6.1 INTRODUCTION

Electrical energy is one the most important forms of energy for us, and finds practical use in all walks of life.

In fact it is considered extremely useful in bringing about the all-round development of any country – be it in agricultural or industrial arena.

Like any other form of energy, electricity needs careful handling. Careless handling can lead to accident or destruction.

Electrical safety measures are very important to protect humans and property.

If proper safety practices are not followed, electricity may cause one or more of the following :

- Severe burns,
- Life long disability, and
- Result in fire accidents destroying the materials/properties, etc.

Objectives

After studying this unit, you should be able to

- describe the purpose of electrical safety,
- list the electrical hazards associated with equipment,
- describe the personal safety and preventive measures,
- discuss the precaution and safety rules to prevent fire accidents, and
- understand electrical safety procedures for general safety.

6.2 ELECTRICAL SAFETY

When a person comes in contact with a wire or a surface, which is charged, a sudden unintended current flows though the body of that person. In such a situation the person is said to have received an electrical shock. This current may cause damage to the nervous system of the affected person.

There could be various reasons for getting an electric shock. All electrical parts, which could come in contact with living being or any other object, are normally covered with a sufficiently thick layer of a non-conducting material. Such a material is called ‘insulation’.

It is possible that the insulation provided on the live (electrically charged) part has become electrically weak/damaged or has aged.

The insulation design itself may be inadequate. With this people making a contact with the equipment or instrument may get a shock and it could be sometimes fatal.

It is also possible that the part in question was never expected to be exposed and people who may un-knowingly touch such a live conductor experience a shock.

A fault in equipment or a system may also result in an electric shock. Further, wrong use, bad position, mal-operation or mishandling may also lead to electrical injury. Natural calamity like lightning discharges (cloud to ground) may result in fatal accidents to living beings and may result in damages to structures/properties.

Check Your Progress 1

What could be the reason for an electrical shock?

6.3 PURPOSE OF ELECTRICAL SAFETY

Purpose of electrical safety is to avoid the dangers associated with handling of electricity or electrical equipment.

➢ **Dangers from Electricity**

Dangers associated with the use of electricity may be classified as follows :

- *Injury from Direct Contact*
  - shock, to nervous system.
  - internal burns.
- *Injury without Current Flow through Body*
  - Direct burns from electric arcs, spattered molten metal, etc.
  - Radiation burns from very heavy arcs.
  - Physical injury from false starting of machine, failure of crane controls, explosion of switchgear, etc.
  - Injury from fire and explosion from electric ignition of flammable vapors, gases, liquids solids.
  - Eye injury from electric arcs (e.g. welder's eye-flash).

- *Injury from Current Flow Induced in or near Human Body by Intense Electromagnetic Fields*
  - Injury from electrocution of whole body.
  - Local injury such as cataract formation in eye.
  - Burns due to metallic objects such as rings, dental, mental in close contact with local parts of body.

An electric shock may result in the following effects :

- Hemorrhage and destruction of tissues and muscular element due to heavy current.
- Temporary or permanent disablement in the form of fractures because of sudden and abrupt falls due to an electric shock.
- Suspension of pumping action of the heart due to muscular contraction. However, within some time limits, the patient can be revived after administering artificial respiration and/or other cardiac procedures.
- Loss of rhythmic functioning of the heart (Ventricular fibrillation).
- Temporary paralysis of nerves centers which may cause failure of respiration if exposure to the shock is of prolonged duration.
- Particular contraction of chest muscles causing breathing difficulties.

The information given above shows the **seriousness of an electrical hazard**. Therefore, it is very important and essential to cut them down as far as possible by observing the safety precautions.

Electrical hazards are mostly costly and can be avoided if a determined effort is made to avert them. Such efforts can only be made out of experience. In preventing such accidents, there is time for foresight as well as for hindsight. A check over the figures of past can enable us to understand their meaning for the future. This helps us to redeem something from the waste of past accidents, therefore, it is always better to look back and then look ahead for moving forward.

Human body is a conductor. When the human body touches a live wire, current completes it way thorough body to the earth,

the muscular functions of the body are paralyzed due to the current's action on the nervous system, the heart and respiratory organs; which may cease to function causing the breath to stop, severe burns, and may result in death.

6.4 ELECTRICAL QUALITY ASSOCIATED WITH HUMAN INJURY

➢ Value or Magnitude of Dangerous Current

At the standard frequency of 50 Hz, even a small alternating current of magnitude 15 to 20 mA passing through the human body, may prevent the victim from releasing his grasp and this is considered the threshold of danger. From 50-80 mA upward, and upto several amperes of current flow, the resulting shock is likely to be fatal. Above this value, lethal internal burns may result.

At frequencies in the range 30000 to 100000 Hz (30-100 kHz), the resulting danger becomes progressively less and the limit on safe current which can flow through body without injury becomes progressively larger. At somewhat less than 1 MHz. the electric shock ceases to occur and the danger from current flow is that of superficial and internal burns.

Direct currents of 500 mA to several Ampere are likely to be lethal due to shock, and above this, internal burns may result.

Oscillatory surge of value from 10 to 30 W-sec. is considered to be the threshold of danger.

- *Values of Dangerous Voltage*

These values depend upon resistance of human body, taken in conjunction with current values in as discussed earlier. In general for 50 Hz alternating current danger limits may be taken as 24 V for children and 60 V for adults. In wet situations, the dangerous voltage may be lesser and may depend on the circumstances.

- *Values of Resistance of Human Body*

Values extend over a great range from several thousands of Ohm with dry hands and low applied voltage to only several hundreds of ohm with damp hands and mains supply voltages of 220 to – 240 V. For safety, it is wise to assume a value of 500 Ohm for dry locations and 200 Ohms or less, for persons working in wet places.

Check Your Progress 2

What happens, when a small current of over 20 mA, 50 Hz, passes through the human body?

_____

_____

6.5 POWER TOOL AND SAFETY

Many accidents result from improper use of tools and/or use of defective tools and equipment, employees should **use only tools, which are in good condition and only for their intended purpose**. **"Right tool for the right job!"**

- **Hot line (i.e. line which is charged) tools require special care** so that abrasion of the insulating coating on the wood is avoided. Proper containers and dry storage should be provided.
- **Rubber protective equipment should be stored away from sunlight** and in cool places. Rubber gloves should never be worn without covers and never worn turned inside out. Goggles or other suitable eye protection should always be worn when there is danger of exposure to caustic substances, harmful light rays or any condition considered to be hazardous to the eye.
- **Ladders should be inspected at regular intervals and maintained to conform to safety measures**. Portable metal and wire-reinforced ladders should not be used unless specifically authorized. Wooden ladders should not be coated with metallic paint nor should paint be used which hides the grain.

