminal of one cell will be adjacent to the positive terminal of the next cell and so on throughout the battery. Cell connectors are placed over the protruding terminal posts and lead burned to them to connect the cells in series. Connectors must be heavy enough to carry the high current required for starting without overheating, (see fig. 2-9).

Sealing Compound

21 Sealing compounds are used to form an acid tight joint between covers and containers. They are blends of specially processed bituminous substances having resistance to flow at high summer temperatures and resistance to cracking at low winter temperatures.



1. Vent
2. Lead Valve
3. Grooved Vent
4. Vent
5. Lead Valve
6. Seat
7. Seated

Figure 2-8 - Non-Leakable Vent-Cap

Terminals

22 Aircraft battery terminals are usually of a threaded design on which the terminal end of cable is secured by a nut or wing nut. Automobile type batteries are provided with tapered posts, the positive post being slightly larger than the negative post and the cable is attached by a terminal clamp.

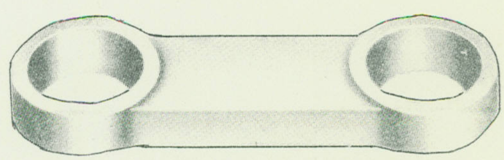


Figure 2-9 - Cell Connector

PART 3

THEORY OF OPERATION

CONVERSION OF ENERGY

1 A law of physics states that: Energy may neither be created or destroyed but may be changed from one form to another. The battery is an example of how this law works. Electrical energy put into the battery by a charging devise is changed into chemical energy. The battery stores this energy until it is needed. The chemical energy then changes back to electrical energy when needed by connecting the battery to a starter, lights, radio etc.

2 If any two dissimilar conducting elements are immersed so they cannot touch each other, in a solution which can attach them chemically (diluted salt, alkali or acid solutions) an electrical pressure or voltage will be developed. If wires from the two elements are connected outside the solution, current or amperes will flow through them. At the same time, a chemical change will take place in at least one of the elements. Thus a simple battery cell may' consist of two plates of dissimilar metals separated from each other and immersed in a solution called "electrolyte".

3 Aircraft and automobile cells are usually of lead element construction with diluted sulphuric acid as explained in Part 2. When a cell is discharged by completing an external circuit, as in switching on the lights the sulphuric acid acts on both positive and negative plate active materials to form a new chemical compound called lead sulphate. The sulphate is supplied by the acid solution (electrolyte) which becomes weaker in concentration as the discharge proceeds. The amount of the acid consumed is in direct proportion to the amount of electricity used from the cell. When the acid in the electrolyte is partially used up by combining with the plates, the battery can no longer deliver electricity at a useful voltage and the battery is said to be discharged. This gradual weakening of the electrolyte in proportion to the electricity delivered is a very useful action because it allows us to use a hydrometer to measure how much unused acid remains with the water in the electrolyte and this information enables us to judge about how much electrical energy is left in the cell. This is explained in a later paragraph.

4 By passing an electric current through the battery in a direction opposite to that of the discharge, the lead sulphate is decomposed. The sulphate is expelled from the plates and returns to the electrolyte, thereby gradually restoring it to its original strength. This action frees the plate active materials of sulphate and they are restored to their original chemical condition, ready to deliver electricity again. Hydrogen and oxygen gases are given off at the negative and positive plates respectively as the plates reach the fully charged condition. This is the result of the decomposition of water by an excess of charging current not utilized by the plates.

5 Figure 3-1 shows the simple arrangement of a lead acid cell with color indicating the composition of the plates and solution. When charged the active portion of the positive plate is lead peroxide and the negative plate is pure sponge lead, both being conductors of electricity. When the cell discharges, the sulphuric acid reacts with both plates to form lead sulphate. This leaves a very weak solution of acid and water in the cell (specific gravity 1.150) since part of the acid has united with the plates. If discharge is continued the active materials on both the positive and negative plates become alike; lead sulphate. There is then, no voltage developed between them and the battery is completely discharged.

CHEMICAL REVERSIBILITY

6 The most valuable characteristic of the lead acid storage battery is its chemical reversibility. This means that unlike the dry-cell battery which must be discarded when it becomes discharged, the storage battery may have an electrical current passed through it in the direction opposite to the direction of discharge and the battery's active chemicals are

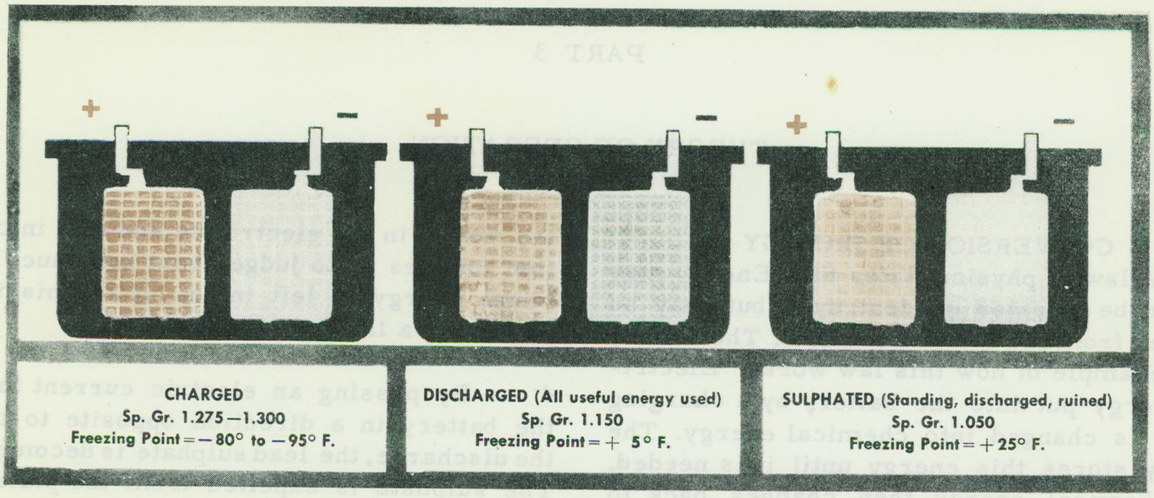


Figure 3-1 - Battery Changes Accompanying Discharge

restored to the "good as new" state. Figure 3-1 indicates what happens when a battery is discharged, or when it is charged.

SELF DISCHARGE

7 The chemical actions which produce the flow of current may continue even though no current is being withdrawn from the battery. When current is being taken from the battery the chemical action between the active materials of the plates and the sulphuric acid in the electrolyte takes place more or less rapidly, depending on the amount of current being withdrawn. However, when the battery is disconnected so that no current is being taken from it, the chemical activities continue, although at a much lower rate. This produces what is known as battery self discharge. This self discharge takes place slowly at low temperatures, but rapidly at high temperatures due to the fact that all chemical reactions are hastened by high temperatures. A partially or fully charged battery at 0°F experiences very little self discharge over a period of two or three months while a fully charged battery at 125°F may discharge itself completely within one week. This is important when allowing batteries to stand without charging particularly in hot weather.

CAPACITY

8 The capacity of a storage battery or the total amount of electrical energy a cell can deliver, depends entirely upon the amount of material available for chemical action. Therefore to increase the capacity of a battery a greater number of plates, or larger, or thicker plates must be used in each cell, with enough electrolyte to react with the active material. Conversely, as a battery sheds active material during charge and discharge, its capacity becomes gradually less. Capacity is measured in ampere hours, which is the number of amperes flowing from a battery on discharge, at a given temperature and down to a given voltage, multiplied by the time in hours the battery will deliver this current. For instance, a battery discharged at two amperes for ten hours would furnish twenty ampere hours. This might be replaced by charging at five amperes for four hours or one ampere for twenty hours.

CAPACITY RATING

9 The capacity rating of aircraft batteries is based on the maximum current which they will deliver for five hours, with a starting temperature of 80°F and a final terminal voltage of 1.75 volts per cell. This is called the battery's "Five Hour Discharge Rate" and the rated capacity of the battery is this rate multiplied by five. For instance, a battery which discharges 6.8 amperes for five hours under the above conditions is rated at 6.8 x 5 equal 34 ampere hours capacity. A second rating applied to aircraft batteries is based on the maximum current they will deliver for five minutes with a starting temperature of 80°F, and a final average terminal voltage of 1.2

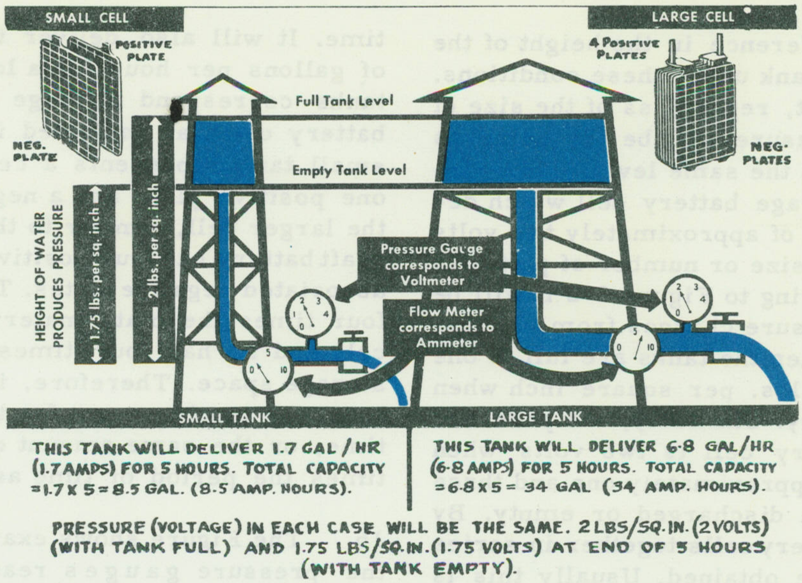


Figure 3-2 - Anology of Battery Cell Capacity

volts per cell. This rating is called the "Five Minute Discharge Rate" and is a measure of the battery's ability in normal starting.

10 The capacity of a battery appears to be lower at a high discharge rate than at a low rate. This is due to the inability of the electrolyte to distribute the charge uniformly through the plates when the surface is being discharged so rapidly. In other words, although the surface of the plate is discharged and the internal resistance of the cell thereby increased, the interior of the plates is still charged. Under these conditions, the battery will recover in a short time and discharge may be continued again. This is particularly true of a cold battery which even though fully charged, will deliver only about 5% of its capacity at a high discharge rate and will crank an engine for only a very short time. For example a thirty-four ampere hour battery at 20°F will deliver only 2.5 ampere hours at a discharge rate of one hundred and fifty amperes, which it will maintain for only three quarters of a minute. The battery is then apparently completely exhausted and will not crank the engine. However, it will recover after a few hours if allowed to stand idle.

VOLTAGE

11 The voltage of a cell on discharge is influenced very strongly by the size of the cell as well as by the state of charge at the beginning of the discharge, the rate of discharge, the electrolyte temperature, the design and condition of the battery. The average voltage of a cell on discharge while cranking, at 80°F may be about ".95 volts whereas at 0°F the voltage may be about 1.4 volts per cell. Generally speaking the larger the cell the higher will be the cranking voltage under any given set of conditions of discharge rate and temperature, but it will never be as high as the open circuit voltage of the cell.

12 In cold weather the viscosity of the acid increases and slows down diffusion of the acid into the plate pores and through the separators. This slows down the rate of the chemical action and lowers the cell voltage, limiting the output of the battery, especially at starting rates. The starting capacity is roughly proportional to the plate area.

