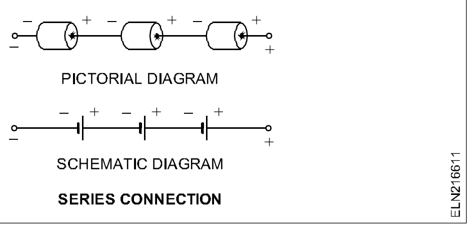
## Grouping of cells

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of cells connected in series and parallel**
- **explain series connections, parallel connection and series-parallel connection of cells**
- **state the method of testing cells.**

**Grouping of cells:** Often an electric circuit requires a voltage or current that a single cell is not capable of supplying alone. In this case it is necessary to connect groups of cells in various series and parallel arrangements.

**Series connections**: Cells are connected in series by connecting the positive terminal of one cell to the negative terminal of the next cell (Fig 1).

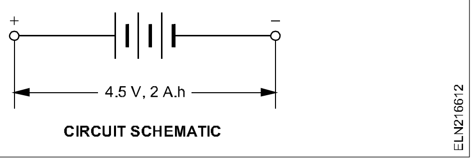
Fig 1




Identical cells are connected in series to obtain a higher voltage than is available from a single cell. With this connection of cells, the output voltage is equal to the sum of the voltages of all the cells. However, the ampere hour (AH) rating remains equal to that of a single cell.

Example: Suppose three `D' flashlight cells are connected in series (Fig 2). Each cell has a rating of 1.5 V and 2 AH The voltage and ampere hour rating of this battery would be:

Fig 2




V Battery = V per cell x No.of cells
= (1.5V) (3)
= 4.5 V

AH Battery rating = AH rating of 1 cell
= 2 AH

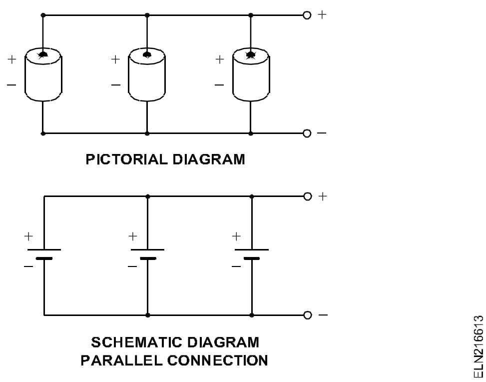
> **If, by mistake, one cell connection is reversed in a series group, its voltage will oppose that of the other cells. This will produce a lower than expected battery output voltage.**

**Example**: Suppose that one of the three `D' flashlight cells of the previous example is connected in reverse, the output voltage then would be:

V Battery = (1.5V)+(1.5V) − (1.5V)
= (3.V) − (1.5V)
= 1.5V.

**Parallel connection:** Cells are connected in parallel by connecting all the positive terminals together and all the negative terminals together (Fig 3).

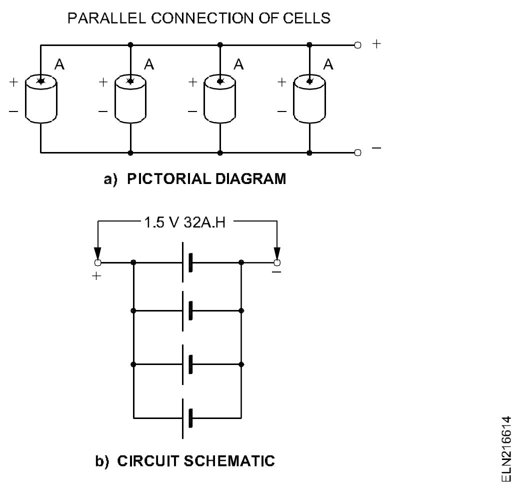
Fig 3




Identical cells are connected in parallel to obtain a higher output current or ampere-hour rating. With this connection of cells, the output ampere hour rating is equal to the sum of the ampere hour ratings of all the cells. However, the output voltage remains the same as the voltage of a single cell.

**Example**: Suppose four cells are connected in parallel (Fig 4). Each cell has a rating of 1.5 V and 8 AH. The voltage and ampere-hour rating of this battery would be:

Fig 4



V Battery = V rating of 1 cell

= 1.5 V

AH Battery rating = AH rating per cell x no. of cells

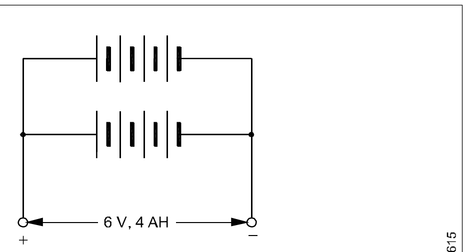
= (8 AH) (4)

= 32 AH

**If, by mistake, a cell connection is reversed in a parallel group, it will act as a short circuit. All cells will discharge their energy through this short circuit path. Maximum current will flow through the short circuit and the cells may be permanently damaged.**

**Series-parallel connection:** Sometimes the requirements of a piece of equipment exceed both voltage and ampere hour rating of a single cell. In this case a series-parallel grouping of cells must be used (Fig 5).

