Cells and Batteries

Objectives : At the end of this lesson you shall be able to
- **state the power sources**
- **list the two main classifications of batteries**
- **state the dry and wet cells**
- **state the primary and secondary cells.**

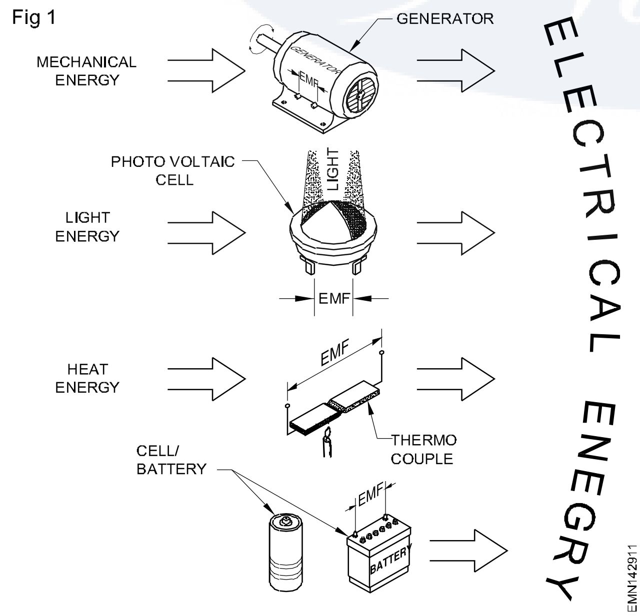
POWER SOURCES

Devices that produce electricity are generally termed as Power sources. These power sources produce electricity by converting some form of energy into electrical energy. As shown in Fig 1, all power sources must first be supplied with external energy such as heat, light or mechanical energy before they can produce electricity with an exception in the case of cell/battery. Batteries are different from the other types of power sources because, energy is provided by chemical reaction in batteries. Therefore, no energy need be supplied from outside for the battery to produce electricity. Hence batteries are one of the most important power sources. In a battery, electrical energy is produced by the chemicals contained within the battery. Cells are the basic units of a battery. Several cells forms to make a battery. Batteries are classified mainly under two categories.

(a) Primary batteries

(b) Secondary batteries

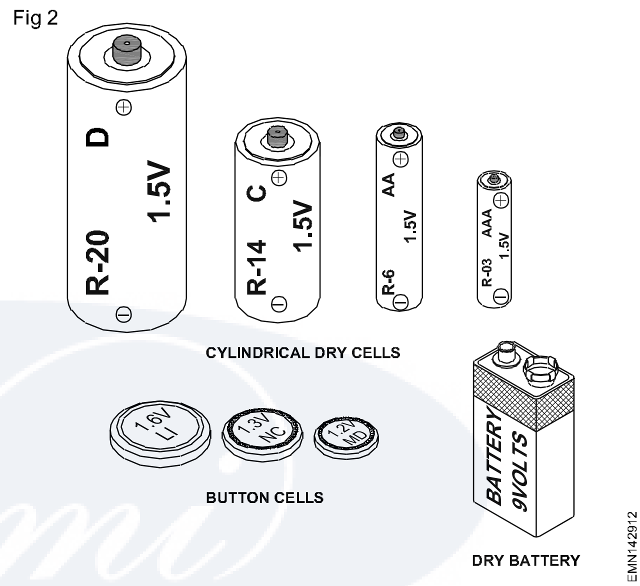
Fig 1



Primary Batteries - Converts chemical energy into electrical energy. This uses the chemicals within it to start the action of energy conversion. The most common types of primary cells and batteries are shown in Fig 2.

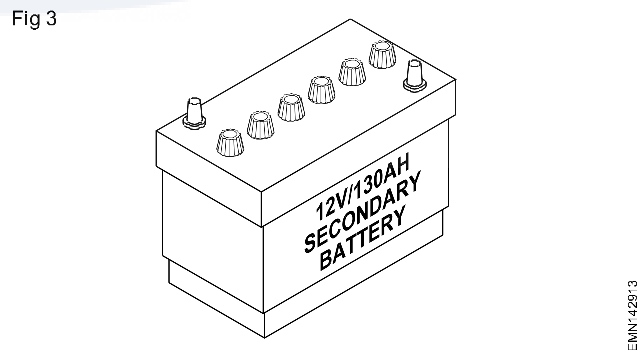
Secondary batteries - These batteries must be first charged with electrical energy. Once the battery is fully charged,it will then convert chemical energy to electrical energy. Secondary batteries first stores electrical energy supplied to it and then supply electrical energy as and when required. Hence secondary batteries are commonly called storage batteries.

Fig 2



A typical secondary storage battery is shown in Fig 3.

Fig 3



A battery may consist of two or more number of cells. The battery shown in Fig 3 has six cells of 2V each. These cells are connected in series to give 12V at battery terminals.

THE CELL

A cell consists of a pair of metal strips called **electrodes** and dipped in a chemical solution called **electrolyte** as shown in Fig 4.