WATER ANOLOGY

13 Battery operation may be explained rather simply by comparison to a water system.

PRESSURE

14 The tanks shown in Figure 3-2 represent storage tanks filled with water, which may be withdrawn by opening the valve at the end of the pipe. A pressure gauge is shown near the valve on each tank for reading the water pressure. This pressure depends upon the height of the tank above the ground. It will be a little greater when the tank is full than when empty

because of the difference in the height of the water level in the tank under these conditions. It will be noted that, regardless of the size of the tanks, the pressure will be the same as long as they are at the same level. This corresponds to a storage battery cell which develops a pressure of approximately two volts regardless of the size or number of plates in the cell. By referring to Figure 3-2 it will be noted that the pressure changes from two lbs. per square inch when the tanks are full to one and three quarter lbs. per square inch when the tanks are empty. Similarly, the pressure of a storage battery cell is two volts when fully charged and approximately one and three quarter volts when discharged or empty. By adding storage battery cells together in series any voltage can be obtained. Usually this is six volts (three cells) to twenty-four volts, (twelve cells). The capacity in terms of flow is not increased by the series arrangement which increases the pressure only.

CAPACITY

15 The two tanks shown in Figure 3-2 are located at the same height so that the same pressure will be read on their pressure gauges, since one tank is much larger than the other, a great deal more water may be taken from it before it must be refilled. The larger tank is thus capable of delivering a greater number of gallons per hour than the smaller tank if they are to supply water for the same period of time. It will also deliver the same number of gallons per hour for a longer time. These tanks correspond to large or small storage battery cells as indicated in the Figure. The small tank represents a cell made up of only one positive plate and a negative plate, while the larger cell, similar to that used in an aircraft battery has four positive plates with their associated negative plates. The larger cell has four times the plate material of the smaller cell and so has four times the capacity, or storage space. Therefore, it will deliver four times as much current for the same period of time, or the same amount of current for four times the period of time as the smaller cell.

16 The Figure shows examples of this with the pressure gauges reading two lbs. per square inch in both cases which corresponds to the two volts pressure developed by either the larger or smaller cell. The flow meters read four times the flow for the larger tank, which corresponds to a discharge of four times the current for a larger cell. Under these conditions, both tanks (or cells) would be emptied in the same period of time.

LOSS OF CAPACITY WITH AGE

17 The capacity of a cell depends upon the amount of useful active material on the plates. This capacity is reduced when the battery gets old because of the constant shedding of active material by the plates during normal opera-

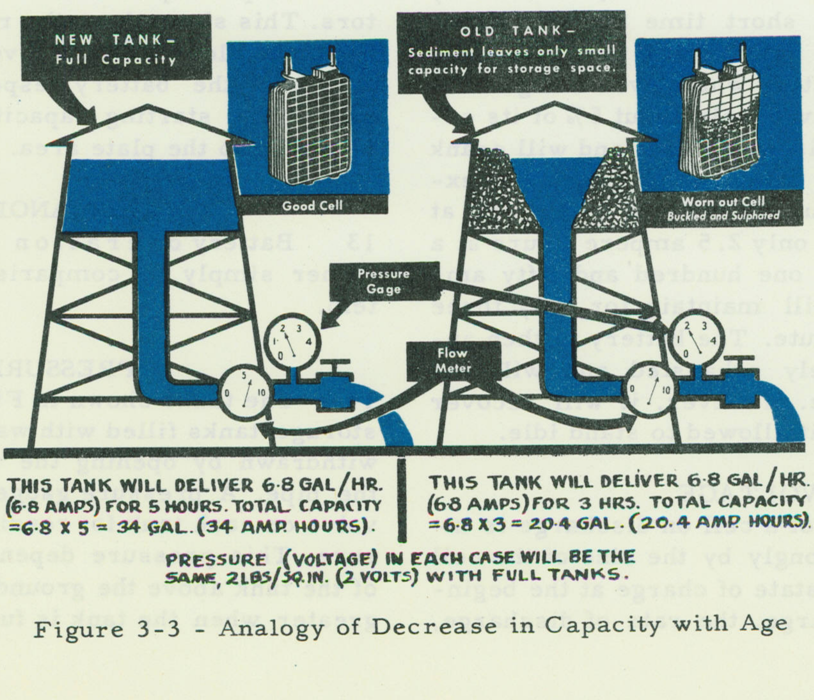
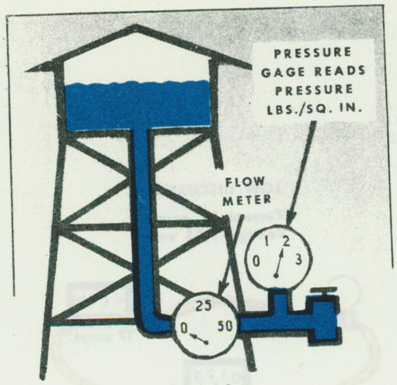
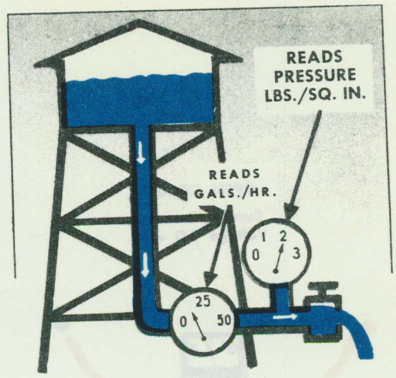


Figure 3-3 - Analogy of Decrease in Capacity with Age



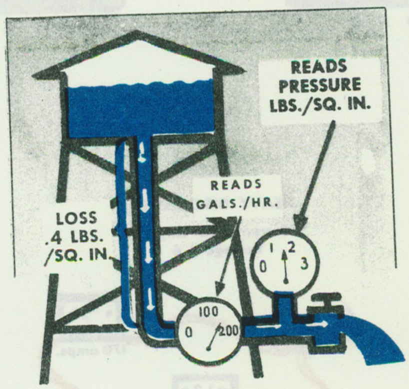
NO 1

This tank is delivering no load. Will maintain 2 lbs./sq. in. (2 volts) indefinitely unless water leaks out.



NO 2

This tank is delivering 17 gal./hour (17 amperes). Will be empty in 2 hours. Pressure (voltage) will remain practically 2 lbs./sq. in. (2 volts) until tank is empty.



NO 3

This tank is delivering 170 gal./hr. (170 amperes). Will be empty in 12 minutes. Pressure (voltage) will not remain at 2 lbs./sq. in. (2 volts) due to the resistance of the pipe to the flow through it, and loss in pressure (voltage) required to overcome this resistance.

Figure 3-4 - Analogy of Voltage Drop with High Discharge Currents.

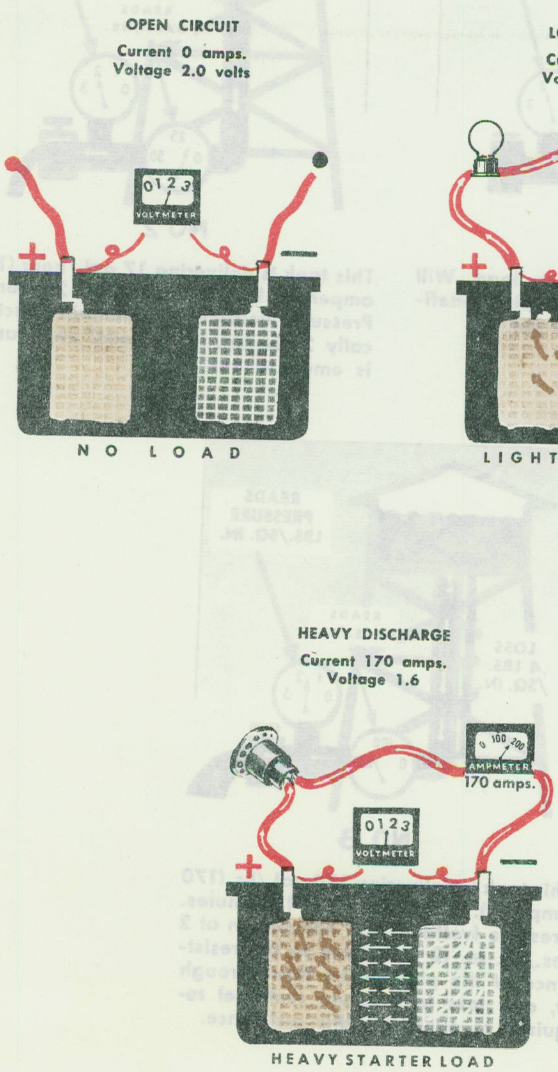


Figure 3-5 - Batteries, Nos. 1, 2 and 3

tion. If 40% of the active material has been shed from the plates or battery, it is equal to only 60% of its original size. Thus what was once a thirty-four ampere hour battery becomes a 20.4 ampere hour battery, and so will store only 60% as much current as when battery was new. This corresponds to the condition in Figure 3-3. The new tank has a capacity of thirty-four gallons corresponding to the new cell having a capacity of thirty-four ampere hours. The old tank is shown partially filled with sediment which leaves a much smaller space for the storage of water (60% in this case or 20.4 gallons). This corresponds to the worn out cell which has shed 40% of its active material and so has only 60% as much storage capacity or active material left (20.4 ampere hours in this case). The pressure or voltage in each case will be the same, two lbs. per square inch for the water tanks or two volts for the cells.

PRESSURE DROP

18 Figure shows an anology for voltage drop which is most noticeable with high discharge currents. The three tanks shown in Figure 3-4 are all of the same height, so that the pressure developed by the height of water in tanks would be the same in each case. The first tank has the valve closed completely so that no water is being withdrawn, and the pressure gauge reads two lbs. per square inch. This pressure will be maintained indefinitely unless there is leakage from the tank. If leakage occurs, the tank will eventually become empty and the pressure will then drop. The second tank shows the valve slightly opened and the flow meter indicates a flow of seventeen gallons per hour which would continue for two hours, as the full tank holds thirty-four gallons. The pressure will remain practically two lbs. per square inch until the tank is empty, although it will actually be slightly under this because of the slight amount of friction as the water flows through the pipe. The third tank valve is shown nearly wide open, discharging one hundred and seventy gallons per hour, shown by the flow of the meter, which would empty the tank in twelve minutes. With water flowing through the pipe at this high rate, a great deal of friction or resistance to flow will be encountered through the pipe so the pressure gauge may read only 1.6 lbs. per square inch. The height of water in the tank is the same as in the other cases, so that the pressure from this height would be two lbs. per square inch. The difference between the two lbs. pressure and the 1.6 lb. pressure indicated on the gauge is the loss of pressure due to the resistance of the pipe to the flow of water through it.

19 The foregoing tank Figure No 1 corresponds to a battery cell with no load connected to it, as shown in Figure 3-5 battery No 1 in which case the voltmeter reads two volts. This voltage will be maintained indefinitely if there is no leakage. However as explained later, there is a small amount of leakage which occurs within the cell which increases at high temperature. Thus a battery will eventually become discharged, due to this leakage, even though no load is connected. Foregoing Figure 3-4, No 2 corresponds to the battery shown in Figure 3-5 No 2 discharging seventeen amperes through a load such as lights only on an aircraft, with radio, lights, pumps etc. turned off. The battery will deliver this load for approximately two hours, as its capacity when full is thirty-four ampere-hours. The voltage of the battery under these conditions is measured by the voltmeter and would be approximately two volts, although actually it will be slightly under this due to the resistance to the flow of the current through the plates and solution in the battery. This resistance is usually neglected for light loads. Foregoing Figure 3-4 tank No 3 in which case the loss would be four lbs. per square inch, the useful pressure at the valve would be only 1.6 lbs. per square inch. This corresponds to Figure 3-5 battery No 3 where the battery is shown with a heavy starter current being withdrawn from the battery which would continue but for a few minutes until the battery was discharged. The voltmeter reads approximately 1.6 volts at the battery terminals under these conditions. Since the voltage of a charged battery is two volts the difference between the two volts and the 1.6 volts shown on the voltmeter represents a loss, or voltage drop, of 4 volts caused by the resistance to the flow of current through the plates and solution within the battery so that the useful voltage is only 1.6 volts.

