Unit-I

Introduction to Electrical Safety

Introduction:

Electricity is used the world over. without electricity, life will become miserable. The advantages are plenty, there are also dangers while using electricity particularly when not safely handled. Many accidents take place while using electricity which is due to several resonsance. one of the reason is we are neither able to see electricity flowing in a wire nor able to here the same. The other reason is familiarity & overconfidance that nothing bad will happen.

Electric Shock:

Electric shock is a Jarring, shaking sensation resulting from contact with electric circuits (or) from the effects of lightning. Electric shock is sudden (unexpected) and it stimulates the body's nervous system. when a shock is experienced by anybody it is because of current passing through the body.

While doing work directly with electric supply (or) machines (or) appliances using electricity, the person may effected.

1. Get a mild shock.
2. Get a severe shock
3. Get a severe shock with burns (or) even dies.

Effects of Electric shock: (or) physiological effects of Electric current:

The effect of electric shock are listed below.

1. Temporary paralysis of a nerve system, which lead to failure of breathing.
2. chest muscles may contact, which also effect breathing & it this continuous death will result.
3. Damaging the heart to small pieces causing the stopping of breathing.
4. Sometimes breathing has stopped, but heart may continue to beat. This condition cause the face to apper blue colour.
5. Depending on the strength of the electric current, body may burns, either superficial (or) deep.
6. Due to stopping of breathing action caused by blockade in the nervous system respiration.

The fibrillation of heart is the most serious cause of death & there is no curve. The injury from the shock is less severe if current does not pass through nerve centres & vital organs.

The seriousness of the electric shock is dependent upon the following factors.

1. The contact area of the body with the supply wire (or) appliance.
2. The contact pressure with the supply wire (or) appliance.

3. The path of current through the body.
4. Whether it is Ac (or) Dc.
5. Wet (or) dry condition.
6. The duration of time in contact with the wire (or) appliance.
7. Mental stress at the time of accidents.

Reasons for Fire Accidents

Reasons for Fire Accidents in Electrical system

1. Touching a bare live conductor.
2. Touching a poorly insulated conductor.
3. Open (or) short circuit due to equipment failure.
4. Static electricity.
5. Lightning.

Effects of Electric Shock

Current	Effect	Results
1mA to 10mA	Nil	Nerves & muscles can bear painful.
10mA to 20mA	Muscles contract	painful
20mA to 50mA	Respiratory system is affected	breathing stop.
50mA to 200mA	Heart is affected	circulation of blood is affected. current is circulated through the brain damaging the gray matter.
above 200mA	Skin is affected	Burning of skin takes place.

Safety Requirements to Prevent Electrical shock:

1. Proper Insulation:

* Use wires & cables with high-quality insulation
* Avoid using damaged cords (or) exposed conductors.

2. Earthing (Grounding):

* provides a safe path for fault current to flow into the earth.
* prevents buidup of voltages that could lead to shock.

3. Use of Residual current Devices (RCD's)/RCCB's

* These devices detect leakage current & disconnect power instantly.
* Highly effective in preventing fatal shocks.

4. Circuit Protection Devices:

* Fuses & MCBs (Miniature circuit Breakers) prevent overcurrent & short circuits.
* Automatically disconnect power during fault conditions.

5. Use of personal Protective Equipment (PPE):

* Insulated gloves, shoes, and tools.
* Rubber mats & safety helmets in electric work areas.

6. Safe work practices:

* Never work on live circuits unless absolutely necessary.
* Always turn off power before repair (or) inspection.
* Follow Lockout - Tagout (LOTO) procedures.

7. Dry working conditions:

* Avoid working with electricity in wet (or) dump environments.

* Keep electrical appliances and hands dry.

8. Warning Signs and Lables:

* Place signs near high-Voltage (or) hazardous areas.
* Use labels to indicate live wires & equipment.

9. Qualified Personnel only:

* only trained & certified professionals should handle electrical systems.
* Unauthorized or unskilled handling increases risk of shock.

10. Regular Inspection and Maintenance:

* Check wiring, tools, and equipments regularly.
* Replace worn-out components to prevent exposure to live parts.

Electrical Safety Hazards

Electrical safety hazards refer to risks and dangers associated with the use of electricity. Understanding these hazards is essential for preventing accidents, injuries, and equipment damage.

Types of Electrical Safety Hazards:

a) Electric Shock
b) Electric Fires
c) Arc Flash
d) Arc Blast
e) Short circuit
f) over loading
g) Electricity & water
h) Improper use of Electrical Equipment.
i) Mechanical damage to cables

a) Electric shock:

* Electric Shock occurs when current passes through the human body.
* It can cause muscle spasms, burns, unconsciousness, or death.

b) Electric Fire:

* The Electric fire caused by over loaded circuits, short circuits & Faulty wiring (or) appliances.
* It may result in property loss and fatalities.

c) Arc Flash:

* Arc Flash is a high-temperature discharge of electricity through air.
* Temperature can reach 20,000°c.
* causes of Arc flash are
  * Loose connections.
  * Faulty equipment
  * Insulation failure

Arc - Blast :

* The Arc - Blast due to the rapid expansion of air and metal.
* The Arc - Blast produces sound, pressure waves, & shrapnel.
* It can cause burns, hearing loss, (or) physical trauma.

e) Short circuit :

* Short circuit is a unintended connection between two conductors.
* Results in high current flow, overheating & potential fire.

f) Overloading :

* When electrical demand exceeds circuit capacity is known as overloading.
* It leads to excessive heat, insulation damage (or) fire.

g) Electricity & water :

* Water is a good conductor.
* In wet conditions increase the risk of shock and short circuits.
* Risk is high in bathrooms, kitchens, and outdoor areas.

h) Improper Use of Electrical Equipment :

* Using damaged (or) incompatible devices.
* Operating equipment with wet hands or in unsafe environments.

i) Mechanical damage to cables :

* Damaged wires expose conductors.
* can lead to electric shock (or) fire if not repaired.

Electrical Arc:

An Electrical Arc is a visible Plasma discharge that happens when electric current flows through the air (or another gas) between two conductors that are not in direct contact. It looks like a bright flash (or) spark and generate "extremely high temperature".

Causes of Electric shock

An arc occurs when,

1. Voltage is high enough to overcome the resistance of air (or insulation).
2. There's a gap between conductors or terminals.
3. The air becomes ionized, allowing current to pass through, [this ionized path is the arc]

Why Are Arcs Dangerous ?

1. High Temperature : Arcs can reach up to 20,000°c – hotter than the surface of the Sun.
2. Burns & Fire Hazard
3. Damage to equipment.
4. Arc Flash.

When we see Electrical Arcs at Switchgear & circuit breakers, Electric welding, short circuits Loose connections & Lightning.

Prevention of Electrical ~~Sho~~ Arc

1. Use Arc Fault circuit interrupters[AFCIs]
2. Maintain tight connections
3. Keep equipment Clean & dry.
4. Use proper insulation & conduct regular inspection.

Arc Blast:

An Arc Blast is a sudden, violent explosion caused by the rapid expansion of air & metal vapors when an electric arc occurs. It often follows or accompanies an arc flash.

Causes of An Arc Blast:

The causes of An Arc Blast are

1. short circuit
2. Faulty equipment
3. Loose connections
4. Poor maintence.
5. switching high-current loads.

Prevention of Arc Blast:

1. Use Arc-rated PPE [personal protective equipment]
2. Install arc-flash relays & detection systems.
3. Follow Lockout-Tagout (LoTo) procedures.
4. Maintain equipment & Regular inspection.

Causes for Electrical Failure:

1. Short circuit Electrical failure occurs when a component, device, or system cannot perform its intended function due to faults or disturbances. Understanding the causes helps in designing safer and more reliable systems.

Major causes of Electrical failure:

a) Short circuit:

* unintended connection between two conductors.
* causes high current flow, overheating & damage.

b) Overloading:

* Load exceeds circuit capacity.
* Results in excessive heat & tripping of circuit breakers.

c) Insulation Failure:

* Damaged or aged insulation leads to leakage (or) short circuit.
* caused by heat, moisture, (or) mechanical wear.

d) Loose connections:

* Poor contact increases resistance.
* Generates heat and may cause sparking (or) arcing.

e) Moisture (or) Water Ingress:

* Water conducts electricity and causes leakage (or) short circuit.
* Common in outdoor (or) underground systems.

f) Voltage Fluctuations / Surges:

* Sudden rise or drop in voltage damages sensitive equipment.

* Causes include lightning, faulty transformers or switching.

g) Mechanical Damage:

* Physical damage to wires (or) cables during handling or installation
* Leads to exposed conductors and failure.

h) Corrosion:

* Occurs at terminals and joints in humid or chemical environments.
* Increases resistance and may lead to failure.

i) Aging of Components:

* Electrical parts degrade over time.
* Reduces efficiency and may fail under normal load.

j) Improper Design or Installation:

* Incorrect wire sizing, lack of protection devices, or poor layout.
* Leads to overheating & poor performance.

Prevention of Electric failure:

1. Use quality components.
2. Perform regular maintenance.
3. Avoid overloading.
4. Ensure proper grounding & insulation.
5. Install protective devices (MCBs, RCCBs, surge protectors)

Unit - I

Introduction To Electrical Safety

Short Questions:

1. Define Electric Shock ?
2. What are the Reasons for Fire Accidents ?
3. Define Electrical Hazards & Types.
4. Define a) Electrical Arc
   b) Arc-Blast
5. What are the Effects of Electric Shock
6. Write causes for Electric failure.

Essay Questions:

1. Explain physiological effects of Electric Shock.
2. Explain about saftey requirements to prevent Electrical shock.
3. Explain about Electrical saftey Hazards.
4. Write & explain causes for Electrical failure.

Safety Components

Introduction:

Safety components are parts of a system, whether mechanical, electrical, or software-based, that are specifically designed to prevent or mitigate hazards, ensuring the overall safety of a machine (or) Process. These components play a crucial role in safety related control systems, contributing to the prevention of accidents & the protection of workers.