Primary and Secondary cells

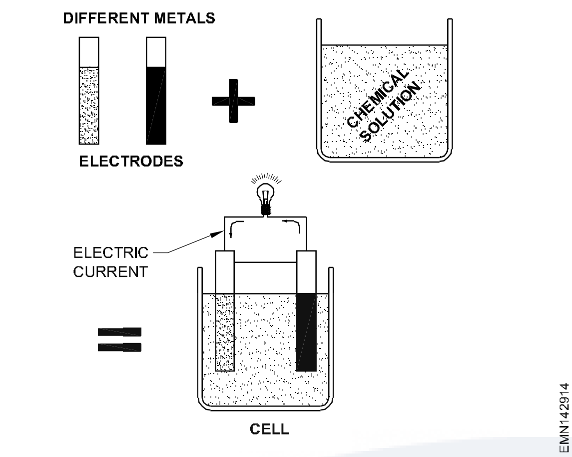
Primary cells are those which once fully used has to be thrown-out or destroyed. This is because the electrodes and electrolyte used in this type of cells cannot be reused.

Hence, primary cells are *non-rechargable* cells. Generally, the electrolyte used in primary cells is of paste form.

Secondary cells are those which once used can be reused by charging them. Hence, secondary cells are rechargable cells. Generally, the electrolyte used in secondary cells is in liquid form. However, there are rechargable cells with paste form electrolyte also.

In this lesson the commercial aspects of primary cells are discussed. Secondary cells are discussed in further lessons.

Fig 4



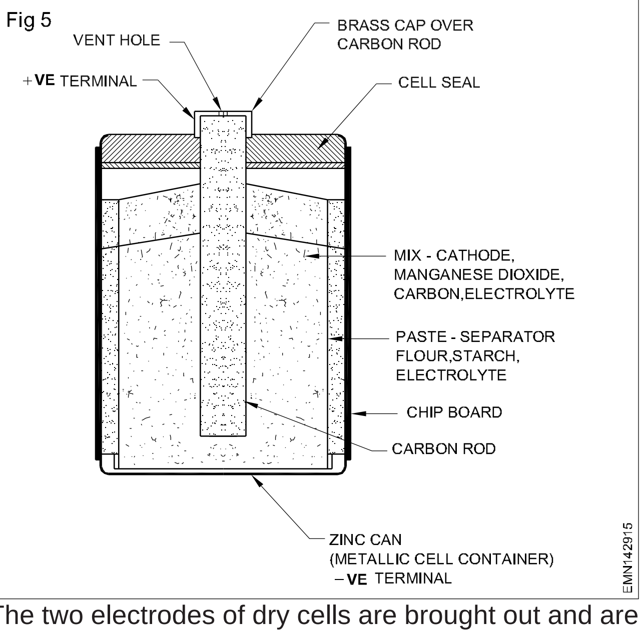
Dry and Wet cells

The electrolyte can be in liquid form or a paste form. Cells with paste form electrolyte are known as DRY cells. Cells with liquid form of electrolyte are called WET cells.

Dry cells and batteries

As the electrolyte used in dry cells is in paste form, it does not spill or leak. Hence, dry cells are used extensively in portable electrical and electronic gadgets. Typical constructional details of a zinc-carbon during cell is shown in Fig 5.

Fig 5



The two electrodes of dry cells are brought out and are available as +ve and -ve terminals of the cell. Usually the metallic cell container serves as the -ve of the cell as shown in Fig 5. The voltage that appears across the terminals depends upon the electrodes and the chemicals used in the cell. The voltage of a cell is so made as to suit the commercial requirement. Generally the voltage across the terminals of a dry cell range between 1.2 to 1.5 volts.

Dry cells and batteries are available in several shapes and sizes to suit commercial requirements. Some popular shapes of dry cells were shown in Fig 2.

Technically, any particular type of cell is defined by the materials used as electrodes and electrolytes in that cell. A dry cell with **zinc** as the -ve electrode, **carbon** as the +ve electrode with **zinc chloride** as the electrolyte is referred to as **zinc-carbon** cell or **zinc chloride** cell.

Similarly a dry cell which uses an alkaline solution as electrolyte is called an **Alkaline cells**.

A Chart on *Types of cells/batteries* given at the end of this lesson lists some popular dry cells along with the names of the materials used for the +ve,-ve electrodes, the electrolyte used, the available sizes, the rated output voltage and their applications.

The use of different materials for their electrodes and electrolytes results in different voltage, current rating discharge characteristics and the shelf life (life of the battery if kept unused).

NOTE: Not all types of cells are suitable for all applications. This is because some appliances draw high initial current or current in pulses which may not suit the discharge characteristics of the cell.

Weak, dead cell

Dry cells are used in various gadgets like flash lights, tape recorders etc, the cells convert the chemical energy built into them into electrical energy. In doing so, the dry cell slowly gets consumed. This means, the voltage across the cell terminals decreases and the current it can supply to the connected load becomes less and less. A stage will reach when the dry cell is no more capable of supplying sufficient voltage/current through the connected load . Then the cell is said to have become **weak** or **dead**.

As a thumb rule, dry cell can be declared unfit for use if, the voltage across its terminals is less than 75% of its rated output voltage.

Example: *A used zinc chloride dry cell with a rated voltage of 1.5 volts has 1.1 volts across its terminals. Find whether the cell is usable or not.*

Rated o/p voltage of the cell is 1.5V.

Measured output of the cell is 1.1V.