Fig 5




SERIES-PARALLEL CONNECTION

The number of cells that must be connected in series to have voltage rating is calculated first and then the number of parallel rows of series connected cells is calculated for required ampere-hour rating.

***Example***: Suppose a battery operated circuit requires 6 V and a capacity of 4 AH (Fig 5). Cells rated at 1.5 V and 2 A H are available to do the job. The required arrangement of cells would then be:

$$\text{No. of cells in series} = \left(\frac{\text{V required}}{\text{V per cell}}\right)$$

$$= \frac{6\text{ V}}{1.5\text{ V}} = 4 \text{ cells}$$

$$\text{No. of parallel rows} = \left(\frac{\text{AH required}}{\text{AH per cell}}\right)$$

$$= \frac{4\text{ AH}}{2\text{ AH}} = 2 \text{ rows.}$$

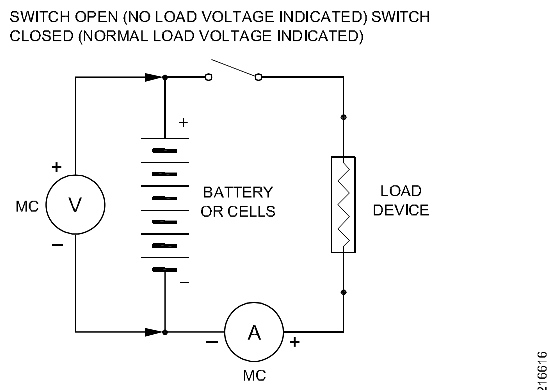
**When connecting groups of cells or batteries in parallel, each group must be at the same voltage level. Paralleling two batteries of unequal voltage levels sets up a difference of potential energy between the two. As a result, the higher voltage battery will discharge its current into the other battery until both are at equal voltage value.**

**Testing primary cells or batteries**: A visual inspection will tell you little about the useful life of a cell or battery unless it has deteriorated to the point where acid is spilling from the case.

A no-load voltage test of the cell of battery is another indication of cell or battery life. This test requires the cell or battery to deliver only a very small amount of current required to operate the voltmeter.

The best method that is used to check a cell or battery is an in-circuit test of the cell or battery voltage with the normal load connected to it (Fig 6). A substantial drop in cell or battery voltage, when normal load is applied, indicates a bad cell or battery.

Fig 6




TESTING A BATTERY UNDER LOAD

# Battery charging method - Battery charger

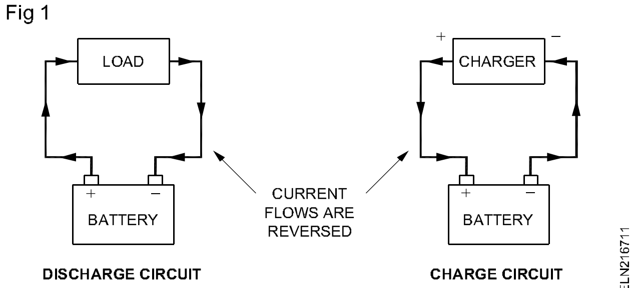
**Objectives:** At the end of this lesson you shall be able to
- **state the necessity of charging a battery**
- **describe the preparation of electolyte**
- **describe the use of a hydrometer and high rate discharge tester**
- **state the precautions to be followed while charging and discharging a battery**
- **describe the different types of charging methods of secondary cells**
- **explain the purpose, construction and working principle of battery charger.**

**Necessity of charging:** During discharge, due to chemical reaction, the active electrodes become smaller and the internal resistance becomes high causing a low output. To reverse the action, send a current (DC) through the battery or cell in the opposite direction to that of the discharge. This process is called charging. The charging can be done through a battery charger.

**Battery chargers**:When the chemical reaction in a rechargeable battery has ended, the battery is said to be discharged and can no longer produce the rated flow of electric current. This battery can be recharged, however, by passing direct current from an outside source to flow through it in a direction opposite to that in which it flowed out of the battery.

When charging a battery, the negative lead of the charger must connect to the negative lead of the battery and the positive lead of the charger to the positive lead of the battery (Fig 1). A reversal of these connections will produce a short circuit and may damage both the charger and the battery.

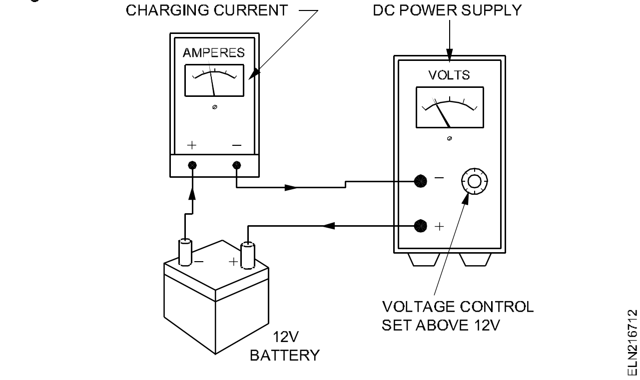
Fig 1




An automobile uses an automatic charging circuit as part of the car's electrical system, which is designed to recharge the battery as required and battery charging is also done using large commercial type battery chargers. Smaller type chargers are also available for use on the smaller nickel-cadmium cells. A simple variable-voltage DC power supply works well as a battery charger.