Introduction to conductors & Insulators:

Conductors: conductors are materials that allow the flow of electric current easily through them due to the presence of free electrons.

Ex: * Metals like copper, Aluminum, Silver, Gold.
* Human body, salt water

Characteristics:

1. conductors have Low electrical resistance.
2. High conductivity
3. conductors are used in wires, cables & circuits for carrying current.

Applications:

conductors are used where we need to transmit electricity, like in electrical wiring and electronic components.

Insulators: Insulators are materials that do not allow the free flow of electric current because they lack free electrons.

Ex: ~~Rupp~~ Rubber, Plastic, Glass, wood, Mica

Characteristics:

1. Insulator have high electrical resistance.
2. Low conductivity.
3. Used for protection and insulation.

Applications

Insulators are used to cover wires and electrical components to prevent accidental contact and shock.

Difference between conductors & Insulators

Conductor	Insulator
1. A conductor is a material that allows the electric current to pass through it.	1. The insulator is a material that does not allow the electric current to pass through it.
2. It stores energy in the form of magnetic field.	2. It does not store energy.
3. The thermal conductivity of the conductor is very high.	3. The thermal conductivity of the insulator is very low.
4. The electric potential of the conductor remains the same at all points	4. The electric potential of the insulator remains zero.
5. The resistance of the conductor is very low.	5. The resistance of the conductor is very high.
6. Examples Metals, aluminium, copper etc.	6. Examples paper, mica, glass etc.

Voltage :

Voltage, also known as electric potential difference (or) electric pressure, is the amount of potential energy per unit of charge between two points in electric circuit. It is push that causes electric charges to move, creating an electrical current. Voltage is measured in Volts (V)

Voltage classifications

Voltage Classifications refer to the grouping of electrical Voltages into different levels based on their magnitude and application. These classifications help in standardizing equipment design, insulation levels, safety protocols & maintenance procedures.

Voltage is classified into a) Low Voltage (LV)
b) Medium Voltage (MV)
c) High voltage (HV)
d) Extra-high Voltage (EHV)
e) Ultra-high Voltage (UHV)

a) Low Voltage (LV)

Typically refers to Voltage up to 1000kV (1kV). This is the Voltage used for most residential & commercial applications, including powering appliances and Lighting.

b) Medium Voltage (MV)

Generally considerded to be above 1kV (1000V) and upto 100kV. Medium Voltage is used in industrial settings, power distribution, & some transmission applications.

c) High Voltage (HV):

Typically refers to Voltages above 100kV and upto 230kV. High Voltage is used for transmitting large amounts of power over long distances.

d) Extra-High Voltage (EHV)

Above 230kV and upto 800kV. EHV is used for even higher capacity power transmission. often for connecting power grids.

f) Ultra-High Voltage (UHV)

Above 800kV. UHV (ulltra-High Voltage) is used for very large scale power transmission, often over long distances.

Note: These are general classifications, & specific Voltage ranges may vary depending on the country, region, & application.

Safety Against overvoltages

Overvoltages: over voltages are sudden rises in Voltage level above the rated insulation level of equipment. These can damage electrical systems causes fires, or endanger human lives.

Types of overvoltages:

over Voltages are two types

1. Internal overvoltages
2. External overvoltages.

1. Internal overvoltages

Internal over voltages are caused by operations like switching operations, Fault & Load changes & Resonance conditions

2. External overvoltages (Transient/surge):

External overvoltages are caused by, Lightning strikes, Electromagnetic pulses.

Effects of overvoltages:

1. Damages to insulation and equipment.
2. Arcing and fire hazards.
3. System breakdown.
4. Data loss in sensitive electronics.

Protection Against overvoltages

1. Surge Arresters (Lightning Arresters)

* Installed at substations, transformers buildings
* Diverts excess voltage safely to earth.

2. Grounding (Earthing) systems

* Provides a safe path for fault currents or surges to dissipate into the earth.
* Protects both equipment & personal.

3. Shielding and Bonding:

* Metallic shielding for cables or enclosures to block electromagnetic interference.
* Bonding ensures all metal parts are at the same potential.

4. Use of Protective Relays

* Detect overvoltage conditions.
* Trip the circuit breaker to isolate fault.

5. Insulation Coordination

* Design equipment insulation levels to withstand expected surges.

6. Zinc Oxide Arresters:

* Common in modern systems.
* High energy-handling capability, no spark gap needed.

7. Capacitors and Filters:

* Absorb and filter voltage spikes in sensitive circuits.

Prevention of overvoltages

* Regular Maintenance of surge arresters.
* Inspection of grounding systems.
* Use of proper rated insulation.
* Avoid long overhead lines in lightning-prone areas.
* Install Shielding near critical electronics.

Safety Against Static Electricity:

Static Electricity:

Static electricity is the imbalance of electric charges on the surface of a material. This imbalance occurs when electrons are transferred between objects, resulting in one object becoming positively charged & the other negatively charged. The imbalance is "static" because the charge doesnot flow like in a typical electrical current.

(or)

Static electricity is an imbalance of electric charges within or on the surface of a material. The charge remains until it can move away by an electric current (or) electrical discharge.

Sources of Static Electricity:

* Rubbing of Materials (clothing, belts, conveyor systems)
* Flow of Liquids or Powders through pipes.
* Walking on synthetic carpets.
* Handling of plastic or insulating materials.

Safety Measures Against Static Electricity:

1. Grounding & Bonding:

Grounding: Connects Charged objects to earth to Safely discharge static.

Bonding: Electrically connects two or more Objects to equalize potential.

Used in: Fuel tankers, pipelines, drums & containers.

2. Humidification (Moisture Control)

* Dry air increases static buildup.
* Maintain relative humidity ≥ 60% in Sensitive environments.
* Use humidifiers in cleanrooms & Labs.

3. Antistatic Materials:

* Use antistatic mats, flooring, clothing, gloves & footwear.
* Prevents buildup of charges on surfaces or people.
* Common in electronics & cleanroom industries.

4. Ionization:

* Ionizers neutralize static charges in the air by emitting ions.

Used in semiconductor manufacuring, medical devices assembly, printing facilities.

5. Use of Antistatic Additives

* Mixed with plastics, fuels, or lubricants to reduce charge buildup.
* Useful in packaging & Powder-handling industries.

6. Proper Handling Procedures

* Avoid fast pouring of flammable liquids
* Use proper lable & signage in static-Sensitivitye areas.
* Train staff in static-safe work practices.

7. Electrostic Discharge (ESD) protection

* Use wrist straps, ESD-safe tools, & grounded Workstations.
* Protect sensitive electronics during manufacture or repair.

Electrical Safety Equipments:

Electrical safety equipment includes a variety of items designed to protect individuals and property from electrical hazards. This equipment ranges from personal protective gear like insulated gloves & boots to device like circuit breakers & ground fault circuit interrupters (GFCIs) that protect electrical circuits

Personal Protective Equipment:

Insulated Gloves and Boots: protect against electric shock & burns when working with energized equipment.

Arc-rated clothing: protects from arc flash hazards, which can cause severe burns.

Hard hats: Protect against falling objects & electrical Hazards.

Safety glasses/face shields:
Protect eyes from sparks, debris & electrical arcs.

Hearing protection:
protect against loud noises from electrical equipment or arcs.

Insulating mats & blankets:
Provide an extra layer of protection when working near energized equipment.

Circuit Protection Devices:

Fuses: protect circuit from overcurrent by breaking the circuit when the current exceeds a specific limit.

Circuit breakers: Similar to fuses, but can be reset after tripping, unlike fuses that need replacement.

Ground fault circuit interrupters (GFCIs): Protect against electrical shock by breaking the circuit when ~~the current exceeds a specific limit.~~ a ground fault is detected.

Surge protectors: protect electronic devices from voltage spikes or surges caused by lightning or other electrical events.

Voltage detectors: used to verify if a circuit is energized before working on it.

Lightning Arresters: Protect electrical systems from damage caused by lightning strikes.

Other Important Equipments:

Insulated tools: Tools with insulated handles to prevent electric shock.

Grounding equipment: Provides a safe path for electrical current in case of a fault.

Lockout/Tagout devices (LOTO):
Used to isolate & de-energize equipment during maintenance or repair.

First Aid kit: Essential for responding to electrical accidents, including burns or shock.

Fire extinguishers for Electrical Safety:

Fire: Fire is a chemical reaction between fuel & oxygen, initiated by heat, that releases energy in the form of light & heat & flame.

Fire = Fuel + Heat + oxygen.

Classification of fires:

Class A: Fires in solid materials like wood, paper, cloth. Use water (or) foam extinguisher

Class B: Fires in flammable liquids like petrol, oil, paint. use foam, CO_2, or dry powder extinguisher.

Class C: Fires in electrical equipment (sc & wiring) use CO_2 or dry powder extinguisher.

Class D: Fires in metal like magnesium titanium use special dry powder extinguisher.

Class K: Fires in cooking oils or fats (kitchen fires) use wet chemical extinguisher.

Fire Extinguisher for Electrical safety:

Fire extinguishers are devices used to control and extinguish fires.

For electrical fires, specific extinguishers are required to avoid electric shock and prevent damage.

Electrical Fires (Class C Fires):

Electrical fires are caused by faulty wiring, overloaded circuits, short circuits or malfunctiong electrical equipment.

These fires cannot be extinguished using water (or) foam, as water conducts electricity & can cause electric shock.

Suitable Fire Extinguishers for Electrical Fires:

1. CO_2 (carbon Dioxide) Fire Extinguisher

* Displaces oxygen & cools the fire.
* Leaves no residue, safe for electronics.
* Ideal for computers, labs, servers & control panels.

2. Dry chemical powder (DCP) Fire Extinguisher

* Non-conductive & breaks the chemical reaction of fire.
* Can be used for class A, B & C fires.
* Common powder types:
  Monoammonium phospate (ABC) or
  Sodium bicarbonate (BC)

3. Clean Agent Fire extinguisher [Ex: FM-200, Halotron]

* Non-toxic, non-conductive, leves no residue.
* Suitable for sensitive electronic equipment.