% Measured output with respect to rated output is

$$\frac{1.1}{1.5} \times 100 = 73.3\ \%$$

Chart for 1.2.29 &1.2.31

TYPES OF CELLS AND THEIR APPLICATIONS

Usual Name/Types	Classification	Negative Electrode (Anode)	Positive Electrode (Cathode)	Electrolyte	Rated output voltage	Available sizes	Applications
Carbon-Zinc (usually called Leclanche cell)	Primary	Zinc	MnO_2/C	Mixture of NH_4Cl and $ZnCl_2$	1.5V	D, C, B, A, AA, AAA	Flash lights, radio, tape batteries and for general purpose.
Carbon-Zinc (Zinc chloride cell)	Primary	Zinc	MnO_2/C	Zinc chloride	1.5V	D,C, B, A, AA, AAA	Electric shaver, electric knives transmitters, cordless drills, tools etc.
Alkaline-Manganese dioxide cell	Primary & rechargeable	Zinc	Manganese dioxide	Aqueous solution of potassium hydroxide	1.5V	D, C, AA	Camera cranking, radio controlled toys, radios & tape recorders.
Mercuric oxide cell	Primary	Zinc	Mercuric oxide	Aqueous solution of potassium hydroxide or sodium hydroxide	1.35V	C, B, AA and button cells	Cameras, watches, hearing aids, calculators etc.
Silver oxide cell	Primary	Zinc	Ag_2O	Aqueous solution of potassium hydroxide or sodium hydroxide	1.5V	Button cells	Hearing aids, digital wrist watch, micro-lamps, lights, meters etc.
Nickle-Cadmium	Rechargeable (Secondary)	Cadmium	Nickel hydroxide	Aqueous solution of potassium hydroxide	1.2V	All sizes of cyclin-drical, rectangular and buttoncells	Portable equipments like radio, tapes etc., rechargeable flash lights, emergency light etc.
Lithium Manganese	Primary	Lithium	Iodine/metallic oxides, sulphides button cells	Organic, inorganic water	3V to 6 V	Medium to large	Electronic watches, cal-culators, heart pacemaker life support equipments & communication equipments.

Secondary batteries - types of charge, discharge and maintanance

Objectives : At the end of this lesson you shall be able to
- **state the applications of lead-acid batteries**
- **describe the construction of lead acid batteries**
- **explain types of secondary cells, their nominal cell voltage, capacity and applications**
- **explain the effect of temperature on AH capacity**
- **state the care and maintenance of lead acid batteries**
- **describe the hydrometer**
- **connect the cells in series, parallel and series-parallel.**

Secondary batteries

Secondary batteries are made of small units known as cells. The main difference between a primary and a secondary cell is that a secondary cell can be recharged. This is because the type of chemicals used in a secondary cell is such, the chemical reaction is reversible.

When a secondary cell is supplying current to a load, the cell is said to be *discharging*. This discharging current gradually neutralizes the separated positive and negative charges at the electrodes (Anode and Cathode).

On the other hand, when current is supplied to a cell, the charges get re-formed on the electrodes due to reverse chemical reaction. This action is known as *charging* the cell. For charging a cell, the charging current is supplied by an external DC voltage source, with the cell behaving as a load.

The process of discharging and recharging is called *cycling* of the cell. As long as the cell is in good condition the discharge and charge cycles can be repeated several hundred times.

Since a secondary cell can be recharged, in other words the charges restored, these cells are called *storage cells*.

The most common type of secondary cell is the *Lead-acid cell*. A battery consisting of a combination of such cells is called *Lead-acid battery*. Lead-acid batteries are commonly used in automobiles such as cars, buses and lorries etc.,

Lead-acid, wet type cells

Lead-acid secondary batteries made of lead-acid are used in almost every automobile, for starting the engine. These batteries supply load current of 100 to 400A to the starter motor of automobiles.

The nominal voltage of a lead-acid cell is 2.2 V. By connecting three or six cells in series, batteries of 6V or 12V is obtained.

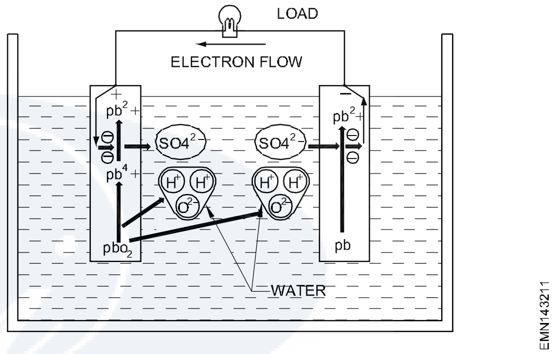
Principle of chemical action

A fully charged lead-acid cell has a lead peroxide (PbO_2) positive electrode, which will be reddish brown in colour and a gray spongy lead (Pb) as the negative electrode. These two electrodes are immersed in an electrolyte which is a diluted solution of sulphuric acid (27% sulphuric acid) having a specific gravity of 1.3. Such a cell produces an output of 2.2 V.

Discharging of lead-acid cells

The chemical action that takes place during the discharging of a lead-acid cell is shown in Fig 1.