**Charging current**: When charging any battery, it is important to set the charging current to a value recommended by the manufacturer. This current is set by adjustment of the output voltage on the charger and read by an ammeter connected in series with the charger and battery (Fig 2). When the battery and charger are at the same voltage, no current flows. The charger voltage is set to a value higher than that of the battery to produce a current flow.

Fig 2




Before charging the battery or cell the following points are to be observed to ascertain the condition of the battery.

1 Specific gravity of the electrolyte
2 Voltage of each cell of the battery
3 Ampere hour capacity of each cell.

**PREPARATION OF ELECTROLYTE**

The electrolyte used in a cell is dilute sulphuric acid having a specific gravity between 1.21 and 1.3. The specific gravity of the acid available in the market is usually 1.835. Therefore, it is necessary to dilute the acid. Remember that for dilution, the acid is gently poured into distilled water and not the water into acid. In this way, the acid is diluted upto a specific gravity of 1.4 and stored. When, it is required to be filled up in the battery, then it is further diluted upto a specific gravity of 1.25.

**Specific gravity**

The ratio of the mass of a given volume of liquid to the mass of the same volume of the water at 4°C, is known as specific gravity of the liquid.

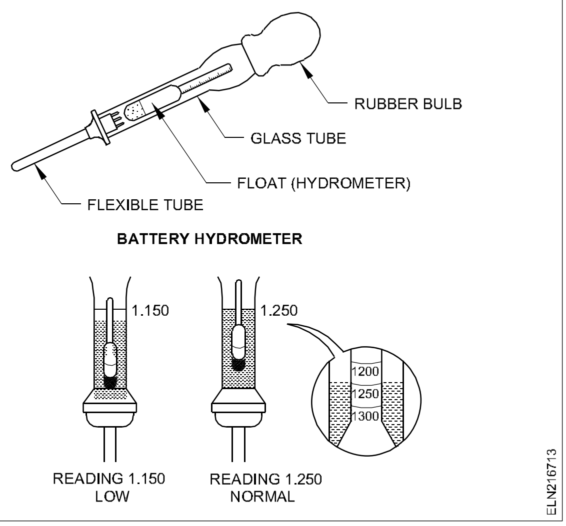
$$\text{Specific gravity} = \frac{\text{(mass of given volume of liquid)}}{\text{(Mass of the same volume of water at 4°C)}}$$

It means that the specific gravity of a liquid is a measure of comparative weights of the same volume of liquid and water at 4°C.It has no unit.

**Instrument for testing the condition of cells:**

**Hydrometer :** The specific gravity of an electrolyte is measured with a hydrometer (Fig 3).

Fig 3




**The main parts**

- Rubber bulb
- Glass tube
- Float
- Flexible rubber tube

The charged condition of battery can be tested by means of a battery hydrometer. This instrument measures the relative density of the battery electrolyte. Since the strength of the electrolyte varies directly with the state of charge of each cell, you need only to find what specific gravity of sulphuric acid remains in each cell electrolyte to determine how much energy is available.

| Cell condition | Hydrometer reading |
|---|---|
| Full charge | 1.26 |
| 50% charge | 1.20 |
| Discharged | 1.15 |

Voltage tests of lead-acid batteries, like primary cells, should be conducted under load. To make a simple light load voltage test of a car battery, check the value of the battery output voltage with and without the headlights on. A maximum load voltage test can be made by metering the battery voltage while operating the starting motor (Fig 4). In the case of a 12V battery, a drop of battery output voltage below 7V indicates the battery is defective or not fully charged.

**High rate discharge tester**: The internal condition of the cell is determined by this test. A low range (0-3V) voltmeter is shunted by a low resistance (Fig 5). The two terminal prods are pressed on to the terminals of a cell for testing. A fully charged cell which is in good condition reads in the range of full charge.

A sulphated old battery will show the discharge reading. The meter is having three colours red, yellow and green - red for fully discharged, yellow for half charge, green for fully charged condition of the cell respectively.

Fig 4

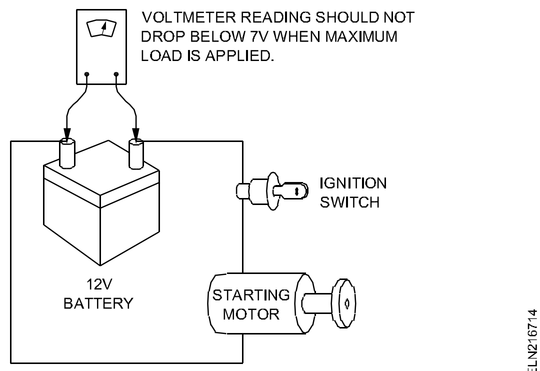
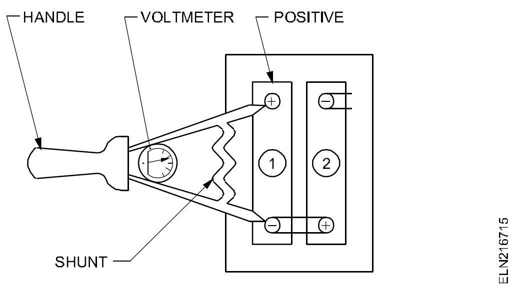



Fig 5




**Voltage of each cell**: The voltage of the cell is measured with a M C voltmeter. The fully charged cell will indicate 2.5 to 2.6V and a fully discharged cell will indicate 1.8V to 1.6V.