Safety precautions

1. Switch off the power source if possible before extinguishing.
2. keep a safe distance (1-2 meters) while discharging CO_2.
3. Avoid touching the metal discharge horn of CO_2 extinguisher.
4. Regularly inspect & maintain extinguishers in labs & electrical homes.

Applications

Fire extinguishers are used in offices, industries, server rooms, laboratories, workshops & homes, where electrical equipments are used.

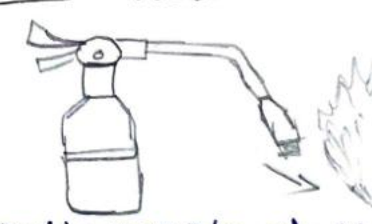
How to use Fire extinguishers

Follow the 'PASS' Method.

Step-1: PULL

pull the safty pin to activate the extinguisher

Step-2: AiM

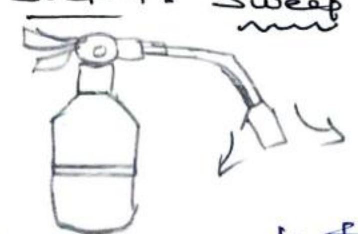


Aim the nozzle at the base of the fire, not the flames

Step-3 - Squeeze

squeeze the handle or lever to release the extinguisng agent

Step-4: Sweep



Sweep the nozzle from side to side coviring the fire completly

Unit - II

Safety Components

Short Questions

1. Define safety components in an electrical system.
2. What is the function of fuse & Name any two devices that protect against overvoltages.
3. classifiy different types of fires and what type of fire extinguisher is used for electrical fires?
4. Define voltage & voltage classifications.
5. List the electrical safety equipments.
6. Define insulators & conductors.

Essay questions

1. Describe the classification of Voltages & explain how overvoltage protection is provided.
2. Differentiate between conductor and insulators
3. Explain about Electrical fire extinguishers. in electrical fire safety.
4. what is static electricity & explain about Safety against static electricity.

Unit - III

Grounding

Introduction: Grounding, also known as earthing, is a crucial electrical safety & performance measure that connects electrical systems to the earth (or) a conductive body serving as a substitute for the earth. This connection provides a low-resistance path for fault current to flow to the ground, minimizing the risk of electric shock & damage to equipment. Grounding also establishes a reference point for voltage, ensuring stable & reliable operation of electrical systems.

Grounding and Bonding

1. Grounding

Grounding means connecting electrical systems or equipment to the earth. This ensures that in case of a fault, excess electricity safely flows into the ground, protecting people and equipment.

Purpose: Grounding provides a low-resistance path for fault currents (ex: from lightning strikes, short circuits) to flow to the earth, minimizing the risk of electric shock & fire.

How it works: connects the current-carrying neutral of the electrical system to the earth.

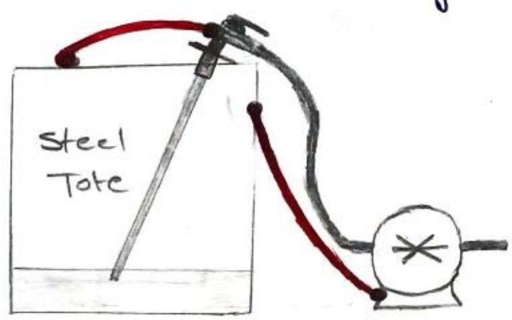
Ex: connecting the neutral wire of an electrical Panel to a grounding electrode (Like a ground rod).

Bonding: Bonding means connecting all metal parts that don't carry current under normal conditions (like enclosures, conduits, frames) together. It ensures all parts are at the same electrical potential to prevent shock hazards.

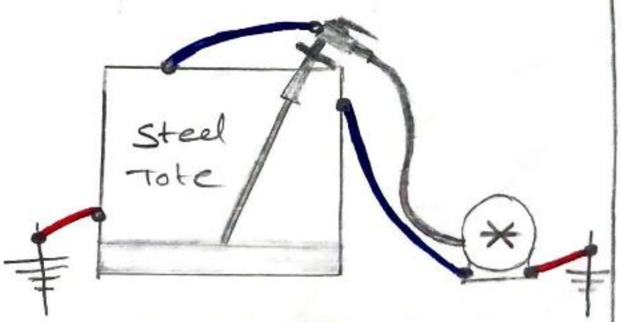
purpose: To eliminate potential difference between conductive parts, preventing shocks by ensuring they are at the same electrical potential and by creating low impedance path for fault currents.

How it works: connects non-current carrying metal parts of equipment together, ensuring they are at the same electrical potential.

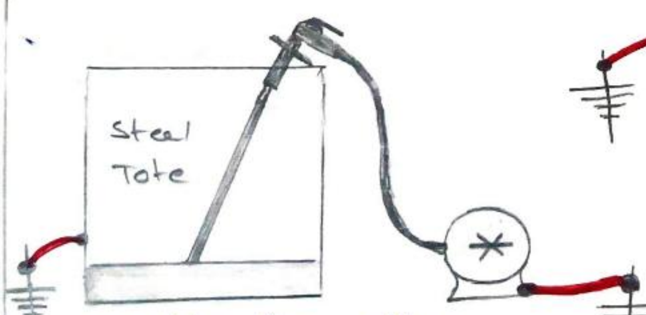
Ex connecting the metal frame of a machine to the electrical system's grounding conductor.



fig(a): Bonding



fig(c): Bonding & Grounding



fig(b): Grounding

Difference between Grounding & Bonding

Grounding	Bonding
1. connects to earth.	1. connects metal parts together.
2. Provides path for fault current to flow to ground.	2. Ensures no voltage difference between conductive parts.
3. Protects from system faults.	3. Protect from touch voltages.
4. Ex: Grounding transformer neutral.	4. Ex: Bonding motor frame to panel enclosure.

General requirements for grounding and Bonding:

The purpose of grounding & bonding is to protect people and equipment from electric shock and fire. To ensure safe path for fault currents & to maintain system voltage stability.

Grounding - general requirements.

1. System grounding: For power systems (like transformers, generators) to stabilize Voltage & clear faults.
2. Equipment grounding is required for all non-current-carrying metal parts of equipment.
3. Use a proper grounding electrode system (rod, plate, or building steel).
4. Grounding electrode conductor (GEC) must be continuous and correctly sized.

5. Grounding must have low resistance to earth (< 5 ohms)

6. Electrical systems over 50V must be grounded.

7. only approved materials (like Al, cu) should be used for grounding.

8. Earthing terminals should be accessible for inspection & testing.

Bonding - General Requirements

1. Bond all metal parts of electrical systems to ensure they are at the same potential.

2. Bonding ensures fault current return properly to the source or ground.

3. Use bonding jumpers across joints or non-continuous metal parts.

4. Enclosures, conduits, pipes cable trays etc. must be bonded.

5. Bonding conductors must be mechanically strong & properly sized.

6. Use listed connectors or lugs for bonding. no loose or makeshift connections.

7. All bonding connections must be permanent & corrosion - resistance.

Classification of Grounding:

Grounding ~~(or earth)~~ can be classified based on purpose, connection method, or application.

1. Based on function
   a) system grounding
   b) Equipment grounding

2. Based on Application
   a) substation Grounding
   b) Lightning Grounding
   c) Electronics / System signal grounding
   d) Static Grounding

System Grounding and Equipment Grounding

System grounding and equipment grounding are two distinct yet complementary electrical safety concepts. System grounding focuses on connecting the neutral point of a power system (like transformer (or) generator) to the earth, while equipment grounding connects the non-current carrying metal parts of electrical equipment to the earth. Both aim to minimize voltage differences and protect against electrical hazards like shocks & equipment damage.

System Grounding

Purpose: primarily to control voltage stress and protect against voltage hazards, including step and touch voltages, especially during ~~fau~~ ground faults.

Mechanism: Involves connecting the neutral point of a power system (ex: the neutral of a transformer) to the earth, often through a grounding electrode.

Benefits: Helps stabilize the system voltage, facilitates the operation of protective devices (like circuit breakers) during ground faults, & can improve the performance of lighting protection systems

Example: Grounding the neutral point of a generator or transformer in a substation.

Equipment Grounding:

purpose: primarily to protect people from electrical shock by providing a low-impedance path for fault currents to flow, ensuring that the non-current carrying metal parts of equipment remain at or near ground potential.

Mechanism: Involves connecting the metallic enclosures & frames of electrical equipment (like motor housings, conduit, & junction boxes) to the grounding system.

Benefits prevents dangerous Voltage build-up on equipment enclosures, minimizing the risk of electric shock to anyone who comes into contact with the equipment during a fault.

Example: Grounding the frame of a refrigerator, the metallic conduit of a wiring system, or the chassis of an electrical panel.

Earthing:

Earthing means the direct connection of the non-current carrying parts of electrical equipments such as metallic frame work, electric motor body, metallic covering of cables, earth terminals of socket outlet, transmission tower etc to earth or ground is known as "Earthing or Grounding".

The Earthing is done by connecting the body of the appliance to earth by employing some good conductor known as "Earth wire". The rod, wire, pipe or plate embedded in earth for the purpose making an effective connection with earth is known as "Earth electrode".

Purpose / Necessity of Earthing:

The main purpose of Earthing is,

1. To save human life from electric Shock.
2. To avoid risk of fire due to earth leakage current through unwanted path.
3. To maintain the line Voltage constant.
4. To ensure that no current carrying conductor rises to a potential with respect to earth than its desired insulation.

