

Guide Rails and Support Elements

■ Importance:

- Ensure the valve gate moves smoothly and maintains proper alignment within the valve body.
- Prevent unwanted lateral movement that could compromise the seal.

■ Functionality:

- Provide tracks or surfaces along which the gate slides.
- Help distribute mechanical loads evenly during actuation.

■ Causes of Wear & Tear / Damage:

- **Friction:** Continuous sliding may cause abrasion of the guide surfaces.
- **Corrosion:** Exposure to water can corrode metal guide rails if not properly protected.
- **Contamination:** Debris and sediment can become lodged, increasing friction and wear.

■ Preventive Maintenance:

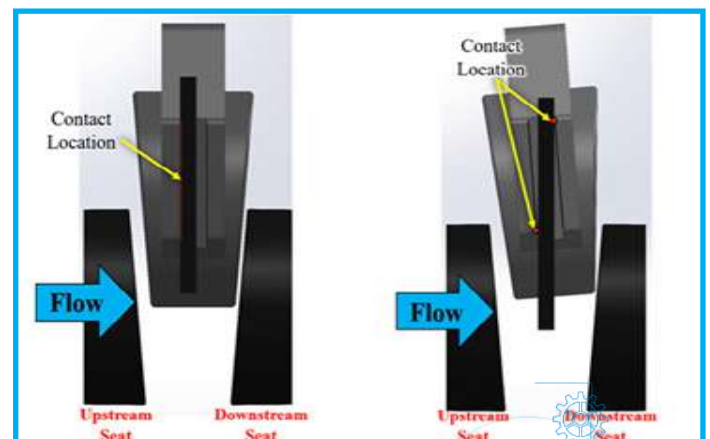
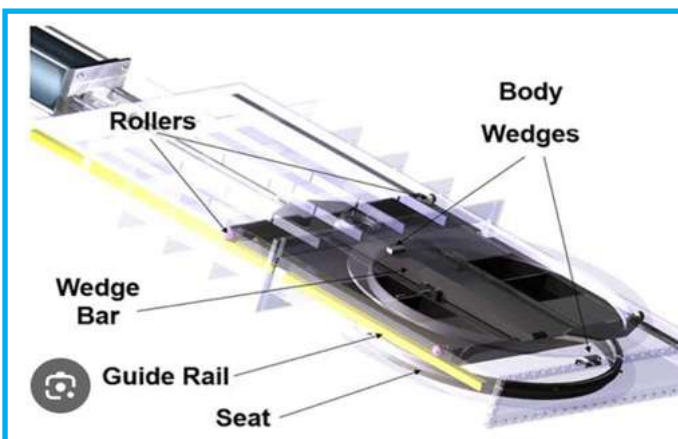
- Regularly clean the guide rails and inspect for smoothness and proper alignment.
- Lubricate guide surfaces as recommended by the manufacturer.
- Apply corrosion protection or replace guides in aggressive environments.

■ Fault Identification:

- **Before Opening:**
 - * Increased resistance or irregular movement of the valve gate during operation.
 - * Noise or vibration indicating misalignment.
- **After Opening:**
 - * Visible wear marks, scoring, or rust on the guide surfaces.
 - * Loose or broken guide elements.

■ Repair Methods:

- Clean and lubricate the rails to restore smooth movement.
- Replace or re-machine worn guide surfaces if damage is advanced.
- Re-align support elements to ensure proper guidance.



Fasteners, Gaskets, and Protective Coatings

■ Importance:

- Fasteners hold the valve body, bonnet, and other components together, while gaskets ensure leak-proof joints.
- Protective coatings extend the service life by guarding against corrosion and abrasion.

■ Functionality:

- Fasteners maintain mechanical integrity.
- Gaskets and seals prevent leakage at joints and interfaces.
- Coatings protect metal surfaces from environmental degradation.

■ Causes of Wear & Tear / Damage:

- **Mechanical Loosening:** Vibration and thermal cycles can loosen bolts and fasteners over time.
- **Material Degradation:** Gaskets and coatings may deteriorate due to heat, chemical exposure, or age.

■ Preventive Maintenance:

- Regularly check and retighten fasteners to the specified torque.
- Inspect and replace gaskets on a scheduled basis.
- Reapply protective coatings if signs of wear or corrosion appear.

■ Fault Identification:

- **Before Opening:**
 - * External leaks near joints or visible gaps in the assembly.
 - * Loose or misaligned components.
- **After Opening:**
 - * Worn, cracked, or compressed gaskets; corroded fasteners; or flaking protective coatings.

■ Repair Methods:

- Replace damaged gaskets and reassemble using proper torque.
- Clean and, if necessary, replace fasteners that show signs of fatigue or corrosion.
- Strip and reapply protective coatings as per manufacturer's recommendations.



General maintenance & repair guidelines

1. Routine Inspections:

- Visually inspect the entire valve assembly for leaks, corrosion, or mechanical wear.
- Operate the valve periodically to ensure smooth movement and check for unusual resistance or noise.

2. Scheduled Preventive Maintenance:

- Clean internal components (body, gate, guide rails) on a set maintenance schedule.
- Replace packing, gaskets, and worn fasteners before they lead to leaks or operational failure.
- Lubricate moving parts and ensure that actuators (manual or motorized) are properly adjusted.

3. Fault Diagnosis and Documentation:

- Record observed symptoms (e.g., leakage, increased operating effort, unusual sounds) for each maintenance cycle.
- Use diagnostic tools (such as torque wrenches, vibration analysers, or infrared thermography) to detect early signs of wear or misalignment.

4. Safe Repair Practices:

- Always de-energize any electrical components (if motorized) and isolate the valve from the system before performing maintenance.
- Follow proper lockout/tagout procedures and wear appropriate personal protective equipment (PPE).
- Refer to manufacturer's guidelines for specific repair procedures on sensitive components.

FINAL NOTES

■ Safety and Compliance:

- Adhere to local and departmental safety standards during all maintenance and repair operations.
- Ensure that all technicians are trained in the specific procedures for sluice valve maintenance and repair.

■ Documentation:

- Keep detailed logs of inspections, maintenance actions, observed faults, and repairs.
- Use this documentation to monitor trends and schedule proactive maintenance.



https://youtube.com/playlist?list=PLu7Qy6fHf-Wzc0GlhFBCtRTc9laMKsmi-Kn&si=n42sTjTcWcrU_Yv_

For more information and videos regarding installation and repairing of Sluice Valve

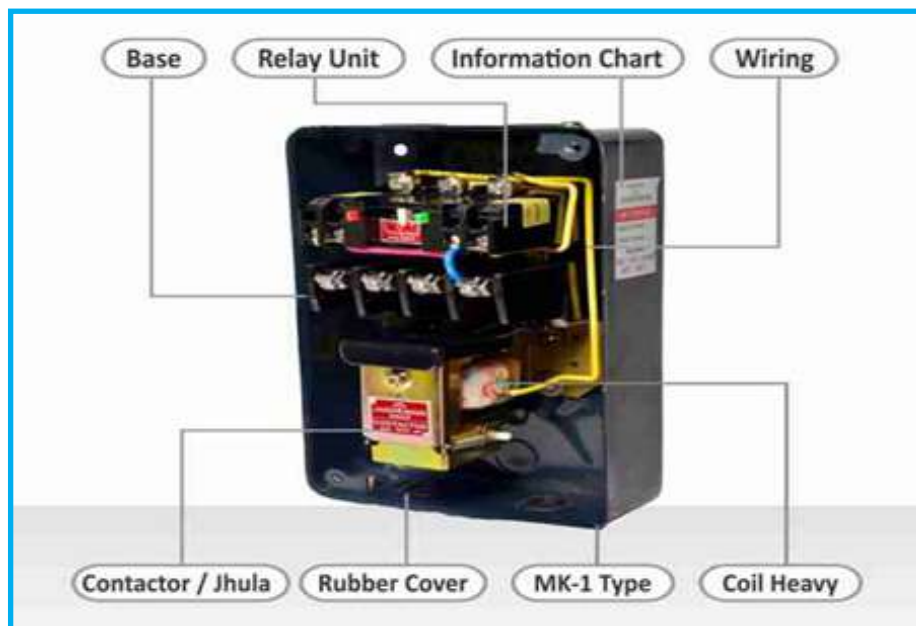


Electrical Items

7. Electrical Items

7.1 Overview of the Electrical Starter

An electrical starter for a pump and motor is a control assembly that safely starts and stops the motor while protecting it from overloads and other electrical faults. Typical components include the main contractor, overload relay, control circuit (with start/stop buttons and indicator lamps), auxiliary contacts, control transformer (if required), fuses or circuit breakers, wiring/terminal blocks, the enclosure, and sometimes a timer or delay relay. Each component works together to ensure smooth operation and protection of the motor.



Components Detail

Each component is explained below according to the following criteria:

1. Importance
2. Functionality
3. Causes of Wear and Tear/Damage
4. Preventive Maintenance
5. Fault Identification (symptoms before opening the assembly and after opening it)
6. Repair Methods

Main Contactor

■ Importance:

- Acts as the primary switch that connects/disconnects power to the motor.
- Is critical for starting and stopping the motor under control commands.

■ Functionality:

- Receives a control signal (from the push buttons or control circuit) and, when energized, closes its contacts to supply full power to the motor.
- Opens the circuit to disconnect power when the motor is stopped or when a fault is detected.

■ Causes of Wear and Tear/Damage:

- Frequent switching cycles causing contact arcing.
- Dust, moisture, or corrosive environments leading to contact degradation.
- Overcurrent or electrical surges that can burn or warp contact surfaces.

■ Preventive Maintenance:

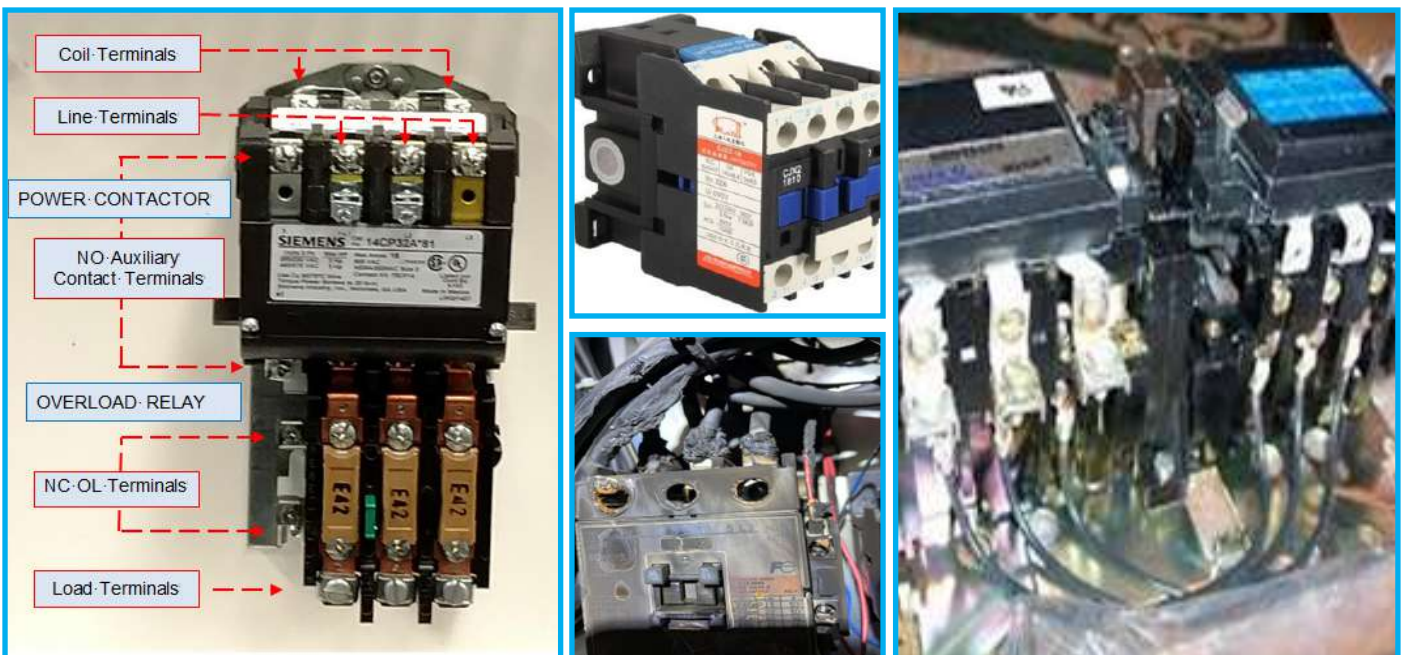
- Regularly inspect and clean contacts to remove dust and corrosive deposits.
- Ensure the contactor is correctly rated for the operating voltage and current.
- Monitor the number of switching cycles and replace contacts if signs of wear appear.

■ Fault Identification:

- Before Opening:
 - * Motor fails to start or exhibits intermittent operation.
 - * Unusual humming or chatter sounds when starting/stopping.
 - * Increased motor current draw or abnormal operation.
- After Opening:
 - * Visible pitting, burn marks, or erosion on the contact surfaces.
 - * Loose or misaligned internal mechanisms.

■ Repair Methods:

- Clean or recondition the contacts if wear is minimal.
- Replace worn or damaged contactor components.
- In severe cases, replace the entire contactor assembly.



Overload Relay

■ Importance:

- Protects the motor from excessive current draw and overheating by tripping the circuit if current exceeds safe levels.

■ Functionality:

- Continuously monitors the motor current.
- Opens the circuit (or signals the contactor to open) when the current exceeds preset limits for a predetermined duration.

■ Causes of Wear and Tear/Damage:

- Repeated thermal cycling and electrical stress may degrade internal components (such as bimetallic strips or thermal elements).
- Dust, moisture, or contamination can affect sensitive elements.
- Calibration drift due to aging components.

■ Preventive Maintenance:

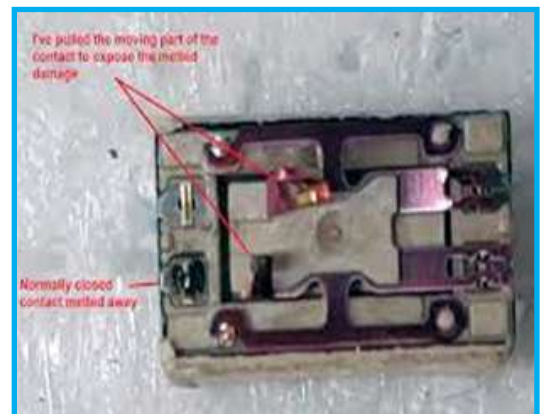
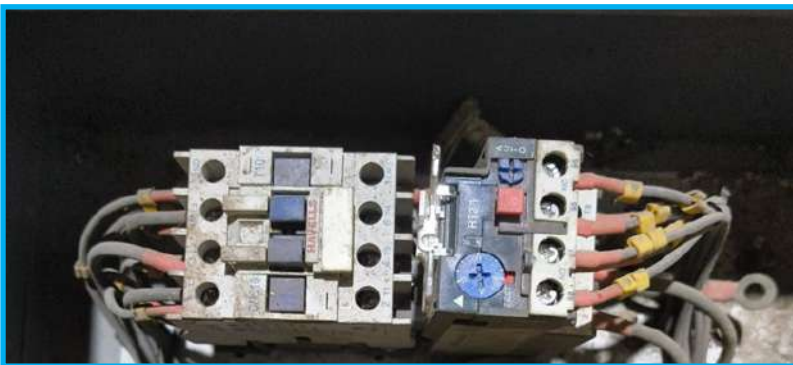
- Periodically test the relay by simulating overload conditions.
- Keep the relay clean and free of dust or moisture.
- Verify calibration against manufacturer specifications.

■ Fault Identification:

- Before Opening:
 - * Frequent or unexplained motor tripping.
 - * Motor overheating or erratic operation.
- After Opening:
 - * Burnt or discolored internal elements, broken bimetallic strips, or damaged contacts.

■ Repair Methods:

- Recalibrate or reset the relay if the fault is minor.
- Replace damaged internal parts (if serviceable) or replace the relay entirely if damage is extensive.



Control Circuit (Start/Stop Push Buttons, Emergency Stop and Indicator Lamps)

■ Importance:

- Provides the human–machine interface for initiating and stopping the motor safely.
- Enhances safety by incorporating emergency stop features and visual status indicators.

■ Functionality:

- Start/Stop buttons send low-voltage control signals to energize or de-energize the main contactor and other components.
- Indicator lamps provide visual feedback on the system’s status (e.g., motor running, fault condition).

■ Causes of Wear and Tear/Damage:

- Mechanical wear from repeated pressing.
- Exposure to dust, moisture, or corrosive agents that degrade contact surfaces.
- Loose wiring or poor connections.

■ Preventive Maintenance:

- Clean push buttons and indicator lenses regularly.
- Inspect wiring and connections for signs of wear or looseness.
- Test the control circuit periodically for proper operation.

■ Fault Identification:

- **Before Opening:**
 - * Unresponsive or sticky push buttons.
 - * Indicator lamps failing to light or providing erratic signals.
 - * Delayed response when starting or stopping the motor.
- **After Opening:**
 - * Worn or pitted contact surfaces inside the push buttons.
 - * Damaged wiring or connectors, or signs of oxidation/corrosion on contacts.

■ Repair Methods:

- Clean contacts and replace any worn push buttons.
- Re-secure or replace loose wiring/connectors.
- Replace faulty indicator lamps with the correct rated units.



Auxiliary Contacts

■ Importance:

- Provide feedback to the control circuit regarding the status of the main contactor (e.g., “closed” or “open” status).
- Often used for interlocking or additional signalling in control systems.

■ Functionality:

- Operate in parallel with the main contacts to supply status signals.
- Help ensure proper sequencing and safe operation of the motor.

■ Causes of Wear and Tear/Damage:

- Frequent operation leading to mechanical wear.
- Contamination from dust, moisture, or corrosive substances.
- Electrical arcing if the contacts are used in high-current applications.

■ Preventive Maintenance:

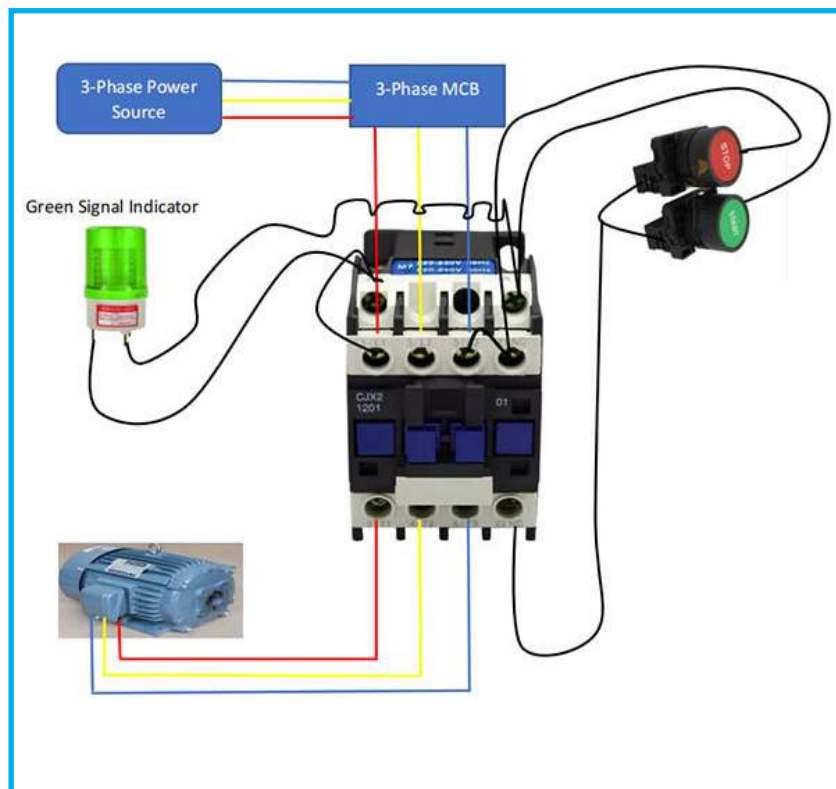
- Regularly test the auxiliary contacts for correct operation.
- Clean contacts to remove any deposits that could impair function.
- Ensure that the contacts are rated for the intended use and environment.

■ Fault Identification:

- **Before Opening:**
 - * Incorrect or inconsistent feedback in the control system.
 - * Erratic motor operation or failure to engage safety interlocks.
- **After Opening:**
 - * Visible wear, corrosion, or pitting on the contact surfaces.
 - * Loose mounting or broken connecting wires.

■ Repair Methods:

- Clean or lightly polish the contacts if minor wear is observed.
- Re-solder or tighten connections.
- Replace the auxiliary contacts if damage is extensive.



Control Transformer (If Applicable)

■ Importance:

- Provides a stepped-down voltage to power the control circuit (often lower than the motor's main supply voltage).
- Enhances safety by isolating the control circuit from high-voltage power.

■ Functionality:

- Converts the incoming line voltage to a lower, safer level (commonly 24 V or 110 V) for control components.

■ Causes of Wear and Tear/Damage:

- Overheating due to overloading or poor ventilation.
- Voltage surges or transient spikes damaging insulation.
- Dust and moisture causing insulation breakdown or corrosion.

■ Preventive Maintenance:

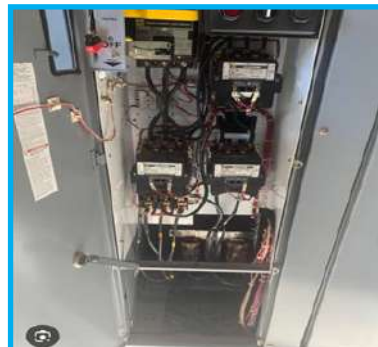
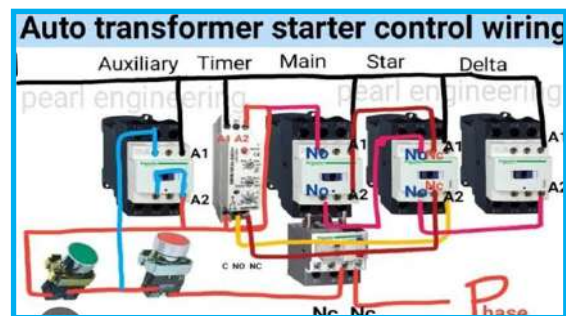
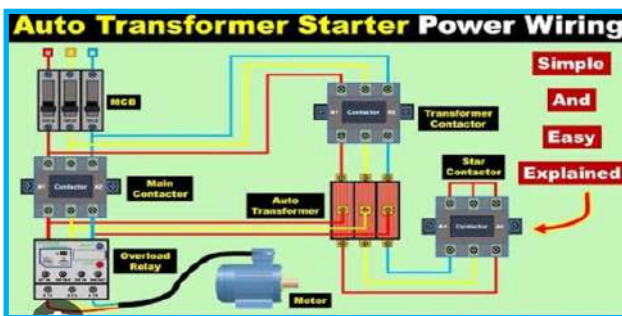
- Verify that the transformer is operating within its rated load.
- Ensure proper ventilation and cooling in the enclosure.
- Periodically measure output voltage and inspect for signs of overheating or discoloration.

■ Fault Identification:

- **Before Opening:**
 - * Inconsistent or unstable control circuit operation.
 - * Failure of indicator lamps or control buttons to operate correctly.
- **After Opening:**
 - * Burn marks, discoloured windings, or degraded insulation.
 - * Loose internal connections or signs of moisture ingress.

■ Repair Methods:

- Replace burnt or damaged windings and repair insulation if feasible.
- In many cases, a severely damaged transformer is replaced entirely.



Fuses / Circuit Breakers

■ Importance:

- Protect the starter and connected circuits from overcurrent conditions and short circuits.
- Help to isolate faults and prevent damage to other components.

■ Functionality:

- Interrupt the circuit when current exceeds the rated value, thereby protecting downstream components.

■ Causes of Wear and Tear/Damage:

- Thermal stress from repeated tripping.
- Overcurrent conditions or voltage surges that exceed the fuse's rating.
- Mechanical degradation in circuit breakers from frequent operation.

■ Preventive Maintenance:

- Regularly inspect fuses for signs of wear or degradation.
- Verify that circuit breakers are properly rated and test them periodically.
- Ensure that connections to fuses and breakers are tight and corrosion-free.