  The base of a ladder should not be placed less than 1/4 of its length from a wall or supporting surface and not farther away than 1/3 of its length unless securely tied in position.

  Stepladders should be fully open when in use. Ladders placed near doorways or in passageways should be protected against being struck by doors or traffic.

Linemen should not wear spur or any other metallic ornament/device not required for immediate use, when working on ladders except where necessary on hook ladders suspended from wood pole structures.

There are standard practices and specifications, which provide guidance on protective devices

➢ Grounding

- Grounding is a very important requirement for protection and safety in any electrical system, be it residential, industrial or in a power system.
- Circuit and system grounding consists of connecting the grounded conductor the equipment grounding conductor the grounding bus bars and all non-current-carrying metal parts to ground. This is accomplished by connecting a properly sized grounding electrode system designed for high current and low resistance earthing.

Three fundamental purposes for grounding an electrical system :

- To limit excessive voltage from lightning, line surges, etc. under extra-ordinary conditions.
- To keep conductor enclosures and non-current-carrying metal enclosures and equipment at zero potential to ground.
- To facilitate the opening of over current protection devices in case of insulation failures.

  Failure of insulation may happen for various reasons like moisture ingress to insulation, mechanical damage, electrical ageing or insects/rodents eating the insulation, softening of insulation due to heat or chemical reaction, etc.

Equipment grounding consists of interconnected networks of equipment grounding conductors and are used to perform the following functions :

- Limit the hazard to personnel (shock voltage) from the usually non current-carrying metal parts of equipment and other conductor enclosures in case of ground faults, and
- Safely conduct ground-fault current for fast operation of the circuit over-current protection devices.

Working space around electrical enclosures or equipment shall be adequate for conducting all anticipated maintenance and operations safely, including sufficient workers rescuing injured personnel.

Spacing shall provide the dimensional clearance for personnel access to equipment likely to require examination or maintenance. Such equipment includes panel boards, switches, circuit breakers, switchgears, etc. These

working clearances are not required of the equipment that is not likely to require sufficient access, but working space is sill required. Sufficient illumination also need be provided around the working space.

Necessary protective equipments and gadget should be available/used, like rubber-insulated gloves, safety clothes, etc. The protective tools and gadgets should be properly stored when not in use. Qualified workers should be trained in safety related practices and safety procedures prior to their handling of the equipment.

Protective grounding should be used on all circuit of 600 V or above or on lesser voltages where residual charges are likely to accumulate, to provide protection to operating personnel and to prevent any electric shock. Proper consideration has to be given for touch and step potential also.

Check Your Progress 3

What is the purpose of grounding in and around an electrical system or equipment?

6.6 EQUIPMENT SAFETY

Electrical hazards associated with equipment are mostly due to :

- Defective wiring which causes short-circuits or grounds;
- Poor installations, misuse, over loading; and
- Aging and attack by foreign substances cause insulation failures with the result that we have either electrical fires or cases of electrocution resulting in deaths or permanent disabilities.

Unless switches and the other control gear are of suitable design, they are likely to cause above stated hazards. These days, with oil immersed switches and circuit breakers, if the handle and the container is not efficiently sealed, the hazard of fire is always there around such switchgear.

Electrical Safety Measures

There is always a possibility of some hazardous areas in the work place, where the atmosphere may have a danger of explosion or, where there are extensive vibrations, etc.

Such location must be provided with appropriate electrical equipment so as to avoid the use of naked wiring, connections, generators, switches, controllers, lamp elements, transformers, and plant vehicles using storage batteries, i.e. any thing which could lead to a spark being created. This may initiate a fire.

In the following, the **factors likely to be a cause of electrical hazards are detailed for periodic and efficient check up**.

Main Board : Check up to avoid electrical hazards
• Fuses should always be of the prescribed rating. • They should never be bridged, so as to bypass the fuse functionality. • The board should be suitable grouted so as not to work loose from its bearings. • The iron-clad equipments such as the main switch, the section isolators and junction boxes should be in perfect mechanical/ working order.

Electrical Installations : Check up to avoid electrical hazards
• The electrical installations should be suitably designed so as to safely carry the electric load without leading to over-heating within the installation. • In every installation a provision for future extensions should always be made, so as to avoid overloading the existing circuitry, whenever additions do take place. • The electrical wires and other accessories should never be allowed to be wet or damp. • Normally the electrical wiring should always be overhead. In case, under the force of circumstances, it is at a lower level, care should be taken not to splash it with corrosive solutions, oil or grease. • Broken fittings and enclosures should be immediately repaired/replaced.

- Different sections of electrical installations should be constantly checked and whichever circuit is getting over heated, it should immediately be attended to, i.e. either the overload should be removed, or the conductor size increased. We should be very particular about providing protective bushings wherever open wires enter a switch box.
- Drop cords of pendent light points should be regularly checked.

Motor : Check up to avoid electrical hazards

- All the equipment should be perfectly grounded with double earth line and these should never be over loaded.
- The circuit should not be frequently started and stopped as a plaything.
- Ventilating ducts for cooling such motors/other equipment should be kept clean and open. The equipment should not be roughly handled so as to cause mechanical damage to the winding. The motor alignment should be perfect so as to avoid unnecessary overloading as a result of wrong alignment. In case of commutated type motors, the brush area should be perfectly enclosed to avoid it being damaged, which is likely to be the cause of sparking. Each motor should be protected with a fuse. Every motor must have an efficient overload and no-volt release.

Lamps and Switches : Check up to avoid electrical hazards

- All terminal connections should be tight to avoid arching.
- There should be no loose parts in a switch; otherwise a short circuit may be caused.
- The lamp holders and switches should never be allowed to get wet and damp.
- Switches should never be placed in a vibration-prone area, to avoid mechanical damage and loosening of its parts.
- Every portable lamp should be fitted with a wire guard. The portable cord should be armored against mechanical damage and consequential electrical hazard. In explosive atmosphere, if tube lights are being used, their ballasts should be frequently checked for over- heating.