Fig 1



During discharge, the lead (Pb) in both the electrodes react with sulphuric acid (H_2So_4) to displace hydrogen and form lead sulphate ($PbSo_4$). This lead sulphate, a whitish material, is somewhat insoluble and hence gets partially coated on both positive and negative plates. Since both plates approach the same material ($PbSo_4$) chemically, the potential difference between these plates begins to decrease. At the same time, the combining of oxygen in the lead peroxide (PbO_2) with the hydrogen atoms of the electrolyte forms water (H_2O) as shown in the equation given below,

$$Pb + PbO_2 + 2H_2So_4 \xrightarrow{\text{Discharge}} 2PbSo_4 + 2H_2O$$

It can be seen from the discharging equation that as the battery discharges (delivers energy to a load), the sulphuric acid solution becomes weaker (more and more diluted) with its specific gravity approaching 1.0.

The coating of whitish lead sulphate on the electrodes and the decrease in specific gravity of the electrolyte makes the voltage of the cell to drop off. Also, the internal resistance of the cell rises due to the sulphate coating on the plates.

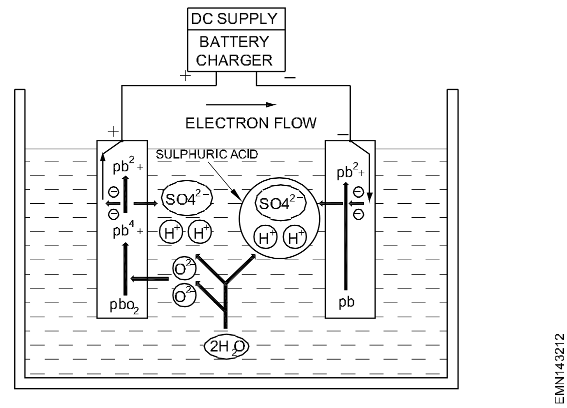
Charging of lead-acid cells

The chemical reaction that takes place during charging of a lead-acid cell is shown in Fig 2.

When a battery charger, having an output voltage (2.5V) which is slightly higher than the nominal voltage of the cell

(2.2V), is connected as shown in Fig 2, the direction of ionic flow gets reversed (refer to Fig 1 for the discharging direction). The electrical energy supplied by the charger causes the recombination of lead sulphate ($PbSo_4$) with hydrogen ions in the electrolyte. Therefore, the excess

Fig 2



water is removed from the electrolyte solution. As the electrolyte returns to its normal strength of sulphuric acid (27%) and the plates return to their original form of lead peroxide and spongy lead, the voltage across the electrodes returns to its nominal value of 2.2 V. The chemical action involved during charging can be represented by the following equation;

At the negative pole:

$PbSO_4$ + 2 electrons $\longrightarrow$ Pb + SO_4

At the positive pole:

$PbSO_4$ - 2 electrons + $2H_2O$ $\longrightarrow$ PbO_2 + So_4^{2-} - $4H^+$

As the above reactions take place simultaneously, the equation can be written as,

$2PbSO_4$ + $2H_2O$ + Electrical energy $\longrightarrow$ $2H_2So_4$ + Pb + PbO_2.

It should be noted that, to charge a lead-acid battery of 12 V (2.2 V x 6 cells), the output voltage of the battery charger used for charging should be between 14.1 V to 15 V, and, its current rating not larger than 30 A. Charging batteries at excessively higher currents can cause boiling of the electrolyte. This reduces the liquid level in the battery and causes buckling and crumbling of the electrodes, thus reducing the life of the cells and hence the battery.

The lead sulphate ($PbSO_4$) which gets coated on the +ve and -ve plates tends to harden into an insoluble salt over a period of time. Hence, it is recommended to fully recharge a battery even if it is not used for quite some time.

Construction of lead-acid batteries

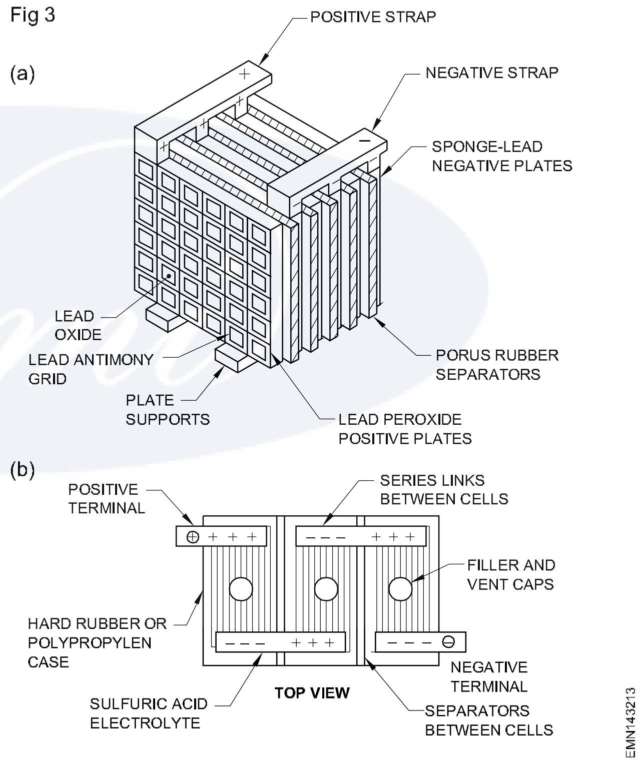
Fig 3 shows the principle behind the construction of commercial lead acid batteries.