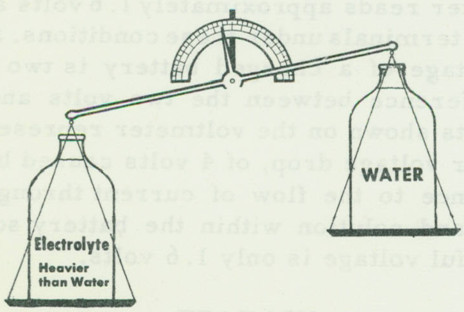
VOLTAGE

20 The open circuit voltage of a cell depends upon the material from which the plates are made and is not affected by the size or number of plates in the cell. Since the composition of the plates in a storage battery changes as it

is discharged, the voltage also changes. The open circuit voltage of a fully charged storage battery is approximately 2.2 volts per cell when first removed from the charging line with no current being drawn from it. This soon drops to about 2.0 volts at a low discharge rate and remains near that point until the battery is practically discharged, after which its voltage drops rapidly. This variation in terminal voltage is caused by two things. One is the voltage produced by the chemical action in the cell, and the other, the voltage drop caused by current flowing through the internal resistance of the cell. The voltage produced by the chemical action decreases as the cell becomes discharged. The voltage drop due to current flowing through the internal resistance varies with the current flowing. The open circuit, or no-load terminal voltage is the same as that produced by the cell's chemical action. However, when a load is turned on, such as lights, radio etc., current flows through the circuit and every part of that circuit tends to oppose or resist the flow of current through it. The greater the current flowing, the greater will be the opposition. This opposition may be expressed in volts and must be substracted from the no-load voltage of the cell to obtain its terminal voltage under load. Thus, the greater the current flowing, the lower will be the terminal voltage of the cell.

VOLTAGE DROP

21 To fully understand this voltage drop, it is necessary to realize that the current flowing from a battery through an external load must complete its circuit back through the battery. Therefore, this same current actually



Electrolyte is heavier than water. When it is 1.28 times as heavy, it is said to be "1.280 Specific Gravity".

Figure 3-6

flows from one group of plates, through the electrolyte within the battery to the other group as well as through the plates themselves. Thus the framework of the plates, and the electrolyte both offer resistance to the flow of this current. Although small, so that it may be neglected for small loads, this resistance becomes a recognizable factor when dealing with heavy currents required for starting motors, gun turrets, inverters etc. Upon charge, the current is flowing in the reverse direction so that this internal resistance causes a slight increase in the cell's voltage. This accounts to some extent for the slightly higher voltage of a battery when it is on charge.

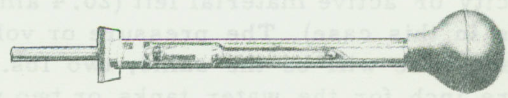


Figure 3-7 - Hydrometer

AGE

22 Age affects the voltage of a battery on charge and discharge. This is due to the gradual loss of capacity during its life, with an accompanying increase in internal resistance. This is indicated by low voltage on discharge.

TEMPERATURE

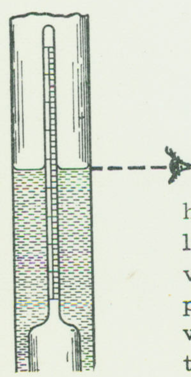
23 The effect of temperature on a battery is a lowering of its internal resistance at higher temperatures and a marked increase in its internal resistance at lower temperatures. Consequently, at high temperatures a lower voltage is required to charge it (only about 2.2 volts per cell at 110°F). At lower temperatures, a much higher voltage is required (about 2.8 volts per cell at 0°F). A battery is not as efficient in cold weather and will deliver less current than normal because of its greater internal resistance. Also its terminal voltage will be lower due to the greater loss within the battery at low temperatures.

ELECTROLYTE SPECIFIC GRAVITY

24 Let us suppose we have a simple balance scale Figure 3-6. On one side we put exactly one pint of water. On the other side we put exactly one pint of battery electrolyte (solution of sulphuric acid in water). The scale would go down on the electrolyte side indicating that the electrolyte is heavier than the pure water.

The electrolyte in a fully charged battery is usually 1.28 times as heavy as an equal volume of pure water when both liquids are at the same temperature. The battery electrolyte would therefore be described as having a "Specific Gravity of 1.280" meaning that its weight is 1.280 times the weight of pure water. When the battery discharges, the sulphuric acid in the electrolyte combines chemically with the plates and the remaining electrolyte becomes lighter in weight. By determining the relative weight of the electrolyte we can tell how much acid has combined with the plates and therefore estimate how much electrical energy is still left in the battery. But actual weighing of the electrolyte would be inconvenient, so we use instead an instrument called a Hydrometer, Figure 3-7. This consists of a glass barrel and bulb syringe for sucking up a sample of the electrolyte to float an enclosed glass hydrometer calibrated to read in terms of Specific Gravity. The depth to which the float sinks in the liquid indicates the relative weight of the liquid compared to water and gives us a measure of the specific gravity of the liquid. The hydrometer floats low in the liquid if the specific gravity is low and it floats high in the liquid if the specific gravity is high. The hydrometer float is made of glass and is equipped with a paper scale built inside the hydrometer with marks on it which must be read on a level even with the liquid surface, and this reading indicates the specific gravity of the liquid.

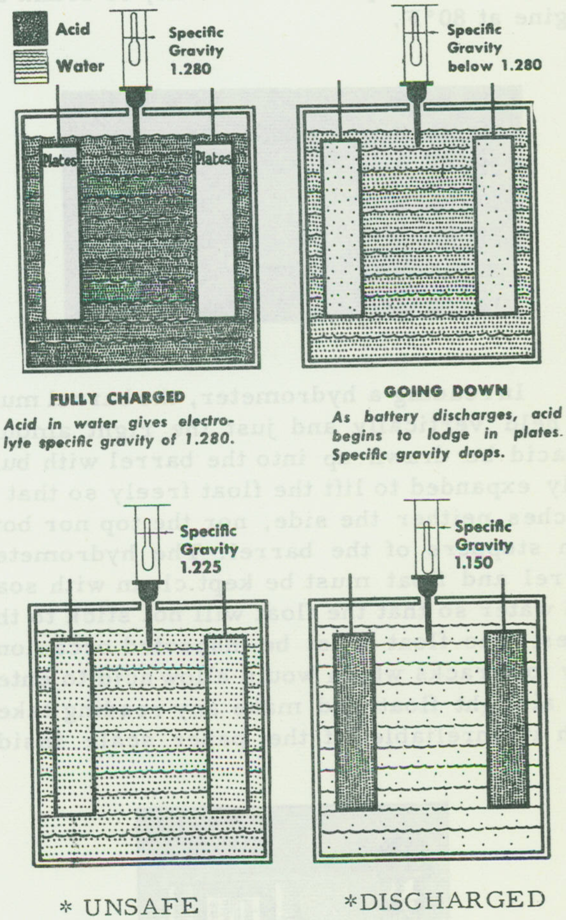
25 Figure 3-8A graphically illustrates the relationship between specific gravity readings and the combination of the acid with the plates for various states of charge. Note the distribution of the acid indicated by the small black dots. Also note the corresponding height of the hydrometer float for each condition.



Correct method of reading hydrometer. Eye on level with liquid surface. Disregard curvature of liquid against glass parts. Do not tilt hydrometer while reading - keep float vertical.

Figure 3-8

26 A hydrometer of the syringe type Figure 3-7 used to measure the specific gravity of the electrolyte in a cell, gives an indication of how much unused sulphuric acid remains in the solution and is therefore a convenient measure of the approximate capacity still available in a normal cell. For accuracy, the liquid



* Battery half discharged. More acid in plates, less in electrolyte. Starting failure in sight if battery is allowed to remain installed.

** Acid almost entirely in plates leaving weak electrolyte behind. Specific gravity lower; almost that of water.

Figure 3-8A

During discharge, as acid combines with both Plate Materials, Hydrometer sinks lower. Note changing position of black dots in illustrations.

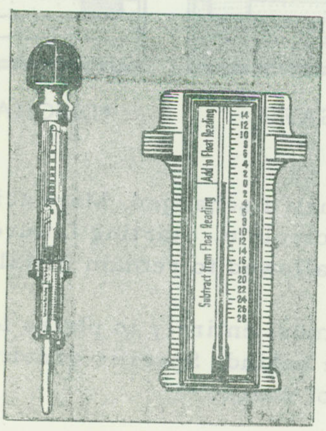
level of the cell should be at normal height when a hydrometer reading is taken and the electrolyte should be thoroughly mixed with any water which may have just been added. Hydrometer readings should, therefore, never be taken immediately after water has been added. The water should be thoroughly mixed with underlying electrolyte, by charging, before hydrometer values are reliable. The following table illustrates a typical range of specific gravity for a cell in various stages of charge with respect to its ability to crank the engine at 80°F.

1.280 Sp. Gr.	100% Charged
1.250 Sp. Gr.	75% Charged
1.220 Sp. Gr.	50% Charged
1.190 Sp. Gr.	25% Charged
1.160 Sp. Gr.	Very little useful capacity
1.130 Sp. Gr.	Discharged

27 In reading a hydrometer, the barrel must be held vertically and just the right amount of acid be drawn up into the barrel with bulb fully expanded to lift the float freely so that it touches neither the side, nor the top nor bottom stoppers of the barrel. The hydrometer barrel and float must be kept clean with soap and water so that the float will not stick to the sides. The float must be inspected occasionally for cracks which would allow acid to enter the airtight float and make any reading taken with it unreliable. If the paper scale inside the float is wet it indicates a leak in the float and the float should be discarded.

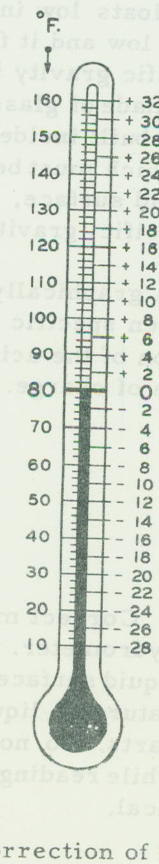
TEMPERATURE ERRORS OF HYDROMETERS

28 No reading on the Hydrometer is strictly correct until a temperature correction has been applied. At ordinary temperatures it is not usually necessary to correct the hydrometer reading for the temperature but at extremes of temperature the correction may be important. Hydrometer floats are calibrated to indicate correctly only at one fixed temperature and if used in electrolyte at any other temperature a correction must be applied. The reason for this lies in the fact that the acid volume expands when it is heated and shrinks when it is cooled. When expanded due to heat, it will not be as dense and will not raise the hydrometer float as high in the acid, so causing the reading to be low. When the acid is cooled the acid shrinks in volume and becomes denser which causes the hydrometer float to rise higher and read too high. The error due to temperature is a known factor and it can be



Thermometer Built into Hydrometer

Figure 3-9



Temperature Correction of Specific Gravity

Figure 3-10

easily corrected if we know the temperature of the acid which surrounds the float in the hydrometer. Draw electrolyte in and out of the hydrometer barrel several times to bring the temperature of the hydrometer float to that of the acid in the cell and then measure the electrolyte temperature in the cell. Some hydrometers, Figure 3-9 have a small thermometer and a correction scale built into them so that the temperature correction can readily be made. The temperature correction amounts to about .004 specific gravity, sometimes referred to as 4 "points" of "gravity" for each 10°F change in temperature. Most battery manufacturers adjust the acid in their batteries so that the specific gravity readings are accurate only when the acid temperature is at 80°F, although some use a reference temperature of 60°F as a standard. But whatever the temperature used as a basis, the correction for temperature is the same, that is .004 specific gravity per 10°F deviation from the standard base temperature.