After determining the condition of the battery or cell, the charging rate, and the method of charging are to be decided. The battery should always be charged at the rates recommended by the manufacturer.

If you charge two or more batteries in series or in parallel, the potential difference between the terminals of the charging unit should not exceed the total voltage of all the batteries being charged in the case of series, and in the case of parallel the charging voltage should not exceed the voltage of a battery.

**Safety precautions**

Before putting the battery under charge, the following precautions are to be followed.

**Topping up**: If the level of the electrolyte on the surface of the plate is less than 10 to 15mm then distilled water should be added to the indicated level of the cell after removing the vent plugs.

**Do not add tap water or well water for topping up.**

**During charge the vent plugs are to be kept open for the escape of gas produced freely.**

**Ventilation**: The room where batteries are to be charged should be well ventilated.

Naked flame should not be brought near the battery or cell when it is under charge.

The terminal posts should be free from corrosion and they must be covered with petroleum jelly before and after charging.

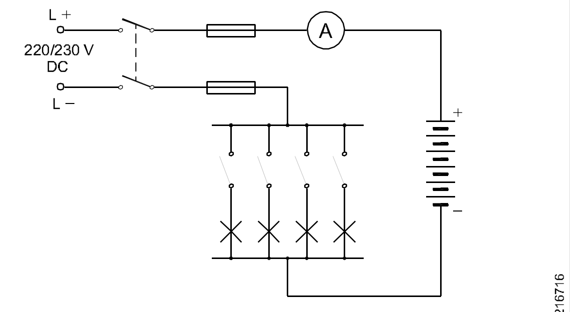
Improper electrolytes must not be used for compensating the electrolyte after it is fully charged.

**The methods of charging the secondary cells are:**

- constant current method
- constant potential method
- rectifier method.

**Constant current method**: This method is used where the supply is high voltage DC 220 V, 110 V, etc. but the battery is of low voltage 6 V, 12 V, etc. The emf of the battery is small in comparison to the supply voltage so a lamp-load or a variable resistor is connected in series with the battery (Fig 6). This causes a loss of energy, so, the method is inefficient.

Fig 6

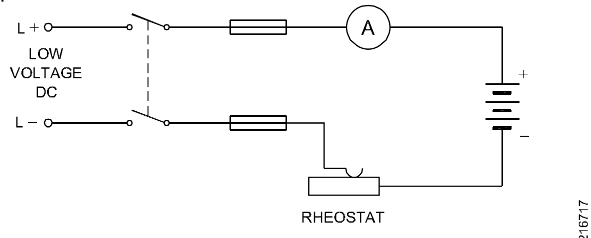



CONSTANT CURRENT METHOD

**Use:** For charging more number of cells at constant current rating.

**Constant potential method**: In this method, the voltage is maintained at a fixed value about 2.3 V per cell; the current decreases as the charging proceeds. A variable resistor is connected in series, so a voltage source of 2.5 to 2.6 V per cell is required. For a 12 V motor car battery, the charging dynamo is of about 15 V. In comparison to the constant current method less power is wasted for charging and less time is taken. Fig 7 shows the connections for a constant potential method of charging batteries.

Fig 7

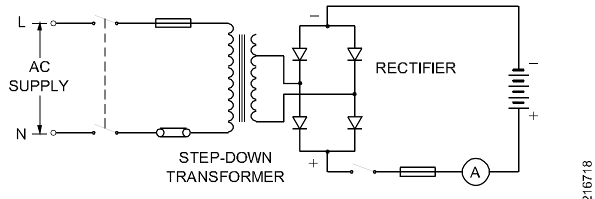



CONSTANT VOLTAGE METHOD

**Use:** For charging batteries of constant voltage rating.

**Rectifier method**: A rectifier for battery charging is generally made of diodes connected in the form of a bridge (Fig 8). A transformer is used to step down the AC voltage to that suitable for diodes. Ammeter, voltmeter, switches and fuses are also used in the rectifier set.

Fig 8




RECTIFIER METHOD

**Trickle charge**: When the battery is charged at a very low rate, that is 2 to 3% of the normal rate for a long period, it is said to be a trickle charge.

**Use**: For central or sub-station batteries and for emergency lighting systems.

**Initial charge**: The first charge of a new, previously uncharged battery is called the initial charge. The process that occurs inside the battery is called forming the cells.

To conduct an initial charge, fill the cells with an electrolyte of a proper specific gravity, then replace the vent plugs. Make sure the holes in the plugs are clear. The battery should also be cool before you begin the initial charge.

**Freshening charge:** When a new battery is put into service for the first time, it may be given a brief charge to ensure that it starts in a fully charged condition. This kind of charge is called a freshening charge. Normally all that is required is charging at the finish rate until no change in specific gravity or voltage occurs over a three hour period.