■ Fault Identification:

• Before Opening:

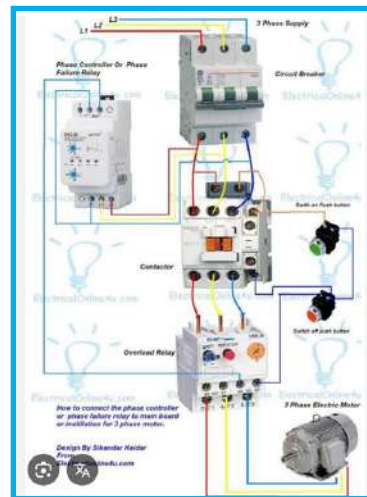
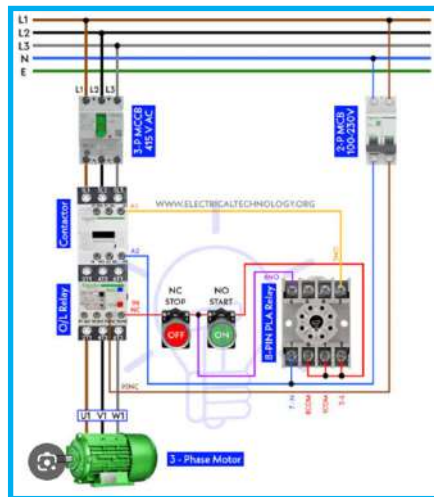
- * Frequent tripping or blown fuses accompanied by loss of power to the control circuit.
- * Intermittent operation of the motor due to unstable supply.

• After Opening:

- * Visible burnt elements, melted contacts, or discoloration on fuse holders and breaker contacts.

■ Repair Methods:

- Replace blown fuses or faulty circuit breakers with components of the correct rating.
- Inspect and, if necessary, clean the fuse holders and breaker contacts to ensure good electrical connections.



Terminal Blocks and Wiring

■ Importance:

- Provide organized, secure electrical connections for all components of the starter.
- Facilitate reliable signal and power distribution throughout the assembly.

■ Functionality:

- Connect various control and power circuits via designated terminal blocks and wiring harnesses.
- Ensure that signals are transmitted accurately and safely between components.

■ Causes of Wear and Tear/Damage:

- Loose or corroded connections caused by environmental exposure.
- Insulation degradation over time due to heat, moisture, or mechanical vibration.
- Physical abrasion or accidental damage during maintenance or operation.

■ Preventive Maintenance:

- Periodically inspect all wiring and terminal connections for signs of corrosion or looseness.
- Tighten connections and replace any worn or damaged wires and terminals.
- Use weatherproof or sealed terminal blocks in harsh environments.

■ Fault Identification:

• Before Opening:

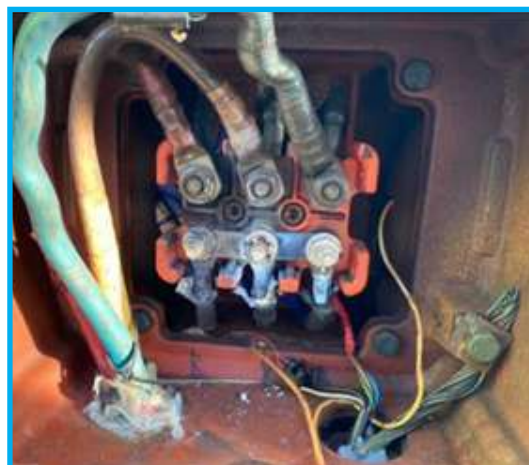
- * Intermittent control circuit malfunctions, voltage drops, or erratic operation of starter components.
- * Alarms or diagnostic readings indicating connection issues.

• After Opening:

- * Corrosion on terminal points, loose or disconnected wires, and frayed insulation.

■ Repair Methods:

- Re-tighten, clean, or replace affected wiring and terminal blocks as needed.
- Re-terminate connections with proper connectors or soldering if required.



Enclosure / Starter Cabinet

■ Importance:

- Physically protects the electrical starter components from dust, moisture, and mechanical damage.
- Provides a safe, organized space for wiring and component installation.

■ Functionality:

- Acts as a barrier against environmental factors and inadvertent human contact with live parts.
- Often includes ventilation or cooling features to help manage internal temperatures.

■ Causes of Wear and Tear/Damage:

- Physical impacts, scratches, or dents from accidental knocks.
- Corrosion due to exposure to moisture or chemicals.
- Seal degradation leading to dust or water ingress.

■ Preventive Maintenance:

- Regularly clean the enclosure to remove dust and debris.
- Inspect seals and gaskets; replace them if signs of wear or hardening are present.
- Check for any structural damage or rust and address promptly.

■ Fault Identification:

- **Before Opening:**
 - * External signs of damage (dents, cracks, or discoloration).
 - * Evidence of water leakage or dust accumulation affecting starter performance.
- **After Opening:**
 - * Rusted mounting points, broken seals, or evidence of water damage on internal components.

■ Repair Methods:

- Repair minor physical damage (e.g., patching cracks or re-sealing edges).
- Replace severely damaged or corroded sections of the enclosure.
- Repaint or treat with corrosion inhibitors where necessary.



Timer/Delay Relay (If Applicable)

■ Importance:

- Provides time delays for controlled start/stop sequences and may be used for soft-start functions.
- Enhances protection by allowing gradual power application to the motor.

■ Functionality:

- Controls timing intervals between commands (for instance, delaying re-energizing the motor after a fault or controlling the ramp-up of voltage).
- Can also provide sequencing for auxiliary functions within the starter.

■ Causes of Wear and Tear/Damage:

- Aging of internal electronic components, capacitors, or resistors.
- Thermal stress from continuous operation or high ambient temperatures.

■ Preventive Maintenance:

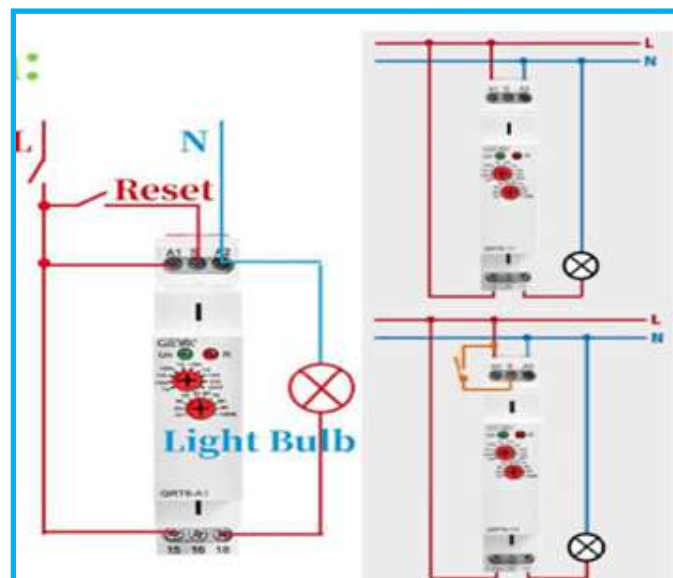
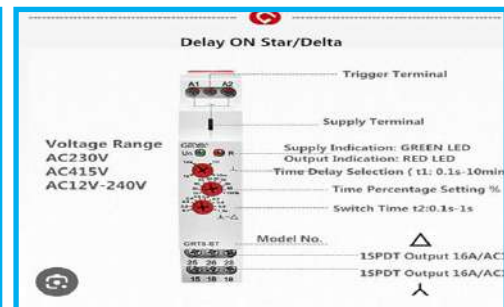
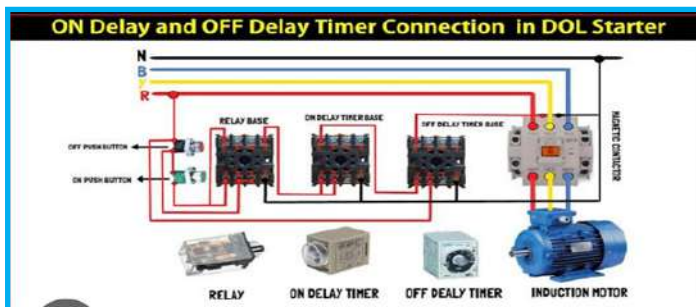
- Periodically test the timing accuracy using a calibrated timing device.
- Keep the timer or relay free of dust and provide adequate ventilation.
- Replace any aging or worn electronic components as recommended by the manufacturer.

■ Fault Identification:

- Before Opening:
 - * Incorrect delay times or erratic starting/stopping sequences.
 - * Inconsistent motor behavior that correlates with timing functions.
- After Opening:
 - * Burnt or damaged circuit boards, scorched resistors, or swollen capacitors.

■ Repair Methods:

- Replace faulty electronic components within the timer module.
- Recalibrate the relay to ensure proper timing.
- If damage is extensive, replace the timer/delay relay unit entirely.



General maintenance & repair guidelines

1. Routine Inspections:

- Perform regular checks on all electrical starter components, noting any unusual sounds, odors, or performance deviations.
- Document any anomalies for trend analysis and proactive repairs.

2. Scheduled Preventive Maintenance:

- Clean and test each component at fixed intervals.
- Replace parts (such as contactor contacts, push buttons, or seals) according to the manufacturer's recommended service life.

3. Fault Diagnosis:

- Use infrared thermography, voltage/current measurements, and visual inspections to detect potential issues before they lead to failure.
- Maintain logs for troubleshooting to assist in root cause analysis during recurring issues.

4. Safe Repair Practices:

- Always de-energize the entire starter assembly before performing any work.
- Follow proper lockout/tagout procedures and wear appropriate personal protective equipment (PPE).
- Consult manufacturer documentation for component-specific repair procedures.

FINAL NOTES

■ Safety and Compliance:

- Adhere strictly to electrical safety standards and local regulations during all maintenance and repair operations.
- Ensure technicians are trained in both electrical and mechanical aspects of the starter assembly.

■ Documentation:

- Record all maintenance, fault findings, and repairs in a logbook for historical tracking and future troubleshooting.



<https://www.youtube.com/playlist?list=PLu7Qy6fHfWzdVMK-6fWqHlGE04t5ofGdFx>

For more information and videos regarding installation and repairing of Starter



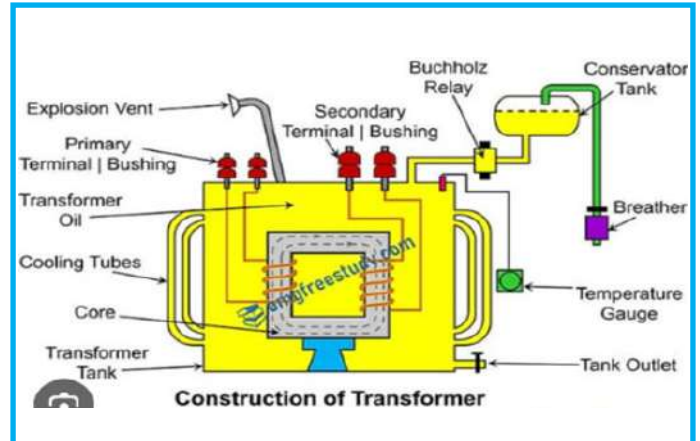
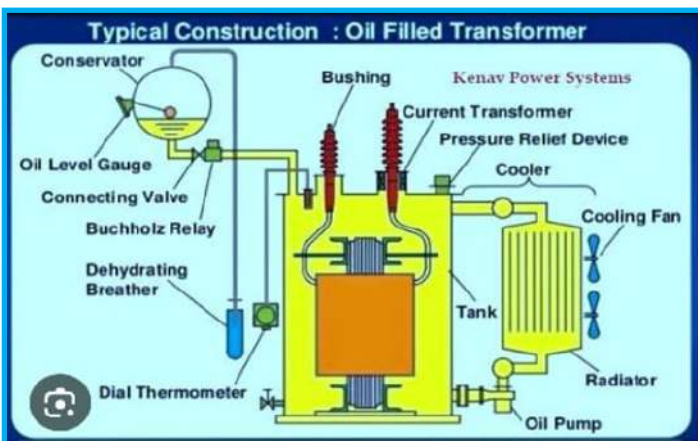
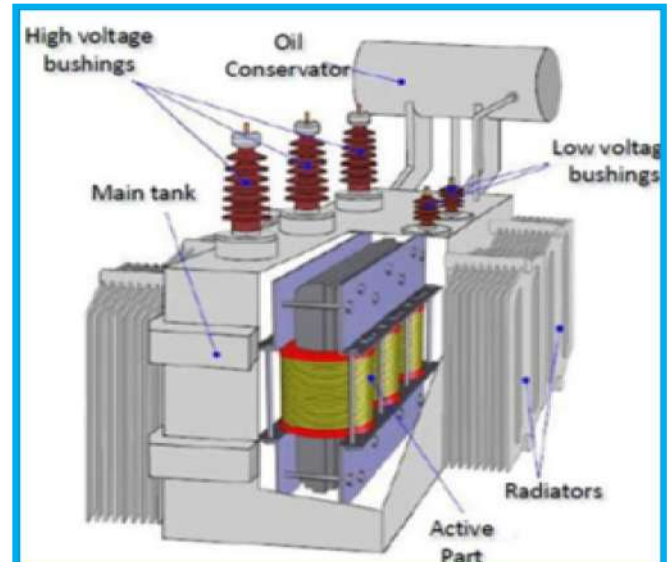


Transformer

7.2 Comprehensive explanation of the major parts of a 25 kVA transformer

What Is a Transformer?

A transformer is a device used in the power transmission of electric energy. The transmission current is AC. It is commonly used to increase or decrease the supply voltage without a change in the frequency of AC between circuits. The transformer works on the basic principles of electromagnetic induction and mutual induction.



Transformer Types

Transformers are used in various fields like power generation grid, distribution sector, transmission and electric energy consumption. There are various types of transformers which are classified based on the following factors:

- Working voltage range
- The medium used in the core
- Winding arrangement
- Installation location

Based on Voltage Levels

Commonly used transformer types, depending on the voltage, are classified as follows:

- Step-up Transformer: They are used between the power generator and the power grid. The secondary output voltage is higher than the input voltage.
- Step-down Transformer: These transformers are used to convert high-voltage primary supply to low-voltage secondary output.



Based on the Medium of Core Used

In a transformer, we will find different types of cores that are used.

- **Air Core Transformer:** The flux linkage between primary and secondary winding is through the air. The coil or windings wound on the non-magnetic strip.
- **Iron Core Transformer:** Windings are wound on multiple iron plates stacked together, which provides a perfect linkage path to generate flux.

Based on the Winding Arrangement

Autotransformer: It will have only one winding wound over a laminated core. The primary and secondary share the same coil. Auto means “self” in the Greek language.

Based on Install Location

- **Power Transformer:** It is used at power generation stations, as they are suitable for high voltage application
- **Distribution Transformer:** It is mostly used at distribution lanes for domestic purposes. They are designed for carrying low voltages. It is very easy to install and characterised by low magnetic losses.
- **Measurement Transformers:** They are mainly used for measuring voltage, current and power.
- **Protection Transformers:** They are used for component protection purposes. In circuits, some components must be protected from voltage fluctuation, etc. Protection transformers ensure component protection.

Working Principle of a Transformer

The transformer works on the principle of Faraday’s law of electromagnetic induction and mutual induction.

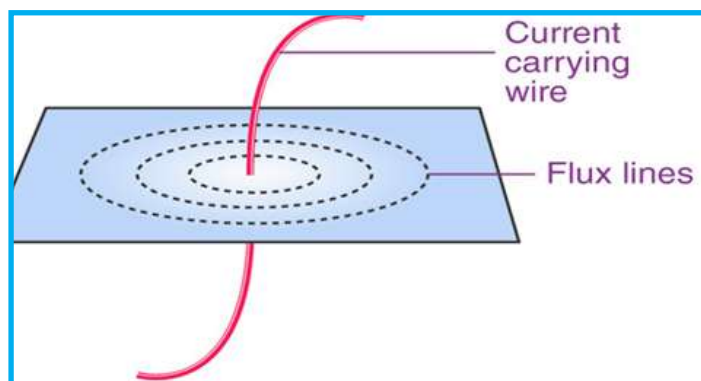
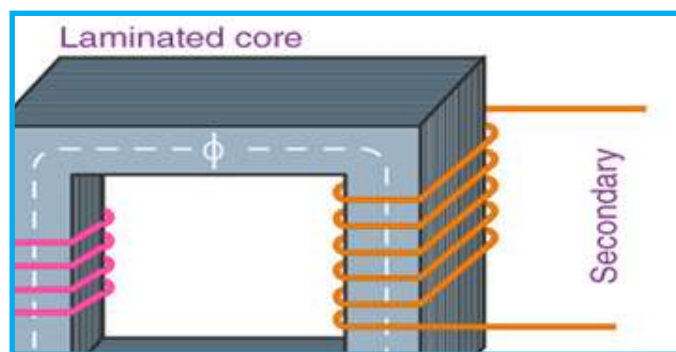
There are usually two coils – primary coil and secondary coil – on the transformer core. The core laminations are joined in the form of strips. The two coils have high mutual inductance. When an alternating current passes through the primary coil, it creates a varying magnetic flux. As per Faraday’s law of electromagnetic induction, this change in magnetic flux induces an EMF (electromotive force) in the secondary coil, which is linked to the core having a primary coil. This is mutual induction.

Overall, a transformer carries out the following operations:

1. Transfer of electrical energy from one circuit to another
2. Transfer of electrical power through electromagnetic induction
3. Electric power transfer without any change in frequency
4. Two circuits are linked with mutual induction

The figure shows the formation of magnetic flux lines around a current-carrying wire. The normal of the plane containing the flux lines is parallel to the normal of a cross-section of a wire.

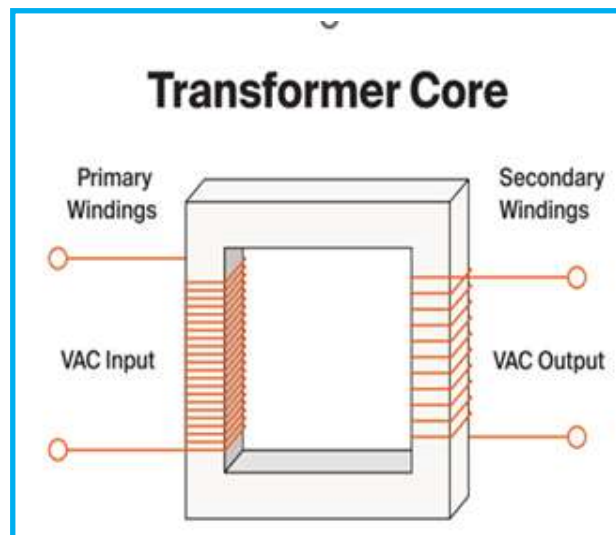
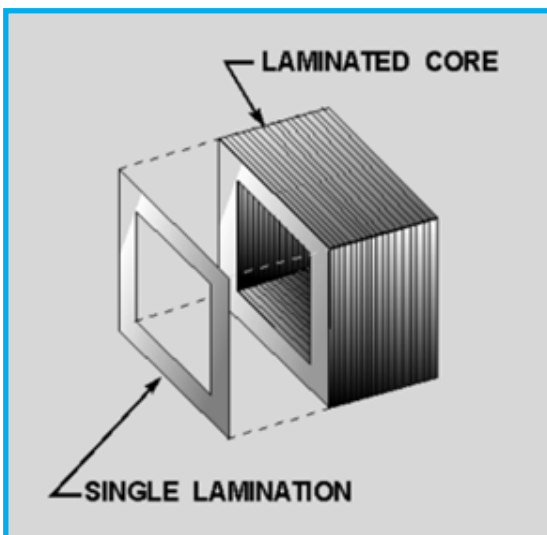
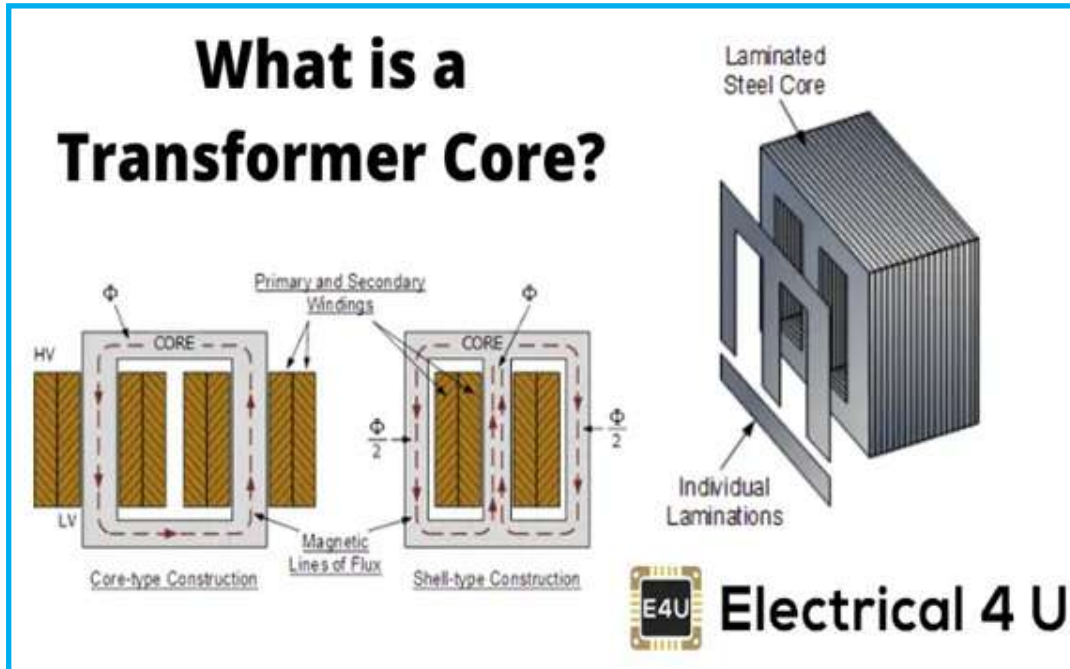
The figure shows the formation of varying magnetic flux lines around a wire wound. The interesting part is that the reverse is also true; when a magnetic flux line fluctuates around a piece of wire, a current will be induced in it. This was what Michael Faraday found in 1831, which is the fundamental working principle of electric generators, as well as transformers.



Transformer Core

Importance:

- The core is the magnetic circuit of the transformer. It provides the path for the magnetic flux and is essential for efficient energy transfer between the primary and secondary windings.
- A well-designed core minimizes energy losses (hysteresis and eddy current losses) and improves overall efficiency.



■ **Functionality:**

- Composed of laminated silicon steel plates, the core concentrates and directs the magnetic flux.
- It reduces losses by breaking up eddy currents and provides the necessary magnetic coupling between windings.

■ **Cause of Wear and Tear/Damage:**

- Mechanical stresses during assembly, vibrations, or short-circuits can cause physical distortion.
- Corrosion or oxidation may occur if the protective coating is damaged.
- Overloading and high temperatures can lead to core saturation, causing additional heating and eventual degradation of insulation around the laminations.

■ **Preventive Maintenance:**

- Regular visual inspections for signs of overheating, rust, or loose laminations.
- Ensure that the cooling system (oil circulation or air cooling) is functioning properly to avoid overheating.
- Keep the transformer clean and free from dust and moisture that can accelerate corrosion.



■ **Fault Identification:**

- **Before Opening:** Listen for unusual humming, buzzing, or vibrations; monitor temperature readings and load conditions.
- **After Opening:** Look for deformations, loose or misaligned laminations, rust spots, or areas with burnt insulation.

■ **Repair Methods:**

- Minor issues (such as loose laminations) can sometimes be rectified by tightening or securing the core structure.
- In cases of significant corrosion or deformation, partial or full replacement of the affected core sections may be required.
- Always ensure repairs are done in a controlled environment to avoid contamination.



Transformer Windings (Primary and Secondary)

■ Importance:

- The windings are the coils where electrical energy is converted from one voltage level to another.
- They are the main components responsible for energy transfer and directly affect the transformer's efficiency and performance.

■ Functionality:

- Copper (or sometimes aluminum) wires are wound around the core to form the primary and secondary windings.
- The primary winding receives the input voltage, and through electromagnetic induction, a proportional voltage is induced in the secondary winding.