Although in Figs 1 and 2, the lead-acid cell electrodes were shown as single plates, in a practical cell, it will not be the case. To increase the surface area and current capacity, a number of positive and negative plates are interleaved and separated by porous rubber sheets as shown in Fig 3a. All the positive plates are electrically connected, and all the negative plates are electrically connected. These parallel connections yield a higher current capacity of the cell with an overall cell output voltage of 2.2V. Several such cells can be connected in series to obtain the required battery voltage. For example, Fig 3b shows three such cells connected in series to produce a 6 volts Lead acid battery.

In lead-acid batteries, since hydrogen gas is produced during recharging, vents (holes) are provided on the battery compartment to let hydrogen and water vapour escape into free air. The vents also help in adding distilled water to the cells to compensate the water evaporated from the electrolyte.

For further details on the construction and manufacturing techniques of lead acid batteries refer reference books listed at the end of this unit.

Fig 3



Current rating of Lead acid batteries

The current rating of a lead acid battery is usually given in ampere-hour (AH) units, based on an 8 hour discharge period. In other words, batteries are rated in terms of how much discharge current they can supply for a specified period of time (often 8 hours). During this time, the cell's output voltage must not drop below 1.7 volts. Typical Ah values of automobile batteries range from 60 Ah to 300 Ah.

For example, A 60-AH battery, used in smaller automobiles, can supply a load current of 60/8 or 7.5 amperes for 8 hours without the cell voltages dropping below 1.7 volts. However this battery can supply less current for longer time (5 amps for 12 hours) or more current for a shorter time (60 amps for 1 hour).

Effect of temperature on AH capacity of Lead-acid batteries

As in the case of primary cells, the capacity of a lead-acid cells also decreases significantly with temperature. These cells lose approximately 0.75% of its rated ampere-hour (Ah) capacity for every 1°F decrease is temperature. At 0°F (–18°C), its capacity is only 60% of the value at 60°F (15.6°C). In cold weather, therefore, it is very important to have an automobile battery always fully charged. In addition, at very cold temperature, the electrolyte freezes more easily as it is diluted by water in the discharged condition.

Keep the batteries always fully charged especially in cold weather conditions.

Specific gravity of electrolyte

Specific gravity is a ratio comparing the weight of a substance with the weight of water. The specific gravity of water is taken as 1 as a reference. For instance, specific gravity of concentrated sulphuric acid is 1.835. This means, sulphuric acid is 1.835 times heavier than water for the same volume.

In a fully charged lead-acid cell, the specific gravity of the electrolyte, which is a mixture of sulphuric acid and water should be 1.28 at room temperature of 70 to 80°F. As the cell discharges, more and more water gets released into the electrolyte, lowering the specific gravity. When the specific gravity of the electrolyte falls down to about 1.150, the cell can be taken as fully discharged. Hence, the state of discharge of a lead-acid cell can be found out by measuring the specific gravity of its electrolyte.

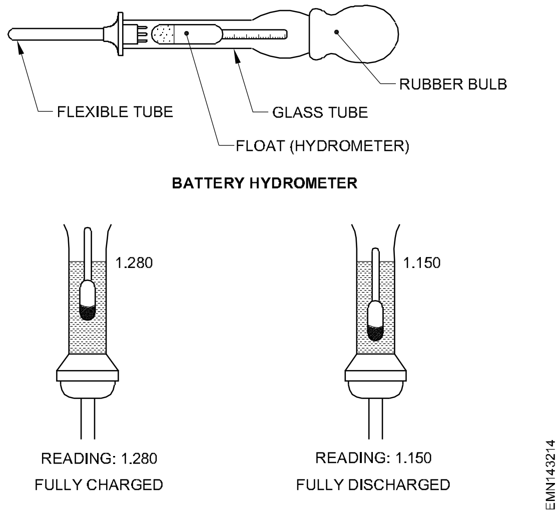
The specific gravity of electrolyte is measured using a instrument known as *Battery hydrometer* as shown in Fig 4 below.

Hydrometer

This meter is used to test the specific gravity of the liquid. It consists of a glass-made tube with bulb. The glass tube is filled with small lead pieces and is fitted with scale on which specific gravity is written as well as the indication of charged to discharged condition of a cell is also written. This hydrometer is kept in another glass-made tube. On one side of this tube a rubber ball is fitted and on the other side, nozal is fitted. When the ball of this meter is pressed and released while keeping this meter in the electrolyte of the cell, the electrolyte comes in the outer glass tube in which hydrometer bulb floats and gives reading with dilute H_2SO_4. The bulb will sink in the electrolyte while with strong H_2SO_4 the bulb will come up Hence, it gives reading. The electrolyte is so filled that the Hydrometer should not stick on the upper head or the bottom of the outer tube.