**Boost charge**: If a battery is in danger of becoming over-discharged during a working shift, you can give it a supplementary charge during a rest period. This boost charge is not a conventional method of charging the storage battery. It is not recommended as a standard procedure. It is generally a high rate charge of short duration, used only to ensure that the battery will last until the end of the shift.

## Battery chargers

Primary batteries need to be replaced by new ones when they get exhausted. However in the recent past certain secondary cells like nickel cadmium cells which look similar to the primary cells could be recharged through low current plug-in cell chargers. On the other hand, primary cells like mercury cells should not be charged. Any attempt to charge them will make the cell to explode which will be dangerous.

Whereas in secondary or rechargeable batteries, supply power to a load till they discharge to a certain level. After this they are to be recharged with the help of battery chargers, and then they are ready for service again. Modern secondary batteries can withstand a large number of charge and discharge cycles under stipulated conditions.

**Battery chargers**: In general a charger is an electrical/electronic device having provision for AC input and DC output. A battery charger is used to put energy into a cell. We know that the chemical reaction in a secondary battery is reversible. The reaction proceeds in one direction when the battery supplies power to a load. The direction of reaction is reversed during charging. This enables storage of electrical energy in the form of chemical energy inside the cell. This stored energy is again converted into electrical energy when the cell is used to supply power to a load.

A battery charger is a simple DC power supply that draws its power from the AC mains and supplies DC power at a voltage higher than that of the battery. Many chargers contain additional accessories to monitor and control the charging process. In general, a battery charger consists of the following four parts.

i) A transformer to step down the AC mains voltage to the desired AC voltage.

ii) A selector switch for voltage and current selection.

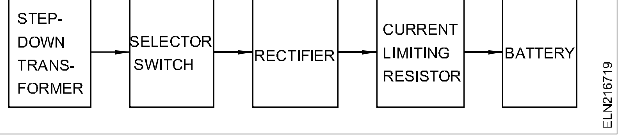
iii) A rectifier to convert AC into a uni-directional DC.

iv) A current limiting circuitry to prevent flow of excessive charging current into the battery under charge.

**Construction**: Fig 9 is a block diagram showing the different components that make a battery charger.

First of all, there is a step down transformer that transforms the high voltage of AC mains into a low AC voltage. The size of the transformer depends on the charging power required. Very small transformers are required for charging small Ni-Cd type batteries, while large size transformers are required to charge heavy duty automobile or emergency light batteries.

Fig 9




The transformers used for battery charging are generally provided with a number of tappings on their secondary side. In addition to stepping down the voltage, the transformer also serves another very important role. It isolates the charging circuit completely from the AC mains and thus completely eliminates the danger of electric shock from high voltage AC mains.

Most of the battery chargers are provided with two selector switches marked i) coarse and ii) fine indication.

The coarse selector switch is for the selection of output voltage according to the voltage of the battery to be charged, example 6V, 12V, 24V, 48V etc.

The fine selector switch is used for selecting either a low or a high rate charging current.

The rectifier converts the low voltage AC into uni-directional DC. There are 3 types of rectifiers which are normally used for a battery charger.

a) Tungsten rectifier

b) Metal rectifier

c) Junction diode rectifier.

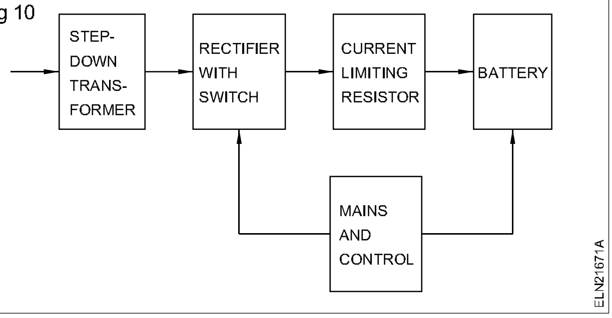
Nowadays, almost all the battery chargers are provided with junction diode which are also called as 'Solid state rectifier units'.

The rectifier unit used in a battery charger may be of half or full wave type. But in most cases full wave bridge rectifiers are used.

The size of diode depends upon the charging current requirements. A number of diode elements/metal rectifiers may be connected in series to withstand the operating voltage in the case of low voltage diodes/metal rectifier. Wherever junction diodes are used, suitable heat sinks are also provided along with the diode or bridge.

Fig 10 is a block diagram showing the different components that make a suitable battery charger for charging batteries in emergency lamp circuits.

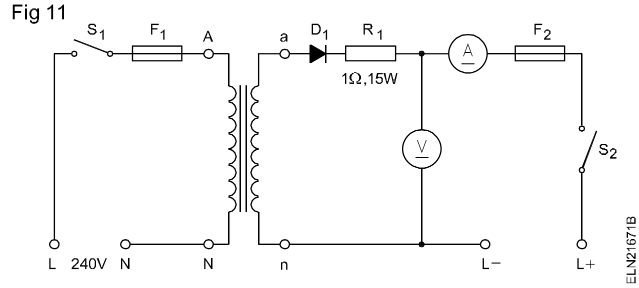
Fig 10




**Working**: A number of circuits are available for battery chargers. Anyhow only the 3 most commonly used circuits are explained here.