■ Cause of Wear and Tear/Damage:

- Thermal cycling (heating and cooling during operation) can cause insulation degradation.
- Overloading, short circuits, or voltage spikes may lead to winding insulation breakdown or burning.
- Vibration and mechanical stresses can lead to winding displacement or loosening of insulation material.

■ Preventive Maintenance:

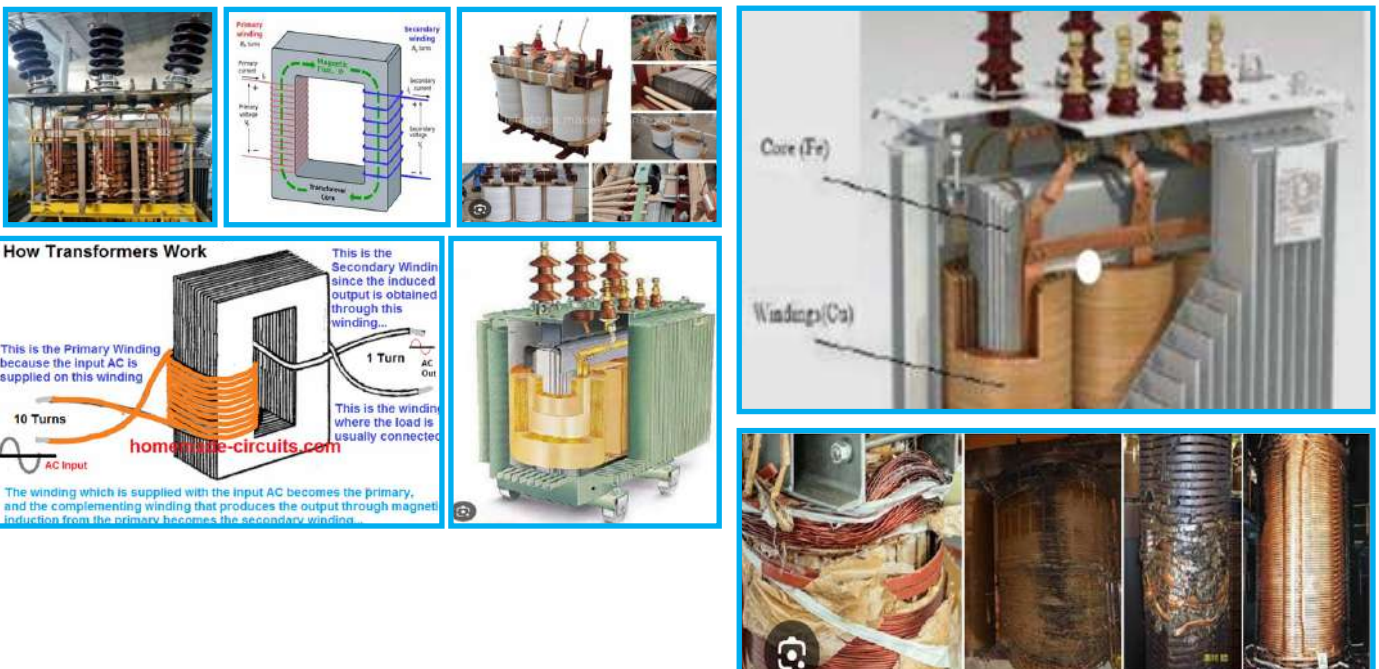
- Monitor load and ambient temperatures, ensuring they remain within the design limits.
- Regularly test insulation resistance and dielectric strength.
- Keep records of operating cycles and thermal performance to detect early signs of degradation.

■ Fault Identification:

- **Before Opening:** Use insulation testers (megger tests) to check for high resistance and monitor unusual temperature rises or sound indicators.
- **After Opening:** Visual inspection for signs of burnt insulation, discoloration, deformation, or displacement of winding coils.

■ Repair Methods:

- Minor insulation issues may be fixed using high-quality insulating varnish reapplication.
- In cases of severe damage, the affected winding section might need rewinding or, in some instances, complete replacement.
- Ensure that any repairs maintain the original winding specifications and insulation standards.



Insulation System (Paper, Oil, Epoxy)

■ Importance:

- Prevents electrical short circuits.
- Ensures safe operation.

■ Functionality:

- Insulation paper or varnish prevents direct contact between windings.
- Oil insulation enhances cooling.

■ Causes of Wear and Tear:

- Aging and exposure to high temperatures.
- Moisture absorption leading to loss of dielectric strength.
- Physical damage due to vibrations.

■ Preventive Maintenance:

- Dielectric testing to check insulation strength.
- Ensuring oil quality in oil-immersed transformers.
- Keeping the transformer dry and clean.

■ Fault Identification:

- Before Opening: Transformer tripping, overheating, oil degradation.
- After Opening: Brittle or damaged insulation, carbon deposits.

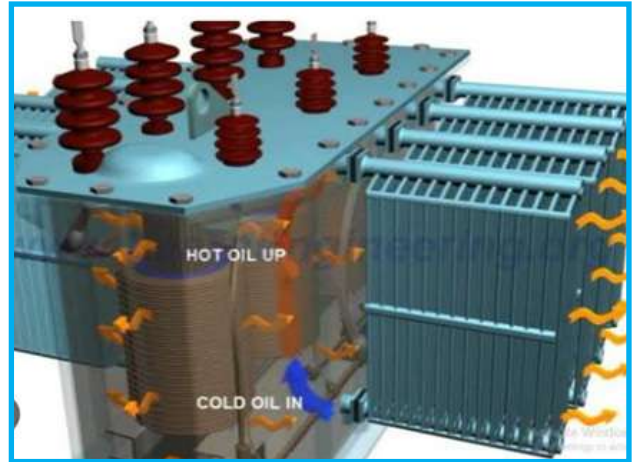
■ Repair Methods:

- Replacing or reapplying insulation.
- Drying and revarnishing affected areas.
- Changing contaminated oil.



Transformer Oil (If Oil-Immersed Type)

- **Importance:**
 - Provides cooling and insulation.
 - Reduces risk of short circuits.
- **Functionality:**
 - Dissipates heat from the core and windings.
 - Prevents electrical discharge.
- **Causes of Wear and Tear:**
 - Contamination with water or dirt.
 - Chemical degradation forming sludge.
 - Loss of dielectric strength.
- **Preventive Maintenance:**
 - Regular oil testing (dielectric strength, moisture content).
 - Filtering or replacing old oil.
 - Checking for leaks.
- **Fault Identification:**
 - Before Opening: Oil discoloration, overheating, leaks.
 - After Opening: Sludge formation, carbon deposits.
- **Repair Methods:**
 - Oil filtration or complete oil change.
 - Sealing leaks.
 - Removing contaminants.



Bushings and Insulators

- **Importance:**
 - Bushings provide safe passage for electrical conductors through the transformer tank, maintaining insulation between live parts and the grounded tank.
 - They ensure a secure connection between the internal windings and external circuits.
- **Functionality:**
 - Typically made of porcelain or composite materials, bushings isolate the live conductor from the transformer body while handling high voltage stresses.
 - They are also designed to distribute electrical fields evenly to prevent corona discharge.
- **Cause of Wear and Tear/Damage:**
 - Aging, environmental factors (humidity, pollution), and thermal stress can lead to cracking or surface deterioration.
 - Mechanical impact or contamination (dirt, salt deposits) may further deteriorate the insulation properties.
- **Preventive Maintenance:**
 - Regular visual inspections for cracks, discoloration, or signs of leakage.
 - Clean the surface with appropriate methods to remove contaminants without damaging the insulating material.
 - Use infrared thermography to detect hot spots or partial discharges around the bushings.

Fault Identification:

- **Before Opening:** Monitor for increased leakage currents or corona discharges; check for abnormal external surface temperatures.
- **After Opening:** Detailed inspection for visible cracks, moisture ingress, or deterioration of the sealing materials.

Repair Methods:

- Small cracks or surface contamination can often be remedied with cleaning, resealing, or applying a suitable insulating coating.
- For extensive damage, complete replacement of the bushings may be necessary to ensure safety and reliability.



Tap Changer (On-Load/Off-Load)

■ Importance:

- The tap changer adjusts the transformer's voltage ratio, ensuring optimal voltage levels are delivered to the load.
- It provides flexibility in operation to compensate for voltage fluctuations and maintain system stability.

■ Functionality:

- By selecting different taps on the winding, the tap changer alters the effective turns ratio.
- On-load tap changers allow adjustments while the transformer is energized, whereas off-load tap changers require de-energization.

■ Cause of Wear and Tear/Damage:

- Frequent switching can lead to contact wear, arcing, and insulation breakdown.
- Mechanical wear of the moving parts and accumulation of contact deposits can impair performance.
- Overloading or poor maintenance may cause premature deterioration.

■ Preventive Maintenance:

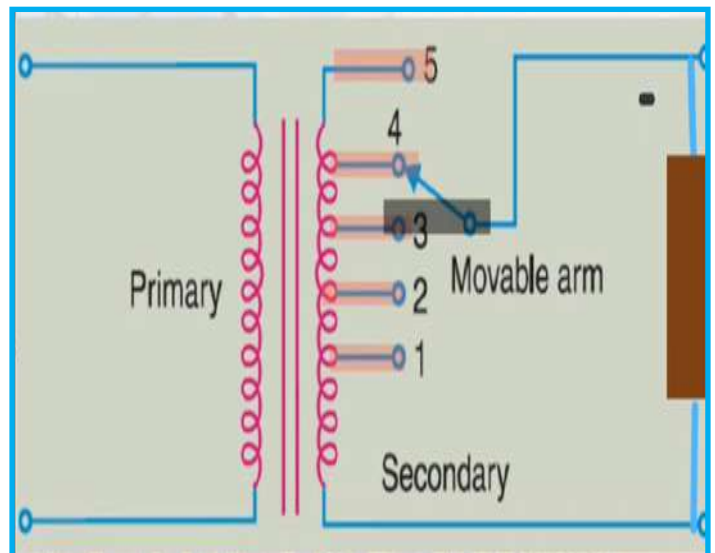
- Regularly check the operating mechanism, contacts, and insulating oils (if applicable).
- Clean contacts to remove any deposits and ensure smooth operation.
- Periodic testing of switching performance under controlled conditions can help detect early signs of wear.

■ Fault Identification:

- **Before Opening:** Look for irregular voltage readings, erratic tap positions, or abnormal noise during operation.
- **After Opening:** Inspect contacts for signs of pitting, excessive wear, arcing damage, or corrosion.

■ Repair Methods:

- Contact cleaning, realignment, or replacement of worn contact parts can often restore functionality.
- In severe cases, the entire tap changer assembly might require refurbishment or replacement.



Cooling System Components (Oil, Radiators, Pumps, Fans)

■ Importance:

- The cooling system maintains the transformer's temperature within safe operating limits.
- Effective cooling is critical for prolonging the life of the transformer and maintaining efficiency.

■ Functionality:

- **Cooling Oil:** Acts as both an insulator and a coolant. It transfers heat from the windings and core to the radiators.
- **Radiators/Heat Exchangers:** Increase the surface area for heat dissipation to the ambient air.
- **Cooling Pumps and Fans:** Actively circulate oil or air to enhance cooling, especially under heavy load conditions.

■ Cause of Wear and Tear/Damage:

- Thermal degradation of oil over time due to oxidation, contamination, or moisture ingress reduces cooling efficiency.
- Mechanical wear on pump components and fan bearings due to continuous operation.
- Blockages or corrosion in radiators can impair heat dissipation.

■ Preventive Maintenance:

- Regular oil testing (dielectric strength, moisture content, acidity) to assess its condition.
- Periodic cleaning and inspection of radiators and cooling fans.
- Lubrication and inspection of pump and fan bearings; replace seals to prevent oil leaks.

■ Fault Identification:

- **Before Opening:** Monitor for temperature spikes, abnormal noises from the pump or fan, and check for oil leaks around cooling circuits.
- **After Opening:** Visually inspect pump components, fan blades, and radiator fins for wear, blockage, corrosion, or oil contamination.

■ Repair Methods:

- Replace degraded oil after proper filtering and testing.
- Clean or replace clogged radiator fins.
- Repair or replace worn pump/fan parts; ensure that replacement components meet the original specifications and quality standards.



Substation Equipment
Transformer - Cooling system



➤ ONAN – Oil Natural Air Natural

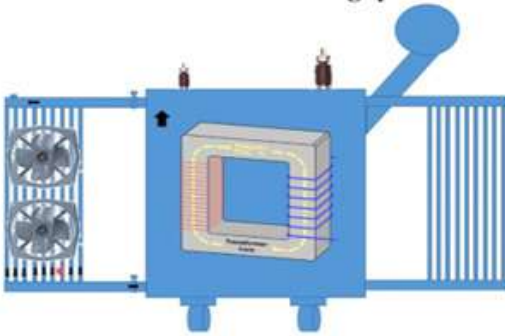
Substation Equipment
Transformer - Cooling system

Types of Transformer cooling

➤ ONAN – Oil Natural Air Natural



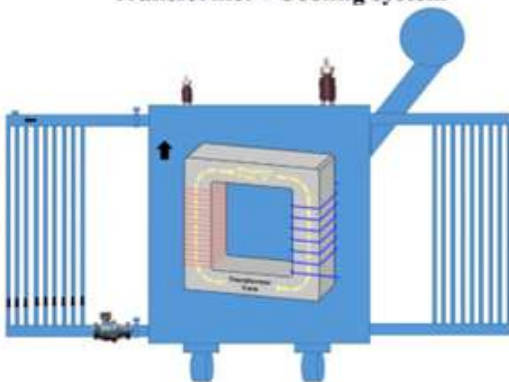
Substation Equipment
Transformer - Cooling system



➤ ONAF – Oil Natural Air Force



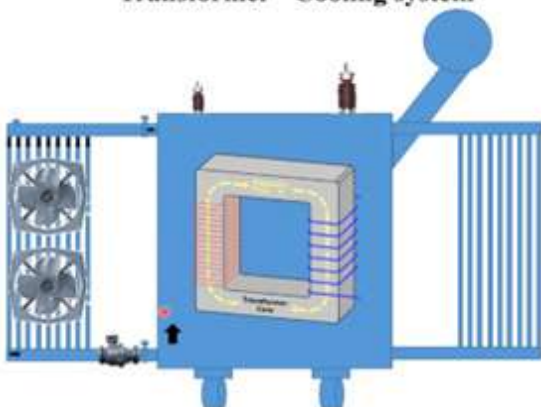
Substation Equipment
Transformer - Cooling system



➤ OFAN – Oil Force Air Natural



Substation Equipment
Transformer - Cooling system



➤ OFAF – Oil Force Air Force

Substation Equipment
Transformer - Cooling system

Types of Transformer cooling

➤ ONAF – Oil Force Air Force



Conservator, Breather, and Oil Level Indicator

■ Importance:

- **Conservator Tank:** Provides space for the expansion and contraction of the cooling oil with temperature changes.
- **Breather:** Filters the air entering the conservator, preventing moisture ingress.
- **Oil Level Indicator:** Allows operators to monitor oil levels, ensuring the system has sufficient insulation and cooling capacity.

■ Functionality:

- The conservator maintains constant pressure within the transformer tank.
- The breather (often filled with silica gel) absorbs moisture, keeping the oil dry.
- The oil level indicator offers a quick visual check of oil quantity.

■ Cause of Wear and Tear/Damage:

- Conservator tanks can suffer from leaks, seal degradation, or corrosion over time.
- Breathers lose their moisture absorption capacity if the silica gel becomes saturated or contaminated.
- Faulty or damaged oil level indicators may result from mechanical impacts or poor environmental conditions.

■ Preventive Maintenance:

- Inspect seals and gaskets on the conservator regularly for leaks.
- Replace or regenerate silica gel in breathers as per manufacturer guidelines.
- Calibrate and check the oil level indicator periodically to ensure accurate readings.

■ Fault Identification:

- **Before Opening:** Check for signs of oil loss, abnormal oil level readings, or damp breathers.
- **After Opening:** Inspect internal components for signs of corrosion, oil contamination, or seal deterioration.

■ Repair Methods:

- Replace worn seals and gaskets on the conservator.
- Clean or replace the breather element to restore moisture-absorption capability.
- Repair or replace faulty oil level indicators to ensure accurate monitoring.



Terminal Boxes and Connection Points

■ Importance:

- Terminal boxes house the connection points between the transformer windings and external circuits, ensuring safe and reliable electrical connections.
- They protect the connections from environmental influences and mechanical damage.

■ Functionality:

- They provide insulation and secure anchorage for wiring and cables, reducing the risk of short circuits.
- Terminal boxes also facilitate safe isolation for maintenance and troubleshooting.

■ Cause of Wear and Tear/Damage:

- Corrosion due to environmental exposure (humidity, salt, pollution).
- Loose connections caused by thermal cycling, vibration, or mechanical stress.
- Degradation of insulating materials due to heat or chemical exposure.

■ Preventive Maintenance:

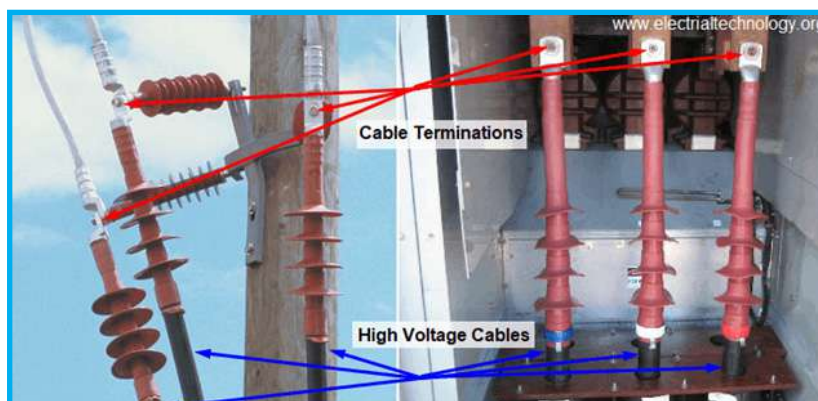
- Periodic cleaning and inspection of connection points to ensure tight and secure connections.
- Use of anti-corrosion coatings and weatherproofing measures in harsh environments.
- Verify proper torque on all connection bolts and check for signs of overheating.

■ Fault Identification:

- Before Opening: Look for indications of loose or arcing connections (flickering lights, abnormal voltages) and use thermal imaging to spot hot connections.
- After Opening: Visual inspection for corrosion, burnt insulation, or signs of moisture ingress.

■ Repair Methods:

- Clean and tighten loose connections.
- Replace corroded terminal blocks or connectors.
- Reapply insulation and sealing compounds where necessary to restore safe operation.



Protection Devices (Buchholz Relay, Temperature Sensors, Pressure Relief Valve)

■ Importance:

- Detects transformer faults early.
- Prevents severe damage.

■ Functionality:

- Buchholz Relay: Detects gas due to internal faults.
- Temperature Sensors: Monitor winding temperature.
- Pressure Relief Valve: Releases excess pressure.

■ Causes of Wear and Tear:

- Sensor failures.
- Blockages in relay mechanisms.
- Incorrect pressure settings.

■ Preventive Maintenance:

- Regularly testing relays and sensors.
- Cleaning moving parts.
- Keeping valves functional and working

■ Fault Identification:

- **Before Opening:** Alarm indications, relay tripping.
- **After Opening:** Blocked sensors, damaged relay contacts.

■ Repair Methods:

- Cleaning or replacing faulty sensors.
- Adjusting pressure relief settings.

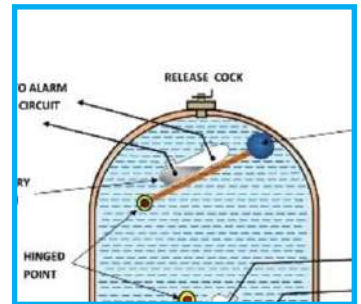
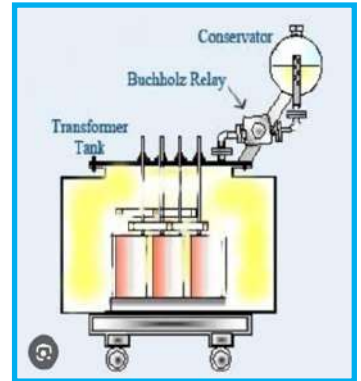


Fig: Buchholz Relay

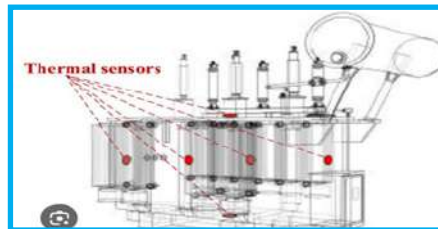


Fig: Thermal Sensor



Fig: Pressure Release Diaphragm

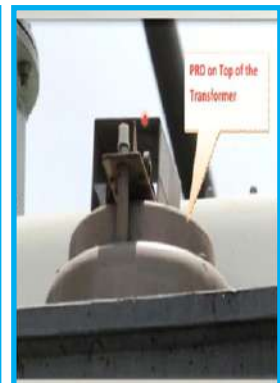


Fig: Pressure Release Device

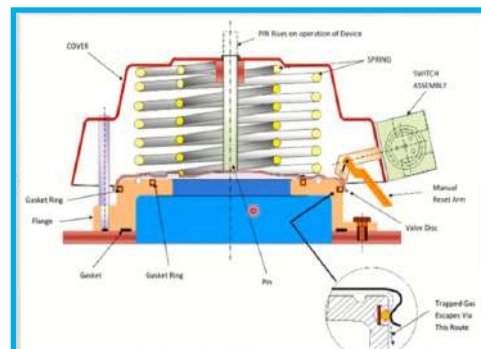


Fig: Working of Pressure Release Device

Summary

This detailed overview covers each major part of a 25 kVA transformer:

- **Core:** Vital for magnetic flux management; requires careful inspection for mechanical and thermal damage.
- **Windings:** Essential for voltage transformation; focus on maintaining insulation integrity and secure winding arrangements.
- **Bushings:** Critical for high-voltage isolation; require regular cleaning and inspection for cracks or moisture.
- **Tap Changer:** Allows voltage adjustments; monitor contact wear and ensure smooth operation.
- **Cooling System:** Keeps temperatures in check; involves regular oil testing, radiator cleaning, and mechanical maintenance of pumps/fans.
- **Conservator/Breather/Oil Level Indicator:** Manage oil expansion and moisture control; periodic checks prevent oil contamination and leakage.
- **Terminal Boxes:** Ensure safe external connections; regular tightening and anti-corrosion measures are essential.

Calculations to find the KVA of Transformer required using some examples

Q. Select a suitable transformer for an Industrial area. The load conditions are as follows :

- Available voltage = 11 KV
- Lighting load = 10 KW
- Demand factor = 0.7
- Required voltage = 440/230 volts
- Industrial load = 50 KW at 0.8 PF
- Diversity factor = 1.46

Solution :

Total connected load

$$\begin{aligned} &= \text{Lighting load} + \text{Industrial load} \\ &= (10 \times 1) \div \text{pf} + (50 \times 1) \div \text{pf} \\ &= 10 + 62.5 \\ &= 72.5 \end{aligned}$$

Maximum demand

$$\begin{aligned} &= \text{Connected load} \times \text{Demand factor} \\ &= 72.5 \times 0.7 \\ &= 50.75 \text{ say } 50 \text{ KVA} \end{aligned}$$

The required capacity of the transformer

$$\begin{aligned} &= \text{Maximum demand} / \text{Diversity factor} \\ &= 50 / 1.46 \\ &= 34.246 \text{ or say } 34 \text{ KVA} \end{aligned}$$

Allowance for future expansion at 20 % of the required capacity

$$\begin{aligned} &= 34 \times 0.2 \\ &= 7 \text{ KVA} \end{aligned}$$

$$\text{Hence capacity of the transformer} = 34 + 7 = 41$$

(41 KVA, 11 KV/440 V 3 -phase is not available)

Market availability = 50 KVA

Therefore, a transformer of 50 KVA, 11 KV/440 V, 3-phase delta-star, **50 Hz is selected.**



Q. A small workshop has the following load to find the transformer capacity required.

- a. A 1 HP, 400 V, 3-phase for drilling machine
- b. A 1/2 HP, 230 V, single phase for Grinding machine
- c. A 3 HP, 400 V, 3-phase motor for lathe machined
- d. A 5 KVA, 230 V, welding transformer.
- e. A milling machine 5 HP, 400 V, 3-phase
- f. . A power Backsaw, 3 HP, 400 V, 3-phase.
- g. Two power sockets
- h. Lamp loads – 25 points
- i. Ceiling fans – 15 nos
- j. Two numbers, high-pressure mercury vapor lamps of 500 W, 1-phase, 230 V, 50 Hz, supply.
- k. Calculate the total connected load. If the demand factor is 0.6 and the diversity factor is 1 %.

