CENTRAL POLYTECHINIC COLLEGE

THARAMANI, CHENNAI

Regulation 2023

1122 Diploma in Fire Technology and Safety

Fire Safety and Fighting Practicum - Manual

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Course Objectives:

The objective of this course is to enable the student to

- Successfully extinguish fires with the use of a fire extinguisher.
- Apply the theory of the fire triangle in preventing fires at work sites.
- Understand the behaviour of fire during its propagation.
- Installation of Fire detection and warning systems
- Communication with employees and others on the premises

Course Outcomes:

On successful completion of this course, the student will be able to

CO1: Identify and select controlling elements.

CO2: Study about the earthing, resistance for motors and cables.

CO3: Prepare the personal protective equipment.

CO4: Explore the performance of single-phase circuit.

CO5: Prepare the relays, conductors, push buttons and limit switch.

UNIT 1 INTRODUCTION

Chemistry of fire, Fire Tetrahedran Spreading methods of fire, Types of flammable fuels & their symbols, Methods of fire Extinguishing, type of fire Extinguishers & their uses, Details about Water Tender, Water Pumps, Ladders, Nozzels, Ropes, Hoses, Risers, Fire Suits, Fire Couplings.

UNIT 2 EMERGENCY PLAN

Manual Call-Point, Fire Alarm, Automatic Fire Alarm, Gas Flooding System, Sensors & Detectors, Philosophy of accident, Causes of accidents & Safety Measures, Do's & Don'ts while major fire & gas leaks. On - site & Off - site Emergency Plan, Plant Layout, Handling & Storage of materials, Safe methods of handling LPG cylinder,Do's & Don'ts in case of LPG Leaks, Personal Protective Equipment & their uses.

List of the Experiments

1. Determination of calorific value of substance.
2. Determination of Fire Load in a Building /facility.
3. Determination of fire Triangle and Principle of fire extinction.
4. Basic fire Fighting using portable Dry Chemical Power fire extinguishers.
5. Basic Firefighting using portable CO2 fire extinguishers.
6. Reading and Demonstration Fire excavation plan.
7. Demonstration on the working of smoke, Beam and Flame detectors.
8. Demonstration of fire hydrant system and dry riser system in a building.
9. Demonstration of personal Protective Equipment used for firefighting.

THEORY

UNIT 1 INTRODUCTION

Chemistry of Fire

1. Introduction

Fire is a rapid chemical reaction known as combustion. It occurs when a fuel combines chemically with oxygen from the air, releasing heat, light, smoke, and various gases.

2. The Fire Triangle

For a fire to start and continue burning, **three basic elements must be present at the same time**. If any one of these elements is removed, the fire will go out.

- **Fuel:** Any combustible material (Solid, Liquid, or Gas) that can catch fire (e.g., wood, petrol, LPG).
- **Oxygen:** The gas present in the air (approx. 21%) that supports the combustion process.
- **Heat:** The energy required to raise the temperature of the fuel to its ignition point to start the fire.

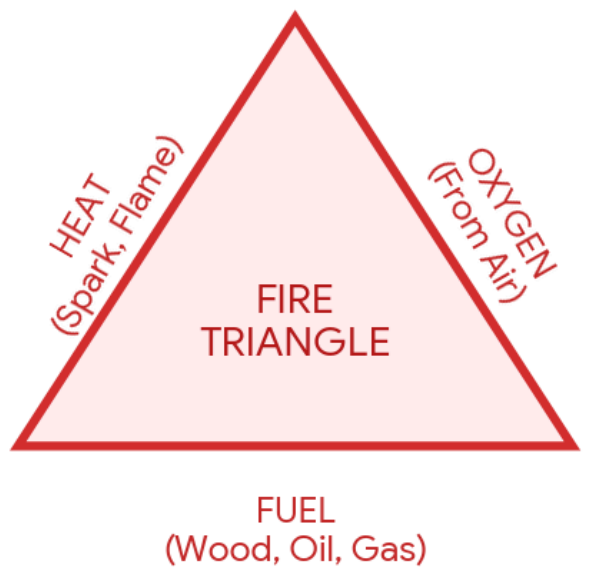


Figure 1: The Fire Triangle (Students can draw this simple triangle in their records).

The Fire Tetrahedron

While the fire triangle explains how a fire starts, advanced science shows that a fourth element is needed to keep the fire going continuously. This creates a 3D pyramid shape called the **Fire Tetrahedron**.

- **Chemical Chain Reaction:** When fuel burns, it releases unstable molecules called free radicals. These radicals react with oxygen to produce more heat, which breaks down more fuel. This self-sustaining loop is the chemical chain reaction.

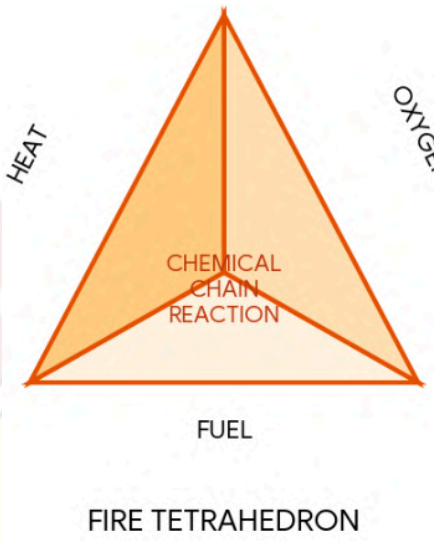


Figure 2: The Fire Tetrahedron (Students can draw this simple pyramid structure in their records).

4. Key Takeaways for Fire Extinguishment

Based on the chemistry of fire, a fire can be put out by eliminating any of the four components:

1. **Starvation (Removing Fuel):** Shutting off a gas valve or clearing away wood.
2. **Smothering (Removing Oxygen):** Covering the fire with a fire blanket or carbon dioxide (CO_2).
3. **Cooling (Removing Heat):** Pouring water to lower the temperature below the ignition point.
4. **Interruption (Breaking the Chain Reaction):** Using Dry Chemical Powder (DCP) extinguishers to stop the chemical reactions.

<u>Spreading Methods of Fire</u>

1. Introduction

Once a fire starts, it naturally seeks to expand by transferring heat energy to surrounding objects. If heat transfers to nearby fuel, that fuel reaches its ignition temperature, causing the fire to expand.

Heat travels from hotter areas to cooler areas through **three main methods**: **Conduction**, **Convection**, and **Radiation**. A fourth method in buildings is **Direct Burning**.

2. Methods of Heat Transfer & Fire Spread

A. Conduction (Spread through Solids)

- **Definition:** The transfer of heat through a solid material from molecule to molecule.
- **Mechanism:** When one end of a metal object (like a steel beam or pipe) is heated by fire, the heat travels along the material. If the other end touches combustible materials (like wood or plastic) in another room, those materials will catch fire.
- **Example:** A metal pipe passing through a wall gets hot and ignites wooden studs on the other side.

B. Convection (Spread through Liquids and Gases)

- **Definition:** The transfer of heat through the movement of hot air, smoke, and gases.
- **Mechanism:** Hot air and smoke expand, become lighter, and rise upwards. In a building, these hot gases travel up stairwells, lift shafts, and ceiling spaces. They accumulate at the top, heating up and igniting materials far away from the original fire.
- **Example:** A fire on the ground floor quickly spreads to the top floor via an open stairwell.

C. Radiation (Spread through Electromagnetic Waves)

- **Definition:** The transfer of heat through space by electromagnetic waves, without needing a physical medium.
- **Mechanism:** Just like the sun heats the earth, a large fire radiates heat outwards in straight lines. This heat passes through air or windows until it hits a solid object. If the object absorbs enough radiant heat, it ignites.
- **Example:** A burning building radiates enough heat across a street to break windows and ignite curtains in the building opposite.

D. Direct Burning

- **Definition:** The simplest form of fire spread where the flame directly touches an unburnt fuel source.
- **Example:** A candle flame directly catching the edge of a curtain.

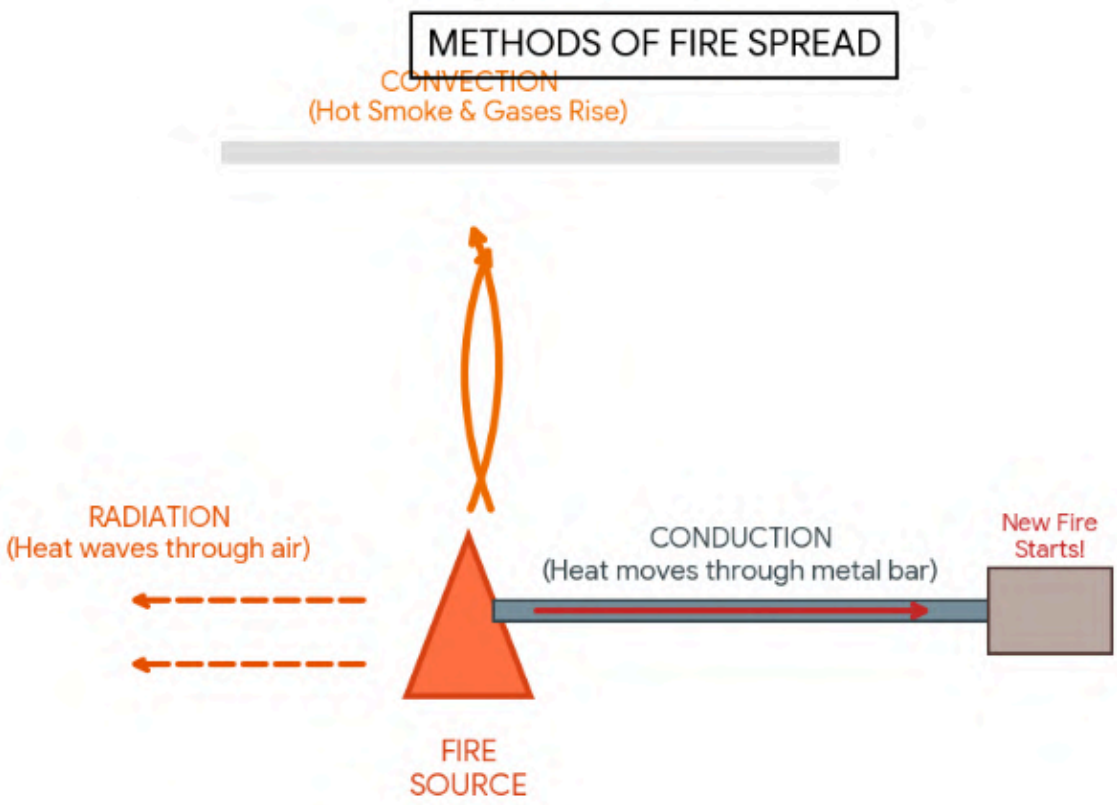


Figure 1: Comprehensive sketch showing Conduction, Convection, and Radiation mechanisms.