**Circuit 1**: The AC main supply to the primary of the step-down transformer is protected by a fuse and controlled by a toggle switch (Fig 11). Step-down secondary voltage is fed to the metal rectifier or diode and the output is passed through a current limiting resistor, an ammeter (to measure the charging current), a fuse and a switch. A voltmeter is connected in the output circuit to measure the output voltage.

Fig 11




This type of circuit is protected only through fuses and needs constant attention during the entire period of battery charging. As the output voltage is fixed, only particular rated voltage batteries or a combination of them could be charged.

**Circuit 2**: In the case of commercial establishments where different voltage rating batteries are required to be charged, the secondary of the transformer has different tappings and the necessary output voltage could be selected through a selector switch (Fig 12).

Further the charging current could be varied through one or more selector switches where tappings are made for lower voltage ranges. A full wave rectifier with four power diodes are used to form the bridge.

**Circuit 3**: The circuit (Fig 13) contains an electronic circuit that continuously monitors the condition of the battery and then regulates the charging current accordingly. This circuit also terminates the charging process when it finds that the battery has charged fully.

In many cases the charging process is not fully cut off but the charging rate is reduced to maintain a small charging current to maintain the battery in top condition. This process is called '**trickle charging**'.

Fig 13

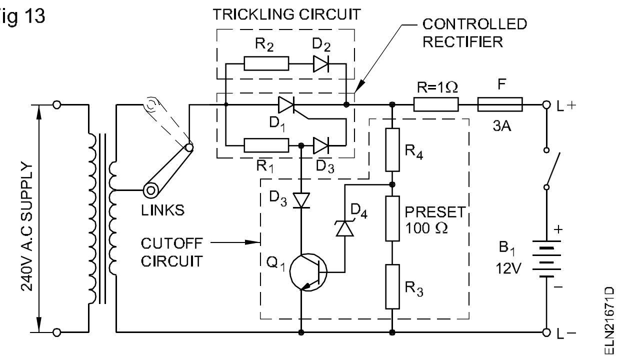
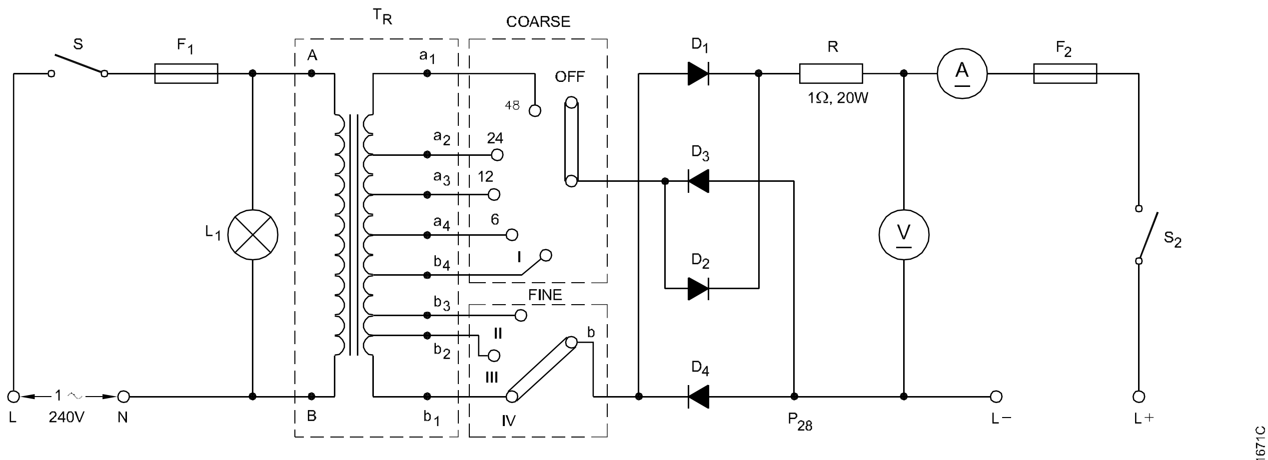



Fig 12




SCHEMATIC DIAGRAM

## Installation, care and maintenance of batteries

**Objectives:** At the end of this lesson you shall be able to
- **list out the guidelines for installation of batteries**
- **state the guidelines for care and maintenance of batteries**
- **state the precaution to be followed while charging and discharging of battery.**

### Guidlines for installation of batteries

The following guide lines to be followed during installation of batteries at residential building

- Location of battery installed should be free from heat sources and flame.
- Battery connection cables should be as short as possible to prevent excessive voltage drop.
- Before connecting the battery the positive and negative poles must be carefully checked to ensure correct installation.
- Authorised and trained person must only be allowed for installation.
- If the batteries to be installed in the accessories like remote controls first open the battery cover, insert the batteries correctly into +ve and -ve ends then close the battery cover and press it to close.
- Do not expose the batteries to heat (or) flame.
- Manufacturer's instruction must be followed when installing the batteries.
- Follow the local, state and National electricity code.
- When installing a battery bank always be careful, since shock hazard may be present.
- Always use protecting/insulating equipment such as gloves, shoes and eye protectors, wrenches and other insulated tools.
- Use proper lifting techniques when working with large batteries.
- Never lift batteries by its terminals.
- Do not allow tools (or) unconnected cables to rest on the top of batteries.
- Never use power tools that may develop more torques while making the batteries terminal connections.
- Do not use chemical cleaner on batteries,they may cause irreversible damage.
- Do not remove vent plugs and Do not add distilled water to the sealed maintanence free (SMF) batteries.
- Ensure that test equipment leads are clean, in good condition and connected with sufficient length to prevent accident.
- Ensure that all monitoring systems are operationable.
- Ensure that battery area and cabinet is properly ventilated.
- Never install batteries in an airtight enclosure.