Solution:

(a) All three-phase motor loads 12 Hp assuming Pf 0.8 and efficiency 85 %

$$\begin{aligned}\text{Therefore, VA} &= (\text{HP} \times 735.5) \div (\text{efficiency} \times \text{Pf}) \\ &= (12 \times 735.5) \div (0.85 \times 0.8) = \mathbf{7853 \text{ VA}}\end{aligned}$$

(b) Taking all single-phase loads:

$$\text{Power sockets} - 2 \times 1000 = \mathbf{2000 \text{ w}}$$

$$\text{Lamps} - 25 \times 40 = \mathbf{1000 \text{ w}}$$

$$\text{Ceiling fans} - 15 \times 80 = \mathbf{1200 \text{ w}}$$

$$\text{Mercury vapour lamps} - 500 \times 2 = \mathbf{1000 \text{ w}}$$

$$\begin{aligned}\text{1/2 HP Grinder} &- (05 \times 735.5) \div (0.8 \times 0.6) \\ &= 766 / 5966 \text{ (efficiency} = 08 \text{ \& Pf} = 0.6)\end{aligned}$$

(c) 5 KVA welding transformer – 5000 VA

$$\begin{aligned}\text{The total load in VA} \\ &= 7853 + 5966 + 5000 \\ &= 18819 \text{ VA} \\ &= 18.819 \text{ KVA}\end{aligned}$$

Actual demand

$$\begin{aligned}&= \text{connected load} \times \text{demand factor} \\ &= 18.819 \times 0.6 \\ &= 11.2914 \text{ KVA}\end{aligned}$$

The required capacity of the transformer

$$\begin{aligned}&= \text{Actual demand} / \text{diversity factor} \\ &= 11.2914 / 1.10 \\ &= 10 \text{ KVA}\end{aligned}$$

Allowance for future expansion at 25 % of the required capacity

$$\begin{aligned}&= 10 \times 1.25 \\ &= 12.83 \text{ KVA.}\end{aligned}$$

Market availability = 15 KVA

Hence, a transformer of 15 KVA, 11 KV/440 V, 3-phase delta-star, 50 Hz is selected.

DTR structure of transformer

A **DTR (Distribution Transformer) Structure** refers to the **supporting framework and installation setup** used for mounting a **distribution transformer (DTR)** in an electrical distribution system. It ensures the safe and stable installation of the transformer, allowing it to efficiently step-down high voltage from the distribution lines to a usable level for residential, commercial, or industrial consumers.

Types of DTR Structures

1. Pole-Mounted Structure:

- Used for small capacity transformers (e.g., 16 kVA to 250 kVA).
- Typically installed on single or double poles depending on capacity.
- Economical and requires minimal space.

2. Plinth-Mounted Structure:

- Used for higher capacity transformers (e.g., 250 kVA and above).
- Installed on a concrete plinth at ground level for easy maintenance.
- Preferred for urban and industrial areas.



Fig: DTR structure of a transformer

Importance of DTR Transformer Structures

- Provides a stable and safe platform for transformer operation.
- Protects electrical equipment from environmental and mechanical stresses.
- Ensures easy access for maintenance and repair.
- Prevents electrical hazards by supporting proper insulation and earthing.

Components of a DTR Transformer Structure

1. **Poles** – Generally, RS joists (Rolled Steel), PSC (Pre-stressed Concrete), or Steel Tubular poles are used to support the transformer and associated equipment.
2. **Cross Arms & Channels** – Made of galvanized iron or mild steel, they provide structural support for insulators and conductors.
3. **Transformer Mounting Platform** – A structure (either pole-mounted or plinth-mounted) to hold the distribution transformer securely.
4. **Lightning Arresters** – Protect the transformer from voltage surges and lightning strikes.
5. **HT & LT Insulators** – High Tension (HT) and Low Tension (LT) insulators are used to prevent leakage currents and ensure safe operation.
6. **HG Fuse (Horn Gap Fuse)** – A protective device placed on the HT side to safeguard the transformer from faults.
7. **AB Switch (Air Break Switch)** – Used to isolate the transformer for maintenance or fault clearance.
8. **LT Protection Box** – Contains fuses or Miniature Circuit Breakers (MCBs) to protect the LT side from overload or short circuits.
9. **Earthing System** – Includes earth electrodes, grounding strips, and rods to ensure proper dissipation of fault currents.
10. **Stay Wires & Guy Rods** – Provide stability to pole-mounted transformers by countering mechanical stresses.

Gang Switch Assembly (Gang Operated Disconnectors)

■ Importance:

- **Safety & Isolation:** Ensures that multiple circuits or parts of the transformer system can be simultaneously isolated for maintenance or emergency shutdown.
- **Operational Efficiency:** Allows coordinated switching, reducing the risk of errors during manual operations.

■ Functionality:

- **Coordinated Operation:** A gang switch links several disconnecting switches together so that all open or close at the same time.
- **Physical Mechanism:** Often uses a common operating mechanism (lever or handle) that moves multiple contacts simultaneously, ensuring all circuits are either connected or isolated.

■ Causes of Wear and Tear:

- **Mechanical Fatigue:** Repeated switching can wear out moving parts, springs, or linkages.
- **Environmental Exposure:** Outdoor installations are subject to weather-related degradation such as corrosion, dust ingress, or UV damage.
- **Improper Operation:** Frequent or forceful operation beyond design limits can lead to misalignment or breakage.

■ Preventive Maintenance:

- **Regular Lubrication:** Keep moving parts well-lubricated to reduce friction and wear.
- **Visual and Functional Inspections:** Periodically inspect for signs of corrosion, looseness, or misalignment.
- **Environmental Protection:** Use protective covers or coatings where applicable to shield the mechanism from adverse weather.

■ Fault Identification:

- **Before Opening:**
- **Operational Symptoms:** Difficulty in moving the switch, unusual resistance or noises during actuation, or failure to engage/disengage completely.
- **System Indicators:** Alarms or interlocks may indicate incomplete isolation.
- **After Opening:**
- **Visible Damage:** Look for worn or broken mechanical linkages, worn-out contacts, rust, or misaligned components.
- **Physical Debris:** Accumulation of corrosion products or dirt that could impede proper movement.

■ Repair Methods:

- **Component Replacement:** Replace worn or broken mechanical parts such as springs, levers, or contacts.
- **Cleaning and Re-Lubrication:** Clean any debris, remove corrosion, and apply proper lubricants.
- **Realignment and Adjustment:** Carefully adjust components to restore proper mechanical operation.



Disconnecting Operator (DO) / External Disconnecter

■ Importance:

- **Safety Isolation:** Provides a clear and visible means of disconnecting the transformer from its supply, ensuring safety during maintenance or emergency conditions.
- **Regulatory Compliance:** Often a required safety feature in transformer installations.

■ Functionality:

- **Manual/Remote Operation:** Typically, the DO can be manually operated (via a handle or lever) or remotely controlled to open/close the circuit breaker or disconnector.
- **Clear Gap Formation:** It ensures a physical gap is created between the transformer and the network, eliminating the risk of accidental energizing.

■ Causes of Wear and Tear:

- **Frequent Operation:** High switching frequency can lead to mechanical degradation.
- **Environmental Factors:** Exposure to dust, moisture, and temperature extremes can cause corrosion and insulation damage.
- **Impact and Vibration:** External shocks or vibrations from nearby equipment may gradually loosen or misalign components.

■ Preventive Maintenance:

- **Routine Testing:** Regularly operate the disconnecting mechanism to ensure smooth functionality.
- **Inspection:** Check for signs of corrosion, wear on contacts, and mechanical misalignment.
- **Environmental Care:** Protect the operator with appropriate housing or enclosures to minimize exposure.

■ Fault Identification:

• Before Opening:

- * **Operational Hints:** Difficulty in operating the mechanism, unusual sounds, or partial movement indicating a developing fault.
- * **Electrical Symptoms:** Erratic readings or unintentional energizing warnings.

• After Opening:

- * **Physical Inspection:** Identify cracked insulation, corroded contacts, or broken linkage mechanisms.
- * **Component Condition:** Look for signs of wear on pivot points and moving components.

■ Repair Methods:

- **Replace Damaged Parts:** Swap out corroded contacts or broken linkage components.
- **Reconditioning:** Clean and re-insulate parts where minor wear has occurred.



External Terminal Boxes and Cable Connections

■ Importance:

- **Electrical Interface:** Serve as the critical point of connection between the transformer and the distribution network.
- **Safety Barrier:** Provide insulation and protection for high-voltage connections.

■ Functionality:

- **Secure Connections:** Ensure that cables are securely fastened and properly insulated to prevent accidental contact or short circuits.
- **Environmental Sealing:** Designed to protect electrical terminations from moisture, dust, and corrosive elements.

■ Causes of Wear and Tear:

- **Corrosion:** Exposure to moisture and salt (in coastal areas) can corrode metal parts.
- **Loose Connections:** Vibration or thermal expansion/contraction may loosen terminals over time.
- **Insulation Breakdown:** UV exposure and aging can cause degradation of insulating materials.

■ Preventive Maintenance:

- **Regular Inspection:** Check connections for tightness, signs of oxidation, and insulation integrity.
- **Cleaning:** Remove dust, debris, and any corrosion products from terminal surfaces.
- **Sealing:** Reapply sealant or insulation materials where needed to maintain a moisture-free environment.

■ Fault Identification:

- **Before Opening:**
 - * **Operational Clues:** Fluctuating voltage readings, arcing, or sparking at terminal connections.
 - * **Visual Signs:** Visible discoloration or moisture accumulation (if accessible externally).
- **After Opening:**
 - * **Physical Damage:** Corroded terminals, cracked insulation, or evidence of arcing (burn marks).
 - * **Loose or Broken Connectors:** Check for any physical deterioration that could impair the connection.

■ Repair Methods:

- **Reseating or Tightening:** Secure any loose connectors and retighten terminals.
- **Cleaning and Re-insulating:** Remove corrosion, apply fresh insulation compounds, and replace damaged connectors.
- **Component Replacement:** Replace terminal boxes or connectors that are beyond repair.



External Control Panels and Monitoring Devices

■ Importance:

- **Real-Time Monitoring:** Displays key operational parameters (voltage, current, temperature, oil level, etc.) essential for safe and efficient transformer operation.
- **Alarm & Protection:** Alerts operators to abnormal conditions, ensuring timely intervention.

■ Functionality:

- **Data Collection & Display:** Integrates sensors and meters that measure various operating conditions.
- **User Interface:** Provides controls for operating external devices such as disconnectors, and may include remote control functions.

■ Causes of Wear and Tear:

- **Environmental Exposure:** Dust, moisture, and temperature extremes can affect sensitive electronic components.
- **Vibration:** Continuous vibration from nearby equipment may loosen connections or cause sensor drift.
- **Aging Components:** Over time, displays and sensor elements may degrade.

■ Preventive Maintenance:

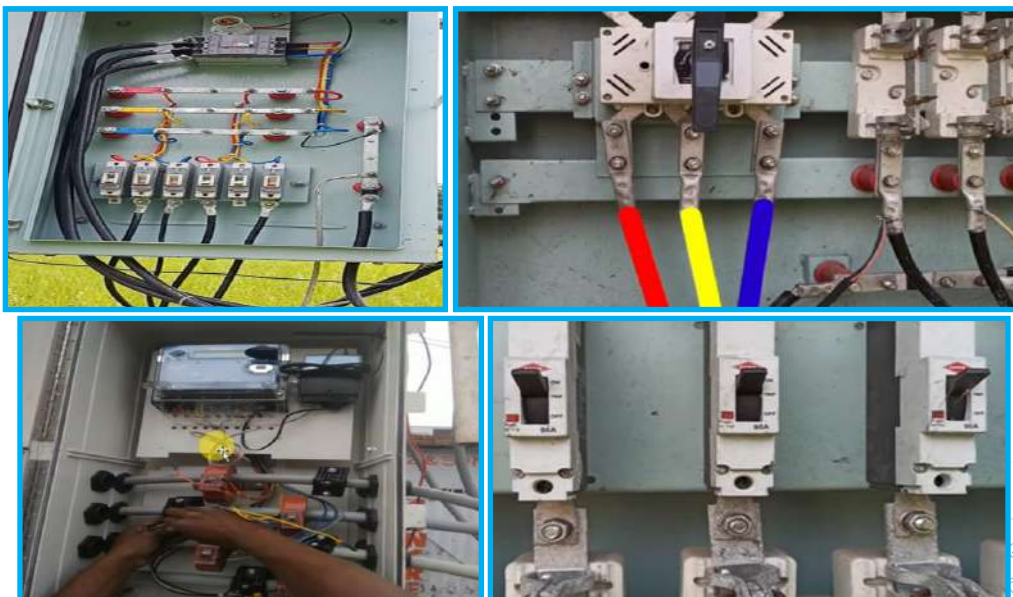
- **Regular Calibration:** Schedule periodic calibration of sensors and meters to ensure accuracy.
- **Cleaning:** Keep the control panel free of dust and moisture using appropriate cleaning techniques.
- **Inspection:** Check wiring and connectors for signs of wear or corrosion.

■ Fault Identification:

- **Before Opening:**
 - * **Erratic Readings:** Inconsistent or out-of-range readings on meters or displays.
 - * **Alarm Indicators:** Warning lights or audible alarms indicating sensor or communication faults.
- **After Opening:**
 - * **Component Damage:** Identify burnt or damaged circuit boards, broken sensors, or loose connections.
 - * **Physical Defects:** Look for moisture ingress or corrosion in connectors and sensor housings.

■ Repair Methods:

- **Component Replacement:** Replace faulty sensors, displays, or circuit boards.
- **Wiring Repairs:** Fix any loose or corroded wiring connections.
- **Recalibration:** After repairs, recalibrate the system to ensure accurate monitoring.



MCCB and Control Panel

Lightning Arresters

11 KV class lightning arrestors are used and lightning arrestors are fixed at the top of the DP structure as you can see in the above image. The function of the lightning arrester is to protect the transformer from lightning tenders. When lightning occurs and falls on the structure the lightning arrester transfers lightning stocks to the ground and thus protects the transformer. A total of three lightning arrestors are provided.

■ Importance

- **Surge Protection:** The lightning arrester is crucial for protecting the transformer and associated equipment from transient over-voltages caused by lightning strikes or switching surges. It ensures that any high voltage spike is diverted safely to ground.
- **Asset Preservation:** By clamping voltage surges, the arrester minimizes insulation stress and prevents damage to transformer windings, prolonging the service life of the entire installation.
- **Safety Enhancement:** It safeguards personnel and equipment by reducing the risk of electrical fires and breakdowns caused by high-voltage surges.

■ Functionality

- **Voltage Clamping:** The arrester remains non-conductive under normal operating conditions but becomes conductive when the voltage exceeds a predefined threshold. This sudden conduction shunts excess energy away from sensitive components.
- **Energy Dissipation:** It absorbs and dissipates the surge energy, converting it into heat, which is then safely dissipated into the atmosphere or ground.
- **Component Composition:** Modern arresters typically consist of metal oxide varistors (MOVs) or zinc oxide (ZnO) blocks. They are housed within an insulated enclosure that ensures safe operation and isolation under normal conditions.

■ Causes of Wear and Tear and Damage

- **Electrical Stress:** Repeated exposure to high surge currents can gradually degrade the metal oxide elements, leading to changes in clamping characteristics.
- **Thermal Cycling:** Surge events produce heat that, when combined with ambient temperature fluctuations, can cause thermal stresses, micro-cracking, or material fatigue.
- **Environmental Factors:** Prolonged exposure to UV radiation, moisture, dust, pollution, and salt (in coastal areas) can deteriorate both the arrester element and its protective housing.
- **Physical Impact:** Mechanical impacts or vibrations may cause misalignment or damage to internal components, including the spark gap or terminal connections.

■ Preventive Maintenance

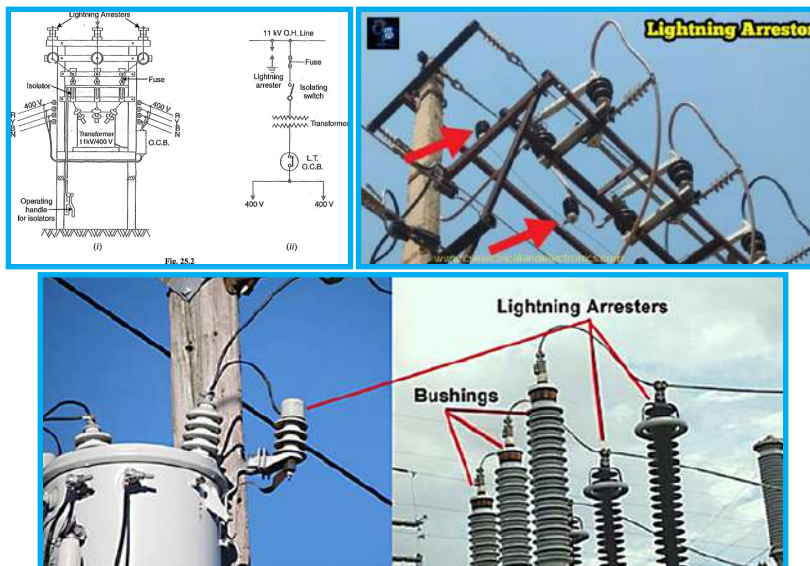
- **Regular Inspections:**
 - * Conduct visual inspections of the arrester housing for cracks, discoloration, or physical damage.
 - * Inspect the mounting hardware, seals, and insulators for any signs of deterioration.
- **Electrical Testing:**
 - * Perform periodic surge tests to check the clamping voltage and leakage current levels.
 - * Monitor insulation resistance to detect early signs of degradation.
- **Cleaning:**
 - * Remove accumulated dust, bird droppings, and other contaminants from the arrester surface and surrounding area.
 - * Ensure that any moisture or pollution ingress is minimized through proper sealing.
- **Environmental Protection:**
 - * Use weatherproof enclosures or coatings to guard against UV and moisture damage.
 - * Ensure that the arrester is installed in a location with proper drainage and minimal exposure to corrosive elements.

■ Fault Identification

- **Before Opening:**
 - * **Abnormal Electrical Behavior:**
 - » Erratic voltage readings or higher than normal leakage currents during routine monitoring.
 - » Sudden tripping of protective relays or unexpected voltage fluctuations in the transformer system.
 - * **Audible or Visual Signs:**
 - » Unusual noises (such as humming or arcing sounds) near the arrester during surge events.
 - » Visible signs of external damage like cracks, discoloration, or moisture on the arrester housing.
- **After Opening (Internal Inspection):**
 - * **Component Damage:**
 - » Inspect the arrester elements (MOVs or ZnO blocks) for signs of physical degradation such as bulging, cracks, or erosion.
 - » Look for discoloration or burnt marks on internal components.
 - * **Mechanical Issues:**
 - » Check for loose or misaligned mounting hardware, degraded seals, and any signs of moisture or corrosion on internal contact surfaces.
 - » Evaluate the condition of the spark gap assembly for proper spacing and electrode integrity.
 - * **Degraded Performance Indicators:**
 - » Reduced clamping performance as determined by post-maintenance electrical tests.
 - » Evidence of thermal damage or cumulative wear affecting the arrester's ability to respond to surges.

■ Repair Methods

- **Component Reconditioning/Replacement:**
 - * **Arrester Elements:** If MOVs or ZnO blocks show significant degradation (e.g., cracks or erosion), they should be replaced. In some cases, cleaning and minor surface treatment may restore functionality if the damage is superficial.
- **Housing and Seals:** Replace any damaged housing components or deteriorated sealants to ensure that moisture and contaminants cannot enter the arrester.
- **Spark Gap Adjustments:**
 - * Clean and re-polish electrodes in the spark gap assembly.
 - * Re-establish proper gap distance through mechanical adjustments if misalignment or wear is observed.
- **Terminal and Grounding Repairs:** Tighten and clean terminal connections, replace any corroded connectors, and ensure that all grounding conductors maintain a low-resistance path.
- **Re-testing and Calibration:** After repairs, conduct comprehensive electrical tests to confirm that the arrester's clamping voltage, leakage current, and overall performance meet the required specifications.



Earthing Connections of a DTR Structure of a Transformer

A robust earthing system in a DTR transformer is critical for operational safety, equipment protection, and system stability. By understanding its functionality and common issues, and by implementing regular preventive maintenance and prompt repair methods, the overall reliability of the transformer can be maintained. This structured approach not only helps in fault identification but also ensures that corrective actions are effectively implemented to prolong the service life of the transformer.

■ Importance of Earthing Connections

- **Safety Protection:** Earthing ensures that in the event of a fault (such as insulation breakdown or short-circuit), excess current is safely diverted to the ground. This minimizes the risk of electrical shock to personnel and reduces the chance of fire or explosion.
- **Equipment Protection:** A proper earth system helps in stabilizing the voltage levels during transient events. It protects transformer windings, bushings, and other sensitive components from over-voltages, thus prolonging the equipment's life.
- **Fault Current Path:** Earthing provides a low impedance path for fault currents. This is critical for the quick operation of protective devices (like fuses and circuit breakers), ensuring that faults are isolated promptly.
- **System Stability:** It helps maintain a reference point (zero potential) for the entire electrical network, which is essential for the proper operation of protection schemes and overall system stability.

■ Functionality of Earthing Connections

- **Grounding of Transformer Tank:** The transformer's metal tank is directly connected to the earth. This connection is vital to ensure that any leakage currents or stray voltages are harmlessly discharged.
- **Neutral Earthing:** In many DTR configurations, the neutral point of the transformer winding is connected to earth through a resistor or reactor. This controls the fault current magnitude and helps in limiting over-voltages during unbalanced faults.
- **Bonding of Metallic Parts:** All accessible metallic parts of the transformer and associated equipment (e.g., bushings, radiators, control panels) are bonded to the earthing system. This prevents dangerous potential differences and ensures any fault current is uniformly distributed to ground.
- **Continuity Assurance:** Earthing connections are designed to be continuous and low-resistance. They use robust connectors, cables, or bus bars to ensure that the integrity of the ground path is maintained under all operating conditions.