NOTE

For an illustration on hydrometer readings when the acid temperature (not the air temperature) is above or below 80°F. It should be noted how misleading a hydrometer reading can be at extremes of temperature unless the temperature correction is taken into account.

EXAMPLE No. 1— Temperature below 80° F.
- **Hydrometer Reading 1.270**
- **Acid Temperature 20° F.**
- **Subtract .024 Sp. Gr.**
- **Corrected Sp. Gr. is 1.246**

EXAMPLE No. 2— Temperature above 80° F.
- **Hydrometer reading 1.255**
- **Acid Temperature 100° F.**
- **Add .008 Sp. Gr.**
- **Corrected Sp. Gr. is 1.263**

In example 1 above, in cold weather a battery might be installed in an aircraft in a partially discharged condition if the hydrometer reading alone was relied upon, since it read 1.270 indicating nearly fully charged if at 80°F, but when the temperature correction is applied, the true value is only 1.246 which corresponds to only about 2.75% charged battery. Such a partially discharged battery should not be installed in an aircraft during severe winter weather, since it may soon fail causing possible danger to the aircraft and unnecessary maintenance work to the ground crews.

Example 2 might be encountered during very hot weather and the hydrometer reading would indicate a partially charged battery when the battery was fully charged. This condition is quite common when batteries are tested on charge or when they have been sitting in a hot place such as in the sun on a hot summer day. Attention is called to the fact that gravity readings may be misleading if taken just after battery has been discharged at a high rate, such as prolonged cranking. This type of discharge weakens the acid in and adjacent to the plates and until this weak acid has had time to diffuse outwardly and mix with the remaining stronger acid in the cell, the gravity readings of acid taken at the top of the cell, will be too high and indicate a higher state of charge than really exists. The acid will slowly mix if the battery stands idle for several hours or the mixing will be more rapid if the battery is charged and the acid mixed by gassing.

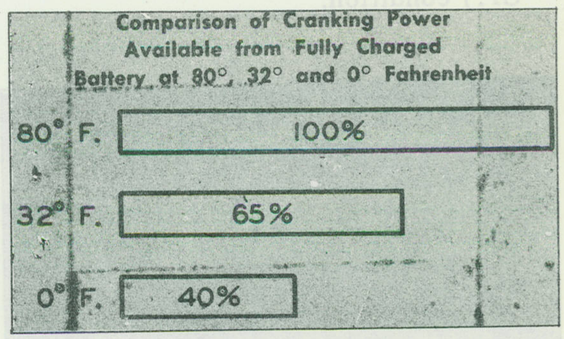


Figure 3-11

29 Effect of Temperature and Oil Viscosity on Battery Performance - Battery capacity is greatly reduced by cold as it has a decided numbing effect on the electro-chemical action. The following comparison Figure 3-11 graphically indicates the extent of the reduction in cranking power when the temperature drops from 80°F to 32°F or to 0°F.

NOTE

Note from the length of the bars that only about 2/5 of the cranking power available at 80°F is available at 0°F even for a battery in good working condition and fully charged. Stiff engine oil adds to the load of starting. The following Figure shows the relation of cranking power at temperatures corresponding to "summer", "freezing" and "zero" temperatures for an automobile engine using SAE 20 crankcase oil. We see that at 0°F the engine requires two and a half times the power to crank it that it required at 80°F. The combined effect of zero cold, in reducing battery capacity to 2/5 of its normal power and the increase in cranking load due to stiff oil to two and a half times the warm weather load, gives us a better appreciation of the job a battery has to do in cold weather and emphasizes the need for keeping a battery in the nearly fully charged condition during cold weather. The importance of keeping a battery charged is shown in Figure 3-12. Here for temperatures of 80°F, and 0°F we have compared the cranking power available in a good battery at the fully charged (1.280 Sp. Gr.) half charged (1.255 Sp. Gr.) and discharged (1.180 Sp. Gr.) condition.

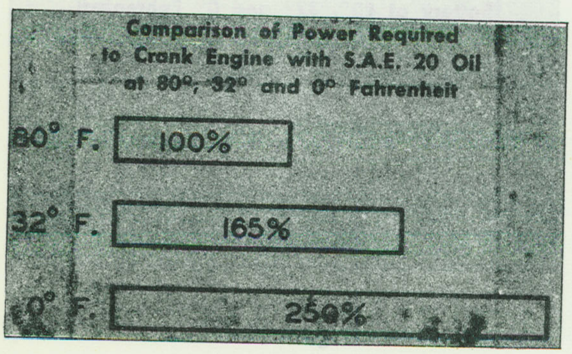


Figure 3-12

NOTE

Note that a nearly discharged battery at 0°F has less than 1/10 the available dranking power of a fully charged battery at 80°F. This emphasizes why it is a wise precaution to keep batteries fully charged and to recharge when the gravity falls to 1.225 or below. A battery discharged to 1.100 specific gravity or less may not crank an engine at any temperature.

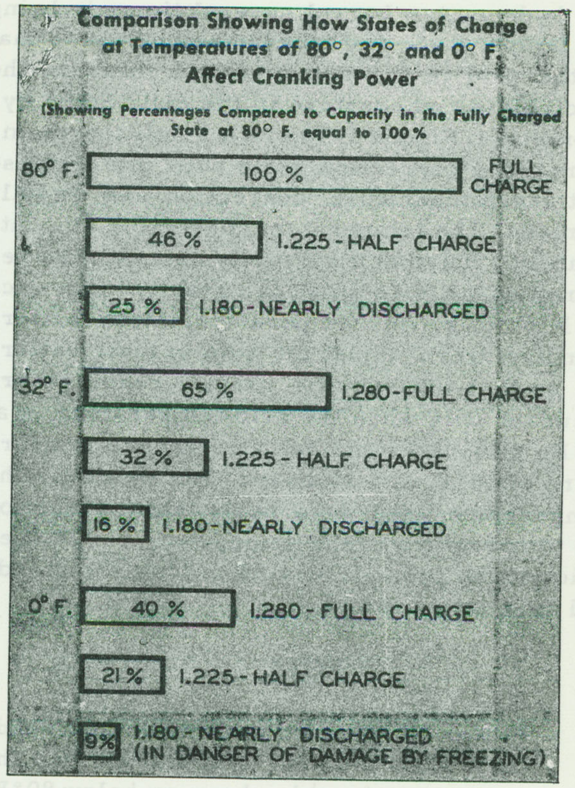


Figure 3-12A

The above gravities Figure 3-12A labeled "half charge" and "nearly discharged" are related to the ability of the battery to crank an engine at 80°F and are not based on the twenty hour discharge at 80°F.

30 In the absence of level indicators, the proper electrolyte level is about "a quarter to a half inch" above the tops of the separators at 80°F (see manufactures instructions for correct levels). The electrolyte level in very cold batteries will be lower than normal so let batteries warm to normal temperature before judging electrolyte levels. Remember to correct hydrometer readings for temperature if accurate values are desired and make due allowances for the time and temperature involved in transit.

PART 4

INSTALLATION

INSPECTION

1 The following inspections are to be carried out in conjunction with the Minor Inspection of the Aircraft:-

(a) Inspect the specific gravity and the level of the electrolyte in the battery.

(b) Inspect battery leads for condition of insulation.

(c) Inspect the terminals and remove any corrosion by brushing with a stiff (but not wire) brush. Then wash with a solution of ordinary sodium bicarbonate and water (1 lb. per gallon) to neutralize any electrolyte remaining on the metal surfaces and rinse with water. After drying, apply a thin coat of terminal grease or vaseline to the metal terminals. Imperfectly lead-plated parts, such as washers or wing nuts, on which the lead coating is worn or scraped off, should be replaced. Always keep vent caps in place during cleaning after which they should be examined to ensure that the gas escape holes are clear.

2 The following is to be carried out in conjunction with the Major Inspection of the aircraft:-

(a) Remove the battery sump (if used) and the connecting hoses. Wash in clean water. Resaturate the soda pads with the solution of sodium bicarbonate and water (see Part 4, para 4). Reinstal the sump and the connecting hoses.

ANTI ACID COATING APPLICATION

3 Coating is to be applied as follows:-

(a) To neutralize the effects of acid on trays and surrounding structure of battery compartment, an application of Anti-Sulphuric Paint or Nonslip Aircraft Walkway Coating (Spec MIL-C-5044) should be applied before the first battery is installed in an aircraft. One coat of Anti-Sulphuric Paint is sufficient and will dry to touch in approximately three hours. If Nonslip Walkway Coating is used, three coats will be required allowing 30 minutes between coats. The final coat will dry to touch in approximately one hour.

NOTE

This treatment is unaffected by sulphuric acid or the sodium bicarbonate solution used to clean compartment.

(b) When replacing batteries, ensure that the container and surrounding area is cleaned of any corrosion and, if necessary, recoated with Dektred.

VENTILATION

4 Because of the gases given off by batteries under charge the battery storage should be well ventilated. Integrally shielded batteries are provided with an opening at each end. Vent tubing is attached to these openings when the battery is installed in the aircraft. One of the vents normally the forward one (intake) shall be exposed to the slipstream. The other vent tube exhaust (rearward) should be connected to the vent opening of the battery which is the lowest when the aircraft is in a taxiing position and should be located in such a manner that battery acid may escape without injury to the aircraft. When a battery drain sump is used, the discharge tube from the battery will be connected to a glass jar sump of not less than one (American) pint capacity and shall extend into the jar approximately one inch. The exhaust tube (from the sump jar) the end of which should be cut off at a 30° angle from the vertical and extended into the sump jar approximately 1/3 its depth, shall be routed to the skin surface of the aircraft and the outlet located in such a manner as to discharge towards the rear. The sump jar will contain a felt pad one inch thick, saturated with a solution of approximately one part sodium bicarbonate and eight parts of water for neutralizing gases and excess battery solution.

MOUNTING

5 On installation of battery, the nuts on the mounting bolts should be snug enough to prevent the battery from moving or shifting about without overstressing the battery case and cover. Too much pressure may cause the sealing compound to crack or may warp the container or cover and permit leakage of gases around the top of the battery.

PART 5

OPERATION

BATTERY SWITCHES

1 Battery switches should always be left in "OFF" position except when the aircraft is in actual service, and all battery disconnect switches should be placed in "OFF" position before attempting a crash landing to avoid danger of fire.

2 The battery should not be used for starting the engine if external power sources are available. By following this instruction, the energy stored in the battery is conserved. This leaves battery energy available for starting the engine in locations where external power units are not available; or for emergency operation.

COLD WEATHER OPERATION

3 The following precaution are to be observed:-

CAUTION

When operated in extremely cold climates (below-17.8°C (0°F)) the battery should have a full charge specific gravity of 1.275 to 1.300. It should also be kept above-1.1°C (30°F) whenever practicable, because of greatly decreased efficiency and low charging rate at low temperature. Auxiliary power should be used, whenever possible, to conserve battery energy. To prevent early depletion of the battery DO NOT OPERATE ELECTRICALLY HEATED FLYING SUITS, GUN TURRETS, OR ANY UNNECESSARY ELECTRICAL DEVICES UNLESS A SUITABLE GENERATOR IS IN OPERATION. FLIGHT SHOULD ALWAYS BE STARTED IN COLD WEATHER WITH THE SPECIFIC GRAVITY OF THE BATTERY 1.250 OR OVER AFTER CORRECTING THE READING FOR TEMPERATURE, because the battery will not charge as rapidly as normal when it is cold. This is due to the fact that chemical action takes place much more slowly at low temperatures, and the internal resistance of the battery is higher. The effect is the same as if a much smaller battery were used.