<u>Types of Flammable Fuels & Their Symbols</u>

1. Introduction

Fuels come in different physical forms: **Solids, Liquids, and Gases**. Understanding the type of fuel involved is critical because each type burns differently and requires a specific type of fire extinguisher.

To help fire safety teams quickly identify hazards, standardized global safety symbols and **Fire Class Letters** are used.

2. Classification of Flammable Fuels

- **Class A: Ordinary Combustibles (Solids)**
  - **Description:** Carbon-based solid materials that leave behind ash when burned.
  - **Examples:** Wood, paper, cloth, rubber, and plastics.
- **Class B: Flammable Liquids**
  - **Description:** Liquids or liquefiable solids that vaporize easily and catch fire. They do not mix with water easily.

    - **Examples:** Petrol, diesel, kerosene, oil-based paints, and solvents.
- **Class C: Flammable Gases**
    - **Description:** Gases that can form an explosive mixture when mixed with oxygen in the air.
    - **Examples:** LPG (Liquefied Petroleum Gas), CNG, methane, and butane.
- **Class D: Combustible Metals**
    - **Description:** Highly reactive alkaline or alkaline-earth metals that burn at extremely high temperatures.
    - **Examples:** Magnesium, titanium, sodium, and potassium.
- **Class F / K: Kitchen Fats and Cooking Oils**
    - **Description:** High-temperature commercial cooking oils and animal fats used in deep fryers.
    - **Examples:** Vegetable oils, sunflower oil, ghee, and lard.
- **Electrical Fires (Unclassified / Class E):**
    - Fires involving **live electrical equipment** (computers, motors, wiring). *Note: Electricity itself is not a fuel, but it acts as the heat source causing surrounding materials to burn.*

3. Fuel Types and Standardized Safety Symbols

Students can draw this highly scannable reference table in their record books. It pairs each fuel type with its respective safety symbol design.

Fuel Class	Fuel Type / State	Standard Icon Symbol Description
Class A	Ordinary Solids (Wood, Paper)	A burning trash can and a pile of burning wood logs
Class B	Flammable Liquids (Petrol, Oil)	A tilted fuel canister/jerrycan pouring out liquid into a puddle of fire
Class C	Flammable Gases (LPG, CNG)	A gas cylinder/tank engulfed in flames
Class D	Combustible Metals (Magnesium)	A burning gear mechanism or metal rod
Class F / K	Cooking Media (Fats, Ghee)	A deep frying pan catching fire

Electrical	Live Appliances (Motors, Wires)	An electrical plug or socket sparked by a lightning bolt



Figure 1: Standardized classification codes used globally for marking fire hazards and equipment.

Methods of Fire Extinguishing

1. Introduction

Extinguishing a fire is based entirely on breaking the **Fire Triangle** or the **Fire Tetrahedron**. If any one of the essential components (Fuel, Heat, Oxygen, or the Chemical Chain Reaction) is removed or interrupted, the fire will instantly go out.

There are **four fundamental physical methods** used to extinguish fires.

2. The Four Methods of Extinguishing

A. Cooling (Removing Heat)

- **Principle:** Lowering the temperature of the burning material below its ignition point.

- **Mechanism:** Water is the most common agent used for cooling. When water is sprayed onto a fire, it absorbs a massive amount of heat energy and turns into steam, cooling the fuel down until it can no longer burn.
- **Best Used For:** Class A fires (Wood, paper, textiles). *Never use water on electrical or oil fires.*

B. Smothering (Removing Oxygen)

- **Principle:** Cutting off or reducing the oxygen supply surrounding the fire.
- **Mechanism:** If the oxygen concentration in the air falls below 16% (from the normal 21%), most fires cannot survive. This is achieved by blanketing the fire with a non-combustible gas like Carbon Dioxide (CO_2), foam, or a physical fire blanket.
- **Best Used For:** Class B fires (Flammable liquids like petrol) and kitchen fires.

C. Starvation (Removing Fuel)

- **Principle:** Isolating or removing the unburnt fuel from the path of the fire.
- **Mechanism:** Without fuel, a fire has nothing left to consume and dies naturally. This can be done by shutting off gas pipelines, removing gas cylinders from a burning room, or creating a "firebreak" (clearing vegetation) in forest fires.
- **Best Used For:** Class C fires (Gas leaks) and bulk storage fires.

D. Interruption / Inhibition (Breaking the Chain Reaction)

- **Principle:** Chemically stopping the rapid molecular chain reaction that keeps a fire alive.
- **Mechanism:** Extinguishing agents like Dry Chemical Powder (DCP) or Halon alternatives are sprayed into the flame zone. These chemicals react with the free radicals in the flame, absorbing them and breaking the flame combustion loop even while heat and oxygen are still present.
- **Best Used For:** Electrical fires, Class B, and Class C fires.

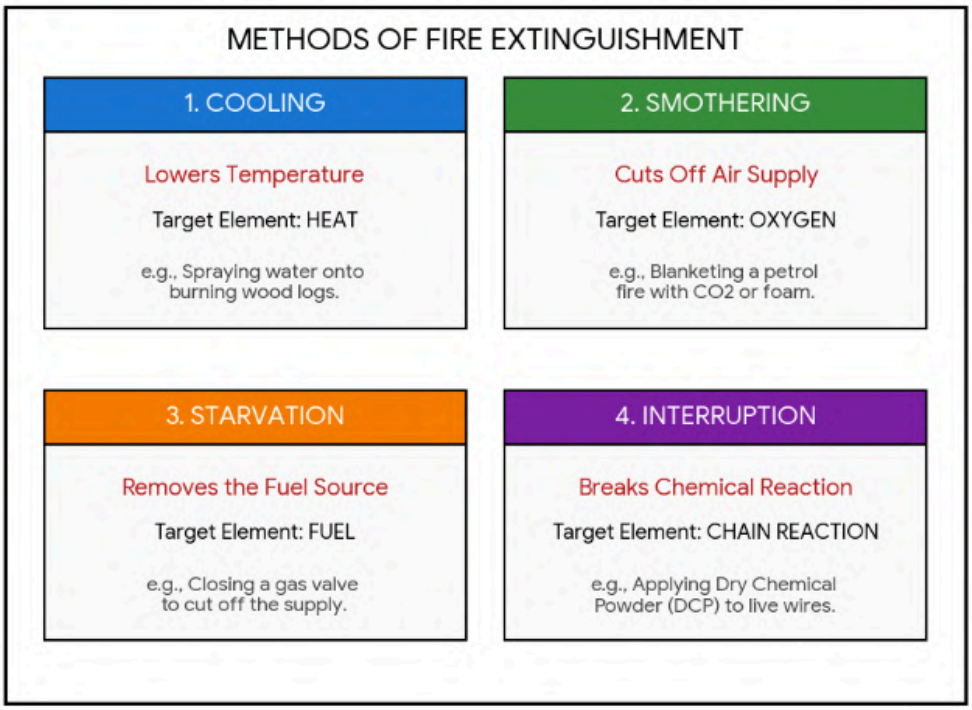


Figure 1: Quad layout of fire extinguishing mechanisms for easy record-book reproduction.

Types of Fire Extinguishers & Their Uses

1. Introduction

No single type of fire extinguisher can be used on every kind of fire. Using the wrong type of extinguisher can be extremely dangerous (for example, spraying water on an electrical or oil fire makes it much worse).

To ensure safety, fire extinguishers are **color-coded** with a distinct colored band on their red bodies so users can identify them instantly.

2. Common Types of Extinguishers and Their Application

A. Water Extinguisher

- **Color Code Band: Bright Red**
- **How it works:** Cools down the fire by removing heat.
- **Best Used For: Class A fires** (Wood, paper, cloth, plastic).
- **DANGER:** Never use on electrical fires (water conducts electricity) or Class B oil fires (oil floats on water and spreads).

B. Foam (AFFF) Extinguisher

- **Color Code Band: Cream**
- **How it works:** Creates a thick blanket over the liquid surface, smothering the fire and sealing flammable vapors away from oxygen.
- **Best Used For: Class B fires** (Petrol, diesel, paints) and **Class A fires**.
- **DANGER:** Do not use on live electrical equipment.

C. Carbon Dioxide (CO_2) Extinguisher

- **Color Code Band: Black** (Features a distinct large discharge horn)
- **How it works:** Displaces oxygen by wrapping the fire area in a cold gas cloud, smothering it without leaving any residue.
- **Best Used For: Electrical Fires** (Safe for computers, machinery) and **Class B liquid fires**.

D. Dry Chemical Powder (DCP) Extinguisher

- **Color Code Band: Blue**
- **How it works:** Interrupts the chemical chain reaction of the flame and forms a barrier between fuel and oxygen.
- **Best Used For: Multi-purpose — Class A, B, and C fires** (Solids, Liquids, and Gases), and safe on electrical risks.

E. Wet Chemical Extinguisher

- **Color Code Band: Yellow**
- **How it works:** Reacts chemically with hot oil to form a soapy, non-combustible cooling layer over the surface (Saponification).
- **Best Used For: Class F / K fires** (Deep kitchen fats, ghee, cooking oil).

Extinguisher Type	Band Color	Class A (Solids)	Class B (Liquids)	Class C (Gases)	Electrical Risk	Class F/K (Kitchen)
Water	**Red**	**YES**	NO	NO	**DANGER**	NO
Foam	**Cream**	**YES**	**YES**	NO	NO	NO
CO_2	**Black**	NO	**YES**	NO	**YES**	NO

DCP (Powder)	**Blue**	**YES**	**YES**	**YES**	**YES**	NO
Wet Chemical	**Yellow**	**YES**	NO	NO	NO	**YES**

Portable Fire Extinguisher Diagram

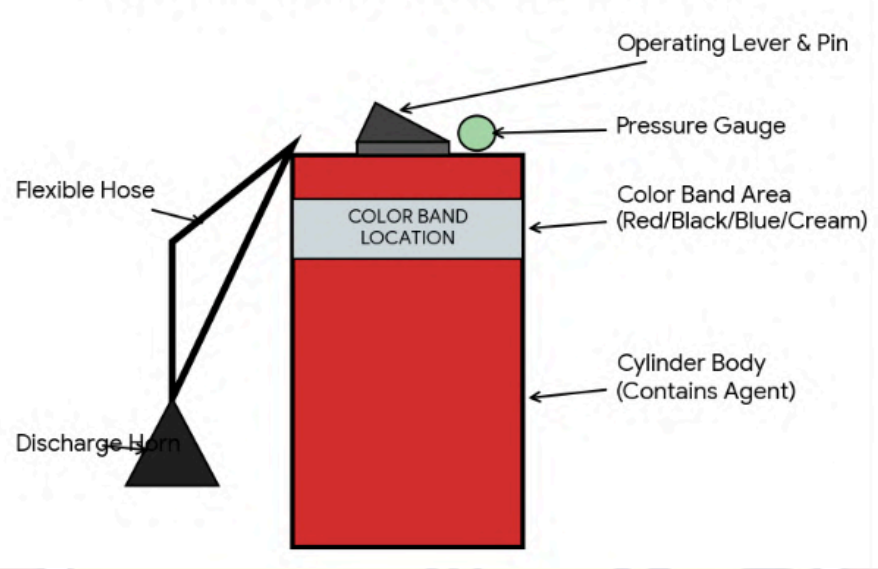


Figure 1: Standard layout of a portable fire extinguisher cylinder with label locations.