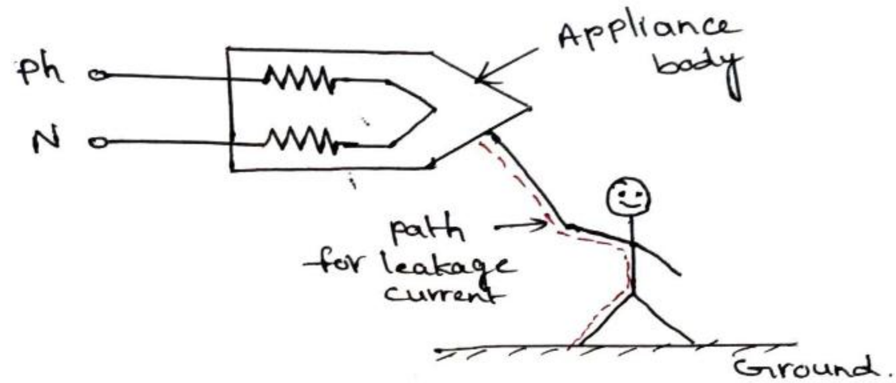


fig: (a): Appliance body not grounded (earthed)

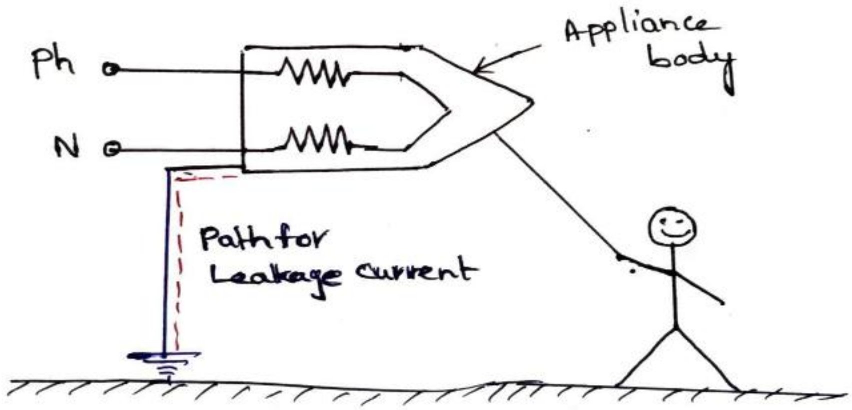


fig (b): Appliance body is grounded

Types of Earthing:

The various methods of earthing in common use are:

1. Rod earthing
2. strip (or) wire earthing.
3. pipe earthing.
4. plate earthing.

1. Rod Earthing:

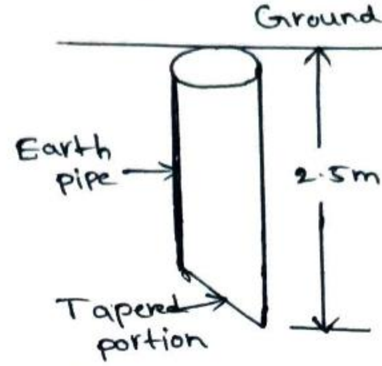


fig: Rod earthing

In this system of earthing solid rod of 12.5 mm dia of copper or 16mm dia of Solid G.I or steel rod of length not less than 2.5 meter is driven Vertically down wards into the earth either by manually or by hammer. Some times it is required to driven more than one rod to reduce the earth resistance to a desired Value. This system is cheap & is suitable for the soil is loose or sandy areas

2. Strip (or) Wire Earthing

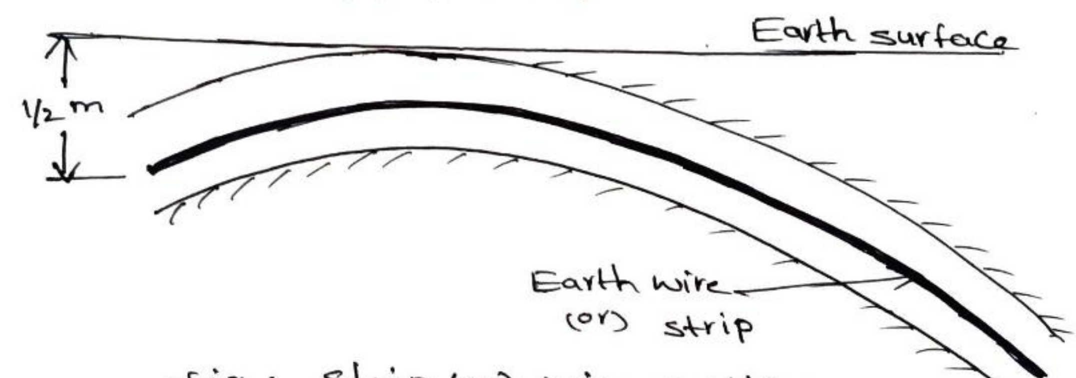


fig: Strip (or) wire earthing

This system is employed in places, where the soil is rocky because in rocky areas the soil excavation work is difficult.

In this system a wire or strip of cross-section 25mm x 1.6mm (3.0mm² if round) if copper (or) 25x4mm (6.0mm² if round) of G.I (or) Steel is buried in the ground in horizontal trenches of minimum depth ½ meter (1½ feet) as shown in fig. The length of wire or strip depends on the requirement of earth resistance, but the length should not less than 15 meters. Inorder to achive required resistance, sometimes more than one wire or strip is laid in parallel to each other.

Pipe Earthing ~~Advantages~~

* common system of Earthing in which a square pit of sides 40cm each is dug about 4 to 5m deep.
* A G.I pipe of 38mm dia & 2.5m long is placed vertically in a pit to work as earth electrode.
* The pipe is placed at minimum depth of 3.75m.
* The pipe in the pit is surrounded by pieces of coke or charcoal & salt in alternat layers.
* The pipe has 12mm dia holes, so that holes to decrease earth resistance.
* At the top, a cement concrete work is made for the protection of pipe from mechanical damage & is provided with a funnel with wire mesh to pour water.
* In summer season the moisture in the soil decreases which causes increase in earth resistance hence 3 or 4 buckets of water are put for every few days.
* The cement concrete work at the top is covered with a iron plate for opening & checking
* The layout of pipe earthing is shown in fig:

Advantages

1. It Requires less space for installation.
2. Easy to install and maintain.
3. Provides longer service life as G.I pipes resist corrosion better in moist soil.
4. Works efficiently in moist soils since water can be poured into the pipe for maitaining low resistance.
5. Economical compared to plate earthing.

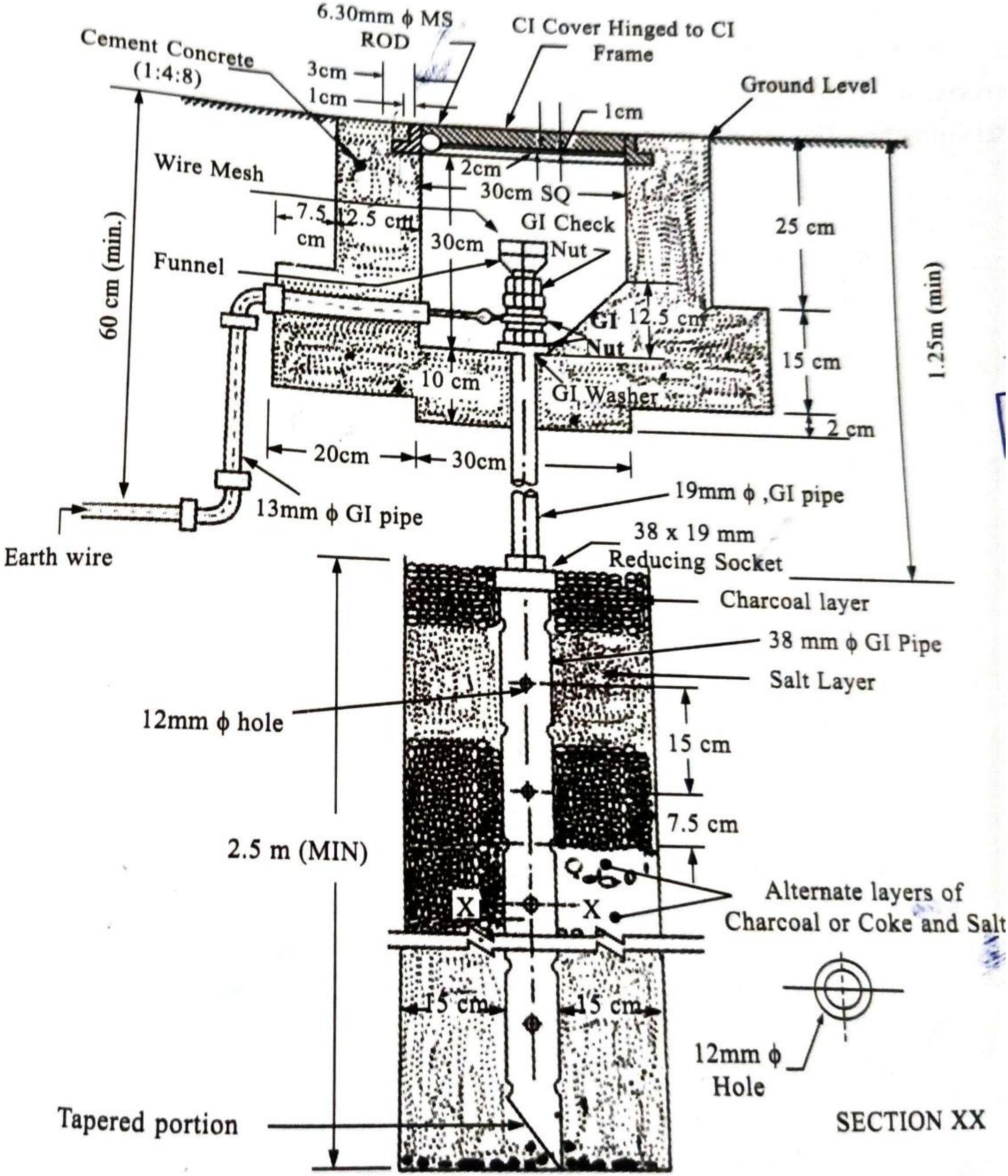


Fig 3.23 : Pipe Earthing

Applications:

1. widly used in domestic installations & small comme-rcial buildings.
2. Suitable for ordinary soil conditions where moisture content is adequate.
3. commonly adopted in rural electrification because of low cost.
4. Used in places where soil resistivity is low.

Plate Earthing

*. In this type of earthing a copper plate of dimension 60cm x 60cm x 3mm or a G.I plate of dimension 60cm x 60cm x 6mm is used as earth electrode.