Reading on the Hydrometer	1280
Full charge	1260
Half charge	1200
Full discharge	1200
or Dead	1180

Fig 4



The importance of specific gravity can be seen from the fact that the open circuit voltage(V) of lead-acid battery is approximately given by,

$$V = \text{Specific gravity} + 0.84.$$

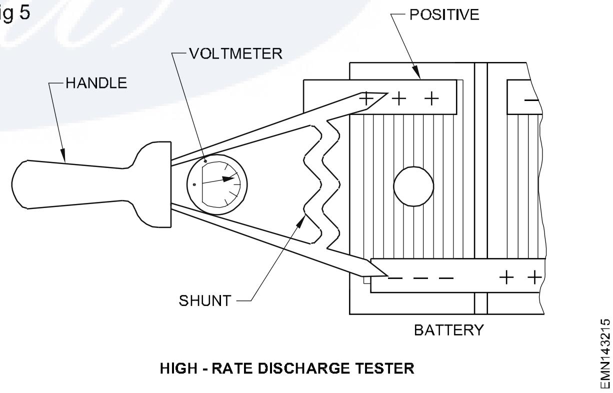
For instance, if the specific gravity is 1.280 then,

$$V=1.280 + 0.84 = 2.12V$$

Instrument for testing condition of cells - High rate discharge tester

The internal condition of a lead-acid battery cell is determined by this test. A low range (0-3V) voltmeter is shunted by a low resistance as shown in Fig 5.

Fig 5



The two terminal prods are pressed on to the terminals of a cell for testing. For fully charged cell the meter pointer points in the range of *full charge* on the meter scale. A sulphated old cell will show the discharge reading. The meter is having three colours red, yellow and green; red for fully discharged, yellow for half charged and green for fully charged condition of the cell respectively.

Topping up of lead-acid battery cells

In normal working condition of a lead-acid battery, the level of the electrolyte solution should be such that all the plates of the cells are fully immersed. If the level of the electrolyte is found to be less, then distilled water should be added to the indicated level of the cell through the vent plugs. This process of maintaining the level of electrolyte in lead-acid battery cell is called topping up.

Do not add tap water or well water for topping up. This will reduce cell life.

When a lead acid battery is being charged, the vent plugs are to be kept open for the gas produced to escape freely into air.

In case of lead-acid batteries used as back-up DC supply in un-interrupted power supplies (UPS), since charging and discharging of batteries is a continuous process, the vent plugs of the batteries will have several holes made on it for the gases produced during charging.

Un-interrupted power supplies are used in Hospitals, Computers etc., where the power failure may prove very costly.

Care and routine maintenance of lead-acid batteries

- DO NOT use battery if it is discharged beyond the minimum value of 1.7V per cell.
- DO NOT leave a discharged battery in that condition for a long time. Even if not in use, keep the battery always fully charged.
- Always maintain the level of the electrolyte 10 to 15 mm above the top of the plates by adding suitable quantity of distilled water (NOT tap water).
- DO NOT add sulphuric acid to maintain specific gravity.
- Keep the vent openings in the filling plug always open to prevent build-up of high pressure due to the gases formed. At least the vent plug should have holes made in it.
- Wash off the acid and corrosion on the battery top using moist cloth, baking soda and water.
- Clean the battery terminals and metal supports up to the bare metal and apply vaseline or petroleum jelly over its surface.
- DO NOT test a discharged battery using a 'High rate discharge tester'.

Some applications of lead-acid batteries

Lead-acid storage battery is the most common type found in commercial market. Lead-acid batteries find a great variety and range of applications. Some common applications are listed below;

- In petrol run motor vehicles like scooters, cars etc.
- In small domestic and industrial private generating plants and in mines.
- Battery run locomotives.
- In emergency lamps for small capacity lighting.
- In uninterrupted power supplies (UPS) for providing reserve supply in the event of mains failure.

Although wet electrolyte lead-acid secondary cells are the most common type, there are other types of secondary cells which find application in certain fields due to their special features. A brief on other types of secondary batteries is given below;

Maintenance free lead-acid batteries

Recent advances in lead-acid cells have resulted in low maintenance and maintenance free batteries. In normal lead-acid batteries, the battery plates contain antimony (4%), as the plates are made of lead antimony. It has been found that the amount of *gassing* i.e. production of hydrogen while charging a cell can be reduced by lowering the amount of antimony in the lead plates. By reducing the antimony in plates to 2%, low maintenance cells can be made. These cells require very little addition of water because very little water is *boiled-off* during charging. Totally maintenance free cells use antimony-free plates allowing complete sealing of battery, since no vents are necessary because gas does not build-up at all. Once sealed, no electrolyte can evaporate from the cell. However in some batteries, a small vent is provided to relieve the pressure arising from altitude changes.

One such maintenance free lead-acid cell is the *Gelled-Electrolyte Lead-acid Cell*. This cell enjoys all the advantages of a wet lead-acid cell but avoids the problems due to liquid electrolyte as it uses a gelled electrolyte. These cells use lead-calcium grids. These cells are completely sealed and can be mounted in any position. A one-way relief valve is provided to release excess pressure if the cell's internal pressure rises too high during charging, and it automatically recloses.

Gelled-electrolyte lead acid batteries are available from 2 V to 12 V with capacities ranging from 0.9 to 20Ah, based on a 20 hour discharge rate. The maximum current for these batteries ranges from 40 to 200 A. These batteries are used in domestic emergency lamps, portable television sets, portable tools and a variety of industrial applications.

Nickel-cadmium (NiCd) cell

Next to lead-acid, these cells are popular because of their ability to deliver high current and can get recycled many times. Also, the cell can be stored for a long time, even when discharged, without any damage. The NiCd cell is available in both sealed and non-sealed designs, but the sealed construction is more common. Nominal output voltage of a nickle-cadmium cell is 1.25 V per cell.