Firefighting Apparatus – Water Tender

1. Introduction

A **Water Tender** (also known as a Fire Tender or Fire Engine) is a highly specialized, heavy-duty mobile vehicle designed specifically for fire fighting and rescue operations. Its primary purpose is to transport a massive volume of water, foam compound, firefighting crew, and specialized equipment directly to the fire scene at high speeds.

2. Essential Technical Specifications & Construction Details

- **Chassis & Engine:** Built on a heavy commercial vehicle chassis (like Tata, Ashok Leyland, or Eicher) powered by a high-torque diesel engine to navigate rough or steep terrains quickly while fully loaded.
- **Water Tank Capacity:**
  - Typically carries between **3,000 to 5,000 litres** of water.
  - The tank is constructed using corrosion-resistant materials like **Stainless Steel (SS 304/316)** or Glass Reinforced Plastic (GRP).

    - Inside the tank, **baffle plates** are fitted to prevent water from splashing sideways while driving, which maintains vehicle stability around sharp corners.
- **Foam Tank Capacity:** Includes a separate small tank carrying around **300 to 500 litres of foam concentrate (AFFF)** to fight Class B liquid fires.
- **Fire Pump (The Heart of the Tender):** Equipped with a rear-mounted **Centrifugal Pump** driven by the vehicle's main engine via a Power Take-Off (PTO) gearbox.
    - **Low-pressure output:** Deliveries approx. 1,800 to 3,200 litres per minute (lpm) at a pressure of $7 to 10 kg/cm^2$.
    - **High-pressure output (for fog/mist):** Up to 300 lpm at $35 to 40 kg/cm^2$.
- **Hose Reel:** Features a built-in high-pressure rubber hose reel (usually 30 to 60 meters long) with a fog nozzle for rapid first-aid firefighting.
- **Lockers & Storage:** Side compartments with rolling shutters house delivery hoses, ladders, ropes, nozzles, breaching pieces, and rescue tools (cutters, hydraulic jacks).

3. Operational Flow of a Water Tender

When a Water Tender operates at a fire scene, it works through three main stages:

1. **Suction Stage:** Water is either drawn directly from its own internal tank or sucked from an external source (like a pond, underground sump, or fire hydrant) using hard suction hoses.
2. **Pressurization Stage:** The engine engages the **PTO system**, spinning the centrifugal pump impellers at high speeds, which instantly pressurizes the water.
3. **Delivery Stage:** Pressurized water is discharged through delivery valves into canvas fire hoses or out through a roof-mounted **Water Monitor** (a heavy-duty water cannon used for massive fires).

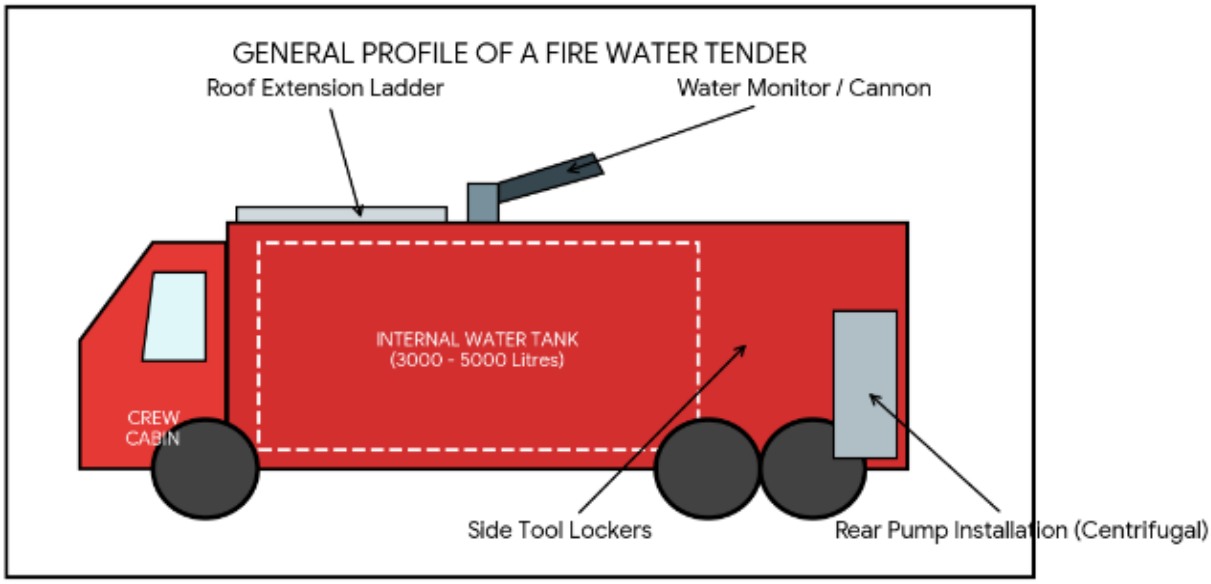


Figure 1: Simplified side-view block layout of a standard Water Tender for record books.

Firefighting Water Pumps

1. Introduction

A **fire pump** is a mechanical device used to draw water from a supply source (such as static tanks, hydrants, or open wells), increase its pressure, and force it out through delivery hoses to the fire zone.In fire services, **Centrifugal Pumps** are the absolute industry standard because they can deliver continuous, massive volumes of water at very high pressures without clogging.

2. Working Principle of a Centrifugal Fire Pump

A centrifugal pump works on the principle of **centrifugal force** (outward throwing force).

1. **Water Entry:** Water enters the center of a rapidly spinning wheel called the **Impeller** through the suction inlet (eye of the impeller).
2. **Kinetic Energy Boost:** As the engine rotates the impeller at high speeds, the water is thrown outwards toward the edges by centrifugal force, gaining massive speed (kinetic energy).
3. **Pressure Conversion:** The water enters a specially designed outer casing called the **Volute Casing**, which gradually widens out. This widening design slows the water speed down, converting the kinetic energy into high **static pressure**.
4. **Discharge:** The highly pressurized water is then forced out through the pump's delivery outlets.

3. Priming and Primers

- **The Problem:** A centrifugal fire pump cannot suck water from a level *below* itself if the suction hose contains air. It cannot pump air because air is too light to generate enough centrifugal force.
- **The Solution (Priming): Priming** is the process of removing all air from the pump casing and suction hose, creating a vacuum so that atmospheric pressure forces water up into the pump.
- **Primers:** Fire tenders are equipped with auxiliary priming devices (like **Exhaust Primers** or **Reciprocating/Piston Primers**) to lift water from open sumps or wells before the main centrifugal pump takes over.

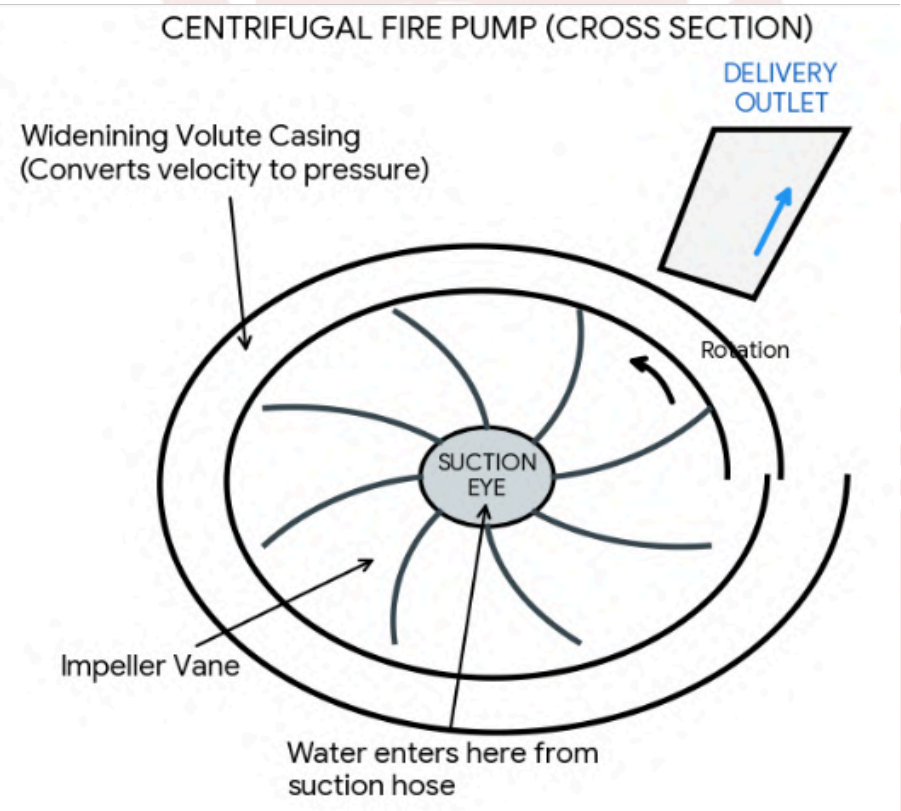


Figure 1: Cross-sectional internal layout of a Centrifugal Fire Pump showing core components.

Firefighting Ladders

1. Introduction

Ladders are essential operational rescue and access tools used by firefighters when stairways or lifts are blocked by fire or smoke. They are designed to safely carry the weight of firefighters carrying heavy equipment, as well as victims being rescued from multi-story buildings.