* A pit is dug about 3m deep from ground level & earth plate is buried with its vertical.
* The space around the earth plate is filled with coke or charcoal & salt in alternate layers.
* The pipe of 19mm dia is connected to the plate for carrying water & is connected with funnel with wire Mesh to pour water.
* The water poured for increasing dampness & moisture which is turn reduce the earth resistance.
* At the top a cement concrete work is made to protect the plate from mechanical damage
* The concrete work is provided with a cost iron cover for carrying periodical opeing and inspection.

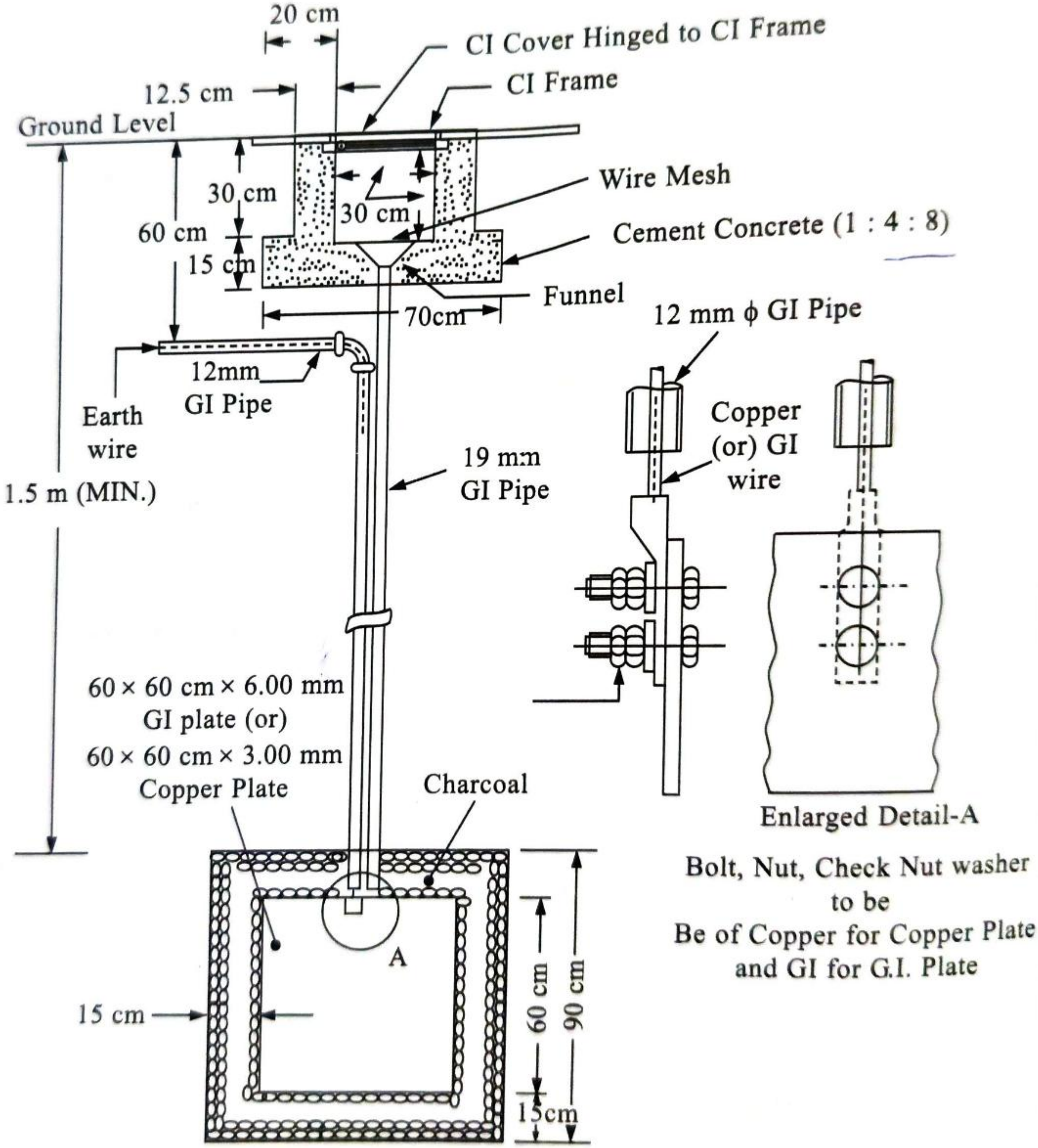


Fig 3.24 : Plate Earthing

Advantages:

* Provides better & more stable earthing resistance compared to pipe earthing.
* Highly reliable for heavy current dissipation during faults.
* can be used in all types of soils.
* Long-lasting when made with copper plate & G.I plate.
* preferred for critical electrical equipment due to consistent performance.

Applications:

* commonly used in large installations, industries & substations.
* preferred where soil resistivity is high & stable earthing is required.
* Suitable for power stations, grid stations & factories where heavy fault current may flow.
* Often used where regulatory standards demand low earth resistance.

Determining Safe Approach Distance

Safe Approach Distance (SAD)

The safe approach distance (SAD) is the minimum distance a person must maintain from an energized electrical conductor (or) circuit part to avoid Electrical Hazards.

The safe approach distance (SAD) is a critical Electrical safety concept for personel working near live Electrical Equipment (or) during fault conditions i.e Lightning strikes (or) Short circuits.

It references to the minimum distance a person must maintain from energined conductors. This distance depends on Safety factors including

1. Voltage Level
2. Type of worker
3. Use of personal protective equipment (PPE)
4. Work Method [live work, Proximity work etc.]

General safe Approac distance Based on standards [OSHA & NFPA 70E]:

1. Un-Qualified persons (or) workers

Unqualified peronnel must not approach Energized parts close tha the distances listed below table.

Voltage (phase-phase)	Minimum Approach Distance
50V to 300V	Avoid current contact's
300V to 750V	3 feet, 6 inches
750V to 15KV	10 feet [3.05 m]
15.KV to 36KV	10 feet, 4 inches (3.14m)
36KV to 46KV	10 feet, 6 incles (3.2m)

2. <u>Qualified persons/workers</u>

For qualified personnel, the safe approach Distance is calculated based on

1. Nominal voltage
2. Type of work being performed
3. Use of Insulating tools & PPE

precautions are in places such as,

1. Insulated Gloves,
2. Arc-rated clothing,
3. Live-Line Tools &
4. Lockout-Tagout procedures.

Steps for Determining safe Approach Distance:

1. Identify system voltage

Determine the nominal phase-to phase (or) phase-to-ground Voltage of the equipment

2. Refer to Applicable standards

* OSHA 29 CFR 1910.333 (US Regulations)
* NFPA 70 E (Arc flash & electrical safety standards)
* IEEE 516 / IS 102 / IEC 61472 (Live working practices)

3. Account for work Type

* Limited Approach Boundary — unqualified persons must not cross.
* Restricted Approach Boundary — only qualified workers with PPE & proper procedures.
* Prohibited Approach Boundary - treated as direct contact; entry only under strict precautions.

4. Use Standard Distance Tables

Example from NFPA 70E, typical Values.

system voltage (KV)	Minimum Approach Distance (phase - phase)
0 - 0.75 kV	Avoid contact
0.75 - 15 kV	0.7m (2ft 3in)
15 - 36 kV	0.9m (3ft)
36 - 72.5 kV	1.5 m (5ft)
72.5 - 121 kV	2.1 m (7ft)
138 - 145 kV	2.3 m (7ft 6in)
230 - 245 kV	3.6 m (12 ft)
345 - 362 kV	4.6 m (15ft)
500 - 550 kV	6.1 m (20.ft)
765 - 800 kV	10.3 m (34 ft)

5. Consider Environmental & work Conditions

* Wet (or) contaminated conditions increase distance.
* Using conductive tools/equipment may require extra clearance.

Determining Arc Hazard category:

Arc Hazard category (ofted called PPE category in NFPA 70E) is determined to protect workers from arc flash energy that can occur when working on (or) near energized equipment.

Steps for Determining Arc Hazard category.

1. Collect System Information

* System voltage kv.
* Available fault current at the equipment.
* protective device clearing time (breake/fuse) trip time
* working distance. i.e. distance from worker to arc source.

2. Perform Arc flash Hazard Analysis

* Use IEEE 1584 equations.
* calculate Incident Energy (IE) in cal/cm² at the working distance.

— formula (simiplified IEEE1584):

$$IE = k \cdot \frac{V \cdot I_{sc} \cdot t}{D^{x}}$$

V = system voltage

I_{sc} = short circuit curent

t = clearing time (sec)

D = Distance (mm)

k, x = constants.

3. Compare with PPE category Table (NEPA 70E)

NEPA 70E gives Arc Flash PPE

~~Cate~~

Category	Incident Energy Range	~~Ener~~ Typical PPE Required
category 1	$1.2 - 4\ cal/cm^2$	Arc-rated clothing, safety glasses, gloves.
category 2	$>4 - 8\ cal/cm^2$	Arc-rated clothing, Arc-rated face shield, leather gloves
category 3	$>8 - 25\ cal/cm^2$	Arc rated clothing, Arc hood, hearing protection.
category 4	$>25 - 40\ cal/cm^2$	Arc rated clothing, full suit, heavy PPE

If ~~IE~~ Incident Energy $> 40\ cal/cm^2$, work is usually prohibited. (too dangerous).

4. Alternative Method - PPE category tables (NEPA 70E Annex H & Table 130.7(c) 15(a)).

* Instead of calculating IE, you can directly use standard tables if:

→ The system meets the listed short-circuit & clearing-time limits &

→ The equipment type is covered like Switch-gear, MCC, Panel boards etc.

~~*~~ .

may be subjected to severe burns. Black skin may completely be turned to white.

1 PROCEDURE OF FIRST - AID IN CASE OF ELECTRIC SHOCK

We do not know when we will come across an electrical accident to some body, may be at home or office or industry. It is always better and necessary to know how to give first aid to such victims before arranging to send the victim to the doctor.