PERFORMANCE

4 Figure 5-1 illustrates the effect of temperature on the actual performance of storage batteries in aircraft. This shows graphically the time required to replace 40 percent of the battery's charge at various temperatures, based on starting flight with a half-charged battery. This shows the much longer time required to charge batteries at temperature below freezing, and indicates that at temperatures below-20°F it is almost impossible to recharge the battery in an aircraft while flying.

IDLE AIRCRAFT

5 When an aircraft located in below zero temperatures is not in use, its battery should be removed and kept in as warm a place as possible, or heated in the aircraft. DO NOT ATTEMPT TO KEEP THE BATTERY WARM BY CHARGING as continued overcharging is detrimental to its life. When available, always use external power for cranking engines and conserve battery for flying operations.

STARTING ENGINES

6 When necessary to start engines with batteries, do not crank the engine continuously until it starts. Crank the engine for short intervals only. Always wait a few minutes between periods of cranking which allows the battery to recover slightly.

SPECIFIC GRAVITY

7 The specific gravity of a fully charged battery should be 1.275 to 1.300. This is important in cold climates in order to prevent the battery from freezing. Lower specific gravities have been used in some tropical locations in an effort to prolong the battery life in these places. These have been discontinued because of the confusion resulting and the possibility of batteries freezing when aircraft are

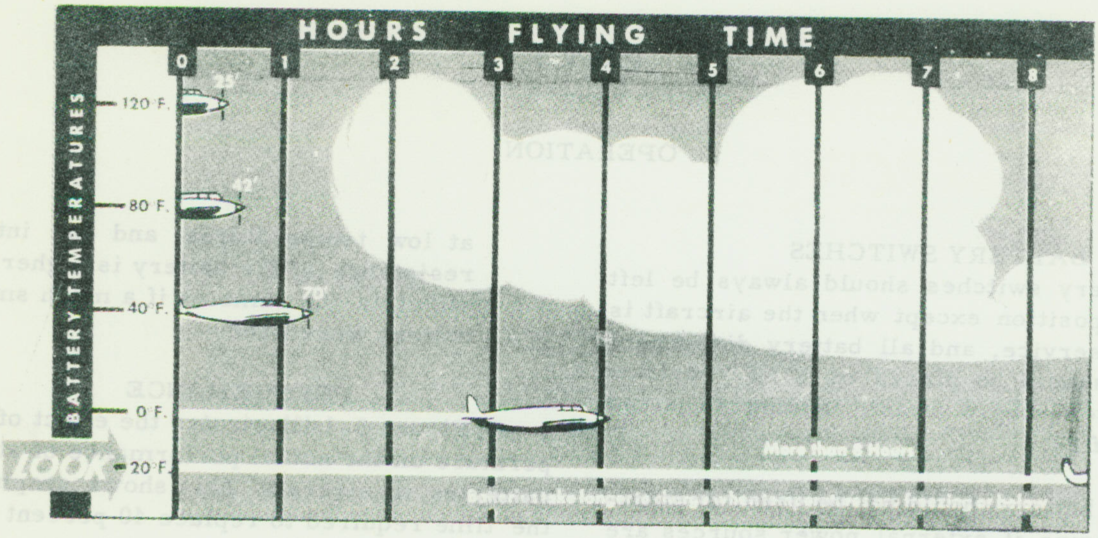
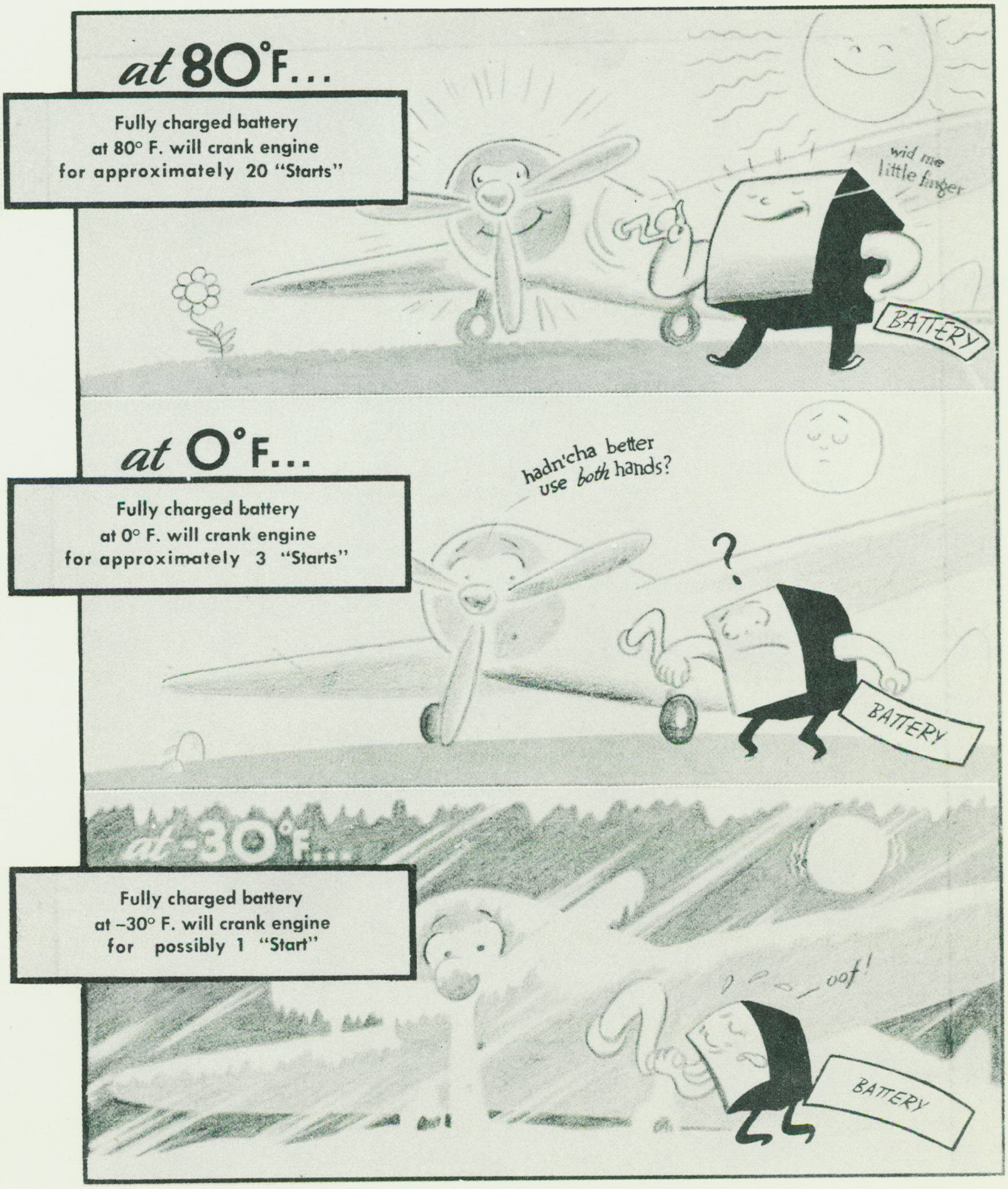


Figure 5-1 Flying Time Required to Recharge Battery at Different Temperatures (Based on Starting Flight With Half Charged Battery).

moved to colder climates or flown at high altitudes.

8 Aircraft operating in cold climates should have their batteries checked to be certain that the specific gravity of the electrolyte is correct. To make this check, remove the batteries from the aircraft and charge fully until two successive hydrometer readings, taken at two hour intervals, show no further increase in specific gravity. Then, if the specific gravity corrected for temperature is not between 1.275 and 1. 300, adjust to that value according to instructions given in Part 7, para. 14.



NOTE: Always use external power for cranking, and conserve battery for flight operations when possible.

Figure 5-2 - Battery Load - Temperature Considerations

PART 6

INSPECTION

DAILY INSPECTION

1 Check Specific Gravity.

(a) Take Hydrometer Reading. Hydrometer readings will be made to check the specific gravity of each battery daily. Use approved Temperature Corrected Hydrometer. Hold the hydrometer in a vertical position where location permits with the hose inserted in the cell to be tested (see figure 6-1). If the battery is so located that this is impossible, hold the hydrometer horizontally and after filling pinch the hose near its end and remove the hydrometer to a position where it can be held vertically. The hydrometer reading should be taken at eye level. Be sure the float is free (not sticking to side of hydrometer). When filling the hydrometer, do not suck in too much electrolyte. Just enough should be drawn in to raise the hydrometer float from the plug upon which it normally rests. Always return the electrolyte to the cell from which it was removed in making the test.

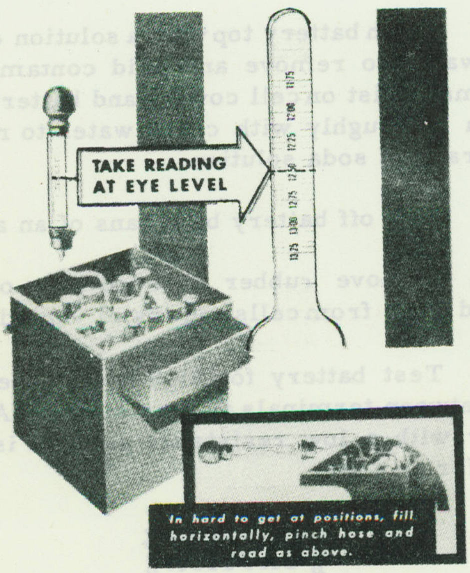


Figure 6-1 - Testing Specific Gravity with Hydrometer

(b) Correct reading for Temperature. The Temperature Corrected Hydrometer has a thermometer which reads the temperature of the electrolyte and shows the correction to be made for various temperatures, (see figure 6-2). If the electrolyte temperature is between 65°F and 95°F, no correction need be made because of the small correction between these temperatures. However, correction should always be made for other temperatures. For

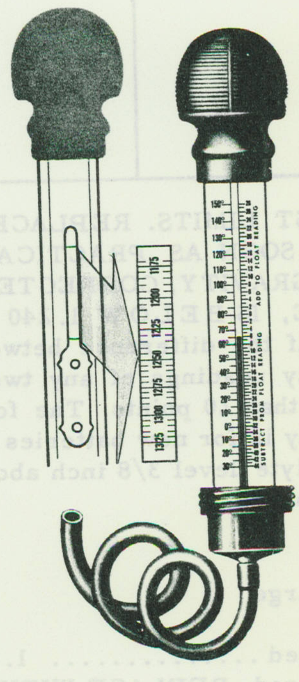


Figure 6-2 - Hydrometer Temperature Correction

example, if its thermometer read 30°F, the correction shown for this temperature is "subtract 20 points". Thus, if the hydrometer reading was 1.250, the actual specific gravity would be 1.250 minus 20 = 1.230. If temperature correcting hydrometer is not available, any hydrometer may be used and the following temperature corrections made for various electrolyte temperatures:-

Electrolyte Temp. F°	Specific Gravity Correction (Points)
140	24
130	20
120	16
110	12
100	8
90	No correction required
80	
70	
60	8
50	12
40	16
30	20
20	24
10	28
0	32
— 10	36
— 20	40
— 30	44

(c) TEST LIMITS. REPLACE THE BATTERY AS SOON AS PRACTICABLE IF ITS SPECIFIC GRAVITY, CORRECTED FOR TEMPERATURE, IS BELOW 1.240 OR ABOVE 1.310, or if the difference between the specific gravity readings of any two of the cells is greater than 20 points. The following specific gravity is for new batteries at 80°F with the electrolyte level 3/8 inch above the top of the protector.