Failure to provide appropriate safe guards against above stated electrical hazards can prove very risky. Electrical hazards are such that a man, who is otherwise fine and kicking, may be no more, if he meets with an electrical hazard. Therefore, the above stated points need constant and expert attention.

Check Your Progress 4

What are the required periodic and efficient checkups for motors and electrical installation to avoid electrical hazards?

6.7 SAFETY EQUIPMENTS, PERSONAL SAFETY AND PREVENTIVE MEASURES

➢ Head Protection

Head protectors may be hard hats and caps made of aluminum, PVC fibreglass, laminated plastic or vulcanized fibre. They may be filled with brackets for fixing welding masks, protective face screen, or a lamp. The hats and caps are provided with replaceable harness and lining, which provides sufficient clearance between the top of the head and the hat-shell.

Soft caps and hoods are also used for protection against heat, spark and other dangerous materials and are made of appropriate materials. Some times, hoods are made with rigid frame, which holds it away from the head.

Figure 6.1 : Personal Safety

➢ Eye and Face Protection

Dusts, flying particles and harmful radiations in the work area, cause numerous eye injuries. While it is difficult to list precisely the various processes in which the worker may be required to wear goggles, the hazards encountered may be stated in terms of :

Reason for Injury	Related Processes
Relatively large flying objects	Chipping, felting, riveting, Sledging, caulking, etc.
Dust and small flying objects	Sealing, grinding, stone-dressing, woodworking.
Splashing of metals	Babbitting, pouring lead joints, casting of metals, galvanizing and dipping in molten metals.
Splashing of liquids, gases and fumes	Handling of acids and other and chemicals.
Reflected light, glare and radiant energy	Foundry work, glass furnaces, welding and cutting arc welding.

Eye protectors may be safety spectacles, mono goggles, impact goggles, welding goggles, foundry goggles, gas tight goggles, face shields, welding helmets, etc.

➢ Hand and Arm Protection

Protection of the hands and arm becomes necessary when workers have to handle materials having sharp edges or when hot and molten metals, chemicals and corrosive substances have to be handled.

The protective devices may be gantlet, gloves, wrist gloves, mittens, hand pads, thumb and fingers guards and sleeves.

It is important not only that the various parts of arms and hand are adequately covered, but that they should be covered by a material suitable for withstanding the specific hazard involved.

➢ Foot and Leg Protection

Adequate foot protection may have to be provided to the workers employed in certain jobs. Risk of injury may be in handling of heavy materials, caustic and corrosive liquids, wet conditions, molten metals, tripping over, etc.

Common foot and leg protective devices are safety shoes and boots, legging, foot-guards and leg-guards. Shoes and boots may be provided with steel toe-box and inner steel sole, and they may be ankle, calf or hip high, as per situation.

The leg-protective may be made of leather, asbestos, neoprene, natural rubber, synthetic rubber, etc.

Leg protectors may be in the form of legging, which may be knee high or they may be spats covering lower skin, ankle and insteps. They may be held in position by straps or spring clips or snap fasteners.

➢ Body Protection

Some times it becomes necessary to provide special protective equipment for the body in the form of **aprons, overalls, jackets and complete head to toe protective suits**.

The nature of potential hazards, degree of the hazard involved and the nature of activities of the person concerned, are important considerations in the selection of safety clothing.

Although complete coverage of the body and legs may not be needed in some cases, and unnecessary safety clothing may hamper the efficiency of the worker, no compromise should be made with the situation-specific mandatory safety requirements. If the requirement for a worker is complete coverage, he should have it.

Learn to use the right tools and methods

Respect electricity be alert!

Safety is everybody's responsibility

Figure 6.2 : Be Safe

Figure 6.3 : Safety Equipment

A guide to use Personal Protective Equipment

Part of Body to be Protected	Equipment	Protects Against
Head	Fibre helmet	Falling objects, hitting against an object during handling, reaction/recoil etc.
	Electrical Resistance helmet	Shock when working with electric lines.
	Crash Helmet	For riding on high-speed vehicle, to avoid scalp injury. Also to avoid injury due to unintentional fall.
Face	Plastic face shield	Against liquid chemical splashing, striking of dust particles or grinding waste
	Welding helmet and shield	From welding fumes, sparks, intense light and ultra-violet rays during arc welding.
	Asbestos hood	Against radiation in and around furnace/other open heat source.
Eye	Panorama goggles with clear plastic visor	Oil and paint splashes, dust and chippings
	Leather mask goggles	Foreign bodies entering the eyes and against smoke/ fumes.
	Spectacle – type goggles with plain shatter proof lens	Foreign bodies entering the eyes. When working on machine and reflected arc rays.
Ear	Ear plugs	High Noise level
	Ear muffs	High Noise level
Nose	Dust Respirator	Against dust and powder particles entering lungs
	Light fume mask	Against acid fumes and other corrosive vapours (< 0.1%)
	Heavy Fume mask	Against heavy fumes and gases (> 0.1%)
	Canister gas mask	Against acid fumes and vapour and gases (2%).

Body	Leather apron	Falling of hot chips, slag, etc. heat radiation
	Asbestos apron	Heat radiation
	PVC apron	Splashing of chemical
	Lead apron	X-ray and Gamma rays
	Safety belt/Safety harness	Falling of persons from height
Hand	Leather gloves	Cuts due to handling of sharp edges
	Asbestos gloves	Heat radiation.
	Acid and alkali proof rubber gloves.	Burns due to handling acids/alkalies.
	Electrical resistance gloves	Electric shock
	Canvas gloves	Contact with oil grease, dirt and other contaminants.
	Lead gloves	X-ray and Gamma rays.
	Hand sleeves	Falling of hot slag, during skin diseases
	Protective Barrier	Skin Diseases
Foot and Legs	Leg Guards	Welding Sparks, injury due to un-intended hit.
	Leather safety boots	Striking against objects, stroke by moving object, fall of object from above and stepping on sharp and/ or hot objects.
	Asbestos safety boots	Heat radiation, stepping on sharp and/or hot objects, striking against stationary object, stroke by moving object and fall of objects from above.
	Gum Boots	Hydraulic testing. Tar raking and tar filling in the procedure gas plant.

Check Your Progress 5

What nature of device is required for eye protection?

6.8 FIRE SAFETY AND PREVENTION

If a small fire is not controlled in its initial stage it goes to the uncontrollable stage – blaze stage fire.