Removal of Victim from Supply : The victim if found fallen on the ground or in sitting position in an unconscious state always suspect that the victim is still in contact with the electric supply. In an anxious state never touch the victim. The event of such a mistake you will also fall into the trap.

Ascertain whether the victim is still in contact. If so, you should stand on a dry wooden plank and remove the victim, otherwise, pull the victim using a dry rope or coconut matting or stick. If possible stand on a rubber mat.

Checking the Victim : Check whether the victim is still breathing send a massage to bring the doctor. If apparently the victim is not breathing, give FIRST AID till the doctor arrives to give further treatment.

AnySc

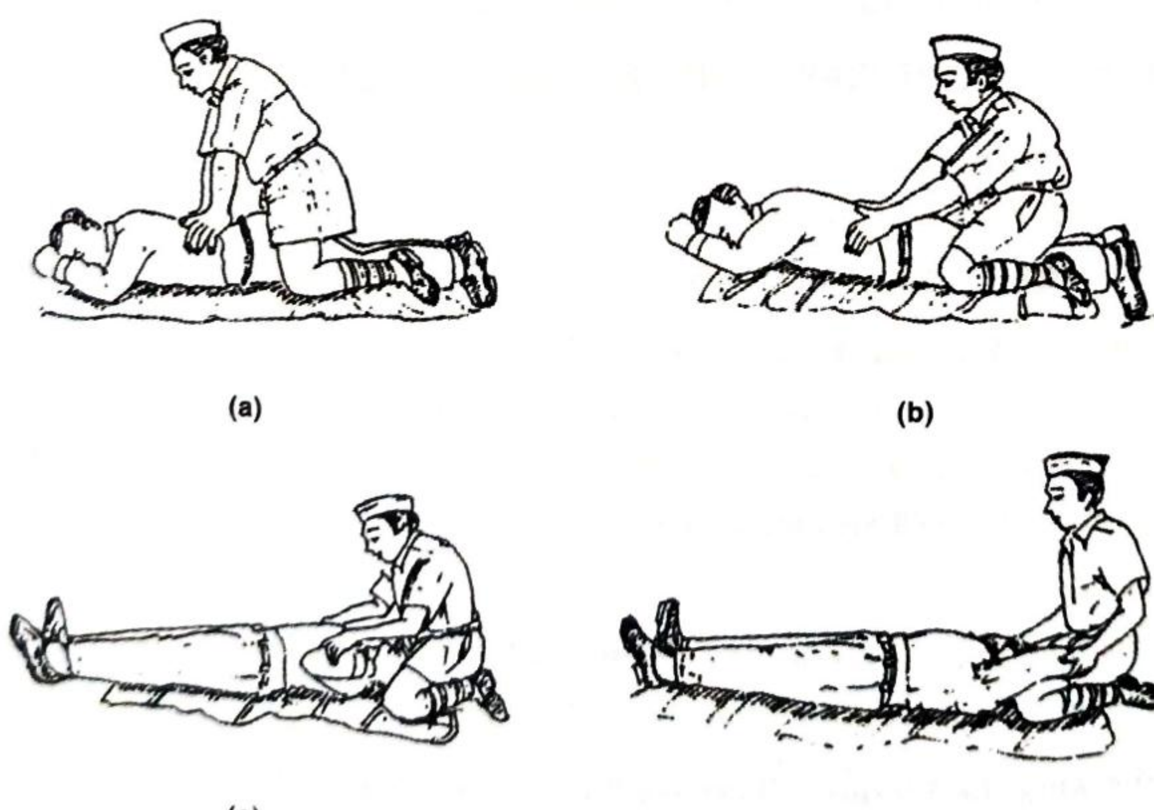
METHOD - I :

Keep the victim as shown in Fig. 1.60 (a) with the face downwards. Kneel over the victim's back placing both the hands on the patient's back near the lowest rib such that the fingers are spread outwards while the thumbs of both the hands almost touch each other and are parallel to the spine.

Rock yourself gently forward, keeping your arms straight pressing slowly for about 2 seconds as shown in Fig. 1.60 (a). Now slowly release the pressure and come to the kneeling position. Repeat this process at the rate of about 15 times a minute. The purpose is to expand and contract the victims lungs and cause breathing. Continue this operation till the natural breathing is re-established. It may take a long time i.e., 30 minutes or even one hour to get the expected result.

If the victim starts breathing, it is better to synchronise your actions until the victim breaths strongly. In some cases it so happens that the victim after a temporary recovery of respiration, again stops breathing. It is therefore, very much necessary to check the breathing of the victim continuously, and if natural breathing stops, artificial respiration should be given as explained above.

Caution : It is important that an unconscious victim should never be given any drink.



(a) (b) (c) (d)

FIG 1.60 : Procedure to be Adopted in Case of Electric Shock

METHOD - II :

Alternatively, if it is advantageous to place the victim on his back, do so, and loosen his cloths around the chest and stomach. Place a pillow under his shoulders. The aim is to make his head fall backwards. Draw his tongue forward and proceed as follows.

You should kneel in a position as shown in Fig. 1.60 (c). Hold the victim just below his elbows and draw his arms over his head until they are horizontal to the ground. Keep them there for about 2 seconds. Bring the patients arms down on each side of his chest, pressing inwards up so as to compress his chest. Keep the arms in this position atleast for 2 seconds.

Repeat the above two positions at the same rate. It is always better if we draw out the patients tongue during each lung inflating (inhalted position) stroke (Fig. 1.60 (c) and release it during each lung deflating stroke (exhaled position as in Fig. 1.60 (d).

METHOD - III : (MOUTH TO MOUTH RESUSCITATION) :

This is very good method and is becoming very popular. *The procedure is as follows :*

Place the patient, so as to lie on his back. If there is some foreign matter like tobacco, chacolate etc., in the mouth, remove it, this will make the air passage clear.

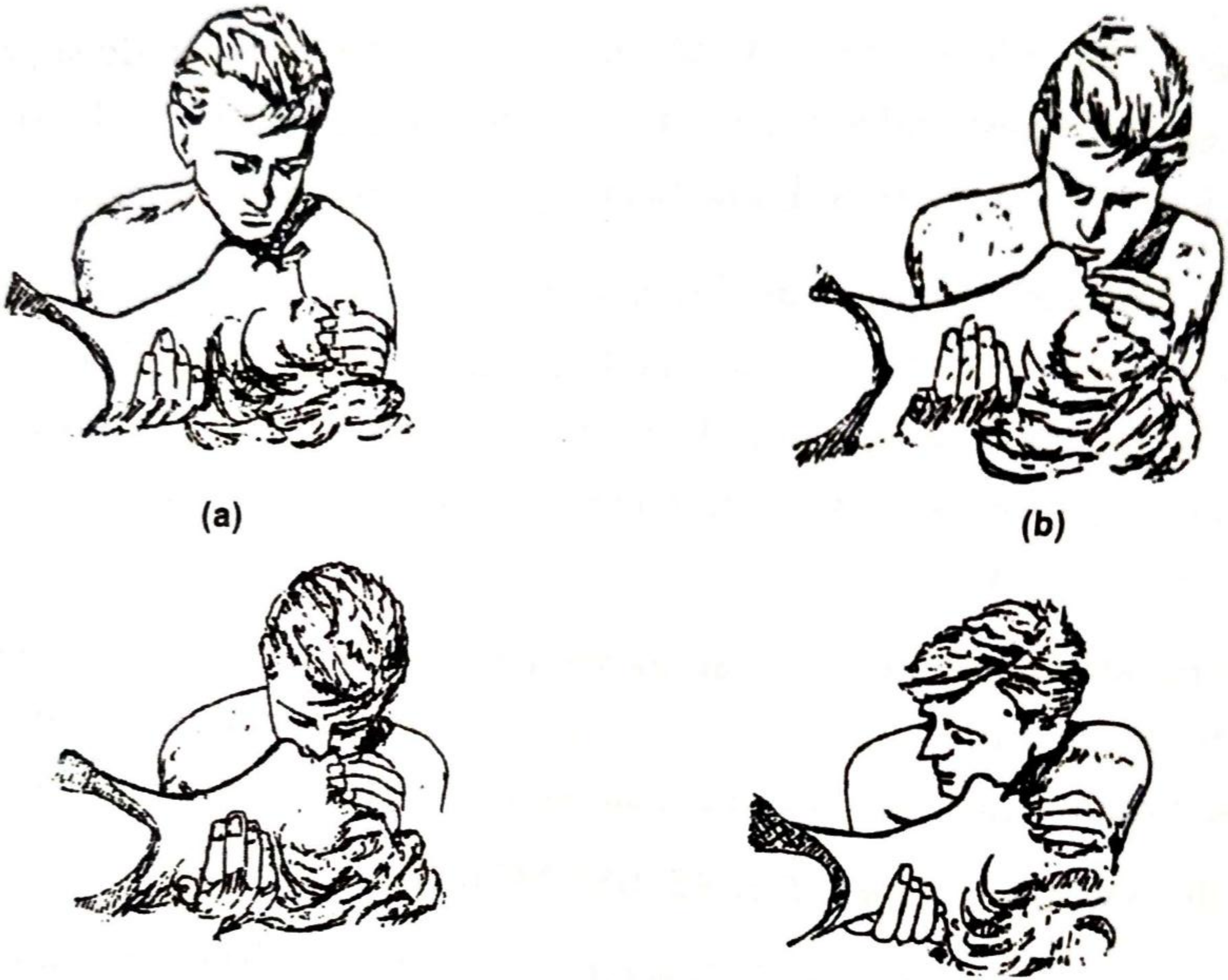
Step 1 : Open the airway of the patient by lifting his neck with one hand while your other hand tilts his head back and down as far as possible such that the chin points upwards (Fig. 1.61 (a)).

Step 2 : Pinch the nostrils (nose) to prevent air leakage. Maintain the open airway by keeping the neck elevated (Fig. 1.61 (b)).

Step 3 : Seal your mouth tightly around the victims mouth and blow the air in. The patients chest should rise (Fig. 1.61 (c)).