### Care and maintenance of batteries

The lead acid batteries must be operated under the right conditions if they are to function properly. Regular maintenance is necessary in order to maintain proper conditions and thus prolong the life of the battery.

The battery should not be discharged beyond the minimum value of voltage say, 1.75 V for 2V battery.

The battery should not be kept under a discharged condition for a long time.

The level of the electrolyte should always be kept to a minimum of 10 to 15 mm above the plates by adding distilled water only.

The battery should never be charged and discharged at a higher rate which weakens the plate structure. It should be done as per the manufacturer's instructions.

The battery should be recharged as early as possible after discharge.

A discharged battery should never be tested with a high rate discharge tester.

The high rate discharge tester should be used only on charged batteries and for less than ten seconds.

The specific gravity of the electrolyte should be checked regularly before and after a battery is put on charge.

The battery charging room should always be well ventilated for the gases to escape freely.

The battery terminals must be free from corrosion. The terminals must always be kept clean and petroleum jelly should be applied on them.

The spilling of the electrolyte over the battery causes corrosion and it should be cleaned with soda water or ammonia water.

If the battery has not been used for a long period then the battery should be put on a trickle charge.

The vent plugs should be kept open while charging, for free liberation of gases.

Avoid overcharging and discharging at a high rate. This causes the plates to bend from their position and buckle.

**Precautions**

Make sure that, while charging, the positive terminal of the charger is connected to the positive terminal of the battery, and the negative terminal of the charger to the negative terminal of the battery. Otherwise, connecting it incorrectly causes very high current which can seriously damage both the battery and the charging unit.

Make sure the cell temperature during charge does not exceed the limit specified (43°C) as per the manufacturer's instruction.

A fully charged battery stored at 100°F (38°C) will loose almost all its charge in 90 days. The same battery stored at 60°F(15°C) will loose a little of its charge in the same period of 90 days. High temperature decreases the charging rate and shortens the life.

The rate of charging at the end of the period called finish rate is most important. It must not exceed the value recommended by the manufacturer.

During recharging, the lead acid battery produces flammable gases. An accidental spark can ignite these gases, causing an explosion inside the battery. Such an explosion can break the battery case and throw acid on the people and equipment in the area.

Do not top up the cell with improper water such as tap water, well water, mineral water or acids which will cause hard sulphation and increase the internal resistance.

Avoid improper cleaning agents for terminal posts and metal parts of the battery like emery or sandpaper. Use only the recommended cleaning agents such as baking soda water(warm), ammonia water, and wipe with cotton cloth or with an old brush.

Always wear safety glasses when working with lead acid cells and batteries. If acid does come in contact with clothing or with the skin, immediately flush with clean water. Then wash with soap and water except for eyes. Wash your hands in soap and water after handling batteries.

## Solar cells

**Objectives:** At the end of this lesson you shall be able to
- **state the necessity of tapping natural resources for energy**
- **state about the solar cell /photo voltaic cell**
- **explain the basic principle, construction and characteristics of the solar cell**
- **calculate the required series, parallel group of solar cell for given power requirement.**

**Heat energy**

Heat energy is the most sought energy for human being to cook the food as well as to keep warm in cold climate. However the use of wood as the fuel for fire, has ended up in deforestation and resulted in drought.

Search of fuel led the man to use coal and then oil. However these commodities are fast dwindling and after few hundred years both may completely vanish from earth. As such it is essential that human race should find alternative source of energy from nature.

Hence the use of natural resources like heat from sun thought by several scientists and one of the solutions to the energy crisis is the invention of solar cells.

**Solar cell / Photovoltaic cell**

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon.It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.

Solar cells are described as being photovoltaic irrespective of whether the source is sunlight or an artificial light. They are used as a photo-detector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires 3 basic attributes:

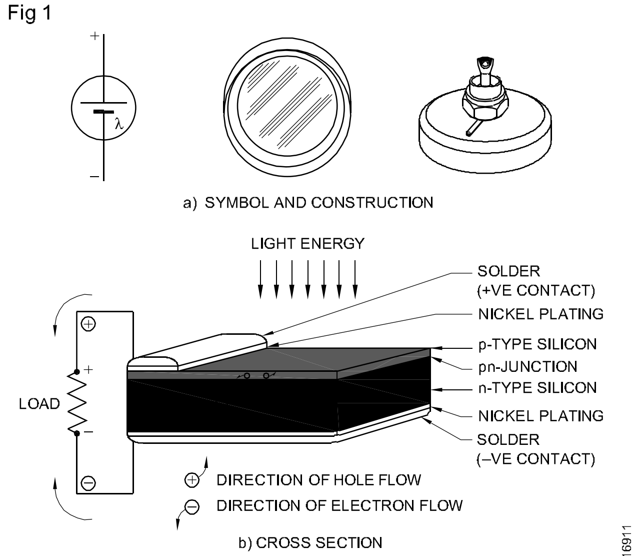
- The absorption of light, generating electron-hole pairs extraction.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

The solar cells is essentially a large photo diode designed to operate as photo voltaic device and to give as much output power as possible. When these cells are under the influence of light rays from sun, they give out about 100 mw/cm$^2$ power.