Detection is expected to be done by the people available at the spot with the help of god given detectors like eyes, nose, ears and skin and warning will be given with the help of mouth. But in this stage immediate attack is very important and it can only be done by training and skills in fire fighting.

Once the fire goes beyond the stage of control, only fire brigade can control the fire. We can only assist the fire brigade in brining the fire under control.

In order to carry out the various jobs involved in fire fighting cycle, there must be a group of trained people available in the form of Fire-fighting Squad.

Basic reason for any fire accident is ignorance and even if people have knowledge about fire, they tend to neglect it. Sixty percent of the fire accidents due to electrical faults, and in fact, are due to usage of substandard materials, nonstandard wiring, improper maintenance, loose connection, over loading and keeping combustible materials underneath main switches or very close to equipments emanating heat.

The fire spreads from one place to another, because of the heat transfer.

In order to keep fire under control at the time of emergency, counter-measures against all the above three principles can be used in combination. When a particular department or zone is on fire and when the fire is in blaze stage, the adjacent areas can be saved by closing all the possible doors and windows, removing flammable materials from the adjacent areas and also by continuous cooling of the surrounding areas. In this manner, heat transfer can be prevented and fire can be kept under control.

Most combustible material, when in the hard solid form, cannot easily catch fire. But when it is thin, weak and in filamentary nature, it may immediately catch fire. For materials in dust form, even a small spark or arc can cause fire, perhaps with blast.

The records in offices kept for years together would have lost strength, become discoloured, mutilated and decomposed. These are susceptible to easily catching fire. If windows and doors are kept open, easy entry of air will aggravated even a small fire.

Important phone numbers should be painted on wall above the phone unit for immediate reference during emergency.

Adequate means of escape from fire must be provided for all personnel in a works factory or office building, and the following four requirements should be satisfied :

- No one should need to go towards the fire in order to escape. All escape routes should be as short as possible, of adequate capacity, and should lead to open air at ground level, either direct or by way of a fire resisting enclosure.
- Protected parts of escape routes should not be exposed at any point to penetration by smoke or fire.
- Escape routes should be clearly marked with arrows at every corner and intersection.

➢ **Different Stages of Fire**

- *Incipient Stage*

  No visible smoke, flame, no significant heat.

- *Smouldering Stage*

  Combustion increases, develops smokes, still no flame-heat also.

- *Flame Stage*

  Fire develops further, ignition occurs and flame starts.

- *Heat Stage*

  Large amount of heat, flame smoke and toxic gases produced.

By observing the following precautions and, safety rules we can prevent fire accident to a great extent.

Precautions and Safety Rules to Prevent Fire Accidents

- ***Do not throw lighted cigaratte-butts*** indiscriminately. Throw them at the appropriate places and ensure that the burning end is put out effectively.
- ***Do not smoke cigarattes in your seat*** in the midst of files. No objection to smoke at a secluded, designated place, provided it is permitted.

- ***Do not accumumlate unwanted*** waste material, such as waste paper, waste cloth, etc. They may be disposed off, then and there, in the bins provided for it.
- ***Do not light a match in your seat carelessly*** when it is necessary let it be done with required precautions.
- ***Do not use naked wired for tapping power from the sockets***. When two ends of cables are to be connected inevitably, use proper insulation tape.
- ***Do not overload the switches and sockets* (*viz*.)** do not use three way sockets from one single outlet due to the danger of excessive current. The cable/wires slowly gets heated up and is likely to cause fire.
- ***Do not store flammable materials like Kerosene or Petrol, except as mandated***.
- ***Do not handle/store crackers in the office***.
- **Do make sure that your switch-off the fan, light** and any other installation near you when you leave the office.

➢ **On Seeing Fire : What to do?**

F First

I Inform

R Rescue

E Extinguish

- Cry “Fire” thus giving an alarm to all.
- Panic should not be caused, as it is more dangerous than the fire itself.
- If fire-fighting equipment is available, it can be used to extinguish fire without panic.
- Nearby combustible materials should be removed, so as to prevent spreading of fire.
- Fire service may be informed if necessary.
- When the fire service personnel arrive, the job should be left to them without causing hindrance.
- If electricity is involved, switch off the supply and confirm it.

- The liquid type extinguishers should not be used unless the electricity is cut off and isolated.
- All persons in that areas or floor should be evicted safely without panic.

Fire Triangle

Fire is a chemical reaction called COMBUSTION (usually oxidation resulting in the release of heat and light). To initiate and maintain this chemical reaction, or in other words for an outbreak of fire occur and continue, the following are essential :

- Fuel – i.e. combustible substance solid, liquid or gas.
- Oxygen – usually air which contains, approx 20.7% oxygen, 79% nitrogen and 0.3% carbon dioxide.
- Heat – Required Heat. It varies from materials to materials.

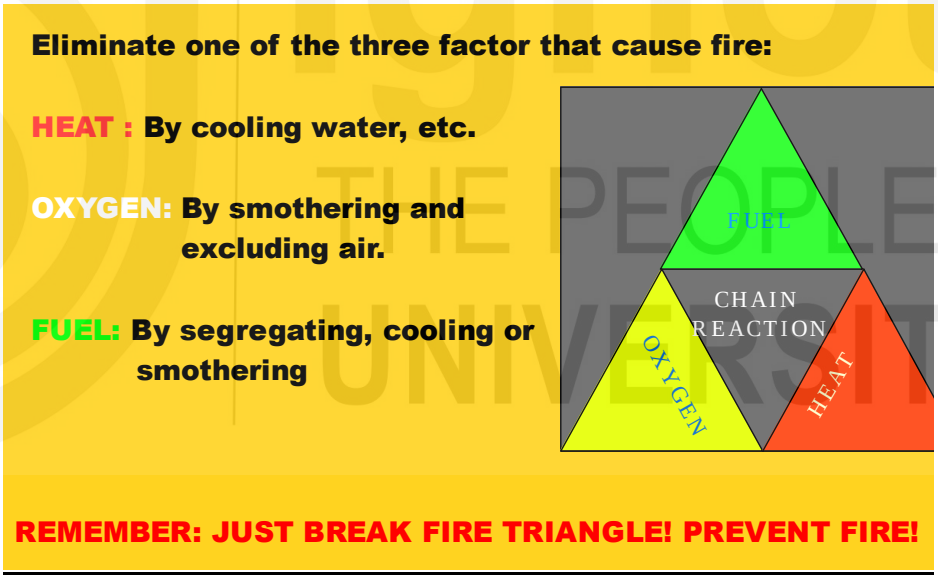

Figure 6.4 : Fire Fighting

Check Your Progress 6

What are the four stages of fire?