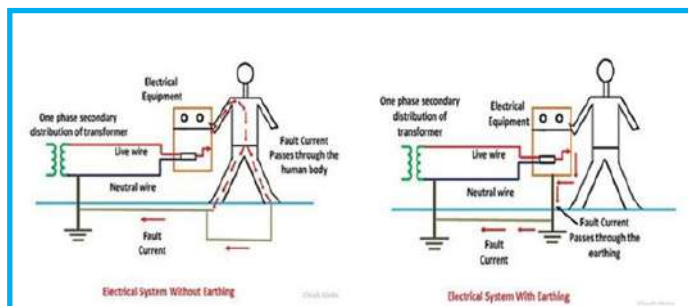


Fig: Earthing Functioning



Fig: GI Clamps and Poles for earthing connection

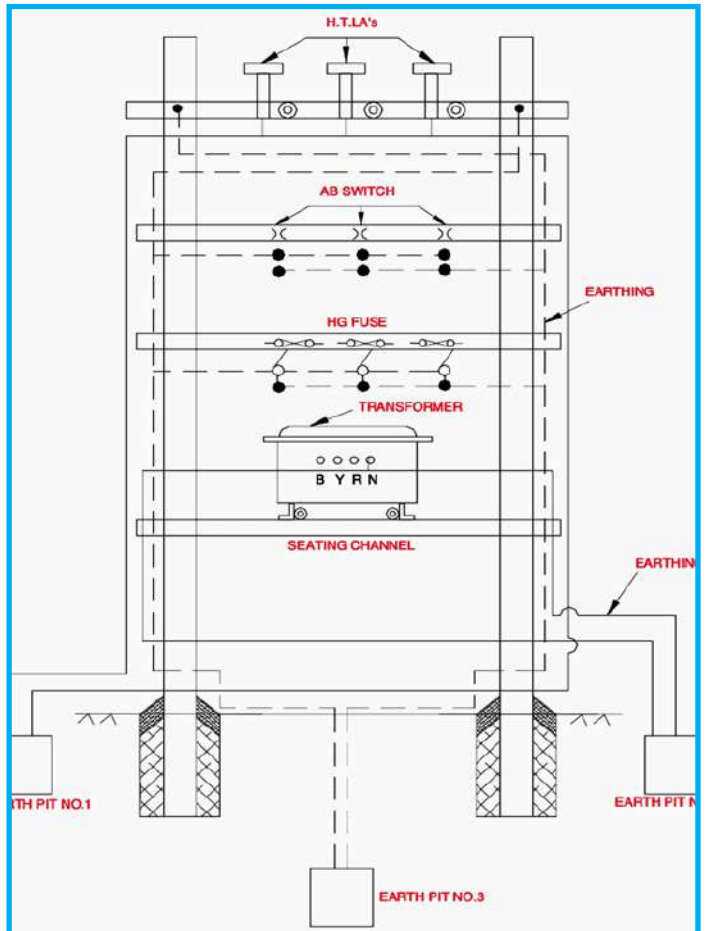
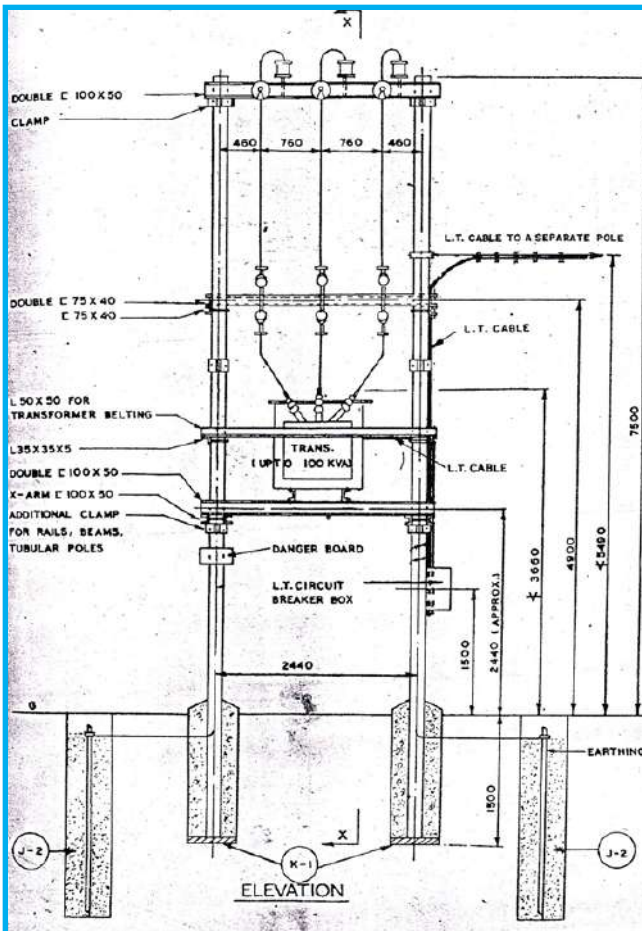
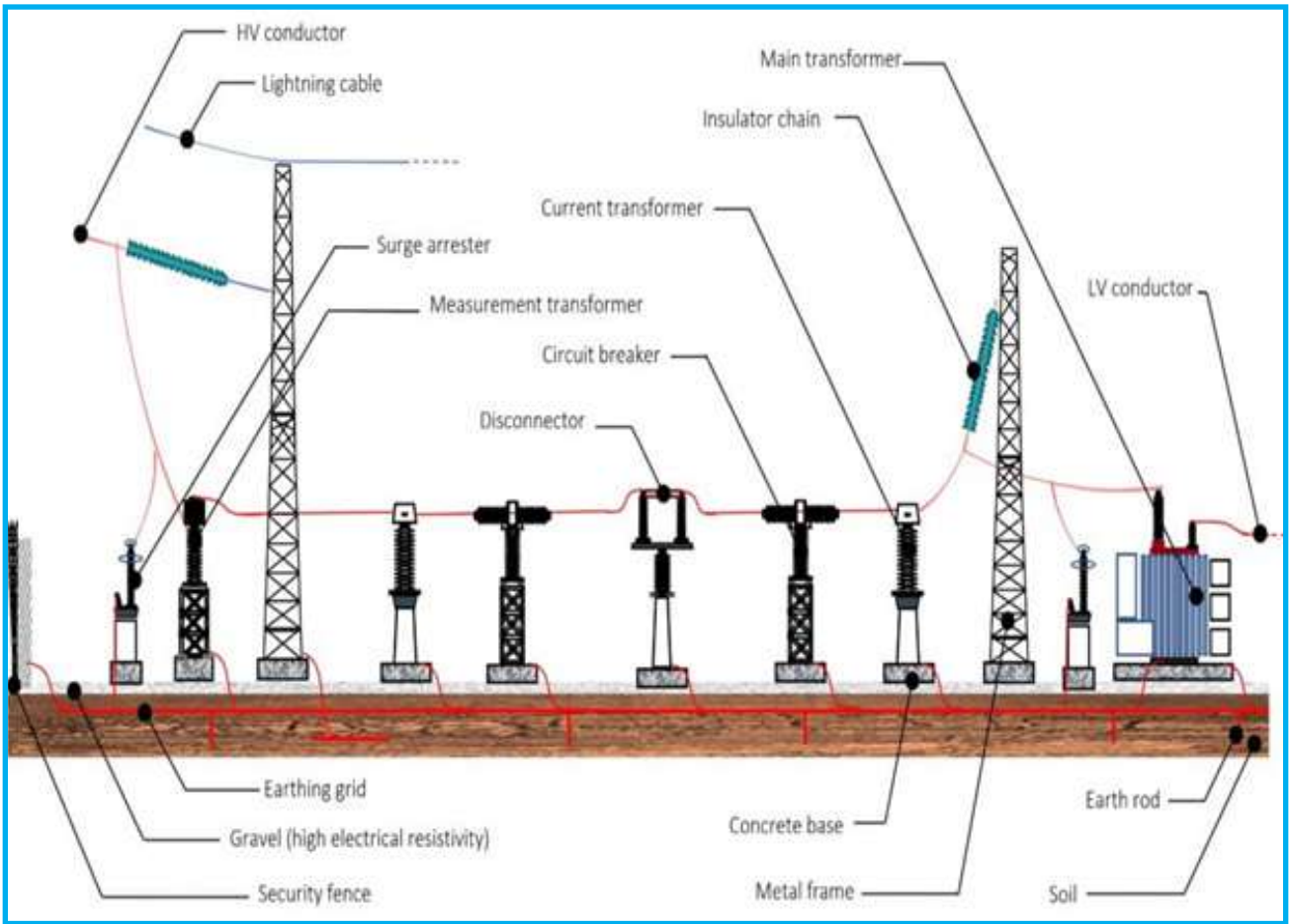


Fig: Earthing Connections of DTR Transformer



■ Causes of Wear and Tear and Damage

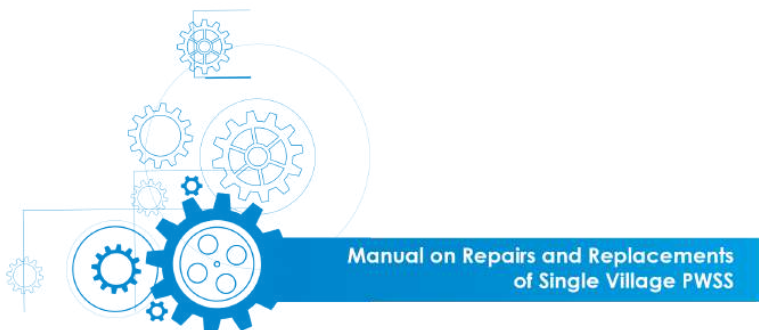
- **Corrosion:** Exposure to moisture, chemicals, and salt (in coastal areas) can corrode the metal connections, leading to increased resistance and potential failure of the earthing path
- **Loose Connections:** Mechanical vibrations, thermal expansion and contraction, or improper installation can cause connectors to loosen over time, reducing the effectiveness of the earthing system.
- **Environmental Degradation:** Dirt, dust, and other environmental contaminants may accumulate on the connections, impeding electrical conductivity.
- **Mechanical Damage:** Accidental impacts, construction activities nearby, or animal activities can physically damage the earthing components.
- **Overheating:** Repeated fault currents or sustained heavy currents might cause excessive heating, which can deteriorate insulation and connector integrity.

■ Preventive Maintenance Practices

- **Regular Visual Inspections:** Check for signs of corrosion, discoloration, or physical damage at the earthing points, connectors, and bonding cables.
- **Continuity Testing:** Use a low-resistance ohmmeter or earth loop impedance tester periodically to verify that the earthing system maintains a low resistance path.
- **Tightening of Connections:** Regularly check and re-tighten bolts, clamps, and connectors. Ensure that any sign of looseness is addressed immediately.
- **Cleaning and Coating:** Remove corrosion or accumulated dirt using appropriate cleaning methods. Reapply anti-corrosion coatings or conformal sealants to protect exposed surfaces.
- **Thermal Imaging:** Conduct thermal scans during operation to identify any hotspots in the earthing connections, which may indicate high-resistance joints or impending failure.
- **Documentation and Record Keeping:** Maintain a log of inspections, tests, and repairs to track the condition of the earthing system over time.

■ Fault Identification: Before and After Opening

- **Before Opening (External Inspection & Testing):**
 - * **Visual Check:** Look for visible signs of wear, rust, or damage on the earthing system components without disassembling the transformer. Abnormal discoloration or moisture ingress might indicate issues.
 - * **Continuity/Resistance Testing:** Measure the resistance of the earthing system using appropriate testers. Values above the recommended threshold (typically below 1 ohm for high-quality systems) signal potential faults.
 - * **Thermal Imaging:** Use infrared cameras to detect abnormal heating at the earthing connections. A hot spot might indicate a high-resistance connection.
 - * **Vibration and Loose Joint Detection:** Check for any unusual vibrations or physical movement around the earthing points which might hint at loose connections.
- **After Opening (Detailed Internal Examination):**
 - * **Component Inspection:** Examine bonding straps, connectors, and the junction box for any signs of physical damage, overheating, or corrosion.
 - * **Insulation and Contact Surfaces:** Inspect for cracked or burnt insulation, which could expose the metal to corrosive elements. Ensure that contact surfaces are clean and undamaged.
 - * **Connection Integrity:** Verify that all connections are secure, free of oxidation, and that no signs of arcing or pitting are present. Use appropriate contact resistance meters if needed.
 - * **Internal Earth Bar:** Check the internal earth bar for any loose bolts, corrosion spots, or improper bonding with the transformer tank and other components.



■ Methods for Repair and Restoration

- **Cleaning and Re-Coating:** Remove corrosion from connectors and contact points using a wire brush or chemical cleaners. After cleaning, reapply anti-corrosion coatings or sealants to protect the surfaces.
- **Replacement of Damaged Components:** Replace any corroded, burnt, or mechanically damaged connectors, cables, or bonding straps with components that meet the manufacturer's specifications.
- **Re-Tightening and Re-Bonding:** Secure loose connections with proper tightening procedures. Ensure that all bonds are re-established using approved fasteners and conductive paste if required.
- **Welding or Brazing:** In cases where the bonding connection has become compromised, repair methods like welding or brazing may be used. These should be carried out by qualified personnel to ensure that the structural integrity and conductivity are restored.
- **Electrical Testing Post-Repair:** After repairs, perform a thorough continuity and insulation resistance test to confirm that the earthing system is fully functional and meets the safety requirements.
- **Documentation of Repairs:** Record all repair activities, including replaced parts, tests conducted, and observations. This documentation will help in future troubleshooting and maintenance planning.

For more information and videos regarding installation and repairing of Transformer and DTR Structure of a Transformer this link can be referred:



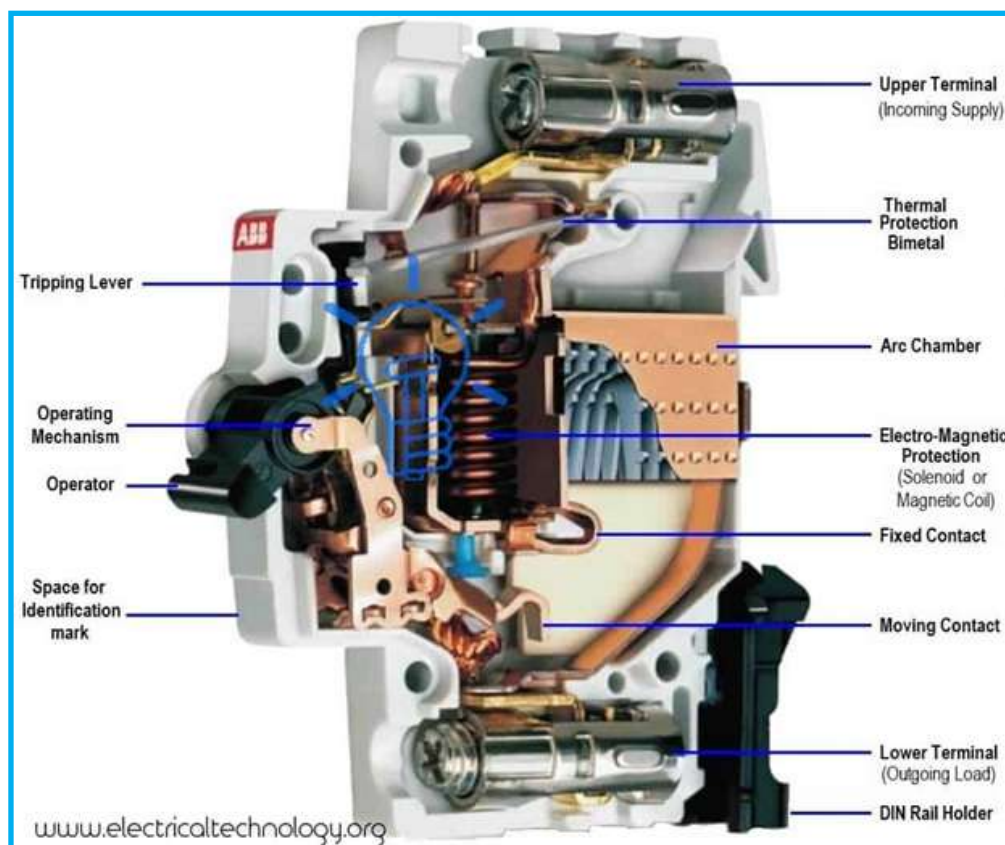
<https://youtube.com/playlist?list=PLu7Qy6fHf-WzfT-6moiRSyoXSvHXPzwuB-c&si=Sv3EL2p680dhBYrb>



7.3 Electrical panel board items

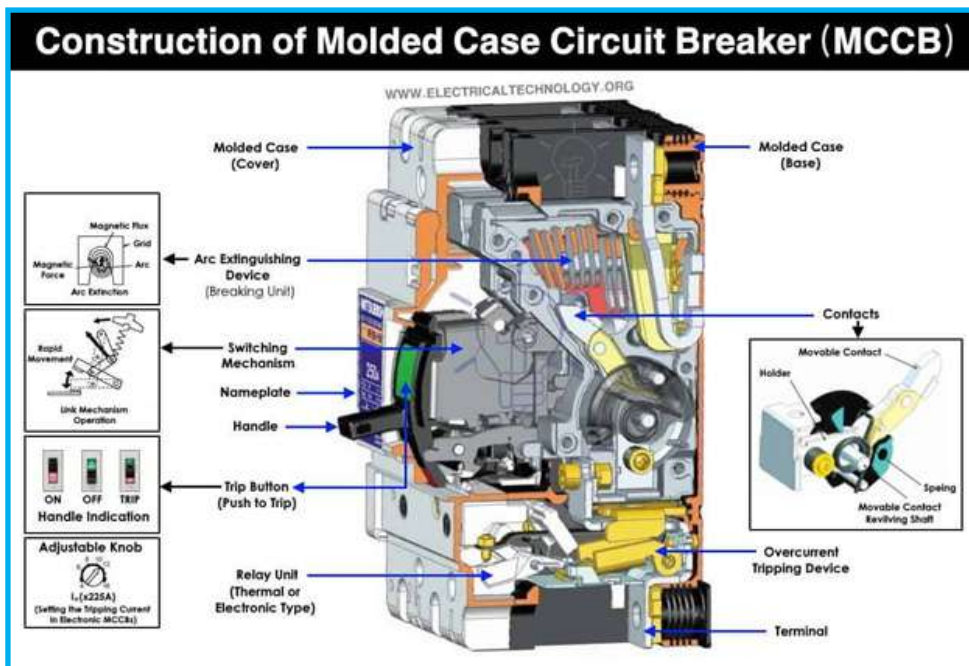
Miniature Circuit Breaker (MCB)

Criteria	Details
Importance	Protects circuits from overloads and short circuits in domestic and small commercial setups.
Functionality	Trips the circuit when current exceeds rated value, preventing fire and damage.
Causes of Wear and Tear	Frequent tripping, loose connections, corrosion of contacts, or improper rating.
Preventive Maintenance	Regularly check tightness, clean terminals, and avoid overloading. Use surge protectors.
Fault Identification	Before opening: Frequent power trips, burning smell, or no power. After opening: Burnt contacts, melted plastic housing, discoloration.
Repair Methods	Typically replaced, not repaired. Ensure correct rating and proper torque on terminals during replacement.



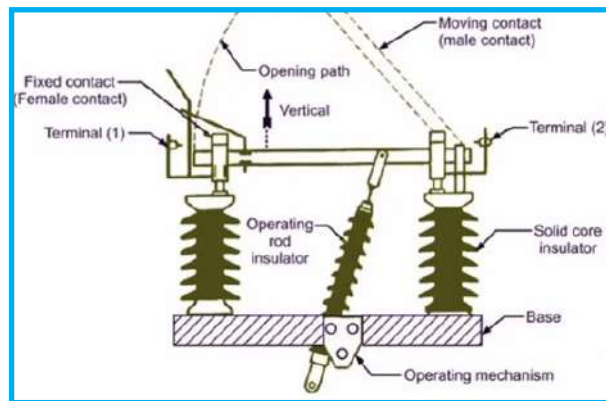
Moulded Case Circuit Breaker (MCCB)

Criteria	Details
Importance	Provides higher capacity protection than MCBs; used in industrial and large commercial installations.
Functionality	Interrupts excessive current with thermal-magnetic/mechanical tripping or electronic trip units.
Causes of Wear and Tear	Frequent overcurrent, high fault current, dusty environment, mechanical fatigue.
Preventive Maintenance	Clean contacts, test trip settings, exercise mechanism periodically.
Fault Identification	Before opening: Overheating, abnormal noise, tripping under load. After opening: Carbon deposits, stuck contacts, or damaged arc chute.
Repair Methods	Serviceable if tripping unit is electronic; otherwise, replace. Some types allow contact kit replacements.



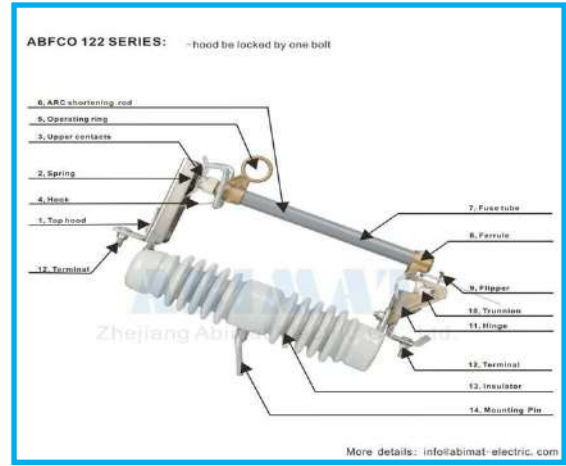
Isolator

Criteria	Details
Importance	Provides mechanical disconnection of power supply for maintenance safety.
Functionality	Manually operated to isolate electrical equipment from live circuits. No load breaking capability.
Causes of Wear and Tear	Mechanical fatigue, corrosion, improper operation under load.
Preventive Maintenance	Operate periodically, keep clean and rust-free, lubricate moving parts.
Fault Identification	Before opening: Switch is jammed, does not isolate fully. After opening: Pitted or misaligned contacts, rust.
Repair Methods	Replace worn-out parts like springs or contacts. Do not use to switch load; ensure off-load operation.



Cutout (Fuse Cutout)

Criteria	Details
Importance	Protects against overcurrent by melting fuse wire and disconnecting power.
Functionality	Fuse link melts when current exceeds rated capacity, disconnecting the circuit.
Causes of Wear and Tear	Overcurrent, aging fuse elements, loose connections, oxidation.
Preventive Maintenance	Check fuse rating, ensure firm grip in holder, clean terminals.
Fault Identification	Before opening: No power supply, fuse link blown indicator. After opening: Burnt fuse link, blackened cover.
Repair Methods	Replace fuse wire with same rated capacity; ensure proper seating and tightness.



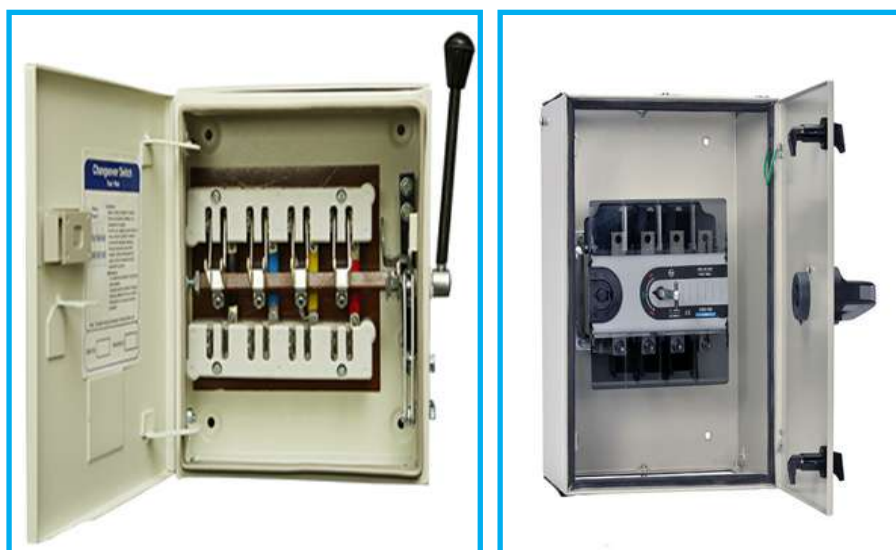
Main Switch

Criteria	Details
Importance	Central control to disconnect entire supply during emergencies or maintenance.
Functionality	Switches ON/OFF the main power supply line manually.
Causes of Wear and Tear	Dust accumulation, loose terminals, overloading, mechanical wear.
Preventive Maintenance	Periodic operation, tightening screws, cleaning contacts.
Fault Identification	Before opening: Cannot operate switch, sparks during operation. After opening: Burnt/eroded contact surfaces.
Repair Methods	Replace contacts or entire unit; tighten terminals and test continuity. Use arc suppressors for high loads.



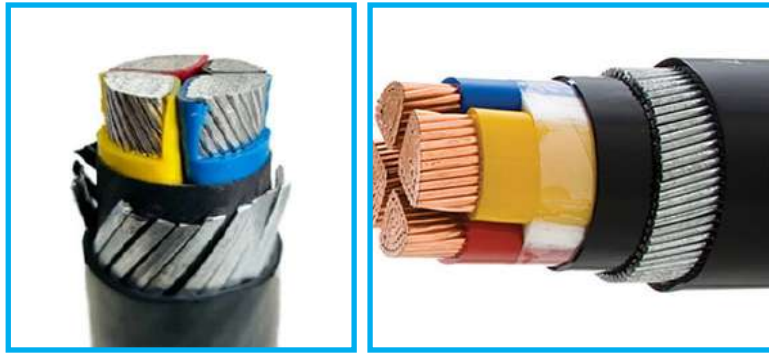
Changeover Switch

Criteria	Details
Importance	Allows safe switching between two power sources (e.g., grid and generator).
Functionality	Manually or automatically shifts power supply source.
Causes of Wear and Tear	Improper switching under load, arcing, dust, worn contacts.
Preventive Maintenance	Clean contacts, test interlocks, lubricate moving parts.
Fault Identification	Before opening: Power not transferring, stuck position. After opening: Damaged contacts, misalignment.
Repair Methods	Replace faulty contact set, align mechanism, or replace complete unit if beyond repair.