Step 4 : Remove your mouth. Release the patients nostrils. Listen for air escaping from the patients lungs. Watch for the patients chest to fall.

Steps 2, 3 and 4 make one breathing in-breathing out cycle. Repeat this cycle by following steps 2, 3, and 4 at 12 to 15 times a minute. Continue until medical help arrives or beathing in the victim is restored. For young ones (infants) cover the entire mouth and nose with your mouth. Use small puffs of air about 20 times per minute.



(a) (b) (c) (d)

FIG 1.61

Electrical safety in Train stations

Railway & metro stations involve high-voltage equipment, traction power, signaling, escalators, lifts & passenger facilities. Electrical safety is critical because of dense public movement and continuous operation.

Sources of Electrical Hazards in Train Stations

1. High Voltage Traction Supply

* overhead equipment (OHE) ~25kV AC in Indian Railways/metros.
* Third rail system (750V DC) in metros.
  Risk: Direct contact, induced Voltage, Flashover

2. Low Voltage Distribution.

* Power supply for lighting, escalators, lifts, air-conditioning signaling.
* Risk: Shock due to faulty insulation or earthing

3. Substations & Transformers

* 132/25 kV Substations for traction supply.
* Risk: Arc flash, equipment failure fire.

4. Crowd Areas

* Wet floors, metallic structures, & human congestion increase risk of shock.

Electrical Safety Measures.

1. Design & Installation

* Adequate insulation, clearances, fencing for sub stations.
* Safe routing of cables (underground with proper trays/conduits).

* Touch-proof switchgear & busbars.

Earthing & Bonding:

* Effective earthing of OHE masts, station buildings, escalators, lifts.
* Equipmential bonding to avoide potential differences.

Protective Devices

* circuit breakers, relays, surge arresters, RCCBs (Residual current circuit Breakers).
* Arc-flash detection systems in high-voltage switchgear.

Operational Safety:

* Lockout-tagout (LOTO) procedures during maintenance.
* Regular thermography & insulation testing.

passenger safety

* warning boards & danger signage near OHE.
* Restricted access to technical rooms
* public awareness: announcements not to cross tracks or touch equipment.

Energency preparedness.

* Fire detection & suppression systems
* Emergency evacuation plans.
* Dedicated staff trained in electrical hazard response.

case-study: Mumbai suburban Railway (India, 2014)

Incident: passenger electrocuted while travelling on the train roof, came in contact with 25kV OHE.

Impact: Fatality, service disruption.

Lesson: Need for stricter anti-trespassing enforcement, fencing & awareness campaigns.

Case study-2 Washington Metro smoke Incident (2015)

Incident: Electrical arcing in a tunnel near L'Enfant plaza station caused heavy smoke.

Impact: 1 death, 80+ hospitalizations.

Lesson: Importance of tunnel Ventilation, arc suppression devices, & quick emergency evacuation protocols.

Electrical safety in swimming pools

Water is an excellent conductor of electricity. Even small leakage current (10-30mA) in a pool can cause electric shock drowing (ESD). pools have pumps, underwater lights, heaters, filtration systems all potential electrical Hazards.

Hazards in swimming Pools

1. Faulty wiring of pumps & lights.
2. Stray currents in water due to damaged insulation.
3. Improper grounding / bonding of ladders, rails, diving boards.
4. Use of portable devices-(radios, chargers) near water.
5. Lightning risk if swimming during storms.

Safety Measures:

1. Electrical Design & installation

1. Follow NEC/IEC/IS standards.
2. Use low-voltage (≤ 12V) lighting underwater.
3. waterproof cables & corrosion-resistant conduits.

2. Grounding & Bonding

1. All metallic parts ladders, rails, diving boards must be bonded.
2. Equipment must be earthed to eleminate shock potential.

3. Protective Devices

1. Install RCD/GFCI (≤ 30mA) on all pool electrical circuits.
2. RCCB/ELCB for leakage current protection.

4. Safe Distances

1. Electrical outlets. minimum 3-5m away from pool.
2. No overhead power lines near pool area.

5. Inspection & Maintenance

1. Regular checks of wiring, lights, & pumps.
2. Replace damaged cables or cracked light fixtures.

6. User Precautions.

1. No electrical appliances near the pool.
2. Do not swim during lightning.
3. life guards trained in CPR & emerengcy rescue.

Case studies

1. Houston Hotel, USA (2013)

Incident: A man died while helping swimmers shocked in pool.

Cause: Faulty pump wiring, improper grounding.

Lesson: pumps must be properly grounded & inspected regularly.

2. Public pool, Delhi, India (2018)

Incident: child electrocuted while holding metal ladder inside pool.

Cause: Ladder was not bonded to grounding System.

Lesson: All metallic fittings must be equipotentially bonded.

Electrical Safety in External lighting

External (outdoor) lighting includes street lights, floodlights, garden' lights, stadium lighting, & building exterior illumination. since these systems are exposed to rain, wind, Soil moisture, dust & lightning they present unique electrical safety challenges.

Hazards in External lighting

1. Electric Shock Hazard

* Leakage current due to damaged insulation.
* Energized lamp posts from poor earthing.

2. Fire Hazards

* Short circuits in underground cables (or) junction boxes.

3. Mechanical Hazards

* Falling poles due to rust, weak foundation or storms.

4. Environmental Hazards

* Lightning strikes on tall lighting poles.
* Flooding around bases of poles leading to contact risks.

Safety Measures

1. Design & Installation.

* Use IP65/IP66-rated weather proof fittings.
* Lay armoured underground cables in conduits.
* Provide strong pole foundations.
* Install light poles away from pedestrain walk ways if possible.

2. Grounding & Bonding

* All metallic poles & lamp posts must be properly earthed.
* Equipotential bonding to eliminate touch voltage.

3. Protection Devices

* RCD/GFCI ($\leq 30\,mA$) for leakage current protection.
* MCBs/fuses for overcurrent.
* Surge protection Devices (SPD's) for lightning protection.

4. Maintenance:

* Inspect poles, cabling & junction boxes regularly.
* Replace corroded poles & damaged insulation
* Test earthing resistance periodically.

5. Use & Public safety:

* Warning signs during maintenance.
* poles should have no exposed live parts.
* Children should be restricted from playing near poles.

Case Stuidies

1. Streetlight Electrocution - Mumbai, India 2015

Incident: A 14-year-old boy electrocuted after touching a street light pole during monsoon.

cause: Faulty underground cable leakage energized the pole.

Findings No earthing, no RCCB protection.

Lesson: streetlights must be eartled & protected with RCCBS.

2. Garden Flood light Shock - UK 2017

Incident: Gardener received severe electric Shock while adjusting outdoor flood light.

cause: water ingress through damaged cable gland.

Findings: No RCD, poor IP protection.

Lesson: outdoor fittings must be IP65+ he -atherproof & connected Via RCD's

Electrical safety in Medical locations:

* patients may have reduced body resistance (wet skin, invasive devices).
* Medical equipment (ECG, Ventilators, ~~daily~~ dialysis, infusion pumps) may connect directly to the body.
* Even microshock (50-100μA) can cause Ventricular fibrillation when applied directly to the heart.
* power failures or faults can interrupt life-saving treatment.

Hazards in Medical Locations

1. Microshock & Macroshock

Small leakage currents from medical devices can affect patients.

2. Power supply Failures

Interruptions can stop Ventilators, dialysis machines, monitors.

3 Faulty Grounding or Bonding

can create dangerous touch voltages on equipment frames.

4. Electromagnetic Interference (EMI)

can distrub pacemakers, monitors & imaging systems.

Safety Measures

1. Electrical Design:

* Medical areas classified as Group 0, 1, 2 (per IEC 60364-7-710/ IS standars).
* Isolated power systems (IPE) with line isolation monitors in ICUs/OTs.

2. protective Devices

* Residual current Devices (RCD'S) with ≤30 mA. trip.
* Isolated transformers for critical areas.
* Surge protection devices (SPD's) to protect sensitive equipment.

3. Backup systems

* UPS & generators for life-saving equipment.
* Automatic transfer switches to ensure continuous supply.

4. Maintenance & Testing

* Regular leakage current testing of equipment
* calibration & safety certification of medical devices.
* periodic earthing resistance. measurement.

5. Staff Training

* Awareness on Safe use of plugs, sockets & equipment.
* Emergency drills for power failures.

Case studies

1. Neonatal ICU Electrocution - India (2019)

Incident An infant died in a neonatal ICU due to electrical leakage from a radiant warmer.

Cause: Faulty wiring inside equipment, no leakage protection.

Findings No RCD installed, poor Maintance practices.

Lesson: Leakage current testing & RCDs are mandatory for neonta l ICU equimpenent.

2. Dialysis unit shock USA (2002):

Incident patients reported mild shocks during dialysis.

Cause : Improper grounding of dialysis machine water pump.

Findings Bonding conductor disconnected.

Lesson: Equipotential bonding of all medical equipment is critical to patient Safety.

Unit - V

Standards For Electrical Safety

Introduction: The electricity Act, 2003 as amended by the electricity. Act, 2003, w.e.f 27-01-2004 with Allied Rules & Regulations, consolidates the Indian Electricity Act, 1910, the Electricity (supply) Act, 1948, Electricity Regulatory commission Act 1998, so the law is rationalized & simplified that the common can get an overall understanding of the law on the subject without roaming through so many enactments.

Indian Electricity Act:

The Electricity Act, 2003 is the backbone of the Indian power sector. Before 2003, electricity sector in India was governed by:

* Indian Electricity Act, 1910
* Electricity (supply) Act, 1948
* Electricity Regulatory commission Act, 1998.

These became outdated, so they were consolidated into the Electricity Act 2003.

This Act is the main law governing generation, transmission, distribution, trading & use of electricity in India.

Objectives of Electricity Act, 2003

* Promote competion in electricity sector
* Ensure supply to all areas including rural electrification.

* protect consumer interests.
* Provide transparent tariff policy.
* Encourage renewable energy & congeneration.
* Establish regulatory commission for oversight.
* Improve Efficiency & quality of supply.