6.9 FIRE EXTINGUISHMENTS

Removal of one or more of the factors of the Triangle of fire is the basic principles of fire extinguishing :

Basic Principles of Fire Extinguishing

- **Starvation**
  - Removal of the fuel from the fire.
- **Smothering/Blanketing**
  - Limiting oxygen from the fire.
- **Cooling**
  - Limitation of the heat to below the ignition temperature.
  - Removing any one of the above three elements like fuel, oxygen or heat.

- **Starvation, Removal of Fuel for Fire**
  - This is a method in which the surrounding materials are removed from the seat of fire and making the fire to starve.
  - Without supply of fuel, fire will be starved and extinguish.
- **Blanketing/Smothering : Removal of Oxygen**
  - This is the method, whereby the oxygen supply to the fire areas will be cut off. Naturally the fire will be off because of lack of oxygen. It is not absolutely necessary to prevent the oxygen supply to the fuel areas completely. Significant reduction is enough. This can be achieved by using cotton blankets, plywood sheets or corrugated boxes over the fuel. Even closing the doors and windows will also serve the same purpose of cutting off the oxygen supply to the affected area. There are different extinguishing media, through which the removal of oxygen can be achieved.
- **Cooling : Removal of Heat**
  - Water is normally used for cooling the fire because it has the best heat absorbing properties.
  - Water is the best fire fighting media for solid fires like wood, leaves, cotton and charcoal.

- Since water is a good conductor of electricity it should not be used in electrical equipments.
- Water density is more than the density of other burning liquid fuels; hence, it should not be used in case of any liquid fuel, in the direct form.

➢ **Classification of Fires**

- *Class A*
  - Fires involving solid fuel of an organic nature.
  - This is the most common class and the most effective agent is generally water.
- *Class B*
  - Fires involving liquids or liquefiable solids.
  - Extinguishing agents include foam, vaporizing liquids, inert gases and dry chemical powders.
  - For fires involving gases or liquefied gases, 'STARVATION' is the only method of extinguishments to consider.
- *Class C*
  - Electrical fires are a separate of fires from Class A, B and D because electricity as such is not a fuel and does not burn.
- *Class D*
  - Fires involving combustible alloys and their metals.
  - Powdered talc, soda ash, limestone and dry sand are normally suitable for this class of fire and dry chemical powder specified for metal fires.

Classes of Fire	Fire Involve
Class A	Wood, paper cloth, trash, plastics, solid combustible materials that are not metals
Class B	Flammable liquids such as gasoline, oil, grease, acetone, any non-metal in a liquid state
Class C	Flammable gasoline such as propane, butane, acetylene
Class D	Metals like potassium, sodium, aluminium, magnesium

Type of Extinguisher	Contents of Inner	Contents of Outer	Maximum Range	Pressure Developed Inside	Where to Use	Where Not
Soda Acid	Sulphuric Acid	Sodium-Bi-Carbonate (solution)	7 M	7 kg/sq.cm	A	B, C, D, E
Foam	Aluminum Sulphate Solution	–do–	7 M	3.5 kg/sq.cm	B, A	C, D, E
Dry Chemical Powder	Co Catridge	–do– Power	3 M	25 kg/sq.cm	B, C, D, E	–
CO_2	–	CO_2	Very Close	53 kg/sq.cm	B, C, E	–
Halon	–	Halon	–do–	–	A, B, C, E	–

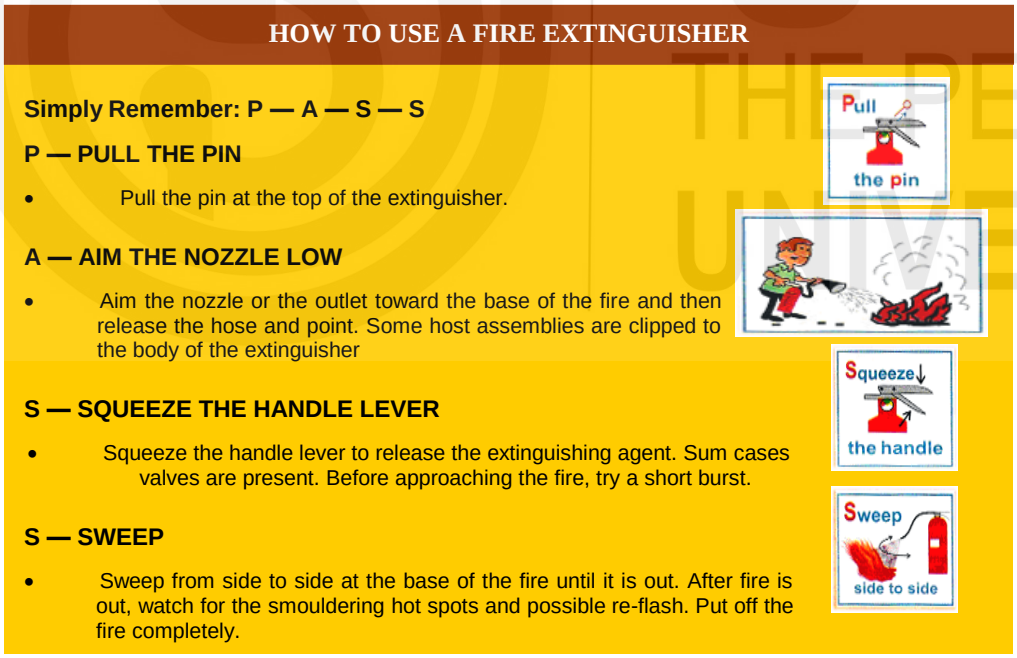

Figure 6.5 : Instruction Label on a Fire Extinguisher

Check Your Progress 7

What are the three factors of fire extinguishing?

6.10 ELECTRICAL FIRE

While electricity is indispensable for industrial development, scientific advancement and, human comfort and prosperity, its hazards are numerous. Several electrical accidents have caused fatalities and fires that resulted in large-scale damage to life and property. Electrical fires are caused by heat, spark or are emanating from electrical source. Fire arises and spreads due to three factors, viz. heat or spark, material or source of heat or spark. In case of electrical fires, the first two factors are more common in places, such as, stores, hotels offices, and places of entertainment, and are mainly due to electrical faults. Consequences may be, particular hazards like flammable liquids or vapour and easily combustible materials being ignited by electrical sparks or heat.