Armoured Cable

Criteria	Details
Importance	Ensures safe transmission of electricity with mechanical protection.
Functionality	Carries current through insulated conductors protected by steel wire armouring.
Causes of Wear and Tear	Moisture ingress, rodent damage, overbending, mechanical impacts, insulation breakdown.
Preventive Maintenance	Avoid sharp bends, proper clamping, check insulation resistance periodically.
Fault Identification	Before opening: Power loss, sparking, cable heating. After opening: Cracked insulation, corroded wires.
Repair Methods	Use cable jointing kits (heat-shrink or resin cast), replace damaged section, test with insulation testers.



BTC Cable

Criteria	Details
Importance	Provides flexible and efficient electrical connectivity, especially for control wiring, internal wiring of panels, and connections in confined or movable locations.
Functionality	Conducts electric current through multiple finely stranded copper wires bunched together, offering higher flexibility and better conductivity.
Causes of Wear and Tear	Overheating due to overloading, abrasion, frequent bending, loose connections, high ambient temperature, and moisture affecting insulation.
Preventive Maintenance	Ensure tight connections, avoid overloading, protect from sharp edges, use proper conduit or casing, and periodically check for insulation cracks or wear.
Fault Identification	Before opening: Voltage drop, flickering of lights, intermittent connection, heating at terminals. After opening: Discolored or oxidized copper, broken strands, melted or cracked insulation.
Repair Methods	Cut and replace damaged section, re-crimp or re-terminate with proper lugs, insulate joints with heat-shrink tubing, and test with continuity and insulation testers.



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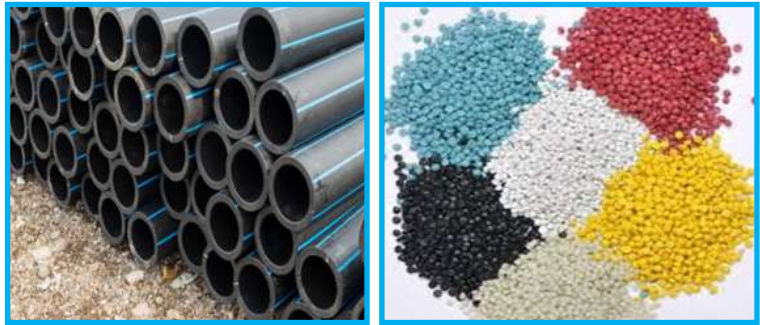
Pipes

8. Pipes

8.1 HDPE (High-Density Polyethylene) Pipes

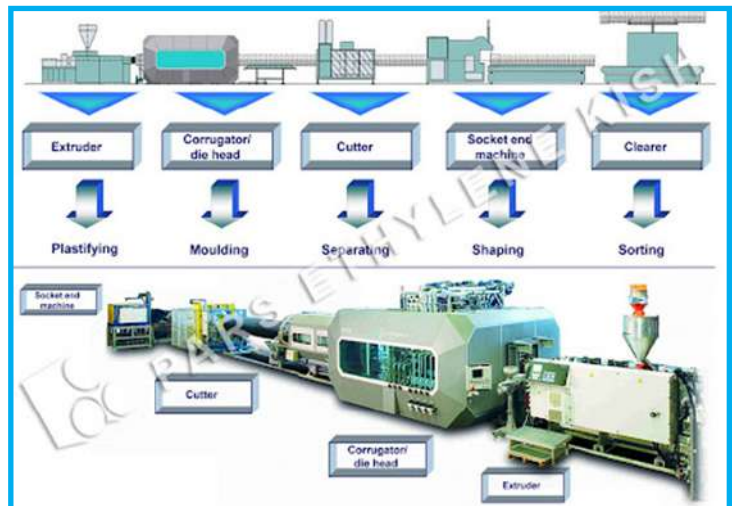
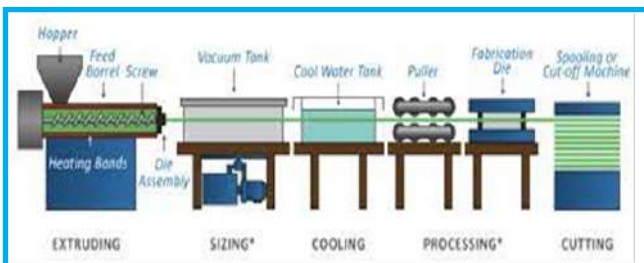
■ Raw Material and Composition

- **Materials:** Made from high-density polyethylene resin.
- **Additives:** May include UV stabilizers, antioxidants, and colorants to enhance performance.



■ Manufacturing Process

- **Process:** Produced using an extrusion process.
- **Steps:** Resin is melted, extruded through a die to form a tube, then cooled in a water bath and cut to required lengths.



■ Advantages and Disadvantages

- **Strength & Durability:** High impact resistance and flexibility; resistant to corrosion.
- **Longevity:** Excellent lifespan under proper installation but may deform under constant heavy load.
- **Efficiency:** Smooth inner surfaces reduce friction losses.
- **Transportability:** Lightweight, which simplifies transport and installation.
- **Cost:** Generally cost-effective; lower material and installation costs.
- **Disadvantages:** Sensitive to high temperatures and UV exposure (if not stabilized), potential for creep under long-term pressure loads.

■ Causes of Defects/Deterioration & Identification

- **Physical Causes:** UV degradation (leading to discoloration or embrittlement), chemical attack from aggressive media, and stress cracking.
- **Mechanical Causes:** Improper installation or handling that causes cracks or deformation.
- **Identification:**
 - * **Visually:** Look for surface cracks, discoloration, or signs of warping.
 - * **Mechanically:** Non-destructive tests (NDT) such as tensile strength or pressure testing to detect internal flaws.



Fig: Damage of HDPE pipe by Improper Jointing of HDPE Pipe

■ **Preventive Measures**

- **Additives:** Use UV stabilizers and antioxidants in the resin formulation.
- **Installation:** Avoid overloading and ensure proper bedding to reduce stress.
- **Storage:** Store pipes in shaded areas away from direct sunlight.
- **Maintenance:** Regular inspections to check for early signs of cracking or deformation.

■ **Methods of Jointing**

- **Butt Fusion Welding:** Ends of pipes are heated and fused together under pressure.



- **Electrofusion Welding:** Uses electrofusion couplers with embedded wires that heat and fuse the pipe ends.

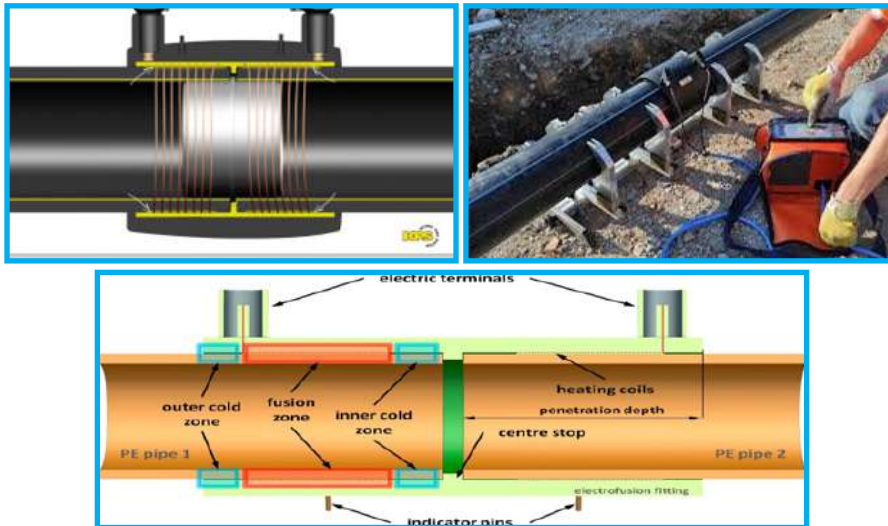


Fig: Electro Fusion Jointing of HDPE Pipe

- **Compression Fittings:** Mechanical joints with tightening nuts.



Fig: Compression fitting of HDPE Pipe

- **Flanged Joints:** Used when disassembly may be required.

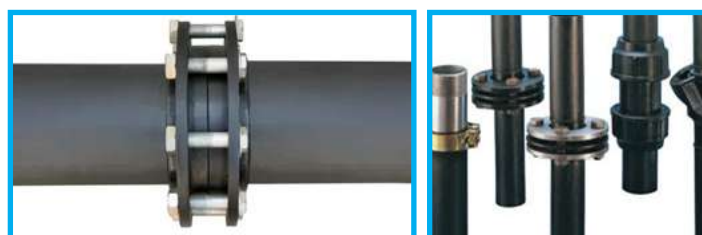


Fig: Flanged Fitting of HDPE Pipe



■ **Common Appliances/Accessories/Bends (45°, 90°)**

- Tees (equal, reducing)
- Reducers (concentric, eccentric)
- End caps
- Couplers (straight, electrofusion)
- Flange adaptors
- Air valves
- Tapping saddles



■ **PP Compression Fittings**

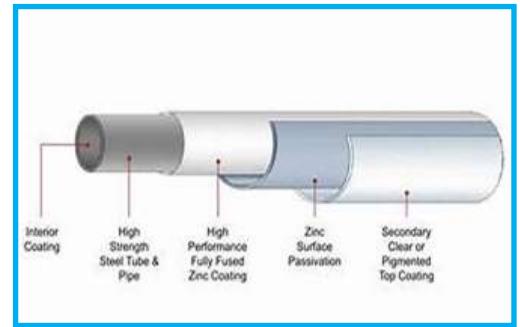


Fig: All fittings of HDPE Pipe

8.2 GI (Galvanized Iron) Pipes

■ Raw Material and Composition

- **Materials:** Constructed from steel.
- **Coating:** A protective zinc layer (via hot-dip or electrogalvanizing) applied to prevent corrosion.



■ Manufacturing Process

- **Process:**
 - * Forming of steel pipes.
 - * Immersion in a molten zinc bath (hot-dip galvanizing) or via electroplating.
- **Finishing:** Post-coating treatments to ensure adhesion and uniformity.

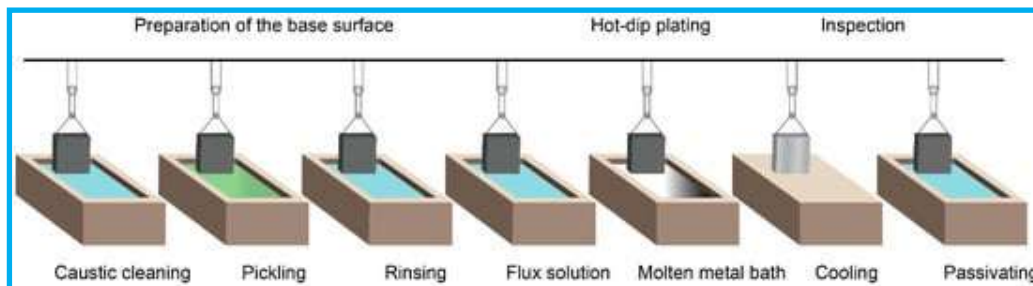


Fig: Manufacturing process of GI Pipe

■ Advantages and Disadvantages

- **Strength & Durability:** Good mechanical strength; zinc coating adds a barrier against corrosion.
- **Longevity:** Can be very durable if the coating remains intact; however, zinc may eventually wear off.
- **Efficiency:** Suitable for high-pressure applications.
- **Transportability:** Heavier than polymer pipes, which can affect handling.
- **Cost:** Moderate; initial cost balanced by durability, though maintenance costs can rise if corrosion begins.
- **Disadvantages:** The coating may deteriorate in aggressive environments, leading to rust.

■ Causes of Defects/Deterioration & Identification

- **Physical Causes:** Mechanical damage to the zinc coating from impacts or scratches.
- **Chemical Causes:** Exposure to salt, acids, or alkaline soils can corrode the zinc layer.
- **Identification:**
 - * Visually: Look for flaking, pitting, or rust spots on the surface.
 - * Mechanically: Use ultrasonic thickness gauging to check for coating loss or corrosion under the surface.



Fig: Damage of GI Pipe by physical and chemical means

■ Preventive Measures

- **Handling:** Avoid physical impacts during transport and installation.
- **Environmental:** Use protective coatings or wraps when used in highly corrosive environments.
- **Inspection:** Schedule regular maintenance and cleaning to remove corrosive deposits.
- **Installation:** Ensure proper alignment and support to minimize mechanical stress.

■ Methods of Jointing

- **Threaded Jointing:** Male and female threaded ends with sealing compound or PTFE tape.



- **Flanged Jointing:** Bolted flanges for large diameter pipes or where frequent dismantling is needed.



- **Welded Jointing (rare for GI):** Can be done but zinc fumes pose hazards.



■ **Common Appliances/Accessories**

Elbows (90°, 45°), Sockets, Unions, Reducers, Tees, Plugs, Nipples, Valves (gate, globe, check), Bibcocks and faucets,



Fig: All GI Fittings required

8.3 DI (Ductile Iron) Pipes

■ Raw Material and Composition

- **Materials:** Iron alloy with added magnesium to create spheroidal (nodular) graphite.
- **Composition:** Contains elements that enhance ductility and impact resistance.



■ Manufacturing Process

- **Process:**
 - * **Recycled Materials:** Ductile iron pipes are made from a high percentage (around 95%) of recycled materials like shredded automobiles, structural steel, and other scrap metal.
 - * **Coke:** Coke, a high-carbon fuel derived from coal, is used in the melting process to provide heat and add carbon to the molten iron.
 - * **Magnesium:** Magnesium is added to the molten metal during the casting process to transform the graphite from flake to spherical form, which improves the strength and ductility of the iron.
 - * **Alloys:**
 - » In addition to the basic iron, carbon, and silicon, other alloys like nickel are sometimes added to the ductile iron for specific properties.
 - » Cast in sand molds under controlled conditions.
 - » Optional internal/external linings (e.g., cement mortar or epoxy) are applied for additional corrosion protection.
- **Finishing:** Machining or coating as needed.

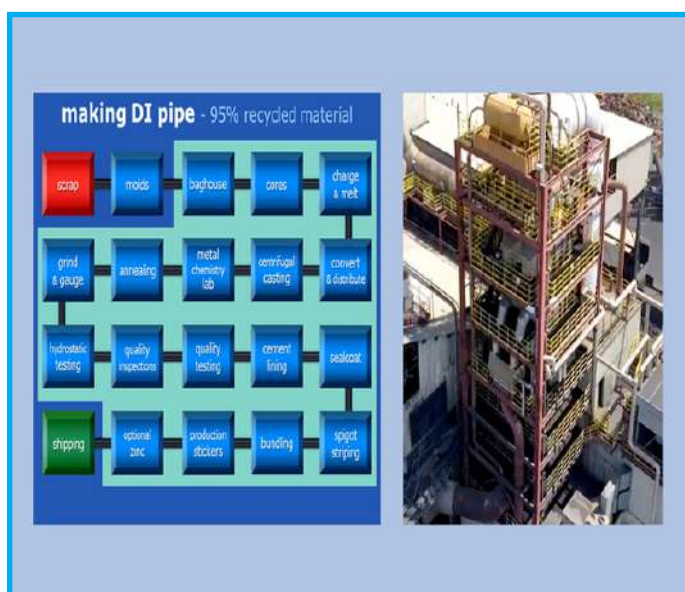


Fig: Addition of carbon, silicon, manganese and magnesium to molten iron scrap to improve its strength and flexibility

■ Advantages and Disadvantages

- **Strength & Durability:** High tensile strength and excellent impact resistance.
- **Longevity:** Long service life with proper lining; however, unlined pipes are susceptible to corrosion.
- **Efficiency:** Suitable for high-pressure and high-load applications.
- **Transportability:** Heavy; requires careful handling.
- **Cost:** Higher initial cost than some polymer pipes, but long-term durability can offset this.
- **Disadvantages:** Weight and the need for protective linings to prevent corrosion.

■ Causes of Defects/Deterioration & Identification

- **Physical Causes:** Casting defects or improper cooling can lead to micro-cracks.
- **Chemical Causes:** Corrosion if protective linings are damaged or absent.
- **Identification:**
 - * Visually: Check for surface rust, chipped lining, or visible cracks.
 - * Mechanically: Conduct pressure tests and ultrasonic or magnetic particle inspections to detect internal flaws.



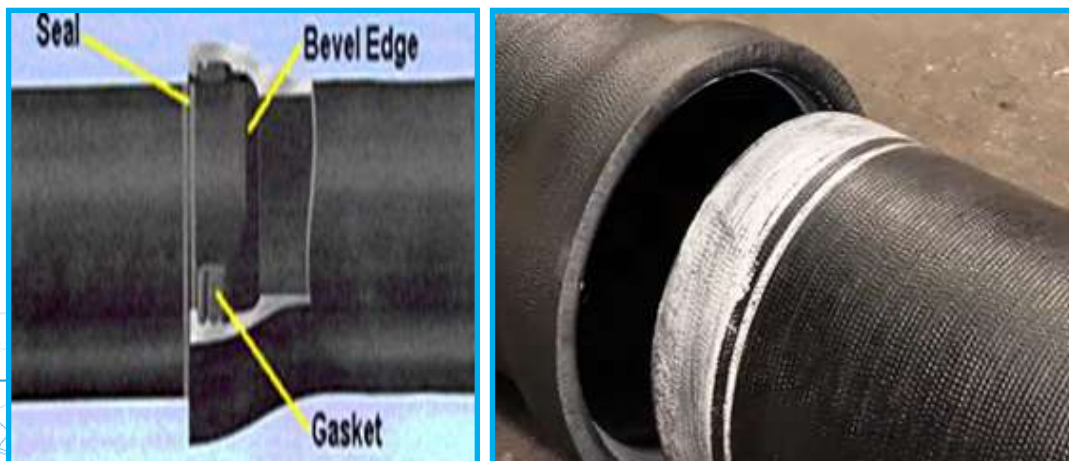
Fig: Casting and Cement lining defect of DI Pipe

■ Preventive Measures

- **Lining:** Ensure high-quality, intact linings (cement mortar or epoxy).
- **Installation:** Use proper bedding and alignment techniques.
- **Inspection:** Regular non-destructive testing (NDT) to monitor lining integrity.
- **Maintenance:** Routine cleaning to prevent buildup of corrosive agents.

■ Methods of Jointing

- **Push-on (Tyton) Joint:** Rubber gasket inserted into socket; pipe spigot pushed in.



- **Mechanical Joint:** Gasket and gland secured with bolts.

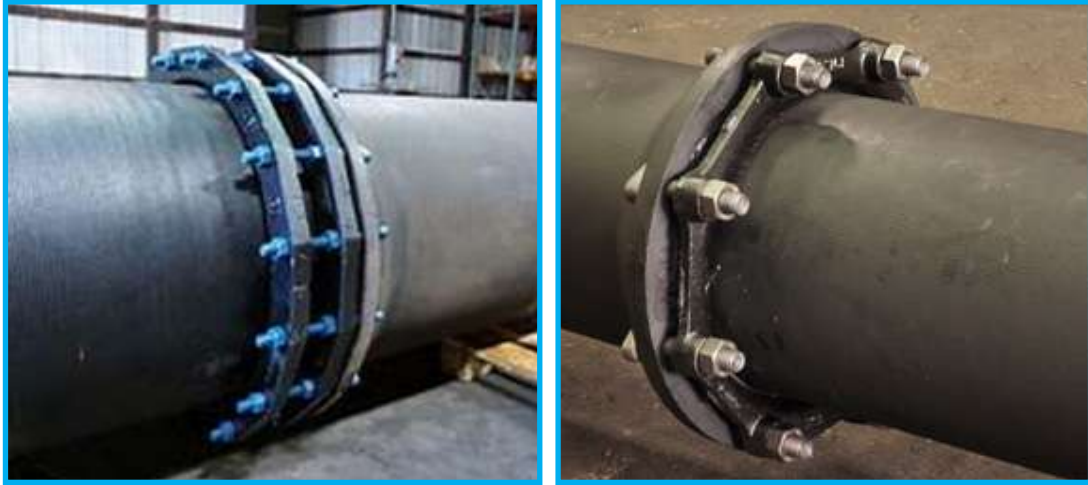


Fig: Mechanical Joint of DI Pipe

- **Flanged Joint:** For fixed connection points like pump sets or valves.



Fig: Flanged Joint of DI Pipe

- **Rubber Ring Joint:** For flexible and leak-proof joints.



Fig: Rubber Ring Joint of DI Pipe



■ **Common Appliances/Accessories**

- Flanged adaptors, Dismantling joints, Tees and crosses, Bends, Air release valves, Sluice/gate valves, End caps, Expansion joints.



Fig: Rubber Ring Joint of DI Pipe



8.4 CI (Cast Iron) Pipes

■ Raw Material and Composition

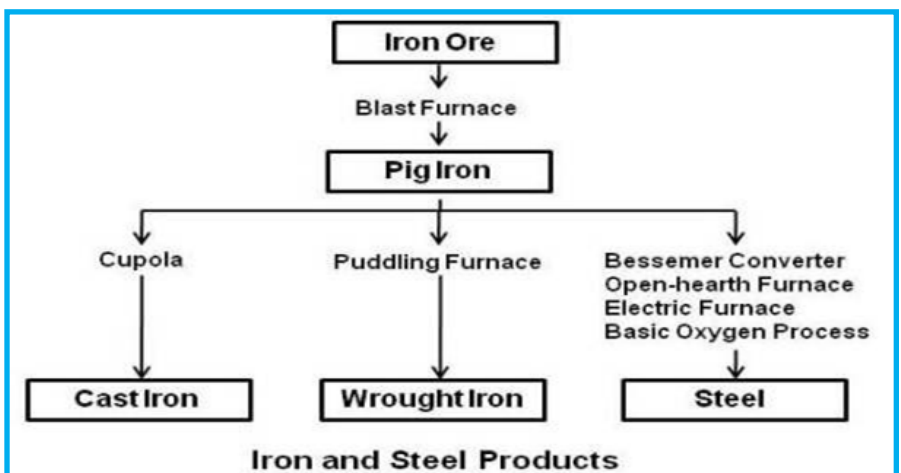
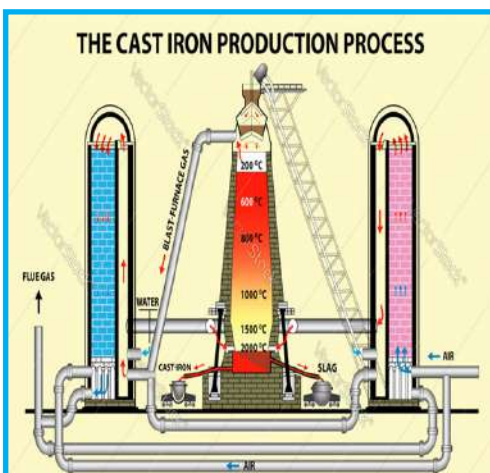
- **Materials:** Traditional cast iron with a high carbon content and graphite flakes an **alloy of iron with high carbon (2–4%)** Cast iron pipes are primarily made from scrap iron, steel scrap, alloys, coke, and limestone. These materials are combined and melted to create the desired composition for the pipe.
- **Properties:** High compressive strength due to its crystalline structure.



Fig: Ductile Pipe and raw scrap iron

■ Manufacturing Process

- **Process:**
 1. Scrap iron and steel scrap:
 - * These recycled materials are a major component of cast iron production, offering a sustainable and cost-effective way to source raw materials.
 - * **Alloys:** Various alloys are added to the molten iron to achieve specific properties like hardness, strength, and corrosion resistance.
 - * **Coke:** Coke, a high-carbon fuel derived from coal, is used to melt the scrap metal and also contributes carbon to the molten iron.
 - * **Limestone:** Limestone acts as a flux, helping to remove impurities from the molten iron.
 - * **Other materials:** Depending on the type of cast iron pipe (e.g., gray cast iron, ductile iron), additional materials like silicon, magnesium, or other alloying elements may be used.
 - * **Pig iron:** Pig iron, the product of melting iron ore in a blast furnace, can also be used as a raw material for cast iron pipe production.
 2. Molten cast iron is poured into sand molds.
 3. Controlled cooling forms the final pipe; machining may follow for dimensional accuracy.
- **Finishing:** Surface treatments may be applied to reduce corrosion.