Generation:

* Delicensed (any one can setup a power plant, except hydro >25MW needs approval).
* captive generation allowed without restrictions.

Transmission

* Interstate transmission regulated by CERC (Central Electricity Regulatory commission), &
* State level transmission transmission regulated by SERC's (State Electricity Regulatory commission).

Distribution

* Distribution licensees must ensure universal service obligation.
* open access in distribution allowed large consumers (≥1MW)
* competition introduced - multiple suppliers can operate.

Trading

Electricity trading recognized as a distinct licensed activity.

Regulatory Commissions

* CERC for central Level
* SERCs for state Level
* Appellate Tribunal for Electricity (APTEL) to hear appeals.

Tariff:

Tariff must be transparent, cost-reflective, & protect consumers.

Rural Electrification

Special provisions for decentralized distributed generation & village electrification.

Renewable Energy

* Renewable purchase obligation (RPO) introduced
* Promotion of renewable energy certificates (REC) mechanism.

Important Amendments

* 2007 Amendment - Distribution of electricity through capactive generation allowed without license.
* 2022 (proposed / Recent) - Greater focus on open access, renewable energy, stricter penalities for non-compliance.

Electricity Rules & Regulation

Indian Electricity Rules

These rules extract from the Indian electricity. rules. Before ~~actuit~~ actually studying Indian Electricity Rules (I E Rules) & other precautions, we should realise why these rules & regulations have been framed. ~~The rules &~~ r~~egulations have~~ by competent authority to

1. Safe guard consumers of electrical energy from shock.
2. Minimise risk of fire.
3. Ensure satisfactory operation of equipment & apparatus used.

Rule-1: Short Title & Commencement

i) These rules may be called the Indian Electricity Rules, 1956. They shall come into force at once.

Rule-2: Definitions

Rule-3: Authorisation

Rule-4: Qualification of Inspectors

General Safety Precautions

Rule-29: Construction, Installation, protection, operation & Maintenance of Electric supply Lines & Apparatus.

Rule-30: Service Lines & Apparatus on consumer's premises.

Rule-31: cut-out consumer's premises

Rule-32: Identification of Earthed Neutral conductor & position of switches & cut-out Therein

Rule-33: Earthed Terminal on consumer's premises

Rule-34: Accessibility of Bare conductors.

Rule-35: Danger Notices.

Rule-37: Supply to Vechicles, cranes, etc.

General conditions Relating to supply use of Energy:

Rule-47: Testing of consumer's Installation

Rule-48: Precautions Against Leakage Before connection.

Rule-49: Leakage on consumer's premises.

Rule-50: Supply & use of Energy.

Rule-51: provisions Applicable to medium, High or Extra-high voltage Installation.

Electric supply lines, systems & Apparatus For Low & medium Voltages

Rule-60: Test for Resistance of Insulation

Rule-61: Connection with Earth.

Rule-62: system at Medium Voltage.

Electric supply Lines, systems & Apparatus for High & Extra-High Voltages

Rule-63: Approval by Inspector

Rule-64: use of Energy at High & Extra-high voltage

Rule-65: Testing, operation & Maintenance.

Rule-67: Connection with Earth.

Rule-69: Pole Type Sub-stations.

Over-Head Lines, Underground cables & Generating stations.

Rule-74: Material and strength

Rule-77: clearance above ground of the Lowest conductor

Rule-85: Maximum Intervals between supports

Rule-86: conditions to Apply where Telecommunications lines & power lines are carried on same supports:

Rule-90: Earthing

Rule-91: Safety & protective Devices

Rule-92: protection Against Lightning.

NFPA 70E Standards

* NFPA 70E is standard for Electrical safety in workplace.
* published by the National Fire protection Association (NFPA), USA.
* companion document to the NEC (National Electrical code, NFPA 70).
* Focuses on electrical safety requirements for protecting workers from electrical Hazards.

purpose

* prevent shock, arc flash & arc blast injuries
* provide safe work practices, PPE requirements, & risk assessment procedures.

1. Establishing Electrically safe work conditions

proper Lockout/tagout (LOTO) procedures.

2. Shock protection

- Approach boundaries (limited, restricted, prohibited)

3. Arc flash protection

* Incident energy Analysis
* Arc flash boundary
* PPE categories

4. Training

* Qualified Vs unqualified personnel
* Regular refresher training

5. Maintanance

safe practices for testing, troubleshooting & equipment servicing.

OSHA Standards

* OSHA = Occupational Safety and Health Administration, U.S Dept of Labor

* OSHA standards are legally enforceable rules to ensure safe & healthy working conditions.
* They cover general industry, construction, maritime & agriculture every thing from fall protection to arc flash hazards & they are legally enforceable.

Types of OSHA Standards

OSHA standards are grouped mainly into:

1. General Industry Standards [29 CFR 1910]
* Electrical Safety (subpart S)
* Hazardous materials
* Walking / working surfaces
* Machine guarding
* PPE

2. Construction Standards [29 CFR 1926]
* Fall protection
* Scaffolding
* Excavation & trenching
* Electrical safety.

3. Maritime standards [29 CFR 1915-1918]
* Shipyard employment
* marine terminals
* Long shoring.

4. Agriculture standard [29 CFR 1928]
* Farm equipment safety.
* Roll-over protective structures
* pesticide handling.

~~OSHA Electrical~~

OSHA Electrical Safety standards

* 29 CFR 1910.303 – Electrical design Safety.
* 29 CFR 1910.305 – wiring methods, components, equipment.
* 29 CFR 1910.333 – Selection & use of work practices (LOTO, deenrgization)
* 29 CFR 1910.335 – PPE & protective equipment for electrical Hazards.

IEEE Standards:

IEEE – Institute of Electrical and Electronics Engineers.

IEEE develops technical standards for electrical electronics, computer, power & communication system. Unlike OSHA/NEC, which are laws & regulations, IEEE standards are industry consensus standards (best practices, widly adopted worldwide)

1. Electrical and power systems

* IEEE 519 → Harmonic control in power systems
* IEEE 1547 → Interconnection of distributed energy resources (DERs) with the grid.
* IEEE C37 series → circuit breakers, relays, & switch gear.
* IEEE 242 (Buff Book) → protection & coordination of industrial power systems.
* IEEE 141 (Red Book) → Electric power distribution for industrial plant

2. Electrical safety:

* IEEE 1584 → Arc flash hazard calculations.
* IEEE (NESC) → National Electrical Safety code (for utility & telecom lines)

3. Electronics & communication

* IEEE 802.x series → Networking (ex: IEEE 802.3 = Ethernent, IEE 802.11 = Wi-Fi)
* IEEE 488 → Instrumentation communication (GPIB)

4. Emerging Technologies

* IEEE 2030 → smart grid interperability.
* IEEE 1547.9 → Microgrid interconnections.
* IEEE 11073 → Health informatics (Medical devices)

NEC

* The National Electrical code (NEC) is a U.S standard for the safe installation of electrical wiring & equipment.
* Published by the NFPA 70.
* First issued in 1897, & updated every 3 years.
* It's not a federal law, but most U.S states adopt it into their building/electrical codes, making it legally enforcable.

→ The 2005 NEC is the 19th Edition. Some of the major changes in 2005 included:

1. Arc-Fault Circuit Interrupters (AFCIs): Requirement extended from outlets & circuits
2. Ground Fault circuit Interrupters (GFCIs): Expanded requirements for kitchens, bathroom, garages, outdoors & unfinished basements.
3. Surge protection: New requirements for TVSS
4. Wiring Methods: clarification on cable installation in wet/damp locations

More details on underground wiring.

5. Emergency systems:
   updates for standby power systems & emergency lighting.
6. New Article Added (2005):
   Article 409: Industrial control panels
   Article 680: swimming pools, Fountains, & similar Installations
   Article 692: Fuel cell systems.
   Article 694: wind Electric system.

NESC

National Electrical Safety code.

* NESC - National Electrical Safety code.
* published by IEEE, first issued in 1914, updated
* every 5 years (latest is 2023)
* It provides safety rules for electric power, communication lines, & utility systems.

The NESC covers:

1. Electric supply station (generation & substation)
2. overhead power lines (construction, clearances, grounding)
3. Underground electric supply & communication cables.
4. work rules for employees who install, operate, or maintain these systems.

Statutary requirements from electrical inspecorate:

Statutary requirements from Electrical Inspectorate generally refers to the mandatory legal & safety obligations that consumers, industries, & utilites must follow as per the Electricity Act, Rules & Regulations of a country. The electrical inspectorate [sometimes called the chief Electrical Inspector's office] is a government authority that enforces these rules to ensure electrical safety, reliability, & compliance with Standards.

The common Statutory requirement checked by Electrical Inspectorate, as show below

1. Installation Approvals

* Prior approval for high-voltage/ extra-high-voltage electrical installations.
* Layout drawings, single-line diagrams & equipment specifications must be submitted.
* compliance with Indian Electricity Rules, CEA Regulations & NEC.

2. Inspction & Testing

* Initial inspection of new electrical installations before energizing.
* periodic inspections of existing installations, especially in factories, hospitals, high-rise building hazardous areas & mines.
* Testing of protective devices (relays CB's, earthing)

3 Licensing & Certification

* Licensing of electrical contractors & wiremen
* competency certificates for supervisors & operators.
* Approval of testing labs & calibration of meters.

4. Safety Requirements

* Adequate earthing/grounding system.
* protection against over-current, short-circuit & electric shock.
* Lightning protection systems in tall structures.
* Fire safety clearance in coordination with the fire department.

5. Energy & Load Regulation

* Ensuring that consumers do not exceed sanctioned load.
* Periodic Verification of energy meters.
* Power factor correction.

6. Accident Investigation & Reporting

* All electrical accidents (fatal & non-fatal) must be reported to the Inspectorate.
* The Inspectorate investigates causes & issues safety recommendations.

7. Compliance with standards

* Following IS/IEC standars for electrical equipment.
* Use of approved materials & BIS certified equipment.