6.10.1 Origin of Electrical Fires

Fires occur in electrical installations in three principal ways. Most insulating materials are in some degree flammable (ceramics, asbestos, alumna, and mica being exceptional) and therefore, serious and continuous overloading is an obvious fire risk. Overloading may also burn up the combustible material in close proximity like wooden, plastic or cardboard and cloth panelling over table runs. Deterioration and breakdown of insulating oil with carbon content will cause transformer fires. Further, sparking and arcing caused by breaks or cracks in conductors, short circuits, damaged insulation and loose joints can produce sparks that may ignite flammable gases, vapours and dusts or powders also. Coal dust can spontaneously and easily ignite. Radiators and electric irons involve fire risk. Red hot fuses which are not properly covered and exposed high wattage bulbs, which may lead to fire, can also be included here.

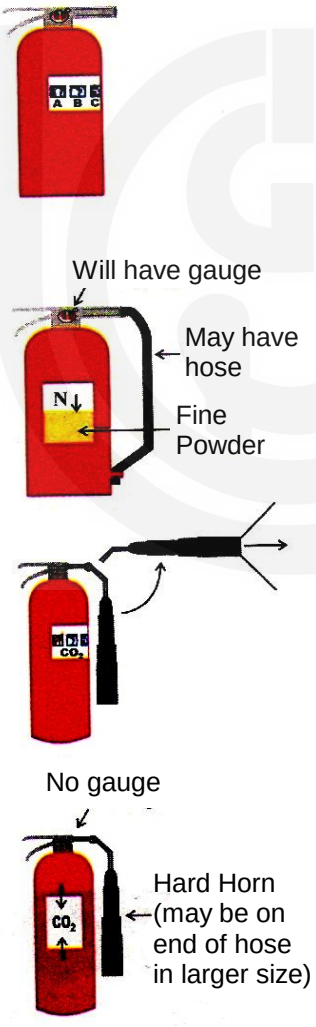

Figure 6.6 : Different Types of Fire Extinguishers

6.10.2 Preventive Measures

A works electrical engineer normally responsible for safety of his equipment and personnel in the given conditions at site should properly assess, appreciate and identify the potential hazards and bestow prompt and adequate thought in planning the layout with due precaution and in coordination the schedule of preventive maintenance and correct sequence of operations. Further, close observation to detect vulnerable aspects of the processes of and safety drills and trouble-shooting exercises for the staff is essential for prevention of electrical fires.

Due to heat contributed by an electrical field, the gas or gas mixture may attain ignition temperature, i.e. temperature at which there will be a

self-propagating flame that can expand. The minimum volume, which must be ignited for the flame to spread, is usually of the order of one cubic millimetre. An electrical spark, especially one caused by discharging a condenser, is an ideal and efficient means of ignition. The design of intrinsically safe electrical circuits or apparatus is based on the principle of minimizing spark energy when a circuit is ruptured. Use of flameproof, intrinsically safe or other appropriate type of electrical equipment is essential in areas having flammable atmosphere.

➢ Circuit Breakers

When sparking or arcing occurs under oil, some of the oil, which is a blend of saturated hydrocarbons, breaks down and flammable vapour is produced. For example, such arcs are produced in circuit breakers immersed in oil, during switching operation. Depending on the magnitude and sequence of current broken and time taken to quench the arc, a substantial gas bubble is formed. If the breaker fails to clear the arc, the evolution of gas continues until the circuit is interrupted elsewhere. Breakdown of insulation on core bolts or interturn insulation on transformer windings is associated with continuous or intermittent sparking.

Failures of circuit breakers of recent design, solely due to inadequate rupturing capacity, are rare. But disastrous explosions leading to failures are caused by lack of maintenance, wrong application, mal operation and bad oil. Oil contamination is caused by frequent operations of clearance of very heavy short circuits in a short period.

The remedy to prevent explosions and oil fires is by attending to finer points of designs, removing copper beads at the contacts, systematic maintenance and oil cleaning or changing. A circuit breaker must have adequate rupturing capacity to make or break rated currents and normal overloads over long periods without distress and to interrupt maximum possible short circuit current without damage.

➢ Isolators

In respect of isolators and isolator switches, the following aspects should be borne in mind.

- To break load current on plain isolator or switch is highly risky and especially with heavy currents and inductive loads now common, it is suicidal. Alternative feed to

transformer or equipment must be checked before isolating the transformer. Otherwise, instead of magnetizing current, load current will be inadvertently broken and flashovers will occur.

- **Skilful opening and closing is necessary to avoid heavy continuous arcing at the contacts.** Maintenance of contacts and check up of uniform clearance on all the three poles is essential.
- Forgetful charging of earthed circuit causes heavy fault currents, severe flashovers and explosions.

➢ Self Generating Sets

Where self-generating sets are owned by consumers, **utmost care is necessary to avoid interlink between main board supply and generator supply**. The equipment or switchgear to be provided and interlocks warranted depend upon the capacity of generator and the processes involved. If the two sources of supply get linked without synchronization, heavy flashovers with serious risk of fire and damage to equipment and personnel may occur. Hence, **high standard of safety is needed.**

➢ Welding Equipment

Fires during electric arc welding are very common. Improper earthing of welding transformer and job, poor condition of welding return cable, bad housekeeping in the surrounding area, inadequate or lack of covering of combustible material, to prevent their contact with welding sparks, are some of the frequent causes of fires during electric arc welding. The welding transformers should be earthed at the secondary winding and return cable should be as good as the line cable. **Fire retardant brattice cloth can be used to cover up combustible material in the neighbourhood.**

➢ Cable Trenches/Galleries

Cable ducts and trenches are the other locations vulnerable to electrical fire hazard. Often cables are bundled haphazardly and laid in ducts. In some environments, oils, flammable liquids or chemical powders leak into ducts and affects the cables making them easily combustible. Rats and rodents eat into the insulation and weaken it causing leakage of electricity and sparking, over a period of time, rags, waste paper, cotton waste and other rejected stuff (at times oily and chemically active) also find their way into cable trenches. In

the absence of regular cleaning, such accumulations present serious fire hazard and add to fire load in the trenches. Fires in the cable trenches can cause dislocation of many or all the sections of the plant, apart from damage to property. Rectification is usually complicated and time consuming.