■ Advantages and Disadvantages

- **Strength & Durability:** Excellent compressive strength and longevity in stable, non-vibratory environments.
- **Longevity:** Long-lasting in low-impact, low-vibration settings.
- **Efficiency:** May have higher friction losses due to rough inner surfaces.
- **Transportability:** Heavy and bulky, requiring careful handling.
- **Cost:** Generally lower material cost but may incur higher installation and handling expenses.
- **Disadvantages:** Brittleness (low tensile strength), difficult to repair, and prone to cracking under shock loads.



■ Causes of Defects/Deterioration & Identification

- **Physical Causes:** Impact damage, chipping, or cracking from external loads.
- **Chemical Causes:** Corrosion (rust) on exposed surfaces.
- **Identification:**
 - * Visually: Look for visible cracks, rust spots, or chipped surfaces.
 - * Mechanically: Sound tests (tapping) can reveal differences in density; NDT methods can assess internal defects.

■ Preventive Measures

- **Handling:** Use proper lifting and transport techniques to avoid impact damage.
- **Protective Coatings:** Apply paints or sealants to minimize corrosion.
- **Installation:** Ensure minimal mechanical stress by using appropriate bedding and supports.
- **Maintenance:** Regular inspection and repair of minor defects before they propagate.

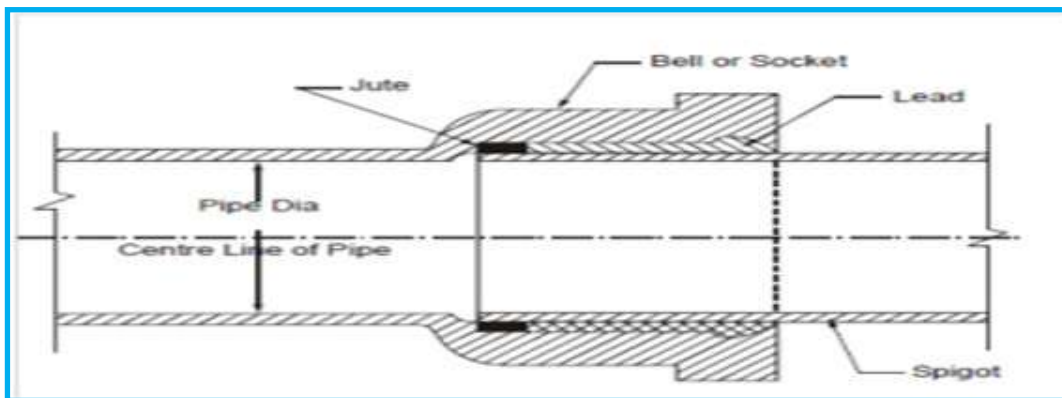
Difference between cast iron and ductile iron pipe

Feature	Cast Iron (CI) Pipe	Ductile Iron (DI) Pipe
Base Material	Iron with high carbon (2–4%)	Iron with lower carbon + magnesium or cerium
Graphite Form	Flake graphite (makes it brittle)	Spheroidal/nodular graphite (adds flexibility and strength)
Ductility	Low (brittle, breaks under stress)	High (can bend, resists cracking)
Tensile Strength	150–300 MPa	420–550 MPa
Impact Resistance	Low	High
Pressure Rating	Up to 7–10 kg/cm ²	Up to 25–64 kg/cm ² depending on class

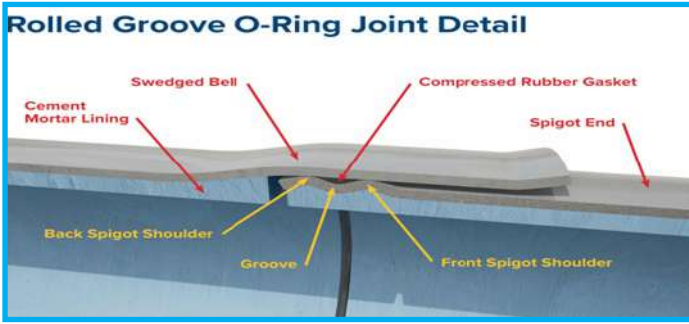
Corrosion Resistance	Moderate (needs internal/external coating)	Better, often lined with cement mortar and coated externally
Manufacturing Process	Sand casting (traditional)	Centrifugal casting (precision and strength)
Surface Finish	Rough (higher friction)	Smooth (better hydraulic flow)
Leakage Risk	Higher (more joints, rigid)	Lower (fewer joints, some flexibility underground movement)
Service Life	50–70 years (if maintained)	75–100+ years (with proper protection)
Common Standards	IS 1536, IS 3989	IS 8329, ISO 2531
Current Usage	Phased out or used in old systems	Widely used in modern water and sewerage pipelines
Weight	Heavier (thicker wall needed for strength)	Lighter (due to higher strength and better design)
Cost	Generally lower upfront	Slightly higher, but more cost-effective over lifespan

■ **Methods of Jointing**

- **Spigot and Socket Joint with Lead Caulking:** Traditional method using lead wool and jute.



- **Rubber Ring Joint:** Uses gaskets for watertight seals.



- **Mechanical Joint:** Bolted glands and gaskets.



- **Flanged Joint:** For fixed equipment or dismantling needs.



■ **Common Appliances/Accessories**

- Bends, Tees, Sockets, Reducers, Inspection pieces, Clean-outs, Manhole rings, Drain plug



Fig: All fittings of CI Pipe

8.5 MS (Mild Steel) Pipes

■ Raw Material and Composition

- **Materials:** Low-carbon steel, generally with 0.05–0.25% carbon content. Steel manufacturing typically involves either the Blast Furnace-Basic Oxygen Furnace (BF-BOF) route or the Electric Arc Furnace (EAF) route. The BF-BOF route uses iron ore and coke to produce “pig iron,” which is then refined in a Basic Oxygen Furnace (BOF) to produce steel. The EAF route primarily uses recycled steel scrap, melting it with electric arcs and potentially adding other materials.
- **Properties:** Balances strength with ductility.

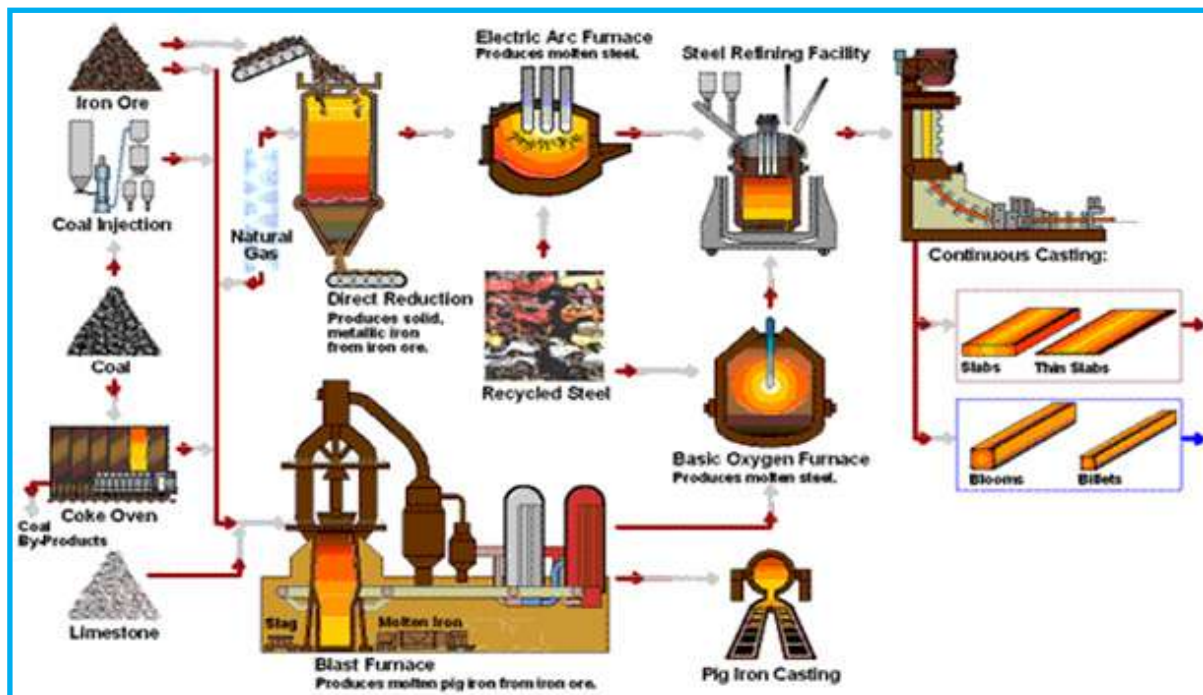
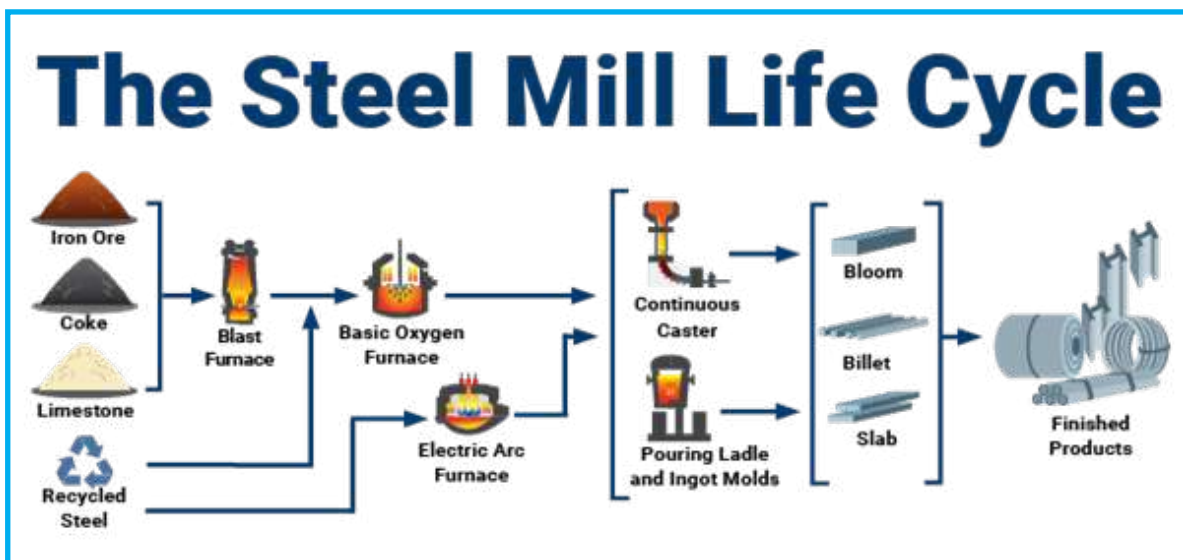
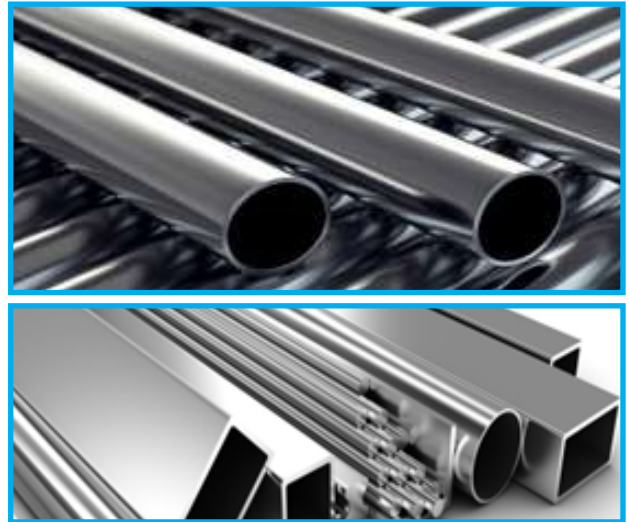


Fig: Steel Pipe and manufacturing process of steel pipe

■ Manufacturing Process

■ Process:

1. Raw Materials and Ironmaking:

- **Iron Ore:** The primary raw material is iron ore, a mineral containing iron oxides and other impurities.
- **Coke:** Coke, produced from coal, is a high-carbon fuel used in the blast furnace.
- **Limestone:** Limestone acts as a flux, helping to remove impurities from the iron ore.

2. Blast Furnace (BF) Process (BF-BOF route):

- The blast furnace is a tall, vertical structure where iron ore, coke, and limestone are mixed and heated at very high temperatures at around 1600 °C
- The coke burns, reducing the iron oxide and forming molten iron, known as “hot metal” or “pig iron”.
- The impurities (slag) are separated and discarded.

3. Basic Oxygen Furnace (BOF) Process (BF-BOF route):

- The hot metal from the blast furnace is then refined in the Basic Oxygen Furnace (BOF).
- A large volume of molten pig iron, scrap steel, and oxygen is introduced into the BOF.
- The oxygen reacts with carbon and other impurities in the hot metal, converting them into gases that are removed.
- Alloying elements (like manganese, nickel, or chromium) may be added to achieve the desired steel grade.



Fig: Scrap iron is melted at furnace at around 1600/1600 °C for 1 to 2 Hour



Fig: Molten Iron is inserted in ventilated chamber container exhaust fans activated to manage fumes and draws out the smoke produced during melting process and as the metal melts impurities within the molten rise to the surface and form a layer

4. Electric Arc Furnace (EAF) Process:

- The EAF process uses electric arcs to melt steel scrap.
- The furnace is charged with steel scrap, and electric arcs between electrodes provide the heat.
- Fluxes are added to remove impurities, forming slag that is separated from the molten steel.
- Alloying elements can also be added to achieve desired steel compositions.

5. Further Processing:

- After refining, the molten steel is cast into various forms, such as ingots, slabs, or billets.
- These are then rolled, forged, or otherwise shaped into the desired steel products.
- Various treatments like heat treatment and surface treatments may be applied to enhance the steel's properties.
 - * Rolled or welded from steel coils.
 - * Pipes may be formed by seamless or welded processes.

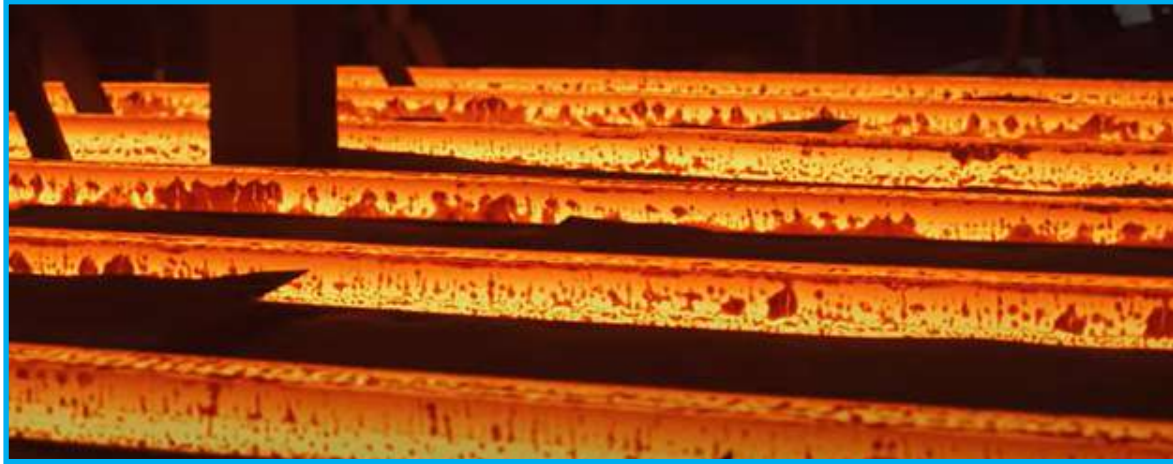


Fig: Molten Steel is solidified

- **Finishing:** Often coated (painted or galvanized) to enhance corrosion resistance.



Fig: Molten Steel is cooled and converted into various shapes by rollers

■ Advantages and Disadvantages

- **Strength & Durability:** Good tensile strength and ductility; weldable.
- **Longevity:** Requires protective coating to prevent rust.
- **Efficiency:** Suitable for a variety of pressures and temperatures.
- **Transportability:** Moderate weight; easier to handle compared to GI or DI.
- **Cost:** Generally economical, especially in low-pressure applications.
- **Disadvantages:** Prone to corrosion if coatings are compromised, and may have a shorter lifespan in aggressive environments.

■ Causes of Defects/Deterioration & Identification

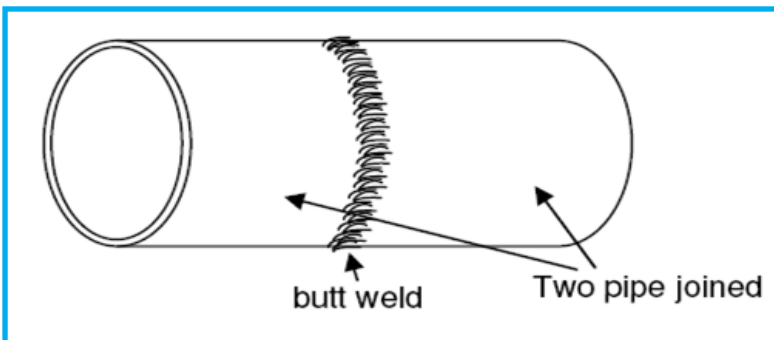
- **Physical Causes:** Mechanical dents, weld defects, or deformation from improper handling.
- **Chemical Causes:** Rust formation due to exposure to moisture and chemicals.
- **Identification:**
 - * **Visually:** Look for rust, pitting, and surface irregularities.
 - * **Mechanically:** Use ultrasonic testing or magnetic particle inspection to check weld quality and thickness.

■ Preventive Measures

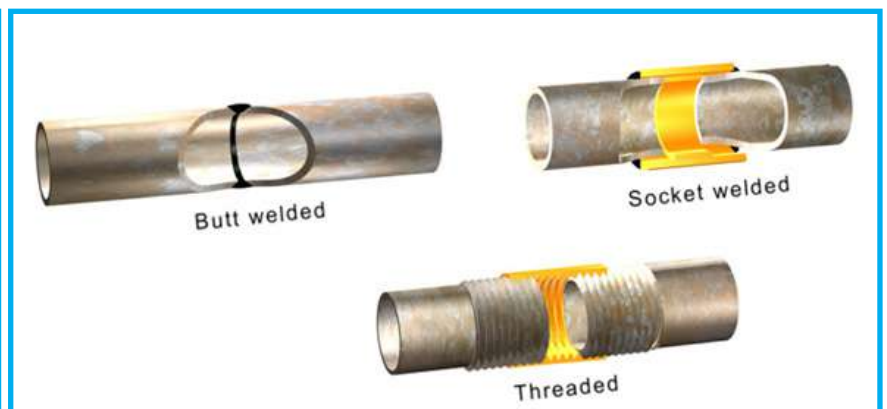
- **Coatings:** Use proper painting, galvanizing, or other protective layers.
- **Installation:** Follow best practices for welding and joint design.
- **Maintenance:** Regular inspections and timely repair of any coating damage.
- **Storage:** Keep in dry, covered environments prior to installation.

■ Methods of Jointing

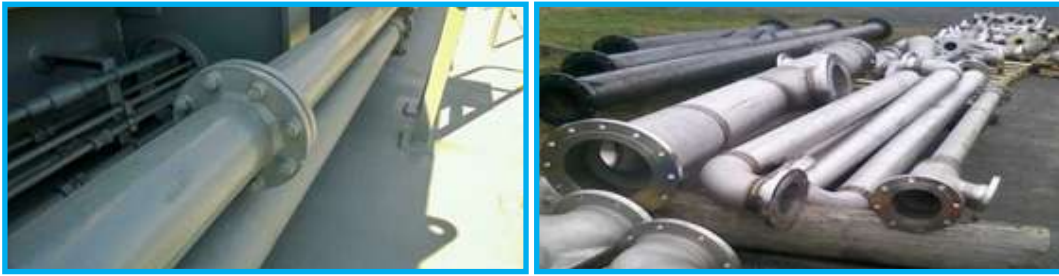
- **Welding (Butt/Socket):** Standard for most MS pipe connections.



- **Screwed/Threaded Joint:** For smaller diameters, sealed with thread compound or PTFE tape.

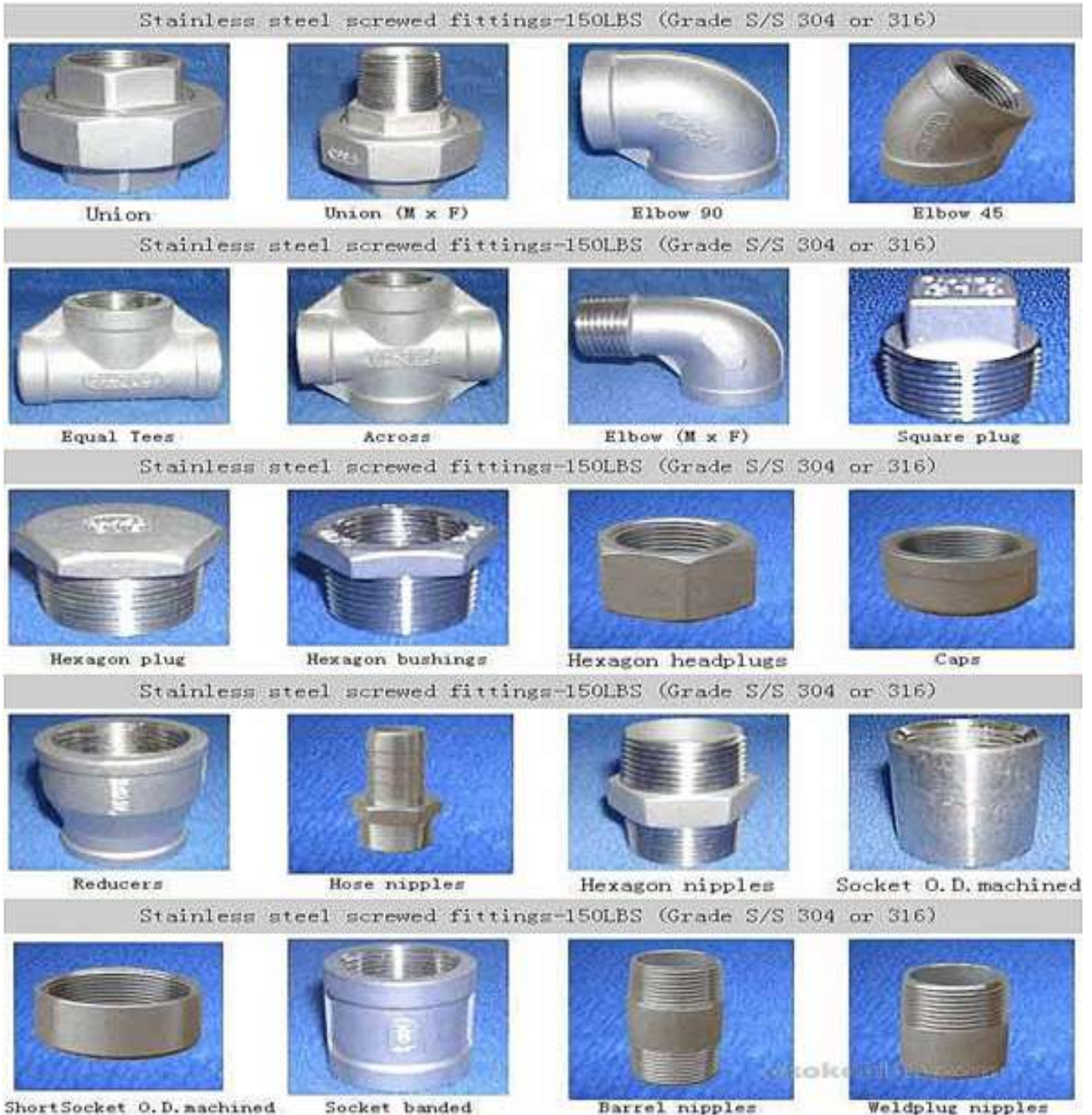


- **Flanged Joint:** Common in industrial piping, with gaskets and bolts.