Fig 1 shows the construction, symbol and cross section of a typical power solar cell. The top surface consist of a extremely thin layer of P-type material through which light can penetrate to the junction.

The nickel plated ring around the P-type material is the positive output terminal, and the bottom plating is the negative output terminal. Commercially produced solar cells will be available in flat strip form for efficient coverage of available surface areas.

Fig 1



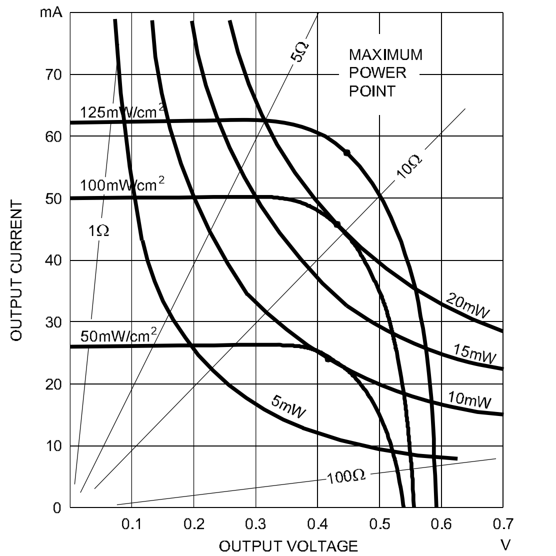

CONSTRUCTION AND CROSS SECTION OF A SOLAR CELL.

According to different manufacturing standards, the output power varies from 50mw/cm$^2$ to 125mw/cm$^2$ (Fig 2). The graph shows the characteristic of a solar cell which gives 100mw/cm$^2$. Considering the characteristic curve it is apparent that the cell will deliver an output current of 50mA when the output terminals are short circuited then the output voltage will be zero.

On the other hand open circuited voltage of the cell will be 0.55mv but the output current is zero. Therefore again the output power is zero. For maximum output power the device must be operated at the knee of the characteristic. In solar cells the output power decreases at high temperature.

Typical output characteristics of power photocell for use as a solar energy converter is shown in Fig 2.

Fig 2

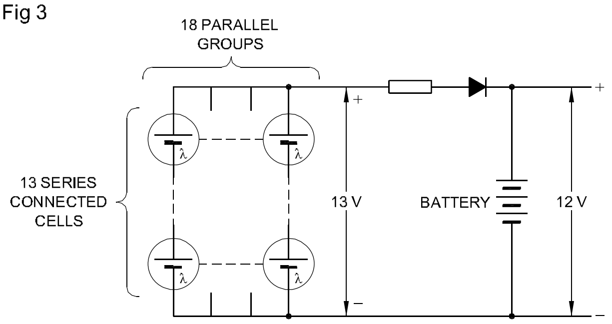



OUTPUT CHARACTERISTICS OF POWER PHOTOCELL FOR USE AS A SOLAR ENERGY CONVERTER

ELN216912

Array of solar cells is connected as a battery charger (Fig 3). Several cells must be connected in series to produce the required output voltage, and number of parallel groups to be provided as per the required output current.

Fig 3




ARRAY OF SOLAR CELLS CONNECTED AS A BATTERY CHARGER

ELN216913

**Example**

A village welfare club is having a black and white TV which operates at 24V taking a current of 3amp for four hours. Normally an array of solar cells are used for charging the 24V batteries and the light source from sun available to energise the cells for about 10hours a day.

Calculate the total number of solar cells of 125mw/cm$^2$ required and the series - parallel grouping of cells.

**Solution**

As per the graph (Fig 2) the solar cells (energy converters) should be operated at approximately 0.45V and 57mA. Assuming the charging voltage should be 10% higher than the battery voltage of 24V the solar cells should supply 26.4 volt for charging the battery circuit.

Number of series connected cells

$$= \frac{\text{Output voltage}}{\text{Cell voltage}} = \frac{26.4\text{V}}{0.45\text{V}}$$

= 58.5 = say 59 cells

The charge taken by the batteries after every day of TV programme willbe be 3 amp x 4hours = 12 ampere hours. This should be supplied by the solar cells in 10 hours. Hence the ampere requirement.

$$= \frac{\text{Ampere hours}}{\text{hours}} = \frac{12}{10}$$

= 1.2 amp

total number of groups of cells in parallel

$$= \frac{\text{output current}}{\text{cell current}} = \frac{1.2\text{ amp}}{57\text{ mA}}$$

= say 21 cells.

The total number of cells required

= Number of cells in series x Number of parallel groups

= **59 x 21 = 1239 cells.**