➢ Poles and Stay Wires

Poles and Stay Wires are to be maintained well and earthed properly. On record are several instances of poles getting uprooted and collapsing on sheds, huts, stored materials like jute, cloth bales, haystacks, causing heavy sparking and resultant fires. Explosion is likely when flammable liquid containers are involved in such accidents.

➢ Wiring

Weak or damaged insulation, broken or loose electrical joints are a source of sparks that may ignite combustible material around. In temporary installations and at construction sites, tents and sheds with bamboo or other dry wood poles rafting and thatch covering are common. Electrical sparks in such installation often lead to major fires as evidenced in several instances of fires in places, e.g. in circus tents, touring cinema talkies, exhibitions and many others. **Electrical wiring in metal conduits is recommended even in temporary installations.**

➢ Other Causes

Electricity can be a source of hidden heat and warrants careful handling, if fires are to be avoided. The following fire incidents throw light on the variety of fire risks associated with electricity and point to the need **for utmost care in dealing with electrical equipment in industrial environment.**

- An ordinary, non-flame roof fan motor in a cellulose spraying cabinet overheated and ignited the cellulose deposits. The fire spread to the whole of the top floor or a large furniture factory and resulted in the death of five employees.
- A boy of 16 was inspecting an emptied bone-degreasing tank with the aid of an unprotected portable lamp, when the glass of the bulk was inadvertently broken and the hot filament ignited vapours emitted from the crevices and plate joints of the interior. His clothes were set on fire but he was able to leave the tank by the lower side inspection opening.

- A static discharge at a type foundry machine resulted in the ignition of white spirit solvent. A worker suffered severe burns and there was some structural damage to the machine.
- Petrol ignited due to shorting of battery terminals. Mechanic's hands were burnt.
- Ignition of overheated oil in an oil-immersed resistance type motor starter. Building seriously damaged.
- Gloves soaked in some inflammable solvent took fire from a low voltage spot welding machine.
- A mechanic attempted to take petrol from a motor driven truck. The petrol ignited when a pipe fell on the battery connections and caused a spark, and as a result, the mechanic sustained burns.
- An explosion was caused by a pneumatic pick piercing a cable in a duct containing petrol vapour, and the operator of the pick sustained burns and bruises.
- Two boys playing with an electric etching pencil accidentally bore a hole through a can of marking out fluid (which has methylated spirit base). The can exploded, causing fire and severe burns to the boys.

➢ Fire Protection of Cables

Structural and other miscellaneous fire protection measures for cable galleries, cable tunnels, cable spreading rooms, etc.

- *Compartmentation*
  - For containment of fire in cable galleries, etc., fire barriers with self-closing fire check doors should be provided. The fire barriers or partitions should be spaced at intervals ranging from 25 m to 60 m depending upon the degree of risks involved both within the cable galleries as well as external hazards.
  - The ventilation system, if provided in the cable gallery, should be interlocked with the automatic fire alarm system, so that in case of fire alarm the ventilation system can be switched off automatically.
  - To avoid the spreading of fire, all the cable entries in walls and floors, the openings for the passage of cables should

be properly sealed with suitable fire resistant sealing material, with a fire rating equivalent to the walls and doors in which it is installed.

- The walls and floors of the cable galleries should be penetrated only by the cables and not by supporting cable rack or tray. This is to prevent the conduction of heat from one side of wall/floor to the other, and to avoid damage to the seal by thermal expansion of the cable rack or tray.
- Where pipes and ducts pass through the walls and floors, fire resistant flexible sleeve systems of equivalent fire rating should be used.
- To avoid ingress of dust, it will be desirable to provide pressurized ventilation in cable galleries at basement and upper floors.
- For dust removal, vacuum should be preferred to compressed air.

- *Fire Hazards of PVC Cables*

PVC is the material widely used for cable sheathing and cable insulation. While self-extinguishing type of PVC are also available, in sustained fires PVC is combustible, the degree of combustibility depending on the type and concentration of the plasticizer used.

The following data apply for PVC cables :

- At approx. 80^{o}C the material begins to soften;
- At approx. 100^{o}C HCl (Hydrogen chloride or Hydrochloric acid) begins to be given off;
- At approx. 160^{o}C 50% of the HCl is given off;
- At approx. 210^{o}C PVC begins to melt; and
- At approx. 300^{o}C 85% HCl will be given off.

It is therefore important to provide for rapid cooling of the cables in the event of fire.

Water has proven to be a very efficient extinguishing agent for cable fires. With suitable draining facilities, particularly if water spray installations are used, the washing out effect reduces the risk of corrosion damage to nearby installations and equipment.

In spite of the efforts to reduce the content of materials that produce corrosive combustion products, the problem of corrosive attacks to equipment cannot be assisted by the ambient humidity.

➢ Cable Racks

- The installation of cable racks shall confirm to the requirements of the National Electrical code.
- Power cables should be installed in cable trays separate from control, signal and instrument wiring/cabling.
- As per recommendation, the minimum spacing between cable trays should be not less than 450 mm and preferably 600 mm, measured from the bottom of the upper tray to the top of the next lower tray
- Cable tray system should be electrically continuous and solidly grounded.
- The cable trays and the supports for the racks should be of non-combustible material, preferably of mild steel.
- There should be at least a spacing of minimum one meter between two adjacent racks, to facilitate fire-fighting operations, in case of fire.
- For special requirements and for hazards areas, it is desirable to apply flame resistant coatings to the cables passing through such areas.
- Trays stacked one above the other should have the cables stacked in descending order with the highest voltage above. Instrument signal wiring should be in the lowest tray.

Note

The degree of fire resistance required for the fire barriers, penetration seals and for the fire resistant coatings applied near the seals, is a controversial point. In the finalized draft of the Indian standard on code of practice for fire protection for cable run, the fire resistance for the coating has been mentioned as minimum 60 minutes, and for the barrier walls, as a minimum 90 minutes, whereas as per central electricity authority norms, the fire resistance rating is to be not less than 3 hours.

➢ **Fire Detection System**

Figure 6.7 : Smoke Detector

Check Your Progress 8

What are the possible causes of electric fire due to wiring?