The chemical equation for the NiCd cell can be written as

$$2Ni(OH)_3 + Cd \underset{\text{discharge}}{\overset{\text{charge}}{\rightleftharpoons}} 2Ni(OH)_2 + Cd(OH)_2.$$

The electrolyte is potassium hydroxide (KOH), but it does not appear in the chemical equation. The reason is that the function of this electrolyte is just to act as a conductor for the transfer of hydroxyl (OH) ions. Therefore, unlike the lead-acid cell, the specific gravity of the electrolyte in the NiCd cell does not change with the state of charge.

The NiCd cell is a true storage cell with a reversible chemical reaction of recharging that can be cycled up to 1000 times. Maximum charging current is equal to the 10-h discharge rate. It should be noted that a new NiCd battery may need charging before use.

Applications include portable power tools, alarm systems, and portable radio or television equipment.

Nickel-iron or Edison cell

This cell was once used extensively in industrial truck and railway applications. However, it has been replaced almost entirely by the lead-acid battery. New methods of construction for less weight, though making this cell a possible alternative in some applications.

The Edison cell has a positive plate of nickel oxide, a negative plate of iron, and an electrolyte of potassium hydroxide in water with a small amount of lithium hydroxide added. The chemical reaction is reversible for recharging. The nominal output is 1.2 V per cell.

Nickel-zinc cell

This type has been used in limited railway applications. There has been renewed interest in it for use in electric cars, because of its high energy density. However, one drawback is its limited cycle life for recharging. The nominal output is 1.6 V per cell.

Alkaline - manganese secondary cells

Alkaline - manganese secondary batteries are maintenance free, hermetically sealed, and will operate in any position. Individual cells use electrodes of zinc and manganese dioxide with an alkaline electrolyte of potassium hydroxide. Each cell has a nominal voltage of 1.5 V. Alkaline-manganese batteries are available in rated Ah capacity of 1 to 4 Ah. The internal resistance of these batteries is appreciably higher than NiCd batteries. Therefore, alkaline manganese batteries are not suitable for large current supplies.

Alkaline manganese batteries have been designed for electronic and electrical appliances where initial cost and low operating cost are of paramount interest. The total number of times the alkaline manganese secondary batteries can be recharged is much less than that of NiCd batteries, but the initial cost is lower.

Charging alkaline manganese batteries is different from that of NiCd batteries. According to the manufacturer's data, the charging should be done at constant current but at a constant voltage. Another difference, when compared with other secondary batteries is that, the alkaline manganese batteries must not be discharged too much; otherwise, the chemical process can be no longer reversed which means they cannot be recharged. It is recommended by the manufacturer not to discharge the cells below 1 volt.

Zinc-chlorine (hydrate) cell

This cell has been under development for use in electric vehicles. It is sometimes considered as a zinc-chloride cell. This type has high energy density with a good cycle life. Nominal output is 2.1 V per cell.

Lithium-iron sulphide cell

This cell is under development for commercial energy applications. Nominal output is 1.6 V per cell. The normal operating temperature is 800 to 900°F which is high compared with the normal operating temperature of the more popular types of cells.

Sodium-sulphur Cell

This is another type of cell being developed for electric vehicle applications. It has the potential of long life at low cost with high efficiency. The cell is designed to operate at temperatures between 550 and 650°F. Its most interesting feature is the use of a ceramic electrolyte.

Lead-acid secondary batteries made of lead-acid are used in almost every automobile, for starting the engine. These batteries supply load current of 100 to 400A to the starter motor of automobiles.

The nominal voltage of a lead-acid cell is 2.2 V. By connecting three or six cells in series, batteries of 6V or 12V is obtained.

Plastic Cells

A recent development in battery technology is the rechargeable plastic cell made from a conductive polymer, which is a combination of organic chemical compounds. These cells could have ten times the power of the lead-acid type with one-tenth the weight and the one-third the volume. In addition, the plastic cell does not require maintenance. One significant application could be for electric vehicles.

A plastic cell consists of an electrolyte between two polymer electrodes. The operation is similar to that of a capacitor. During charge, electrons are transferred from the positive electrode to the negative electrode by a dc source. On discharge, the stored electrons are driven through the external circuit to provide current in the load.

Application of maintenance free Gelled Electrolyte Lead-acid batteries

Since Gelled electrolyte lead-acid batteries are maintenance free and can be placed in any position, these batteries are extensively used in almost all types of portable equipments. The most common application of Gel-batteries can be found in *emergency lamps*. Emergency lamps are nothing but stand-by light sources, used in the event of main's failure. The type of lamp used could be a miniature tube light or a simple filament lamp. Emergency lamps which use miniature tube lights need a special circuit known as *inverter*. The function of the inverter circuit is to convert a low DC voltage into a high AC voltage.

Recharging lead-acid batteries

Recall that lead-acid batteries are rechargeable. Once the cell voltages of a lead-acid battery falls below 1.8 V, the battery needs recharging. This discharged state of battery can be found by measuring the specific gravity of the electrolyte (1.150) or by measuring the voltage across the cells of the battery.

To charge a lead-acid battery, an equipment known as Battery charger is used. A battery charger is nothing but a DC voltage source which can supply the necessary voltage and charging current to the battery.