2. Classification & Types of Ladders

- **Extension Ladder:**
  - **Description:** A multi-section ladder where one or more moving sections (called extensions or "fly" sections) slide up and down within a fixed base section.
  - **Mechanism:** Raised using a rope and pulley system (called a halyard) and locked into position using automatic spring-loaded hooks called **pawns**.
  - **Standard Lengths:** Extension ladders used in fire tenders typically extend up to **10.5 meters** or **14 meters**.
- **Hook / Pompier Ladder:**
  - **Description:** A lightweight, single-section ladder featuring a large, serrated steel hook at the top.
  - **Usage:** Used to climb vertically from window to window on multi-story buildings where external rescue options are limited. The hook is anchored securely over a window sill.
- **Scaling Ladder:**
  - **Description:** Small, rigid sections of ladders designed with interlocking sockets at the top and bottom.
  - **Usage:** Multiple scaling sections can be slotted together sequentially by the crew on-site to build up to a desired height.
- **Turntable / Aerial Ladder (Vehicle Mounted):**
  - **Description:** A large, hydraulically operated extension ladder mounted permanently on a heavy truck bed with a rotating turntable base. It can extend up to **30 to 50 meters** or more.

3. Safe Working Angle rule (The 1:4 Rule)

For an extension ladder to remain completely stable and safe to climb, it must be pitched against a wall at a specific angle (approximately **75 degrees**).

- **The Rule:** The distance from the base of the wall to the heel of the ladder must be exactly **one-fourth (1/4th) of the working height** of the ladder.
- *Example:* If the ladder is extended up to a height of 12 meters on a wall, the base of the ladder must be placed exactly 3 meters away from the wall.

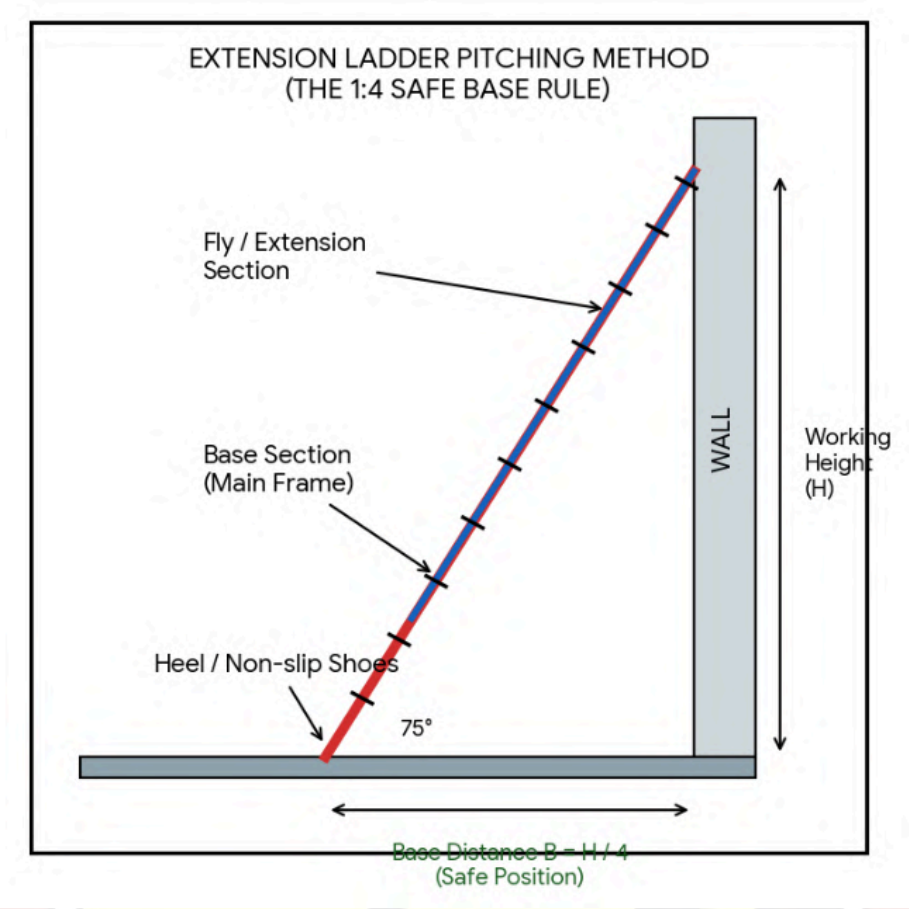


Figure 1: Mathematical placement guide for fire service extension ladders to avoid slipping or tipping.

Fire Nozzles

A **fire nozzle** is a mechanical device attached to the discharge end of a fire hose line. Its primary functions are:

1. **Velocity Control**: Convert pressure energy into kinetic energy to increase jet reach.
2. **Flow Rate Control**: Regulate the volume of extinguishing agent discharged per minute (LPM/GPM).
3. **Stream Patterning**: Shape the discharged water into a solid stream, fog pattern, or water curtain.
4. **Shut-off Valve Mechanism**: Allow firefighters to start, stop, or throttle water flow at the point of operation.

2. Key Components of a Fire Fighting Nozzle

- **Inlet Coupling**: Threaded or instantaneous male/female fitting (e.g., 63 mm Instantaneous Coupling as per IS:903) for connection to the hose line.

- **Control Valve / Bale Handle**: Operates a internal ball valve or poppet valve to open or stop water supply.
- **Nozzle Body / Barrel**: Smooth interior conduit designed to minimize friction loss.
- **Baffle & Pattern Adjustment Ring**: Rotating sleeve at the tip to switch stream output between straight stream and variable fog patterns.

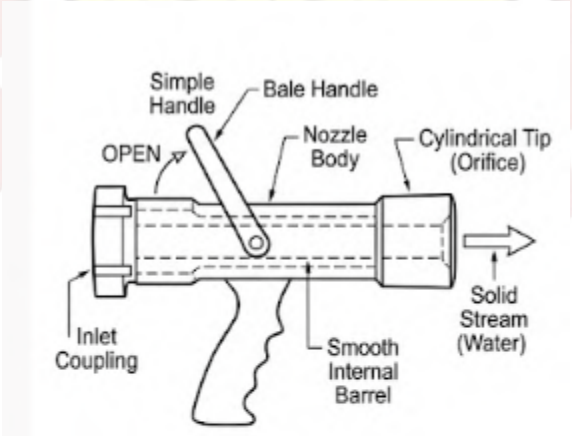


3. Classification of Fire Fighting Nozzles

A. Smooth Bore (Solid Stream) Nozzle

Provides a solid column of water with maximum reach and deep penetration power. It operates at lower nozzle pressures (around 3.5 bar) and produces minimal fog or fine spray.

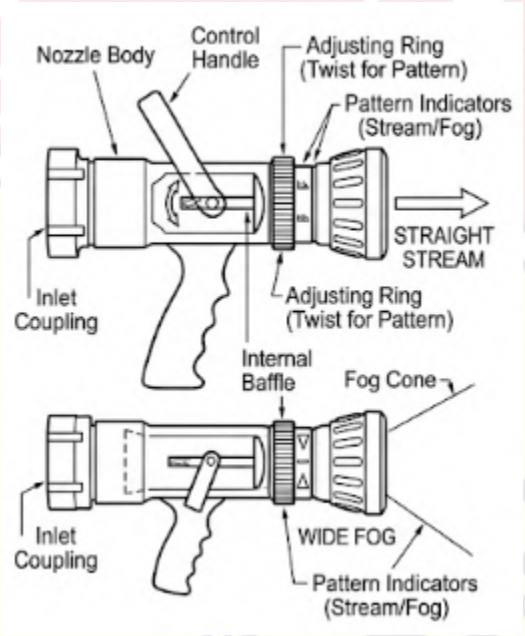
- **Key Features**: High reach, minimal stream breakup, reduced firefighter reaction force, lower operating pressure.
- **Primary Application**: Class A structural fires, deep-seated industrial fires.



B. Constant / Variable Fog (Combination) Nozzle

Allows the operator to manually select or continuously adjust the spray pattern from a straight stream to a wide-angle fog curtain.

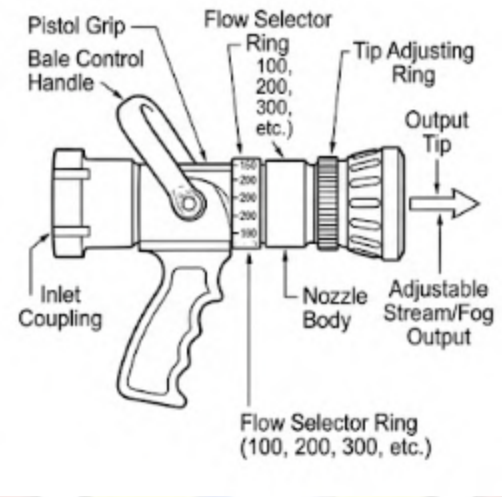
- **Key Features**: High heat absorption due to broken water droplets, creates a protective water shield for firefighters, absorbs smoke and gases.
- **Primary Application**: Compartment fire suppression, gas fire cooling, firefighter thermal protection.



C. Diffuser / Controlling Nozzle (London Light Alloy Nozzle)

Standard manual fire service nozzle allowing quick switching between **Off**, **Jet**, and **Spray/Fog**.

- **Key Features**: Compact design, constructed from light alloy (aluminum), multi-purpose setting without changing tips.
- **Primary Application**: General municipal and industrial fire brigade first-response lines.



D. Revolving / Cellar Nozzle

Specialized nozzle designed for confined space firefighting where direct access by personnel is impossible.

- **Key Features**: Offset spray orifices spin the head under water pressure, dispersing water in a 360° spherical pattern.
- **Primary Application**: Basements, ship holds, cellars, and ceiling voids.