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6.11 DO's AND DON'TS FOR ELECTRICAL SAFETY

Do's and Don't for Electrical Safety

Domestic Consumers		
Sl. No.	**Do's**	**Don'ts**
1	Use standard plug to tap supply from a plug point	Avoid tapping of supply by inserting bare wires
2	Always use standard materials with ISI marks, even if it costs more	Don't use brackets to tie wire or ropes. Do not dry clothes on wires or cables
3	Fused bulbs may be replaced only after the switch is off	Changing the fused bulbs when the switch is on, is dangerous
4	Use always properly earthed three pin plugs to connect refrigerators, wet grinders, mixies, washing machines, iron boxes and geysers etc.	Don't touch an electric switch or appliance when you hands are wet or bleeding from a cut. Don't keep the lamp holders without lamp.
5	Use only lamp holders with 1 amps rating.	Don't purchase sub standard electrical fitting to save money which may result in serious accidents.
6		Don't connect mixies, refrigerators, washing machine, wet grinders, Iron boxes and geysers through unearthed plug pin, which may cause serious accidents.

Electrical Safety Measures

Commercial Consumers		
Sl. No.	**Do's**	**Don'ts**
1	All wiring work should be undertaken by licensed wiring controllers	Don't travel on vehicles loaded with goods beyond the permissible height. This may cause electrical fatal accident due to coming into contact with overhead electrical lines.
2		Don't tie advertisement boards, flags etc. to the electric post.

Industrial Consumers		
Sl. No.	**Do's**	**Don'ts**
1	Place "Men working" signboards on all switches before commencing work.	Don't close switches unless you are familiar with the circuit, which it controls and also know the reason for its being kept open.
2	Ensure that all the controlling switches are opened and locked or the fuse withdrawn before working on any circuit or apparatus.	Don't touch or tamper with any electrical gear or conductor. Unless you have made sure it is dead and earthed. High voltage apparatus may give leakage shock or flash over even without touching, without being connected to a visible source.
3	Treat circuit as alive until they are proven to be dead.	Don't test a circuit with bare fingers or hand or other make shift devices to determine whether or not it is alive.
4	Turn away your face whenever an arc or flash is expected.	Don't close or open a switch or fuse slowly or hesitatingly. Do it quickly, positive and firmly.
5	Please see that all splices and connection are secure.	Don't use wires with poor and/ or deteriorated insulation.
6	Discharge to earth thoroughly, all cables before working on the cores.	Don't be in haste and careless. This has caused many accidents.
7	Do test rubber gloves periodically.	Don't throw water on live electric equipment in case of fire. It is dangerous.
8	Do place rubber mats in front of Electrical switchboards.	Don't use fire extinguishers on electrical equipment unless it is clearly marked as suitable for that purpose.
9	Make Sure that all employees are familiar with the location and use of fire fighting apparatus.	Don't work on a pole or elevated position when line is alive, without the safety belt and rubber gloves, and unless a competent person stands on the ground nearby to direct operations and give warning.

10	Make sure when using the fire hose, that the jet of water breaks into a fine spray, before coming in contact with live electrical apparatus.	Don't use a ladder without a lashing rope otherwise the ladder should be held firmly by another person, with no chance of slipping.
11	Check fire extinguishers periodically to ensure that they are all in good condition.	Don't go near running belts and machines.
12	Please concentrate on the work you are doing.	Don't remove danger boards and other warming signs without instruction or interfere with safety barriers or go beyond them without the mandatory precautions.
13	Use sand or blankets to control fire involving electrical accidents.	Don't bring a naked flame near oil filled equipment and battery. Smoking in the battery room is prohibited.
14	Do examine before use, all the safety appliances such as gloves, safety belt, mats, ladders, goggles, ropes, etc. for their soundless	Don't allow visitors and unauthorised persons to touch or handle electrical apparatus or come within the danger zone of HV apparatus.
15	Do report immediately to In charge any dangerous conditions or any dangerous practices, which you may observe during your work.	Don't enter excavations and cable trenches, which give out obnoxious smell, or work in badly lit ventilated and congested areas.
16	Do warn others when they seem to be in danger near a live conductor or apparatus	

6.12 LET US SUM UP

In this unit, we learnt about safety when working with electricity. We know that electricity is perhaps the best form of energy or power to use, being clean and simple to use. At the same time, in the absence of sufficient precautions, use or rather mis-application of electricity can lead to major disaster. Among the more important hazards touching electricity, are, shock, smoke, fire and secondary effects such as, explosion, arcing, welding splutter, grinding dust, paint vapours, etc.

In this unit, we have also learnt some precautions to take when working with electricity and electrical equipment. We have learnt the classes of fires and the fire-fighting methods. We have additionally learnt about the steps to take to avoid fire and the hazard associated with fire.

6.13 TERMINAL QUESTIONS

(a) What are the classes of Fire?

(b) How can we do to prevent accident to our person?

(c) What are the important safety do's and don'ts?

(d) Write various precautions and safety rules to prevent fire accident?

6.14 ANSWERS TO CHECK YOUR PROGRESS

Ans. 1

There are three possible causes for electric shock: poor or inadequate insulation, degraded insulation or accidentally exposed conductor.

Ans. 2

A current of 15-20 mA is the threshold of dangerous current. At this level the human grasp may not open.

Ans. 3

Grounding or earthing around an electrical circuit is undertaken to take care of any mal-operation or accident concerning that circuit, which may otherwise allow unintended and dangerous levels of electrical activity in the region, This may lead to damage to the equipment, or even electric shock to the person handling the equipment. Grounding allows a path of low resistance, to safely carry away the dangerous current, and thus prevent damage or shock.

Ans. 4

Refers Section 6.6.

Ans. 5

To protect the eye from accidental damage, the basic device is a suitable form of goggles. However, at times a facemask may be considered in its place.

Ans. 6

Incipient Stage, Smouldering Stage, Flame Stage and Heat Stage.

Ans. 7

These are : Starvation, Smothering and Cooling.

Ans. 8

The two main reasons are : Sparking due to weak or poor insulation, or due to intermittent contact due to cracked or broken conductors.

6.15 ANSWERS TO TERMINAL QUESTIONS

(a) There are four main classes of fires. Theses are named as A, B, C, D and are listed with some details under Section 6.9 of this block.

(b) While the most important action would be to eliminate the causes of accidents, in real life this may not be feasible. The next precaution or method is to make use of protective gear. The details of these is listed under Section 6.7.

(c) These are too many to be listed here. Instead, refer to the Section 6.11.

(d) Refer Section 6.8.