State of Charge	Specific Gravity
Fully Charged	1.275 to 1.300
1/3 Discharged. REPLACE WITH FULLY CHARGED BATTERY IF BELOW THIS READING	1.240
2/3 Discharged. Not sufficient capacity for satisfactory operation	1.200
Completely Discharged	1.150

ADDITION OF WATER

2 The following procedures to apply:

(a) When necessary to add water to a battery, use distilled water. Clean drinking water may be used if distilled water is not available.

(b) If the electrolyte level can be seen and specific gravity readings can be taken with a hydrometer, add no water. When adding water, DO NOT ADD HIGHER THAN 3/8 INCH above the protector as too much water will cause the electrolyte to leak out the vents when the aircraft is in operation.

(c) To add water to a cell, fill the self-leveling syringe with water and insert it into the cell. Hold in a vertical position regardless of level of battery and fill the cell. Then withdraw excess water back into the syringe until air is sucked in, which leaves the electrolyte at the proper level, (see figure 6-3).

(d) If battery is exposed to temperatures below freezing, do not add water unless the battery will be charged immediately after adding, so that the water will become mixed thoroughly with the electrolyte. Otherwise, it will stay on top and freeze.

MINOR INSPECTION
(After every 50 hours use in aircraft)

3 AN Type shielded batteries: Remove battery from aircraft and clean thoroughly as follows:

(a) Remove vent plugs from battery cells and instal unvented plugs, or, instal vent plug covers made from applicable rubber hose.

(b) Wash battery top with a solution of soda and water to remove any acid contamination that may exist on cell covers and battery case. Flush thoroughly with clean water to remove any trace of soda solution.

(c) Dry off battery by means of an air jet.

(d) Remove rubber vent covers, or, unvented plugs from cells and instal vented plugs.

(e) Test battery for high resistance leakage between terminals and metal case. A voltmeter with a low resistance per volt is to be used for this test.

CAUTION

Unvented plugs installed when cleaning batteries are to be of such a length that the battery cover cannot be inadvertently fitted if the unvented plugs are left in the cells after cleaning.

NOTE

Unvented plugs may be manufactured locally, or old vent plugs modified to meet requirement above. Another method of protection is to cut suitable rubber hose into lengths as required under "Caution" and sealed at one end with wooden plugs. These covers must fit snugly over the vent plug of the battery cell to prevent contamination entering the vent hole of the plug.

MAJOR INSPECTION
(After every 100 hours use in aircraft)

4 Battery Capacity Test: Remove the battery from the aircraft and test as follows:-

(a) Charge battery fully. See Part 7 paragraph 12.

(b) Overcharge two hours at normal rate.

(c) Check specific gravity of all cells.

(d) Adjust specific gravity if above 1.310 or below 1.260, (refer to Part 7, Para. 14).

(e) Allow to stand 12 hours.

(f) Capacity test with battery capacity tester.

(g) Recharge fully if battery passes test. This will require about five hours at normal rate.

CHARGING VOLTAGE TEST

5 Charging voltage test is as follows:-

NOTE

This test, while fairly accurate, is not as certain as the capacity test covered above and should be used only if battery capacity tester is not available.

(a) Charge battery fully. See Part 7, Paragraph 12.

(b) Overcharge two hours at normal rate.

(c) Check specific gravity of all cells.

(d) Adjust specific gravity if above 1.310 or below 1.260, (refer to Part 7, Para. 14).

(e) Check terminal voltage while charging at normal rate. Reject battery if its terminal voltage under these conditions is less than the value given in the following table for the type and temperature of the battery being checked.

Temperature Degrees Fahrenheit	6 Cell Volts	12 Cell Volts
35° ----- to ----- 44°	15.5	30.9
45° ----- to ----- 54°	15.3	30.6
55° ----- to ----- 64°	15.1	30.2
65° ----- to ----- 74°	14.9	29.9
75° ----- to ----- 84°	14.7	29.5
85° ----- to ----- 94°	14.6	29.1
95° ----- to ----- 104°	14.4	28.8
105° ----- to ----- 114°	14.2	28.4
115° ----- to ----- 124°	14.0	28.1
125° ----- to ----- 135°	13.8	27.7

NOTE

Minor and major inspections of the battery are not to be confused with minor and major inspections of the aircraft. Times between battery inspections are calculated using the flying hours for the aircraft in which the battery is installed.

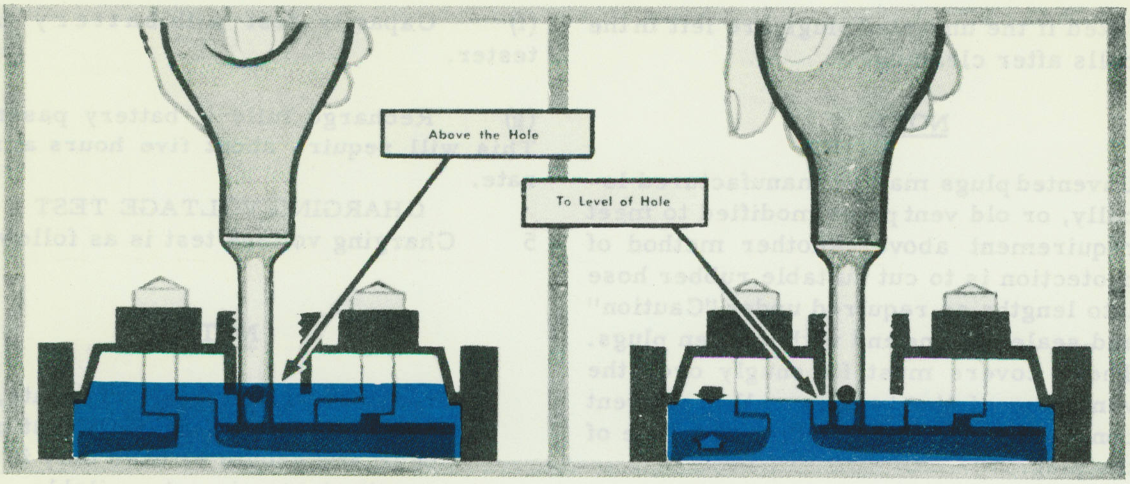


Figure 6-3 - Self-Leveling Syringe

INSPECTION CHART

OPERATION	Daily	Battery Minor	Battery Major	Aircraft Minor	Aircraft Major
Check specific gravity, correct for temperature and if necessary, replace.	x	x	x	x	x
Add water if unable to take specific gravity reading. Fill to 3/8 inch above protector over separators.	x	x		x	x
Inspect battery lid gasket for condition.	x	x	x	x	x
Inspect battery lid for condition and proper fit.	x	x	x	x	x
Inspect for leakage. Replace battery if leakage is indicated.	x	x		x	x
Inspect vent tube. Clean out if clogged.				x	x
Clean battery thoroughly (if AN type shielded battery).		x			
Check felt pad in battery sump for proper condition and if dry, resaturate.				x	
Clean battery sump and connecting hoses.					x
Test capacity. Reject from active service if below standard.			x		

PART 7

CARE AND MAINTENANCE

PREPARATION OF ELECTROLYTE

1 Electrolyte for lead-acid storage batteries, stored and issued by the Air Force, is concentrated commercial grade sulphuric acid and has a specific gravity of 1.835. Either the 1.350 or 1.835 specific gravity sulphuric acid must be mixed with distilled or drinking water to lower it to the proper specific gravity for filling batteries.

HANDLING

2 Sulphuric acid or battery electrolyte may cause painful burns if allowed to get on the hands or other parts of the body. Personnel engaged in the handling or mixing of electrolyte should be very careful to avoid hazards from this cause. They should wear goggles, rubber aprons, rubber gloves and rubber boots or rubber overshoes. When sulphuric acid and water are mixed together to produce battery electrolyte, heat is generated chemically by the process which raises the temperature of the resulting mixture. Therefore, when mixing electrolyte, always pour the acid into the water slowly, and stir to mix. NEVER POUR WATER INTO THE ACID SINCE HEAT MAY BE GENERATED SO RAPIDLY THAT THE ACID WILL BE THROWN UPON THE OPERATOR. The container should be glass, earthenware, lead-lined wood or a similar vessel that is resistant to sulphuric acid and can stand the heat generated in mixing the water and acid. Allow the electrolyte to cool below 90°F before using. When checking the specific gravity of the electrolyte, always correct the reading for temperature.

3 The electrolyte may be siphoned into the cells of the battery by means of a small diameter hose, or may be put in by means of a syringe. Do not exceed the level of 3/8 inch above the protector on top of the separators. Ordinarily, after filling, only water need be added from time to time. However, if spillage is known to have occurred, add electrolyte of approximately the same specific gravity as that remaining in the cells. Then recharge and adjust the full charge specific gravity if necessary.

PROPER SPECIFIC GRAVITY

4 The proportions of water and acid to use depend upon the specific gravity desired and are approximately as follows:-

Gravity Desired	For Each Gal. of Acid	For Each Gal. of 1.835 Acid
1.240	3/4 gal. water	3 1/2 gal. water
1.275	1/2 gal. water	2 3/4 gal. water
1.300	1/3 gal. water	2 1/2 gal. water
1.340	1/7 gal. water	2 gal. water
1.400		2 1/2 gal. water

5 The proper specific gravity of the electrolyte used for filling new batteries (which are shipped with plates dry charged) is 1.275. Although some small battery life in the tropics may be sacrificed, a more uniform operation will result by using a universal fill 1.275 to 1.300 specific gravity for a fully charged battery.

OTHER ELECTROLYTE

6 Never use any special or patented solutions in aircraft batteries. Most of these are detrimental to the life and proper operation of the battery. THE USE OF ANYTHING EXCEPT DISTILLED WATER, DRINKING WATER, OR BATTERY ELECTROLYTE IN AIRCRAFT BATTERIES IS PROHIBITED.

7 After a battery has had the electrolyte added, it cannot again be made dry by removing the electrolyte and sealing the battery. Such procedure would only ruin the battery.

PREPARATION OF BATTERY FOR CHARGING

General

8 Before placing a battery on charge, it should be prepared in the following manner.

(a) Clean the outside of the case and the top of the battery with a hose and plenty of water. Use a solution of bicarbonate of soda to remove any corrosion that may be on the terminals. Inspect the physical condition of the battery.

(b) Remove the filler caps and inspect the battery internally. If the level is low, add distilled or drinking water to bring the level to approximately 3/8 inch above the protector on top of the separators.

(c) While batteries are being charged, the vent caps will be unscrewed but should be left setting over the cell opening in order to prevent the gassing and spraying of electrolyte over the top and any foreign matter from falling into the battery.

(d) Place the battery on the charging bench and connect it properly in the charging circuit as described below.

NOTE

Batteries must be recharged if their specific gravity is below 1.240.

CHARGING EQUIPMENT

9 Storage batteries can be charged only with direct current. If alternating current only is available, it must be changed to direct current by a rectifier or motor generator set.

CONSTANT POTENTIAL - PARALLEL CHARGING

10 Motor generator sets are used for constant potential, parallel charging systems. For charging aircraft batteries by this method, extremely close voltage regulation must be maintained at all points. This requires very heavy buss bars on the charging bench and an exceptionally well designed motor generator that several discharged batteries may be connected to the buss bars in parallel with a fully charged one. Under these conditions, the buss voltage must be maintained constant (even though these discharged batteries may take 50 amp. each from the line) in order to prevent discharge of the charged battery. The generator voltage must not increase, to compensate for buss bar voltage drop, as this might apply too high a voltage to the charged battery and overcharge it.