4. Nozzle Hydraulics & Flow Formulae

1. **Discharge Formula for Smooth Bore Nozzles**:

$$Q = 0.0667 \times C_d \times d^2 \times \sqrt{P}$$

- Q = Discharge in Litres Per Minute (LPM)
- C_d = Coefficient of discharge (typically $0.97 - 0.99$)
- d = Nozzle orifice diameter in mm
- P = Nozzle pressure in bar

2. **Nozzle Reaction Force**:

$$NR = 1.57 \times d^2 \times P$$

- NR = Nozzle reaction in Newtons (N)
- d = Orifice diameter (mm)
- P = Pressure (bar)

Fire Service Ropes

1. Classification of Fire Service Ropes

Fire service ropes are classified based on their intended safety use:

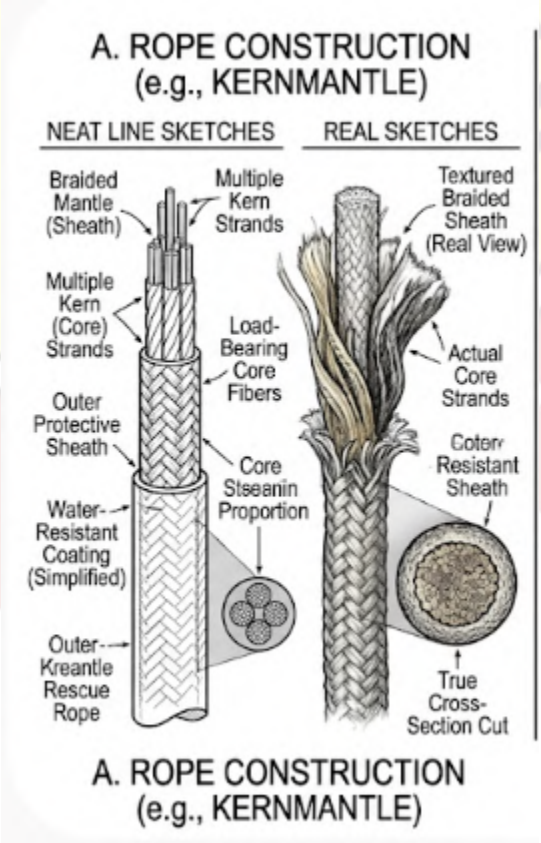
- **Life Safety Rope**: Dedicated strictly for rescue operations, evacuating personnel, or supporting a firefighter's weight. Must be discarded or downgraded if subject to shock loading.
- **Utility Rope**: Used for hoisting equipment, securing ladders, anchoring objects, or establishing cordon boundaries. *Never used for human rescue.*

2. Rope Construction Methods

A. Kernmantle Construction (Standard Rescue Rope)

Consists of two distinct structural parts:

- **Kern (Core)**: Inner load-bearing core providing **75% to 80%** of the total tensile strength.
- **Mantle (Sheath)**: Outer woven jacket protecting the core from abrasion, dirt, and UV damage (provides 20–25% strength).



B. Dynamic vs. Static Kernmantle Ropes

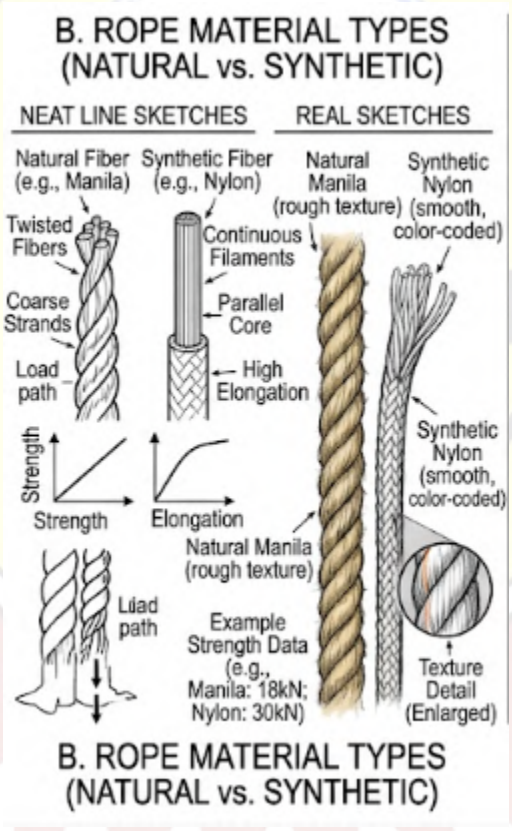
- **Static Kernmantle**: High resistance to stretch (low elongation, < 10%). Standard choice for fire service rescue, haul systems, and rappelling.
- **Dynamic Kernmantle**: High elasticity designed to absorb high-impact energy from fall protection (used in lead climbing).

C. Laid / Twisted Construction

Fibers are twisted into yarns, yarns into strands, and three or more strands are twisted together to form the rope.

- **Characteristics**: Exposed load-bearing fibers along the entire length; susceptible to severe abrasion and twisting under load. Mostly restricted to utility roles.

3. Fiber Materials: Synthetic vs. Natural



Parameter	Natural Fiber (Manila, Sisal, Hemp)	Synthetic Fiber (Nylon, Polyester, Kevlar)
Tensile Strength	Lower load carrying capacity	High load carrying capacity (up to 3x higher)
Rot / Mold Resistance	Poor (organic material rots when stored wet)	Excellent (impervious to rot and fungus)
Chemical Resistance	Low tolerance to acids/alkalis	Moderate to high resistance to common chemicals
Continuous Length	Short overlapping fibers	Continuous filament fibers

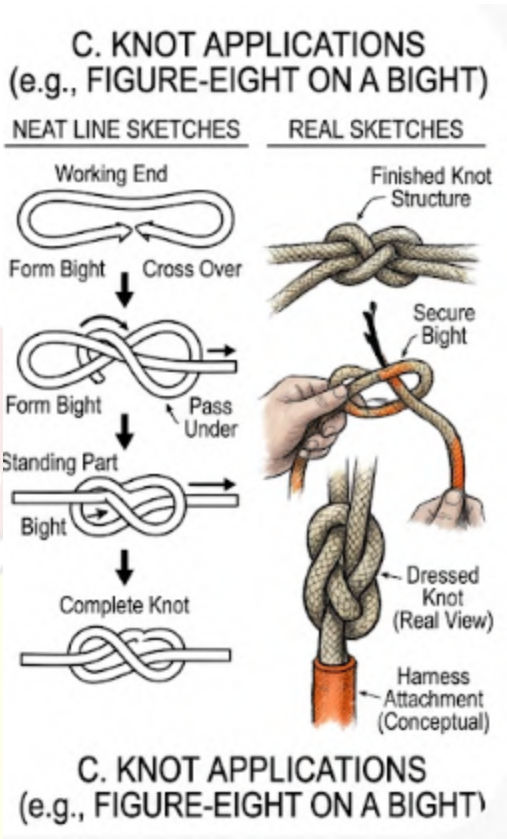
4. Fundamental Knots, Bends, and Hitches

Firefighters must master three primary knot categories:

1. **Loop Knots**: Form a fixed loop in a rope (e.g., *Figure-Eight on a Bight*, *Bowline*).
2. **Bends**: Used to join two ropes together (e.g., *Sheet Bend*, *Figure-Eight Bend*).
3. **Hitches**: Used to attach a rope around an object such as a hose, pipe, or ladder rung (e.g., *Clove Hitch*, *Timber Hitch*).

5. Maintenance, Inspection, and Care Rules

1. **Inspection**: Perform visual and tactile inspection along the entire length before and after every drill. Feel for soft spots, bunching, diameter reduction, or charred fibers.
2. **Cleaning**: Wash in cool water using mild, non-bleaching detergent. Air-dry out of direct sunlight.
3. **Storage**: Keep in clean rope bags stored in cool, dry compartments away from direct heat, chemicals, gasoline fumes, and sharp edges.
4. **Log Maintenance**: Maintain a **Rope History Log** recording date of purchase, manufacturer specs, dates used, load history, inspection records, and retirement dates.



Fire hoses

Fire hoses are flexible conduits used to convey water or extinguishing agents under pressure from a water source to the point of discharge.

1. Classification of Fire Hoses

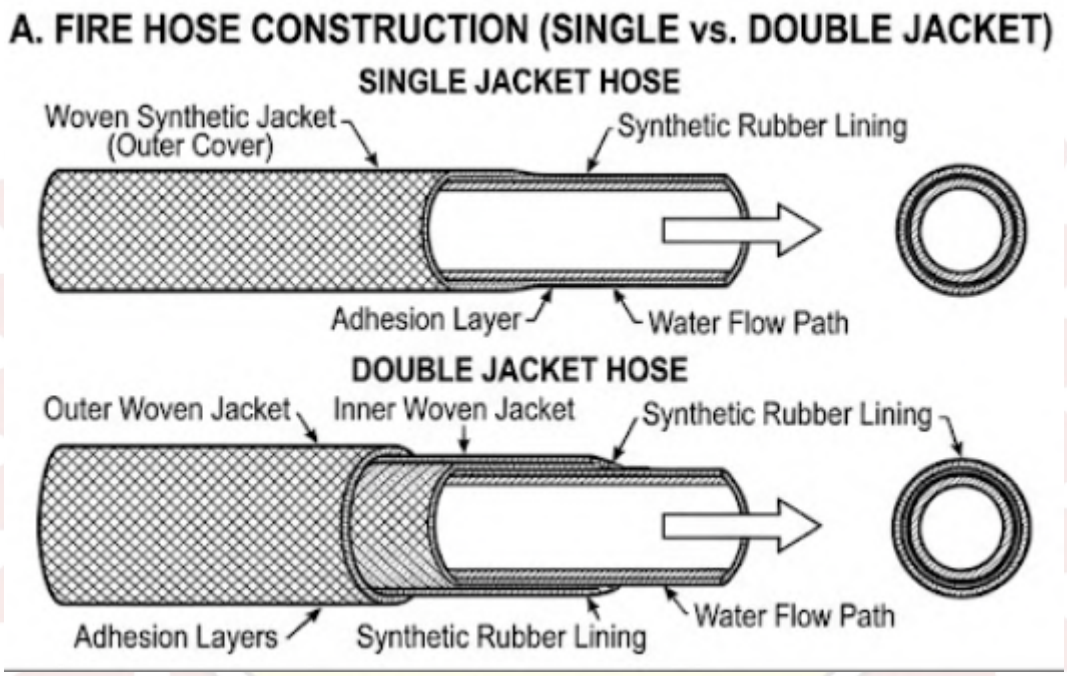
They are broadly classified into two categories:

- **Delivery Hose**: Flexible hose operating under positive internal pressure to deliver water from a pump or hydrant to the fire ground.
    - *Percolating Hose*: Unlined woven canvas hose that allows water to seep through the jacket to cool and protect the hose against embers.
    - *Non-Percolating Hose*: Hose with a smooth inner lining (rubber or synthetic polymer) that prevents water loss and reduces friction.
- **Suction Hose**: Rigid or semi-rigid reinforced hose capable of withstanding external atmospheric pressure without collapsing during negative-pressure draft operations from open water sources (ponds, sumps, tanks).