There are two main methods of charging batteries. They are;

1 Constant current battery charging

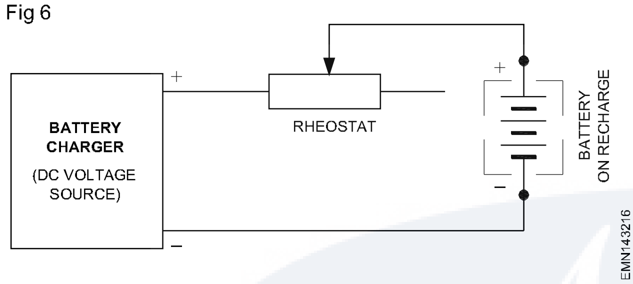
2 Constant voltage battery charging.

1) Constant current battery charging

In this method of charging batteries, the charging current supplied to the battery is kept at a prescribed (by the battery manufacturer) constant value. The amount of this constant current varies depending upon the Ah capacity of the battery. The value of constant charging current should not be excessive as this would cause excessive gassing. Excessive value current rises the cell temperature above the safe limit (generally 40°C) which will reduce the life of the battery.

Fig 6 shows a very simple method of constant current charging system.

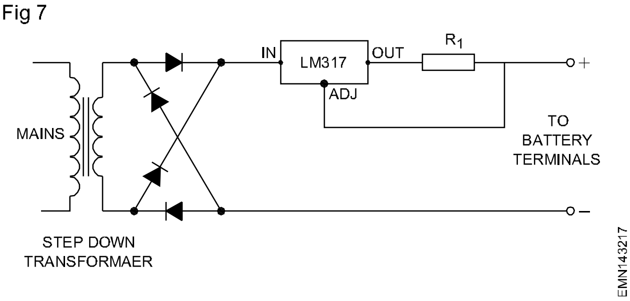
Fig 6



In constant current charging, the output DC voltage of the charger will be generally twice the nominal voltage of the battery to be charged. But, the charging current is controlled by varying the rheostat connected in series with the battery. For example, to charge a 12 V battery, the DC voltage source can be 24 V, but the charging current will be kept controlled say, 1 ampere with the help of the rheostat.

With the introduction of voltage regulator integrated circuits like LM317, it has become very simple and less expensive to make constant current battery chargers. Fig 7 shows a simple constant current battery charger using LM317. This charger can be used for any type of battery charging as long as the charging current is less than 1.5 Amperes.

Fig 7



Current can be set at any value between 10 mA and 1.5 A in the circuit at Fig 7. To have higher currents, suitable external power transistors can be used. In Fig 7, the input voltage to the regulator IC (LM317) should be 1.5 times the battery voltage (to be charged) plus 3 V. LM317 used in Fig 7 is immune to output shorts or reverse battery connections. Hence, the charger will always be safe.

The disadvantage of constant current battery charging is that it takes comparatively long time to fully charge the battery. But, the charge efficiency, which is defined as, is high compared to constant voltage battery charging.

$$\text{Charge efficiency} = \frac{\text{Charge stored by the battery}}{\text{Charge supplied to the battery}}$$

2) Constant voltage battery charging

In this method, the voltage applied across the battery terminals is kept constant, but no control is imposed on the charging current. Therefore, the battery draws large charging current in the beginning and as the cells gets charged, the charging current decreases to a small value.

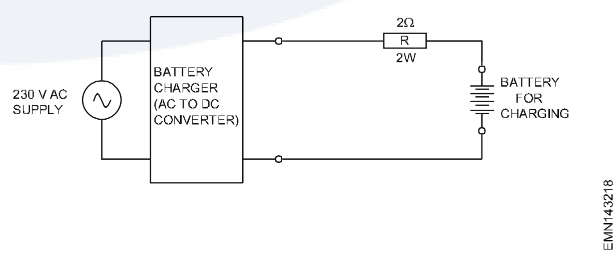
In this method, the time required for charging is reduced to half compared to the constant current charging. But, the charge efficiency gets reduced by approximately 10%.

In constant voltage charging, the voltage applied to the cells for charging should be fixed at about 2.3 to 2.5 volt per cell and not more. For instance, for a 12 volts car battery, the DC voltage output of the charger should be between 14 V to 15 V.

Simple constant voltage battery charging shown in Fig.8. Generally for converting AC into DC. Rectifier circuits are used. For pricision operation, Thyristor based rectifiers also used.

Resistor R is used to limit the initial charging surge current from becoming excessively high. This is because excessive current may damage the diode and transformer of the battery charger unit.

Fig 8



TRICKLE Charging

Whenever a storage battery is used as an emergency reserve, as in the case of un-interrupted power supply (UPS), it is necessary to keep the batteries fully charged and ready for use at any time if the mains supply fails.

A fully charged battery, which is not connected to any load is expected to maintain its terminal voltage. But, due to internal leakage in the battery and other open circuit losses, the battery voltage slowly falls even in idle or open circuit condition. Therefore, to keep it in fully charged condition, the battery should be supplied with a charging current which is small and just sufficient to compensate the idle condition or open circuit losses. This small current charging is known as Trickle charging. Trickle charging keeps the battery always fully charged and in ready to use condition, so that, the battery can be fully made use of in emergency conditions.