■ **Common Appliances/Accessories**

- Bends and elbows, Reducers, Expansion bellows, Flange adaptors, Air release valves, Y-strainers, Valves (globe, gate, butterfly), Sight glasses.



Comparison of various types of Metallic Pipes

Aspect	Galvanized Steel	Stainless Steel	Galvanized Iron (GI)	Mild Steel	Cast Iron	Ductile Iron	Wrought Iron
Manufacturing	Carbon steel is dipped in molten zinc to form a protective zinc coating.	Alloy of steel with at least 10.5% chromium.	Typically mild steel or pure iron coated with zinc, usually via hot-dip galvanizing.	Produced by reducing iron ore and carbon, then forming and shaping.	Produced by melting pig iron with scrap iron and pouring into Molds.	Made by adding nodular graphite to cast iron to improve ductility.	Low carbon iron produced using puddling and forging, rarely used today.
Corrosion Resistance	Zinc coating acts as a sacrificial barrier; protects steel even if scratched.	Chromium forms a self-healing passive layer that resists rust and corrosion.	Zinc coating offers corrosion resistance but is less durable than stainless steel.	Poor corrosion resistance; needs painting or galvanizing.	Good in compressive corrosion; poor in tensile or moist conditions.	Better than cast iron; can be coated for improved resistance.	Moderate corrosion resistance; better than mild steel but lower than stainless steel.
Durability	Zinc coating can wear off over time, exposing steel to corrosion.	Extremely durable, retains corrosion resistance even in harsh environments.	Less durable than stainless steel; zinc layer wears down with time and exposure.	Durable when protected; vulnerable to rust otherwise.	Brittle and prone to cracking; good under compression.	Highly durable; resists impact and pressure well.	Durable, malleable, and tough; used historically in decorative work.
Strength	Depends on the carbon steel base; generally stronger than GI.	High strength due to alloying elements; maintains integrity under stress.	Lower strength compared to galvanized steel; based on mild steel or pure iron.	Moderate strength; used in general construction.	High compressive strength; low tensile strength.	High tensile and compressive strength.	Moderate tensile strength; very malleable.
Tensile strength (MPa)	~300–550 MPa	~500–750 MPa	~250–400 MPa	~400–550 MPa	~150–200 MPa	~420–550 MPa	~250–300 MPa
Brittleness	Low to moderate	Very low	Moderate	Low	High (brittle)	Low	Very low
Cost (Pipe per Piece)	₹700–₹1,000	₹2,000–₹2,500	₹700–₹900	₹600–₹900	₹800–₹1,100	₹900–₹1,300	₹1,500+

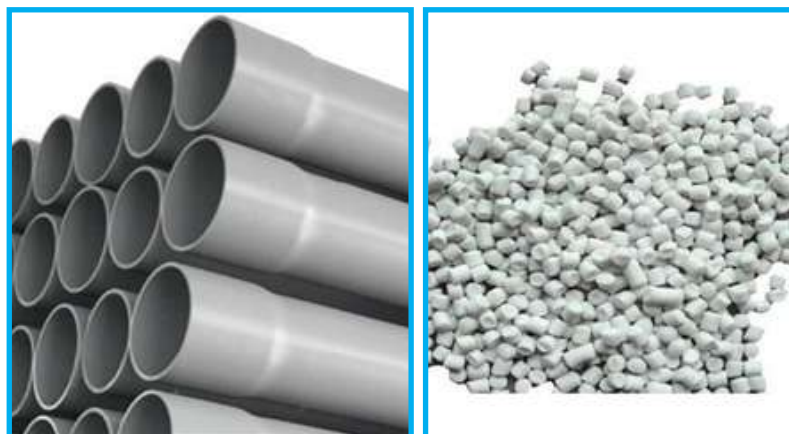


Aspect	Galvanized Steel	Stainless Steel	Galvanized Iron (GI)	Mild Steel	Cast Iron	Ductile Iron	Wrought Iron
Cost (Per Quintal)	₹6,000– ₹6,500	₹16,000– ₹18,000	₹6,000– ₹6,500	₹5,000– ₹6,000	₹4,000– ₹5,000	₹5,000– ₹6,000	₹7,000– ₹8,000
Applications	Used in construction, fencing, structural parts, HVAC ducts, etc.	Used in medical, marine, chemical, and food-grade applications.	Common in roofing sheets, pipes, water tanks, rural construction, and general utility items.	Widely used in construction, automotive, pipes, furniture.	Drainage, manhole covers, engine blocks, machine bases.	Water mains, sewer lines, pressure pipelines, industrial fittings.	Gates, railings, historical structures, ornamental pieces.

8.6 PVC (Polyvinyl Chloride) Pipes

Raw Material and Composition

- Materials:** Made from PVC resin mixed with additives such as stabilizers, plasticizers (if needed), and pigments. PVC pipes are manufactured through an extrusion process where raw PVC material is fed into a twin-screw extruder, melted, and then extruded through a die to form the pipe shape, which is then cooled and cut to the desired length
- Properties:** Rigid formulation designed for plumbing and drainage applications.



Manufacturing Process

Process:

1. Raw Material Preparation:

- PVC powder or pellets are mixed with additives in a mixing machine, then fed into the twin-screw extruder.



Fig: Raw materials are placed into the machine after filtration

2. Melting and Heating:

- The extruder melts and heats the raw material in multiple zones, ensuring it's ready to be shaped.



Fig: Extruder Machine

3. Extrusion:

- The molten material is forced through a die, which gives it the desired circular shape and wall thickness.

4. Cooling:

- The extruded pipe is cooled, typically with a water-cooling system, to solidify the PVC and maintain its shape.



Fig: Pipe is cooled here by spraying water

5. Cutting and Finishing:

- The pipe is then cut to the desired length and may undergo additional finishing processes, such as printing or packaging.



Fig: Size and shape are given by the machine

- * Manufactured by an extrusion process where the PVC compound is melted and forced through a die.
- * Pipes are cooled in a water bath and then cut to length.
- **Finishing:** May include surface texturing or markings for installation.



Fig: Pipe is cut and socket made and printed by the machine



■ Advantages and Disadvantages

- **Strength & Durability:** Good chemical resistance and rigidity for most water applications.
- **Longevity:** Long service life if installed and maintained properly.
- **Efficiency:** Smooth internal surfaces aid in low-friction fluid transport.
- **Transportability:** Lightweight and easy to handle.
- **Cost:** Low-cost relative to metallic pipes.
- **Disadvantages:**
 - * Lower temperature resistance (may soften in high heat).
 - * Can become brittle in cold temperatures.
 - * Environmental concerns regarding plastic additives over time.

■ Causes of Defects/Deterioration & Identification

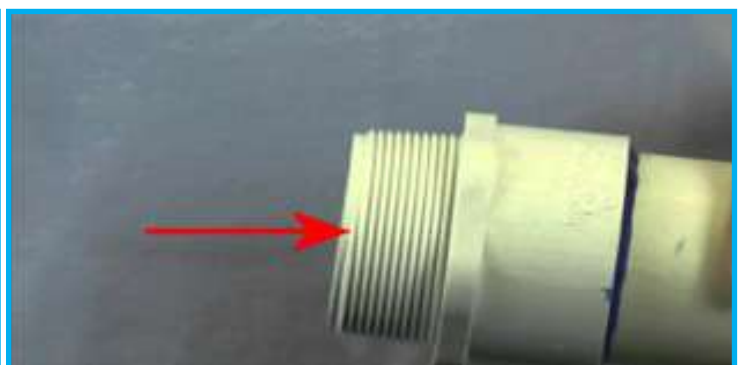
- **Physical Causes:** Overloading, bending stresses, or impacts leading to cracks or warping.
- **Chemical Causes:** UV degradation (if not formulated with stabilizers) or attack by incompatible chemicals.
- **Identification:**
 - * Visually: Check for cracks, warping, discoloration, or surface irregularities.
 - * Mechanically: Dimensional inspections and pressure tests can reveal weaknesses.

■ Preventive Measures

- **Additives:** Incorporate UV inhibitors and heat stabilizers during production.
- **Installation:** Follow guidelines to avoid stress concentrations and improper bending.
- **Maintenance:** Regular inspection and cleaning to remove deposits that might lead to degradation.
- **Storage:** Protect from prolonged direct sunlight exposure before installation.

■ Methods of Joining

- **Solvent Cement Joint:** Adhesive (solvent) softens and fuses pipe and fitting.
- **Rubber Ring/Sleeve Joint:** Used for sewer lines; allows flexibility.
- **Threaded Joint (less common):** For connections with valves or other equipment.



■ Common Appliances/Accessories

- Couplings, Elbows, Tees, Reducers, End Caps, unions, Valves (Ball, Check), Vent Cocks etc.



8.7 PPR Pipes

■ Raw Material and Composition

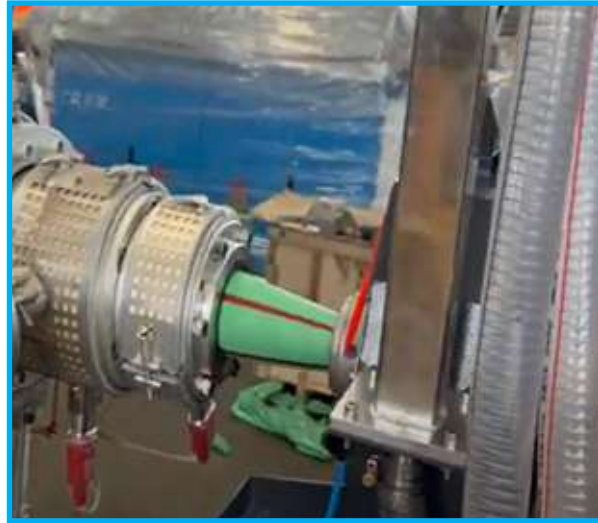
- **Materials:**
 - * Made from polypropylene random copolymer resins that may include color pigments and stabilizers.
 - * Formulated without plasticizers, yielding a ductile yet robust material
 - * PPR pipes are manufactured through an extrusion process where heated Polypropylene Random Copolymer (PPR) material is forced through a die, forming the pipe's shape and internal diameter. The material is typically pre-mixed with other ingredients, heated to a molten state, and then extruded into the desired pipe profile. Fittings are often created through a molding process.
- **Properties:**
 - * Exhibits good chemical resistance, temperature tolerance, and a degree of flexibility.
 - * Ideal for both hot and cold water applications due to its controlled expansion and contraction properties.



■ Manufacturing Process

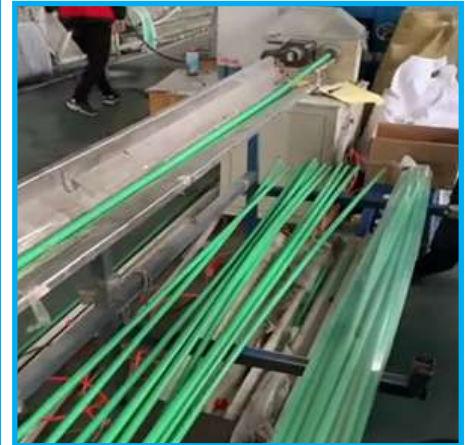
• Extrusion Process:

- * Manufactured by a continuous extrusion process that shapes the piping with smooth inner surfaces.
- * Consistent diameter control and wall thickness are achieved through precision extrusion lines.



• Quality Assurance and Finishing:

- * Pipes are often subject to quality controls that test physical dimensions, pressure ratings, and surface uniformity.
- * Finishing processes result in smooth exteriors, ensuring aesthetic appeal and reducing friction losses.



- **Fittings Production:** Fittings are produced using a similar extrusion or injection molding process, specifically designed for fusion welding applications.

■ Advantages and Disadvantages

• Advantages:

- **Chemical and Thermal Resistance:** Resistant to a wide range of chemicals and can handle high-temperature water (up to 75°C or above in some grades).
- **Longevity and Low Maintenance:** Extremely durable with minimal degradation over extended periods when installed and maintained properly.
- **Smooth Flow Characteristics:** The smooth inner surface contributes to efficient flow, reducing energy losses and turbulence.
- **Environmental Benefits:** Being fully recyclable, PPR pipes are considered environmentally friendlier compared to some other alternatives.
- **Ease of Fusion:** Allow for strong, homogeneous joints that become part of the pipeline structure.

- **Disadvantages:**
- **Cost:** Generally, more expensive than some alternatives (e.g., CPVC or basic PVC) due to material and production costs.
- **Handling Sensitivity:** Although inherently flexible, improper handling (especially during joining) can lead to cracking or incomplete fusion joints.
- **Brittleness Under Extreme Conditions:** Exposure to severe low temperatures or inappropriate installation conditions may reduce impact resistance.

■ Causes of Defects/Deterioration & Identification

• Physical Causes:

- **Stress Cracking:** Can occur from improper handling, excessive bending, or repeated mechanical shocks.
- **Improper Fusion:** Defects in joining methods can create weak points or micro-cracks along the joint area.

• Chemical Causes:

- **UV Degradation:** Prolonged exposure to sunlight can lead to surface embrittlement if not adequately protected.
- **Chemical Attack:** Exposure to aggressive chemicals not compatible with PPR, though this is less common in potable water applications.

• Identification of Defects:

- **Visual Inspection:** Look for fine cracks, discoloration, or chips on the surface. Defective fusion joints often show irregular, non-homogeneous bonding.
- **Mechanical Testing:** Impact and tensile tests can be conducted on sample sections or joints to assess mechanical integrity.
- **Leak Detection:** In-service leaks at joints or along the pipe length may indicate deterioration or defect presence.

■ Preventive Measures

• Handling and Installation:

- * Ensure careful transport and installation to avoid mechanical impacts or bending beyond allowable limits.
- * Adhere closely to manufacturer guidelines regarding allowable bending radii and handling precautions.

• UV and Environmental Protection:

- * Use UV-resistant coatings or protective sleeves in outdoor installations.
- * Store pipes away from direct sunlight before installation to minimize premature degradation.

• Quality Control During Installation:

- Employ rigorous on-site inspections during the fusion process to confirm that joints are being made at correct temperatures and pressures.
- Train installers in proper fusion techniques to minimize the risk of defects.

- **Regular Maintenance:** Inspect pipelines periodically for early signs of cracking or joint failure, and address minor defects before they propagate.

■ Methods of Joints and Fittings

- PPR pipe connections are predominantly achieved through fusion welding techniques, ensuring a continuous, homogeneous joint that functions as a single piece of piping. The two principal methods are:

1. Butt Fusion Welding



- **Process:**
 - * Involves heating the ends of two PPR pipes or a pipe and a fitting until the material reaches a molten state.
 - * The heated ends are then pressed together under controlled pressure, forming a seamless joint once cooled.
- **Advantages:**
 - * Creates joints with strength equivalent to the pipe itself.
 - * Ideal for long, straight runs of piping where alignment is easy to maintain.
- **Quality Checks:**
 - * Must ensure proper heating time, uniform temperature, and correct alignment during fusion.

2. Socket (or Socket Fusion) Welding



- **Process:**
 - * One end of the pipe is heated, and then inserted into the socket of a matching fitting that has also been heated.
 - * The interface is held together to form a fusion bond upon cooling.
- **Advantages:**
 - * Particularly useful for joining pipes to fittings (such as elbows, tees, and reducers) where precise dimensional tolerances are required.
 - * The method simplifies the installation of branch connections.
- **Considerations:**
 - * Requires specialized equipment to uniformly heat the socket and pipe end.
 - * Alignment and proper insertion depth are critical to ensure a leak-proof bond.

3. Alternative Mechanical Fittings

- **Mechanical (or Press) Fittings:**
 - * In scenarios where fusion is not practical (for instance, during repairs or transitional modifications), mechanical fittings that use seals, gaskets, and compression rings are available.
 - * These provide a temporary or semi-permanent solution but often do not match the homogeneous strength of fused joints.



- **Application Considerations:**

- * Typically used for connecting PPR to other materials or for installations where fusion welding equipment is unavailable.
- * Should only be used according to manufacturer specifications and within approved pressure ratings.

- **Common Appliances/Accessories**

- **Elbows**

- **Purpose:** Change the direction of the pipe run—typically by 45° or 70°.
- **Characteristics:**
 - * Manufactured with smooth curves to maintain flow efficiency and minimize turbulence.
 - * Available in different radii (short radius for compact spaces or long radius for gradual turns).
- **Application:** Ideal for routing around obstacles and adapting to architectural layouts.



- **Tees**

- **Purpose:** Provide a branch connection for joining three pipes, forming a T-shaped configuration.
- **Characteristics:**
 - * Consist of a main run and a branch, with precise internal geometries to ensure a smooth transition.
 - * Designed to produce minimal pressure drop when connected via socket fusion.
- **Application:** Commonly used in plumbing and heating systems where water distribution is required.



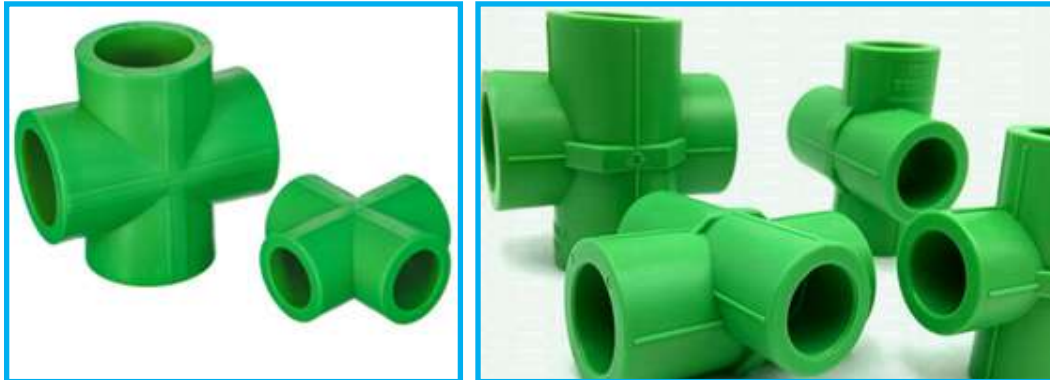
- **Reducers and Increases**

- **Purpose:** Change the pipe diameter between sections of piping.
- **Characteristics:**
 - * Reducers: Transition from a larger pipe to a smaller pipe.
 - * Increases: Transition from a smaller pipe to a larger pipe.
 - * Manufactured to ensure a smooth, seamless change in flow area without sudden turbulence.
- **Application:** Useful in systems where the pipe diameter is adjusted to control the flow rate or to accommodate different fittings.



■ Crosses

- **Purpose:** Join four branches at a common central point, forming a cross shape.
- **Characteristics:**
 - * Provide balanced distribution of flow among the four connected pipes.
 - * Require careful installation to maintain alignment and integrity of each branch.
- **Application:** Typically used in complex networks or systems where multiple branch connections are needed from a central manifold.



■ Couplings and Sleeves

- **Purpose:** Connect two pipes in a straight line or join pipe sections where fusion welding may be impractical.
- **Characteristics:**
 - * Often used as a bridging element in cases of minor adjustments or temporary repairs.
 - * Ensure that the connection maintains the homogeneity of the system, sometimes relying on mechanical pressure fittings.
- **Application:** Useful in minor repairs or transitional applications where a conventional fusion joint isn't feasible.



■ End Caps and Plugs

- **Purpose:** Seal off the end of a pipe system to prevent leakage or contamination.
- **Characteristics:**
 - * Designed to attach securely through fusion or mechanical locking.
 - * Ensure a uniform surface and prevent ingress of foreign materials.
- **Application:** Common in dead-end sections of water or heating systems.



■ **Specialty Fittings**

- **Branching Fittings:** Designed for specific applications requiring more than one branch connection (e.g., reducing tees, or multiple branch fittings for water distribution).



- **Adapters:** Used to connect PPR piping to other piping systems (such as metal or CPVC) through a transition method, ensuring compatibility between different materials.



- **Valves and Controls:** Although not traditional “fittings” per se, valves and control devices are integrated into PPR systems and are designed for fusion connection to maintain system integrity.

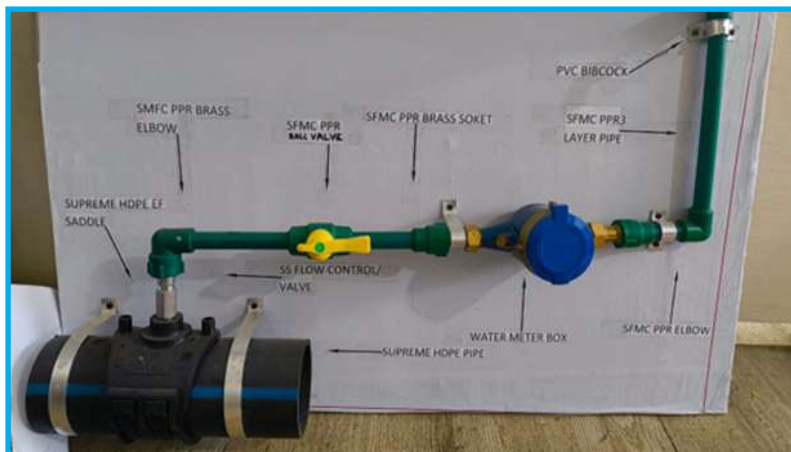


Fig: PPR Pipe fitting with saddle piece and flow control valve to HDPE Pipe

8.8 CPVC (Chlorinated Polyvinyl Chloride) Pipes

■ Raw Material and Composition

- **Materials:** Made from PVC resin that has been chlorinated, with stabilizers and other additives.
- **Properties:** Higher chlorine content gives increased temperature and chemical resistance compared to standard PVC.
- CPVC pipes are manufactured through a chlorination process starting with PVC resin. This process involves reacting PVC with chlorine, typically using a water slurry or fluidized bed, and initiating the reaction with ultraviolet light. The resulting chlorinated PVC is then compounded with additives for desired properties before being extruded into pipes.



■ Manufacturing Process

- **Process:**

1. Raw Materials:

CPVC production begins with polyvinyl chloride (PVC) resin, which is then treated with chlorine.



2. Chlorination:

The PVC resin is reacted with chlorine, usually in a water slurry or fluidized bed. This reaction replaces hydrogen atoms in the PVC with chlorine atoms.

3. Reaction Initiation:

The chlorination process is initiated by ultraviolet light or other thermal or UV energy.

4. Compounding:

After chlorination, the CPVC is mixed with additives like stabilizers, processing aids, and colorants to achieve the desired properties and processing characteristics.

5. Extrusion: The compounded CPVC is then extruded into pipes, fittings, and other shapes using specialized equipment.

* Similar extrusion process to PVC but with formulations requiring stricter temperature control.

* Cooling and cutting to specification.

- **Finishing:** Surface treatments may be applied to enhance UV resistance.

■ Advantages and Disadvantages

• Strength & Durability:

* Better performance at higher temperatures.

* Good chemical resistance and strength.

• **Longevity:** Longer lifespan in hot water applications.

• **Efficiency:** Maintains smooth internal surfaces even under thermal stress.

• **Transportability:** Relatively lightweight.

• **Cost:** Generally more expensive than standard PVC.

• Disadvantages:

* More prone to brittleness in colder climates.

* Higher material cost can affect project budgets.

■ Causes of Defects/Deterioration & Identification

• **Physical Causes:** Thermal stresses, improper bending, or installation leading to cracks.

• **Chemical Causes:** Exposure to aggressive chemicals that can attack the polymer matrix.

• Identification:

* Visually: Look for stress cracks, warping, or discoloration.

* Mechanically: Pressure tests and impact tests can help detect early failure signs.

■ Preventive Measures

• **Temperature Control:** Avoid exposing CPVC to rapid temperature fluctuations.

• **Installation:** Use proper bending radii and support methods.

• **Maintenance:** Regular inspection and cleaning to remove chemical residues.

• **UV Protection:** When used outdoors, apply UV-protective coatings or covers.

■ Methods of Jointing

• **Solvent Cement Joint:** Special CPVC solvent for chemical bonding.

• **Threaded Joints:** Common at the ends of systems for valves and taps.

• **Flanged Joints:** Used in industrial CPVC piping.

■ Common Appliances/Accessories

- CPVC elbows and bends
- Tees and crosses
- Adapters (male/female threaded)
- Union fittings
- Valves (CPVC ball and gate valves)
- End caps
- Transition fittings (metal to CPVC)