NOTE

This type of equipment is not regularly supplied by the Air Force, but may be used in emergency cases, provided it meets the following specifications:-

(a) A 250-watt, .1-ohm current limiting resistor must be inserted between each battery and the buss bars.

(b) Twenty-eight volts for 24-volt batteries or fourteen volts for the 12-volt batteries, plus or minus not more than two percent, must be maintained between all points on the buss bars, from no load to maximum load.

(c) Connections for this type charger are shown in Figure 1, showing that the positive terminal of each battery is connected to the positive buss bar through a .1-ohm 250-watt current limiting resistor, and the negative terminal of each battery is connected directly to the negative buss-bar. The charging voltage must be maintained as above, at all times. The charging current at start of charge will be somewhat higher than the normal current but will gradually decrease as the battery becomes charged so that the finish charge will be less than one-half the normal charging current.

CONSTANT CURRENT - SERIES CHARGING

11 Bulb type rectifiers are the most commonly used for constant current, series charging. Controls are provided to adjust rates, and an ammeter is employed for indication of the charging rate. Connections for this type of charger are shown in Figure 2, showing that the positive terminal of one battery is connected to the negative terminal of the adjoining battery, etc. The group of batteries in series have the positive terminal of one end battery connected to the positive terminal of the charger, and the negative terminal of the opposite end battery connected to the negative terminal of the charger. However, when different size batteries are to be charged, two of the smaller capacity batteries having similar voltage and capacity may be connected in parallel, and the two then connected in the charging circuit in series with the larger capacity batteries as though they were a single battery having double the capacity of each, as shown in Figure 3. Different combinations of various sized bat-

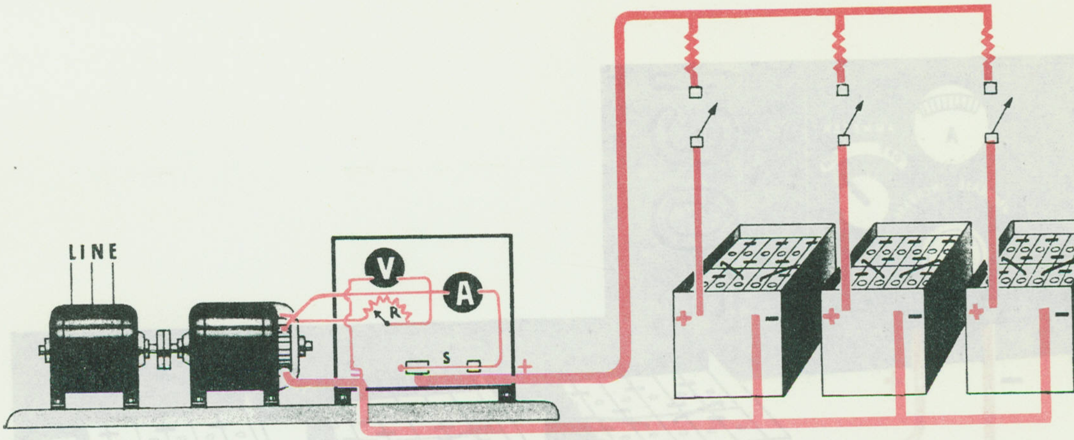


Figure 7-1 - Constant Potential Charging Circuit

teries may be connected in this manner to make more efficient use of the charger. With such a combination the capacity of the smallest size battery, or parallel group of batteries, in the string determines the maximum charging current for the entire string. Normal charging current for circuit shown in Figure 7-3 would be six amperes.

CAUTION

Battery maintenance personnel should exercise extreme care when attaching or detaching battery charging leads to prevent short circuit flashes as this may ignite hydrogen gas generated in the battery cells during charging, thus causing battery to explode. Be sure that the power switch is in the "off" position at the rectifier prior to disconnecting or connecting battery leads to batteries.

CHARGING

Starting Charge (Series Charging).

12 Adjust the controls to give the charging rate recommended for the type battery being charged. It is desirable to use the same size batteries in series in one string; otherwise the smallest size battery in the string determines the maximum charging current for the entire string. See EO 40-5A-9 Part 2, paragraph 8, for details on initial charging.

13 Batteries undergoing charge should be inspected at intervals of two hours (after initial four hours) and a specific gravity reading taken of the positive end cell of each battery. Maintain suitable records of specific gravity readings for reference in subsequent gravity checks. All specific gravity readings should be corrected for temperature in accordance with temperature correction data shown on the Hydrometer and in the table in Part 6, paragraph 1(b). The temperature rise of the battery, obtained by a thermometer reading of the electrolyte, should never exceed 15°F above the surrounding air temperature. (In the absence of a thermometer, note the temperature of the battery with the fingers. If it feels uncomfortably warm to the hand it is too hot). It should be kept below that point by reducing the charging rate, if necessary, since higher temperatures are detrimental to the life of the battery. Remove battery from charging line when after four hours of charging two successive readings taken two hours apart show no increase in specific gravity of the electrolyte. As a battery reaches a charged condition, gas bubbles rise to the surface of the electrolyte. This is a normal condition. However, if the charge is continued for too long a period or at too high a rate, excessive gassing will occur. In this case, the electrolyte appears to be boiling violently and the charging rate should be reduced or battery removed if fully charged.

ADJUSTING SPECIFIC GRAVITY

General

14 Unless electrolyte is actually lost through spilling or leaking, or acid has been added, the full charge specific gravity of the electrolyte will not require adjusting during the life of the battery, since it decreases very little with age. It should be adjusted only if continued

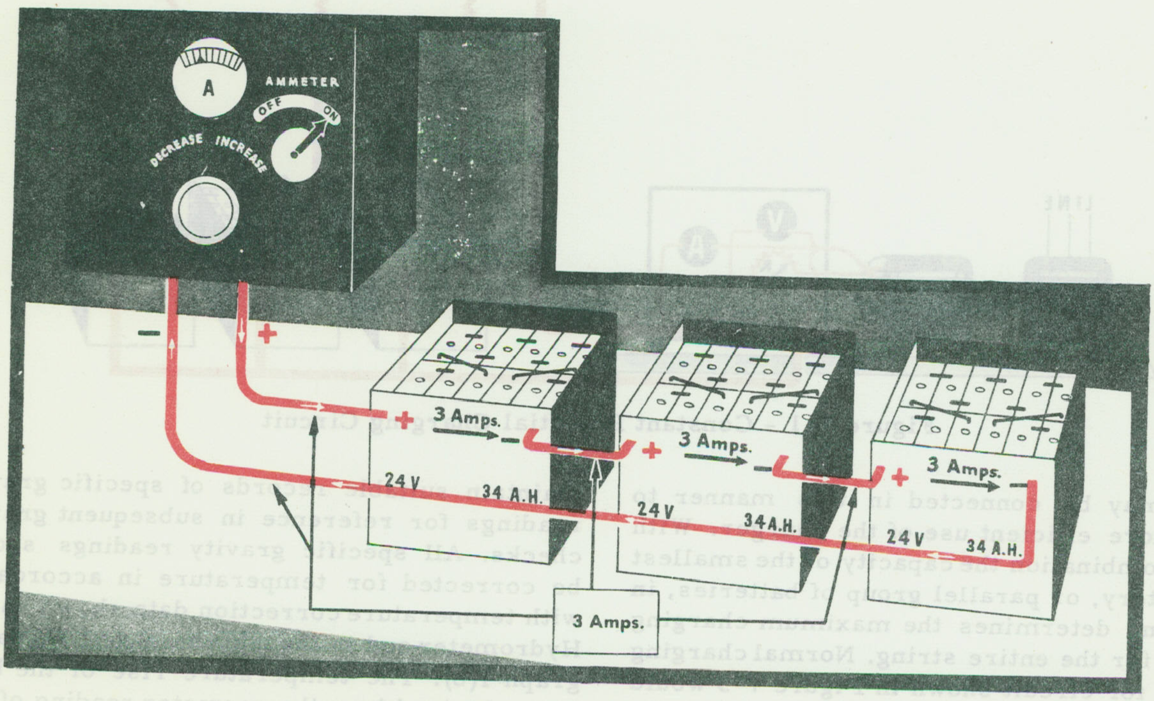


Figure 7-2 - Constant Current Charging Circuit

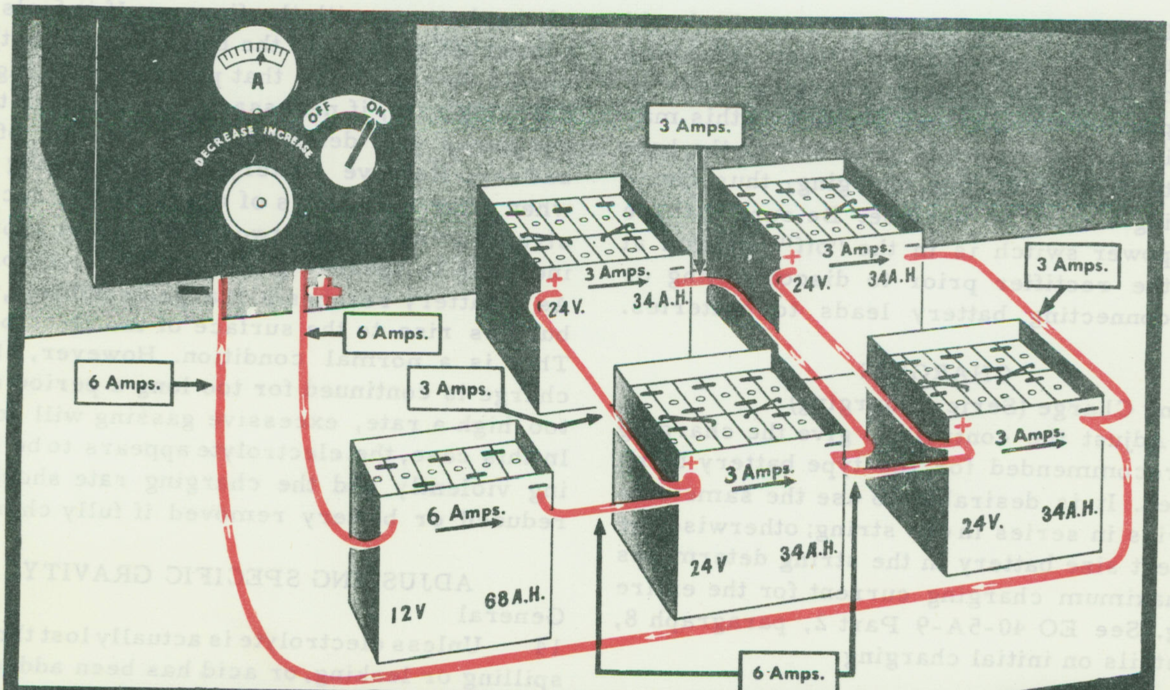


Figure 7-3 - Constant Current Charging Circuit charging results in readings above 1.310 or below 1.260.

PROCEDURE

15 The following procedure applies:-

(a) Charge at normal rate until the specific gravity shows no further rise with all cells gassing and then charge for two hours longer. (Never adjust the specific gravity of a cell that does not gas on charge).