2. Construction of Fire Hoses

Single Jacket vs. Double Jacket Construction

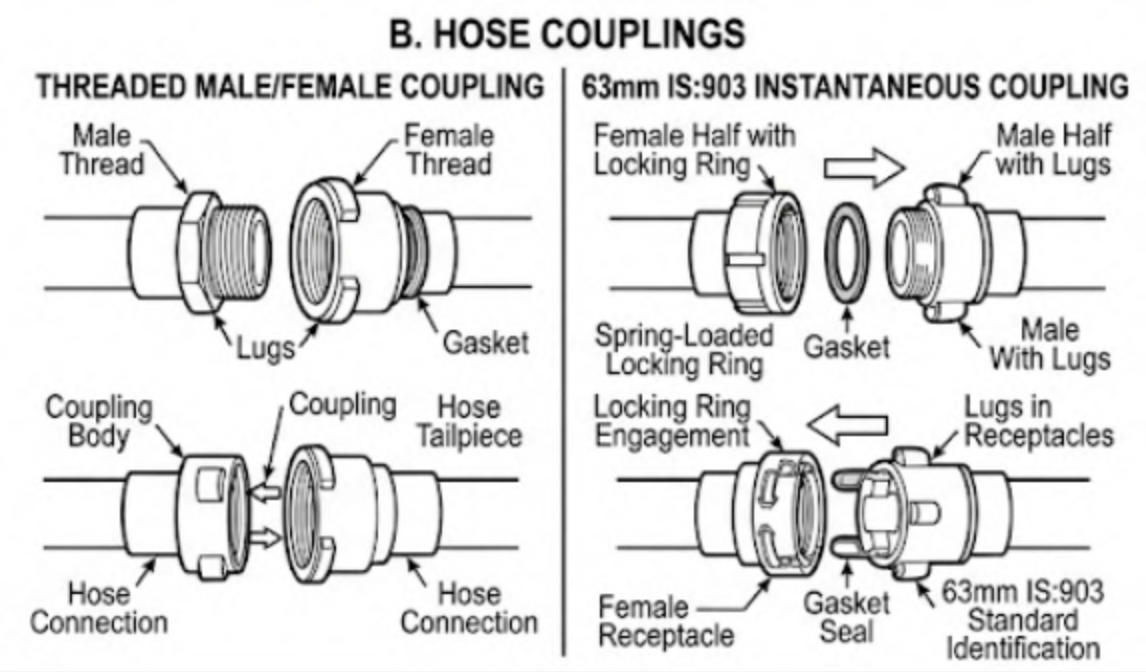
1. **Outer Woven Jacket**: Woven from high-tenacity synthetic fibers (polyester, nylon) or natural flax/hemp. Protects against mechanical abrasion and thermal radiation.
2. **Double Jacket**: Features an additional secondary woven jacket over the primary casing for higher burst pressure resistance in heavy industrial applications.
3. **Inner Rubber Lining**: Smooth vulcanized rubber or EPDM membrane chemically bonded to the inside. Minimizes internal surface friction loss and seals against leakage.



3. Hose Couplings & Fittings

Couplings connect hose lengths together, or connect hose lines to pumps, hydrants, and nozzles.

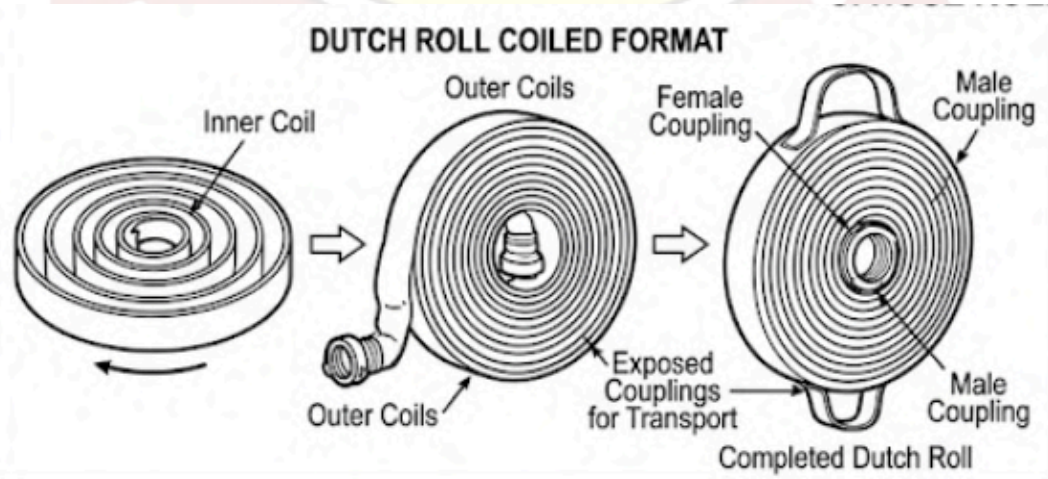
- **Instantaneous Coupling (IS: 903 Standard)**: The standard quick-release coupling used across Indian fire services (63 mm nominal size).
    - *Male Half*: Has a smooth cylindrical spigot with an outer locking groove.
    - *Female Half*: Features spring-loaded bronze/brass locking lugs that snap automatically into the male spigot groove upon insertion.
- **Threaded Coupling**: Screw-thread connections (male/female) secured using a spanner wrench, primarily used on hard suction hoses to ensure an airtight seal under vacuum.

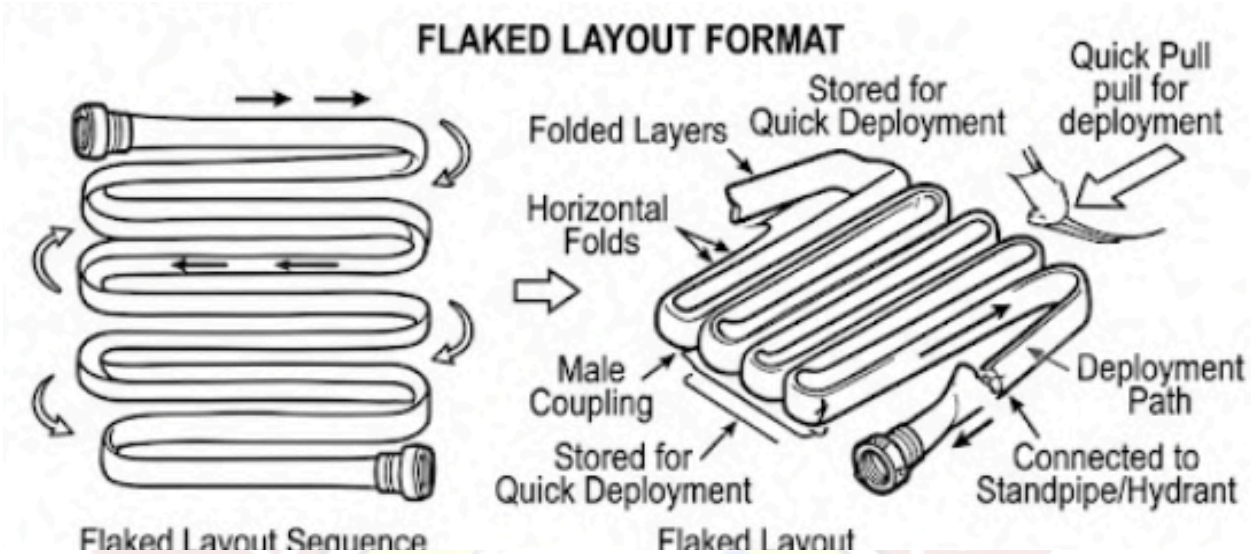


4. Hose Rolling and Layout Methods

Firefighters roll and store hose lines to ensure rapid, snag-free deployment:

1. **Dutch Roll (Double Coil)**: Hose is folded in half with the female coupling overlapping the male coupling by about 1 meter, then rolled tightly from the bend toward the couplings. Allows both couplings to be unrolled simultaneously without twisting.
2. **Roll-on-Flange (Single Roll)**: Rolled tightly starting from the male coupling inward, leaving the female coupling accessible on the outside for rapid connection to hydrants.
3. **Flaked Layout**: Laid back and forth in zig-zag folds inside hose lockers or vehicle beds for instant pull-out deployment.





5. Inspection, Testing, and Care Rules

1. **Hydraulic Pressure Test**: Conduct annual hydrostatic proof testing at specified pressures (typically 14 bar / 200 psi for delivery hoses) to check for jacket defects or lining separation.
2. **Washing and Drying**: Wash thoroughly with clean water after use to remove dirt, mud, and chemical residues. Air-dry on hose towers or drying racks out of direct sunlight to prevent rubber rot.
3. **Storage**: Store rolled hoses in well-ventilated racks away from oils, acids, vehicle exhaust fumes, and rodents.
4. **Hose Record Maintenance**: Maintain a log entry for each hose length detailing date of manufacture, test pressures, repairs, and service history.

Fire Fighting Riser Systems

A **Riser System** is a vertical network of pipework permanently installed in multi-story or high-rise buildings. It delivers water from a underground storage tank, municipal supply, or fire tender to landing valves located on each floor, giving firefighters rapid access to pressurized water without dragging heavy hoses up stairwells.

2. Classification of Riser Systems

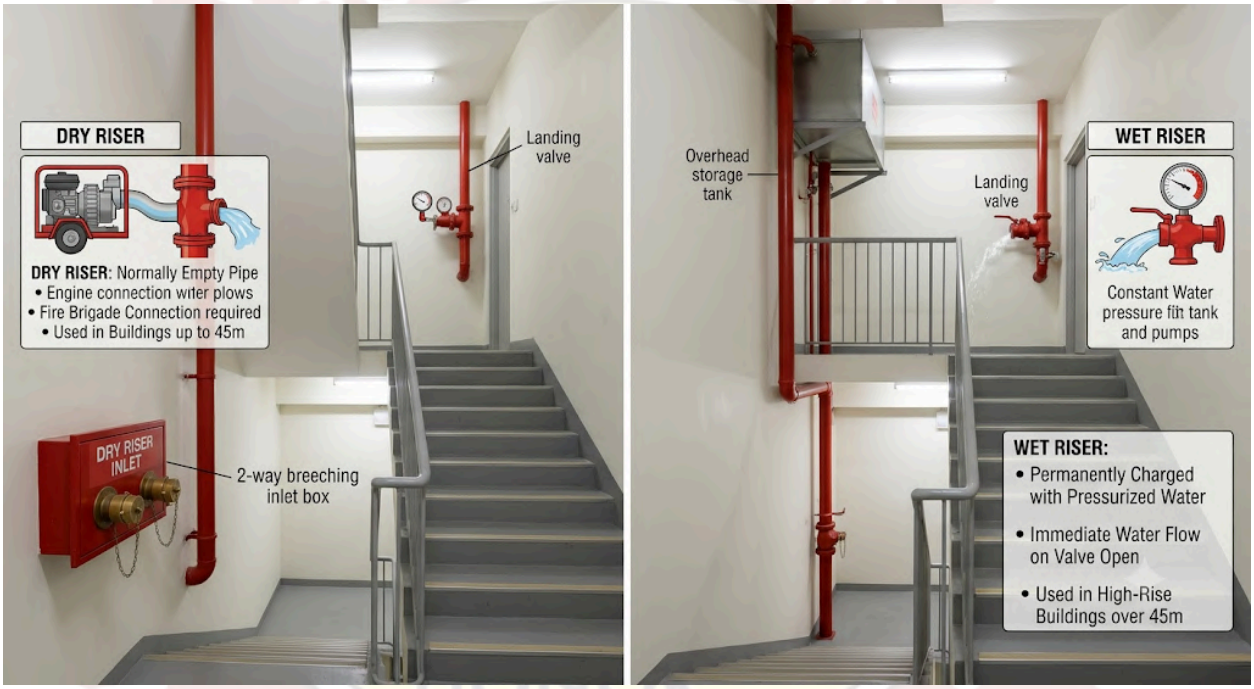
A. Dry Riser System

- **Definition**: A vertical pipe network that stays empty of water under normal conditions.
- **Working Principle**: When a fire occurs, the fire brigade connects their pump engine to the external **Breeching Inlet** at ground level to pump water upward into the system.

- **Application**: Used in buildings up to 45 meters in height (as per NBC India guidelines).

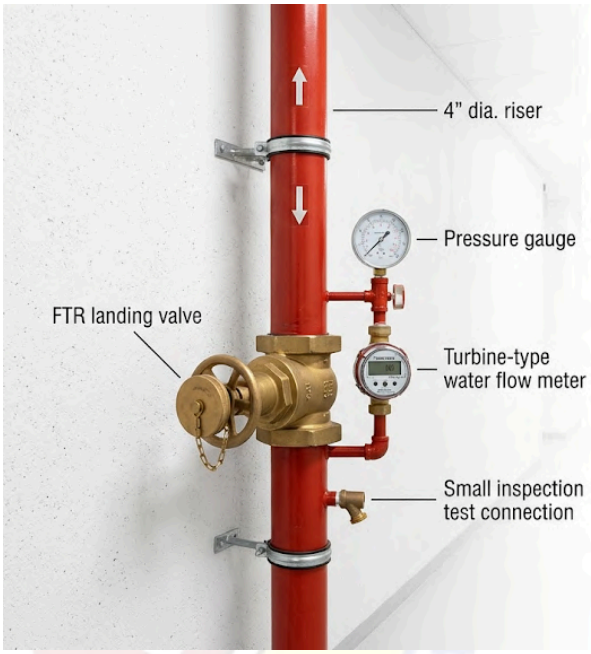
B. Wet Riser System

- **Definition**: A vertical pipe system permanently charged with pressurized water from an automatic fire pump and overhead/underground storage tanks.
- **Working Principle**: Water flows immediately as soon as a firefighter opens any landing valve on any floor. The drop in pressure automatically triggers the main fire pumps.
- **Application**: Mandatory for high-rise buildings exceeding 45 meters in height and high-hazard commercial structures.



C. Downcomer System

- **Definition**: A system connected to an overhead roof tank, feeding water downward to landing valves on lower floors via gravity, supported by a roof-mounted booster pump.





4. Key Components of Riser Systems

1. **Breeching Inlet (2-Way / 4-Way)**: Positioned at ground level outside the building inside a red metallic box. Features 63 mm instantaneous male inlets with non-return valves so fire engines can pump water into the dry riser.
2. **Landing Valve**: Internal outlet valve (IS: 5290 standard) fitted on every floor level inside fire escape staircases or lobbies to connect hose lines.
3. **Air Release Valve**: Located at the highest point of the vertical stack to bleed out trapped air when filling the system with water.
4. **Drain Valve**: Fitted at the bottom-most point of the riser stack to drain water completely for maintenance.
5. **Pressure Reducing Valve (PRV)**: Installed on lower floors of wet risers to restrict nozzle static pressure under 7 bar for firefighter safety.

5. Technical Specifications & NBC (India) Guidelines

System Component	Technical Requirement / Standard
Minimum Pipe Diameter	100 mm (4-inch) for buildings up to 45m; 150 mm (6-inch) for taller buildings

Landing Valve Specification	63 mm Instantaneous Outlet (IS: 5290)
Design Flow Rate (Wet Riser)	Minimum 2280 LPM (Liters Per Minute) at highest outlet
Minimum Running Pressure	3.5 bar (kg/cm^2) at the top-most landing valve
Maximum Static Pressure	7.0 bar at any landing valve (PRV required if higher)

6. Inspection, Testing, and Maintenance

1. **Hydrostatic Test**: Test dry and wet riser pipes annually at a minimum pressure of 14 bar (kg/cm^2) for at least 2 hours to check for joint leaks.
2. **Breeching Inlet Check**: Verify rubber washers, caps, and spring-loaded non-return flaps operate freely without jamming.
3. **Flow & Pressure Test**: Open the roof-top landing valve annually to verify the automatic pump start mechanism and measure static/running pressure using a pitot gauge.
4. **Visual Inspection**: Ensure all landing valves have blank caps tied with leather straps, handles are intact, and valve cabinets are clear of obstructions.

Fire Suits

Fire Suits commonly referred to as a Turnout Suit or Fire Proximity Suit.The primary objective of this equipment is to protect the wearer from heat, flame, steam, water, and mechanical hazards while maintaining enough mobility to perform rescue operations.

A firefighter is never just in a "suit"; they are in an *ensemble* where every component must overlap perfectly to prevent gaps and protect against thermal penetration.

1. Structure and Layers: The Multi-Layer Defense

The most critical point relevant to fire suits is their layered construction. You do not just wear one thick piece of fabric; you wear a system that manages different hazards.

A modern turnout suit (coat and pants) is constructed using a three-layer composite:

Layer	Primary Functions	Key Material Features (DOTE Terminology)
A. Outer Shell	**Flame Defense & Durability:** The first line of defense. It resists direct flame, abrasion, tears, and repels water/chemicals.	Inherently flame-resistant fibers like **Nomex®** and **Kevlar®**. The weave provides high tensile strength.
B. Moisture Barrier	**Waterproof & Breathable:** Prevents external water (from hoses/rain) from entering while allowing sweat vapor to escape. This is crucial for preventing *steam burns* and reducing *heat stress*.	A specialized membrane (like **ePTFE** or **Gore-Tex®**) laminated to a fabric substrate. It prevents water penetration but allows microscopic vapor molecules to pass.
C. Thermal Liner	**Thermal Insulation:** Provides the bulk of the thermal protection by trapping air. This layer resists heat transfer from the fire environment to the firefighter's body.	A quilted construction of insulating batting (often Nomex/Kevlar blends) faced with a smooth face cloth. The **quilted air pockets** provide the insulation value.



2. Important Features and Integration Points (Practical Use)

- **DRAG RESCUE DEVICE (DRD):** Found on the back of the coat collar, this is a reinforced internal harness loop. It allows a downed or unconscious firefighter to be dragged to safety efficiently without manipulating their limbs, keeping them flat against the ground.
- **COAT CLOSURE SYSTEM:** This must use a non-melting closure (like a heavy-duty zipper) covered by a deep *storm flap* that is secured with *hook-and-loop (Velcro®)*. This double-seal prevents water and heat from penetrating the zipper.
- **INTEGRATION & OVERLAP:**
    - **Wrist:** The coat sleeves are long, with knit wristlets (often Nomex) that must integrate *inside* the glove gauntlet.
    - **Collar:** The coat has a high, padded thermal collar that seals around the base of the *SCBA mask* and *helmet shroud*.
    - **Waist/Ankle:** The *pants* must overlap the coat by at least 12 inches when bending. Pants cuffs must be long enough to cover the top of the *boots* during any movement.
- **REINFORCEMENTS:** Areas of high wear, such as knees and elbows, must feature extra padded reinforcements (often covered with durable materials like Arashield®) for mechanical protection when crawling or kneeling.


1. DRAG RESCUE DEVICE (DRD)
Reinforced internal harness loop at back of coat collar for efficient dragging of a downed firefighter.
2. COAT CLOSURE SYSTEM
Double-seal (non-melting zipper and Velcro®-secured deep storm flap) prevents water/heat penetration.
INTEGRATION & OVERLAP
3a. Wrist Integration:
Knit wristlet inside glove gauntlet.
3b. High Thermal Collar:
Seals neck area.
3c. Waist Overlap:
Minimum 12-inch overlap required.
3d. Ankle Overlap:
Pants cuff covers boot top.
4a. Knee Reinforcement
(e.g., Arashield®): Padded protection for crawling/kneeling.
4b. Elbow Reinforcement:
Padded protection.



Fire Hose Couplings

A **fire hose coupling** is a robust mechanical device permanently attached to the end of a fire hose. Its primary purpose is to allow firefighters to quickly and securely connect:

1. One length of hose to another length to extend the water line.
2. A hose line to a water source (e.g., a fire hydrant or fire pump).
3. A hose line to a discharge appliance (e.g., a fire nozzle, monitor, or breeching).

2. Important Properties of an Effective Coupling

A coupling must possess the following characteristics to be reliable on the fire ground:

- **Quick Connection/Disconnection:** Speed is critical in firefighting.
- **Watertight Seal:** Must not leak, as water loss reduces pressure at the nozzle.
- **Secure Locking Mechanism:** Must not accidentally detach when pressurized or when dragged over rough ground.
- **Durability:** Made of robust, corrosion-resistant materials (like gunmetal, brass, or lightweight aluminum alloy) to withstand rough handling and extreme conditions.

3. Classification of Couplings (By Connection Method)

Couplings are broadly classified by how they connect.

A. Sexless (Non-Threaded or "Hermaphrodite") Couplings

These couplings look identical on both ends of the hose. They do not have a separate male or female design. The connection is made by aligning the interlocking parts and twisting or pushing them together. These are favored for fast deployment as there is no need to ensure the correct "gender" is facing the water source.

The Instantaneous Coupling (Standard IS: 903)

This is the standard coupling used throughout Indian fire services for **delivery hoses**. It is a **push-to-connect** mechanism. The 63 mm nominal diameter (internal) is the standard size.

- **Male Part:** Features a plain cylindrical spigot with an external annular (ring) groove.
- **Female Part:** Features a receiving socket and two spring-loaded brass locking lugs.

When the male spigot is pushed into the female socket, the spring-loaded lugs snap into the groove on the male part automatically, locking the connection instantly. A rubber gasket inside the female part ensures a watertight seal under pressure. Disconnection is made by pulling back on the lugs manually.

Sexed (Threaded) Couplings

These couplings have a distinct **Male** (external thread) and **Female** (internal thread) end. To make a connection, the male end must always face the water source (e.g., the hydrant or pump discharge), and the female end must always face the direction of the fire.