16 To adjust low specific gravity upwards, withdraw some of the electrolyte from the battery. Replace it at once with the electrolyte of higher specific gravity. DO NOT ALLOW A CELL TO STAND PARTIALLY EMPTY. The right amount to withdraw is determined by trail, as the lower the specific gravity reading of the battery, the more electrolyte must be replaced with the stronger solution. Continue

Temperature Degrees Fahrenheit	1 Cell Volts	6 Cell Volts	12 Cell Volts
35° --to-- 44°	2.57	15.5	30.9
45° --to-- 54°	2.55	15.3	30.6
55° --to-- 64°	2.52	15.1	30.2
65° --to-- 74°	2.49	14.9	29.9
75° --to-- 84°	2.46	14.7	29.5
85° --to-- 94°	2.43	14.6	29.1
95° --to-- 104°	2.40	14.4	28.8
105° --to-- 114°	2.36	14.2	28.4
115° --to-- 124°	2.34	14.0	28.1
125° --to-- 135°	2.31	13.8	27.7

NOTE

If below this voltage, reject the battery.

(b) Check specific gravity of all cells.

(c) Check terminal voltage while charging at normal rate if specific gravity of any cell is above 1.310 or below 1.260. If the voltage is above that given in the following table, adjust specific gravity as below. If only 1 or 2 cells require adjustment, the voltage of these cells should be above the value shown for single cells.

charge until all cells have been gassing for one hour and again check the specific gravity of the cells. If not 1.275 to 1.300, repeat the adjustment. To adjust high gravity downwards, withdraw electrolyte and replace it with water. Charge at the normal rate until all cells have been gassing for an hour. Then if the specific gravity is not between 1.275 to 1.300, repeat the adjustment.

17 INSPECTION CHART

OPERATION	Daily	Battery Minor	Battery Major	Aircraft Minor	Aircraft Major
Check specific gravity, correct for temperature and if necessary, replace.	x	x	x	x	x
Add water if unable to take specific gravity reading. Fill to 3/8 inch above protector over separators.	x			x	x
Inspect battery lid gasket for condition.	x	x	x	x	x

INSPECTION CHART (CONT'D)					
OPERATION	Daily	Battery Minor	Battery Major	Aircraft Minor	Aircraft Major
Inspect battery lid for condition and proper fit.	x	x	x	x	x
Inspect for leakage. Replace battery if leakage is indicated.	x	x		x	x
Inspect vent tube. Clean out if clogged.				x	x
Clean battery thoroughly (if AN type shielded battery).		x			
Check felt pad in battery sump for proper condition and if dry, resaturate.				x	
Clean battery sump and connecting hoses.					x
Test capacity. Reject from active service if below standard.			x		

BATTERY RECORDS

18 In order to ensure that all aircraft batteries in Service use are maintained in a serviceable condition, and to make available statistical data on aircraft battery types, records are to be initiated by user units as follows:

(a) A "Battery Life and Installation Record" card is to be originated by the Electrical Section. Speciman card shown in Figure 7-4.

(b) On receipt of a battery for initial charge the electrical section of Repair Flight or Squadron is to allot a coded number to the battery as shown in Figure 7-5. Each number will consist of a group of letters and a number. The letters will be the particular Units code, (e.g. UP for Station Uplands) while the numbers will run from #1 consecutively for each particular type of battery, e.g., if there are ten 5J/65 batteries in use at Station Uplands they will be numbered UP1 to UP10 inclusive, similarly if there are also thirty 5J/174 batteries, they will be numbered UP1 to UP30 inclusive. When a battery becomes unserviceable the serial number for the battery can be used for the replacement battery and a new card made up.

(c) The 8" x 5 1/2" record card (fig. 7-4) is to be filled in as follows:

(1) Heading - Battery Life and Installation Record.

(2) Section and Reference - RCAF Section and Reference Number (CAP 10).

(3) Make - Manufacturer's name.

(4) Date - Date battery was manufactured or shipped from factory.

(5) Type - AN or manufacturers type.

(6) Volts - Rated voltage of battery.

(7) AH - Ampere hour at specified rate.

(8) Serial No. - Local code and serial number of battery.

(9) Column 1 - Date put into service or removed from aircraft.

(10) Column 2 - Registration number of aircraft from which removed.

(11) Column 3 and 4 - Voltage on load and specific gravity of electrolyte.

(12) Column 5 - Hours of operation taken from L14 of aircraft from when battery installed to when removed.

(13) Column 6 - Signature of tradesman removing battery.

(14) Column 7 and 8 - Time and date battery placed On charge - Off charge.

(15) Column 9 and 10 - Voltage on load after charge. Specific gravity of electrolyte.

(16) Column 11 - Capacity test (Section 6 paragraph 7).

(17) Column 12 - Signature of battery room attendant.

(18) Column 13 - Remarks:

NOTE

Electrical personnel in Repair Flight or Squadron are responsible for entries in sub-paras. (1) to (8) inclusive and sub-paras. (14) to (18) inclusive. Electrical personnel in Servicing Squadron are responsible for entries in sub-paras. (9) to (13) inclusive.

(d) The battery record card is to accompany the battery at all times and is to be kept on file in the Battery Shop when battery is in for charging and/or storage. When battery is used for installation in an aircraft the record card is to accompany the battery and placed in a card holder in or near the battery stowage of the aircraft. When the battery is removed from an aircraft the necessary entries are to be made on the record card and sent to the Battery Shop with the battery. If a battery is installed in a visiting aircraft the card of the unserviceable battery is to be removed from

BATTERY LIFE AND INSTALLATION RECORD

SEC	REF	MAKE	DATE OF MFG	TYPE	VOLTS	AH	RATE	SER. NO.
5J	174	GOULD	2-7-49	AN3150-2	24	36	5HR	UP 12

DATE	FROM A/C	VOLTS	S.G.	TOTAL HRS USED	SIGN	TIME & DATE CHARGE ON	OFF	ON LOAD VOLTS	S.G.	CAPACITY TEST	SIGN	REMARKS
23·3·50	for initial charge				—	0900 24·3·50	1600 25·3·50	2.35	1.285	—	E Jones	new battery initial charge
12·4·50	MUSTANG 1079	1.84	1.18	22	K. Moore	1300 12·4·50	1100 14·4·50	2.30	1.282	—	E Jones	
7·5·50	MUSTANG 1020	1.92	1.190	34	J. Ames	11.00 7·5·50	1500 9·5·50	2 32	1.283	—	E Jones	
31·7·50	MUSTANG 1079	1.95	1.23	64	K. Moore	1000 31·7·50	0900 1·8·50	2.30	1.283	—	E Jones	
1·9·50	MUSTANG 1002	1.87	1.20	86	W. Smith	0900 2·9·50	1700 3·9·50	2.32	1.284	—	E Jones	
30·9·50	MUSTANG 1020	1.81	1.17	101	J. Ames	0900 1·10·50	1500 2·10·50	2.30	1.282	95%	E Jones	Major inspection
23·10·50	MUSTANG 1065	1.84	1.18	136	A Hatch	0900 8·11·50	1600 9·11·50	2.31	1.281	-	E Jones	
3·12·50	MITCHELL KB109	1.92	1.22	158	W. Smith	1100 3·12·50	1700 4·12·50	2.28	1.275	-	E Jones	
7·12·50	Storage				E. Jones	1200 28·12·50	1000 29·12·50	2.29	1.276	-	E. Jones	Removed from storage
26·1·51	MUSTANG 1065	1.94	1.23	186	A. Hatch	0900 29·1·51	1200 30·1·51	2.25	1.275	-	A Leach	
2·3·51	MITCHELL KB 109	1.84	1.19	207	W. Smith	1300 2·3·51	1600 3·5·51	2.20	1.276	90%	E. Jones	major inspection
30·3·51	F86 10027	1.87	1.21	230	L. Brown	0900 31·3·51	1700 1·4·51	2.25	1.275	—	E Jones	
12·5·51	MUSTANG 1002	1.85	1.20	285	J. Ames	0900 13·5·51	1700 14·5·51	2.25	1.276	—	A Leach	Repaired cracked sealing
4·6·51	MUSTANG 1065	1.93	1.25	302	A. Hatch	1100 4·6·51	1700 5·6·51	2.20	1.278	82%	A Leach	
30·7·51	MITCHELL KB 109	1.85	1.17	366	W. Smith	0900 31·7·51	1600 1·8·51	2.12	1.275	—	E. Jones	
6·9·51	MUSTANG 1002	1.92	1.26	410	A. Hatch	0900 7·9·51	1700 8·9·51	2.15	1.272	72%	E Jones	ground use only

Figure 7-4 - Battery Life and Installation Record

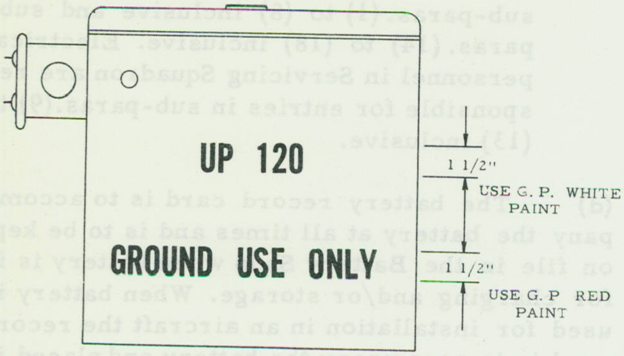


Figure 7-5 - Sample Battery Markings

the card holder of the aircraft and replacement battery card inserted. Batteries may have more than one code serial number through these exchanges but the original card is to remain with the battery at all times and new serial number recorded below old one.

Reports

(e) An omnibus UCR is to be submitted on the last day of March and September listing all aircraft batteries that have become unserviceable during that six month period. This report should list Section and Reference numbers, manufacturer's name and type and total hours operated for each battery. The total hours of operation is to be taken from when the battery was installed until time of failure or when the rated capacity has dropped to less than 75 percent.

(f) Batteries having less than 75 percent of rated capacity are to be classified as unfit for aircraft use and are to be marked for GROUND USE ONLY (fig. 7-5) or reported for disposal. No record is required on a battery after it has been classified for GROUND USE ONLY.

PART 8

SAFETY PRECAUTIONS AND FIRST AID

1 The following neutralizing agents and other materials are to be kept in a battery room in a readily accessible position for use in an emergency.

(a) Bicarbonate of soda in a saturated solution.

(b) Bicarbonate of soda in a 5 percent solution, obtained from station medical room and clearly marked "For Eyes Only".

(c) Ammonia in dilute solution.

(d) Olive Oil.

(e) First Aid Kit.

(f) Borax Powder.

(g) Sawdust.

PROTECTIVE CLOTHING

2 When handling storage batteries or acid, aprons and rubber gloves are to be worn; in addition goggles must be used when mixing electrolyte. After use, these articles must be rinsed free of acid and dried thoroughly. To avoid cracking or perishing they should be stored in a cool place, the aprons being hung with as few folds as possible.

NAKED LIGHTS

3 The gases given off during battery charging are highly inflammable, therefore naked lights are not to be brought into charging rooms, or at anytime used to examine a battery.

SPILT ACID

4 When acid has been spilt on the floor or benches, it should be soaked up with sawdust, which should be removed and buried. The surface should then be washed with a saturated solution of bicarbonate of soda and finally with warm water until all signs of acid are removed.

5 When acid has been splashed on clothing, a little dilute solution of ammonia or saturated solution of bicarbonate of soda should be applied. The affected part should then be rinsed with plenty of water.

6 When acid comes into contact with the skin a saturated solution of bicarbonate of soda should be applied immediately. This should be followed by washing with warm water. If the skin is badly burned, a little olive oil should be applied afterwards.

7 If acid is splashed into the eye, bathe immediately with a 5 percent solution of bicarbonate of soda, followed by plenty of warm water.

CAUTION

On no account should ammonia be put into the eye.

NOTE

In cases where doubt exists as to the extent of an injury, or a burn appears severe, report to the Medical Officer immediately.