- **Gender:** Male (external threads) and Female (internal threads).
- **Thread Type:** British Standard Pipe (BSP) or National Standard Thread (NST) are common, but they must match to connect.
- **Connection Method:** Screwed together, typically requiring specialized spanner wrenches to fully tighten or loosen.
- **Common Use:** Used on **suction hoses** (connecting the pump to a static water source like a tank or river) because threaded connections provide a superior airtight seal, which is critical for creating a vacuum during drafting operations.

Key Terminology for Couplings

1. **Lugs:** Protrusions on the coupling body designed to provide a grip for hand tightening or for use with a coupling spanner wrench. Common types include rocker lugs (standard on delivery hoses) and pin lugs.
2. **Swivel:** A feature on female threaded couplings that allows the threaded collar to rotate independently of the hose body, preventing the entire hose length from twisting during connection.
3. **Higbee Cut (or Blunt Start):** The intentional flattening of the start of the first thread on threaded couplings. This prevents cross-threading when making connections quickly or blindly.
4. **Tailpiece (or Shank):** The part of the coupling that extends into the hose and is secured using compression rings, clamps, or wire binding.

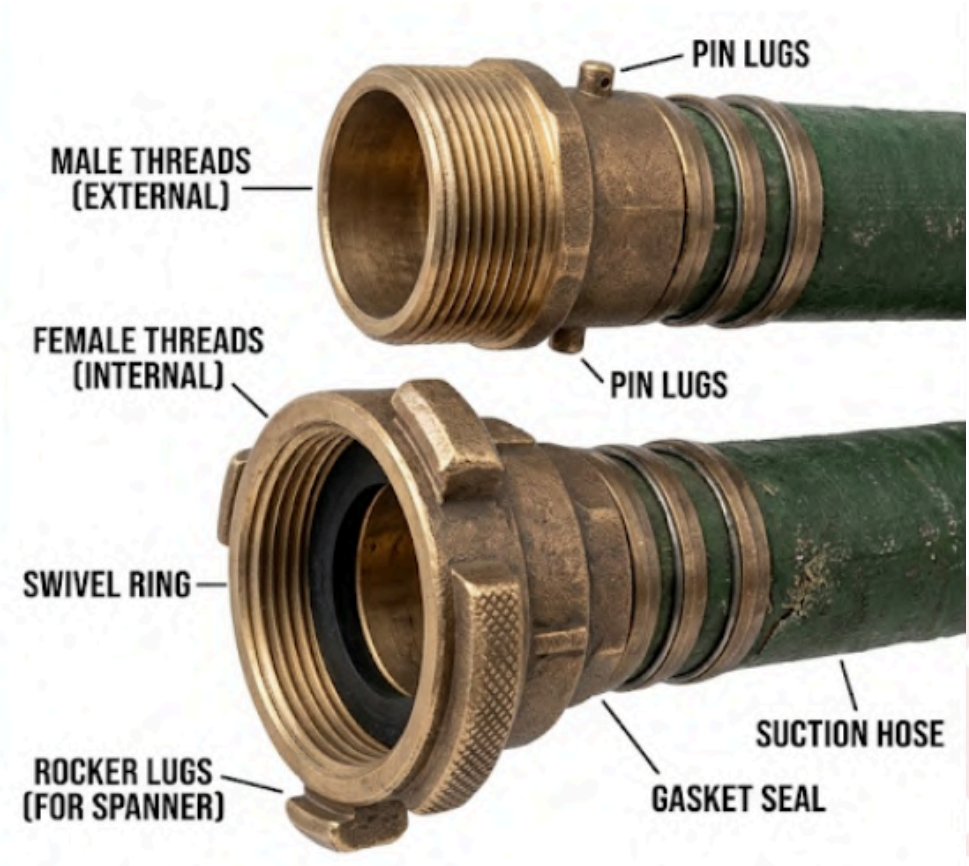
Real-World Fire Hose Couplings – Technical Comparison

Left Side: Sexed Threaded Coupling (Suction Hose Type) This image shows a heavy-duty gunmetal coupling typically used on suction hoses.

- The **Male coupling** is shown with prominent external standard threads and small pin lugs.
- The **Female coupling** is shown with internal threads, a large **swivel ring**, and prominent **rocker lugs**, allowing for a secure grip with a coupling spanner to create an airtight seal critical for drafting operations.

Right Side: Sexless Instantaneous Coupling (IS: 903 Delivery Hose Type) This image shows the standard lightweight aluminum alloy coupling used for high-pressure delivery hoses throughout India.

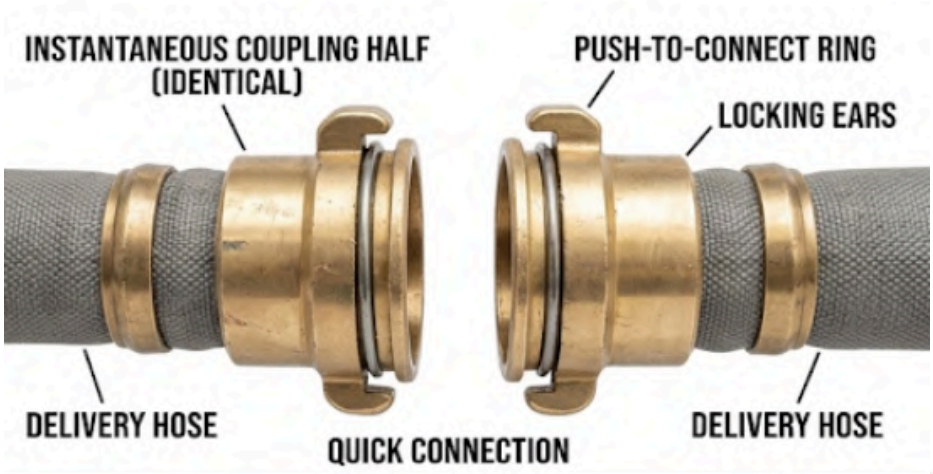
- The **Male half** (lower section) is a plain **spigot** with an annular locking groove.
- The **Female half** (upper section) features two spring-loaded, textured **pull lugs**. This is a quick **push-to-connect** system.



Operational Scenario – Instantaneous Couplings in Use

This photograph captures the practical scenario described in your objective: an active deployment.

- The **Male** and **Female** instantaneous couplings are shown securely connected, extending a long high-pressure water line across rough terrain toward the fire ground. The robust aluminum alloy construction is evident, designed to withstand abuse.
- A firefighter is visible in the background, operating a fire nozzle that is already discharging a stream, demonstrating the successful integration of the extended water line.





LABORE
HONOR
CHENNAI

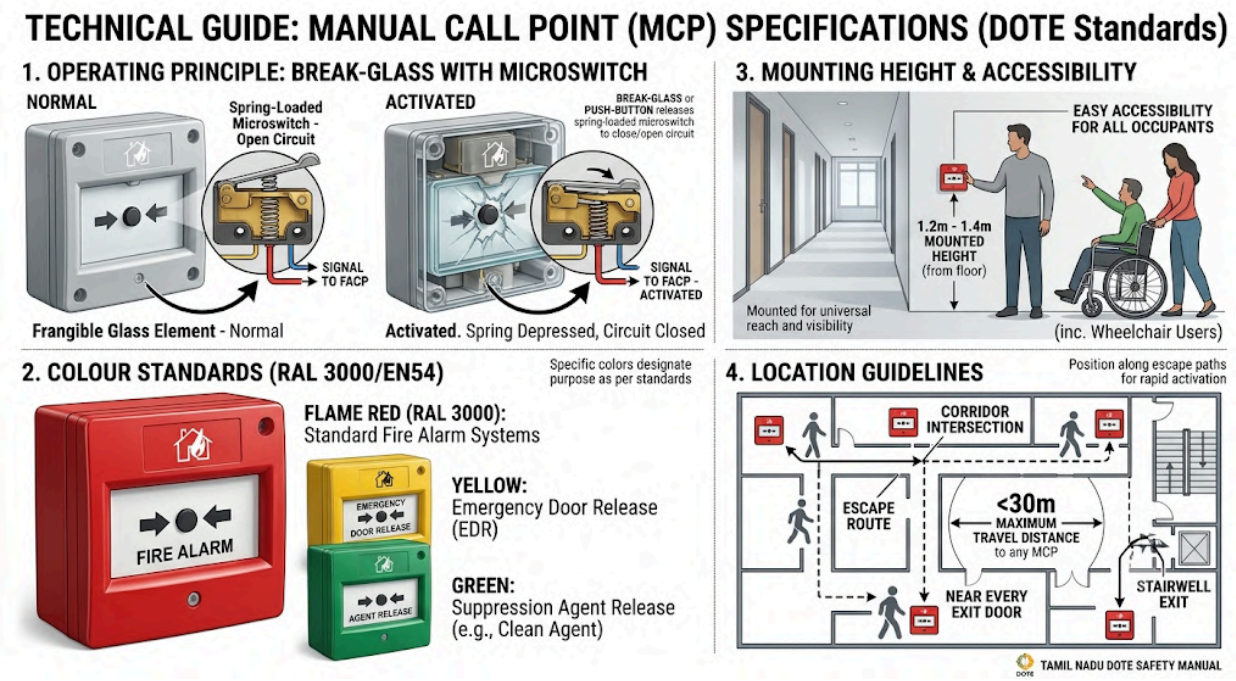
UNIT 2 EMERGENCY PLAN

Manual Call Point (MCP)

A Manual Call Point (MCP)—commonly known as a manual break-glass unit or pull station—is an initiating device within an automatic fire alarm system (FACP). It enables any occupant who discovers a fire, smoke hazard, or emergency to manually trigger the building-wide fire alarm, alert security/occupants, and initiate emergency response and evacuation protocols.

Key Technical Specifications & Standards (IS: 2189 / NBC Standards)

- **Operating Principle**: Break-glass element (frangible glass/plastic element) or push-button trigger that releases a spring-loaded microswitch to close/open an electrical circuit sent to the Fire Alarm Control Panel (FACP).
- **Colour Standard**: Flame Red (RAL 3000) housing for standard fire alarm systems; Yellow/Green for Emergency Door Release (EDR) or suppression agent release.
- **Mounting Height**: Installed at a height of **1.2 meters to 1.4 meters** above finished floor level for easy accessibility by all occupants (including wheelchair users).
- **Location Guidelines**: Positioned along escape routes, stairwell exits, corridor intersections, and near every exit door so that no person in a building needs to travel more than **30 meters** to reach an MCP.

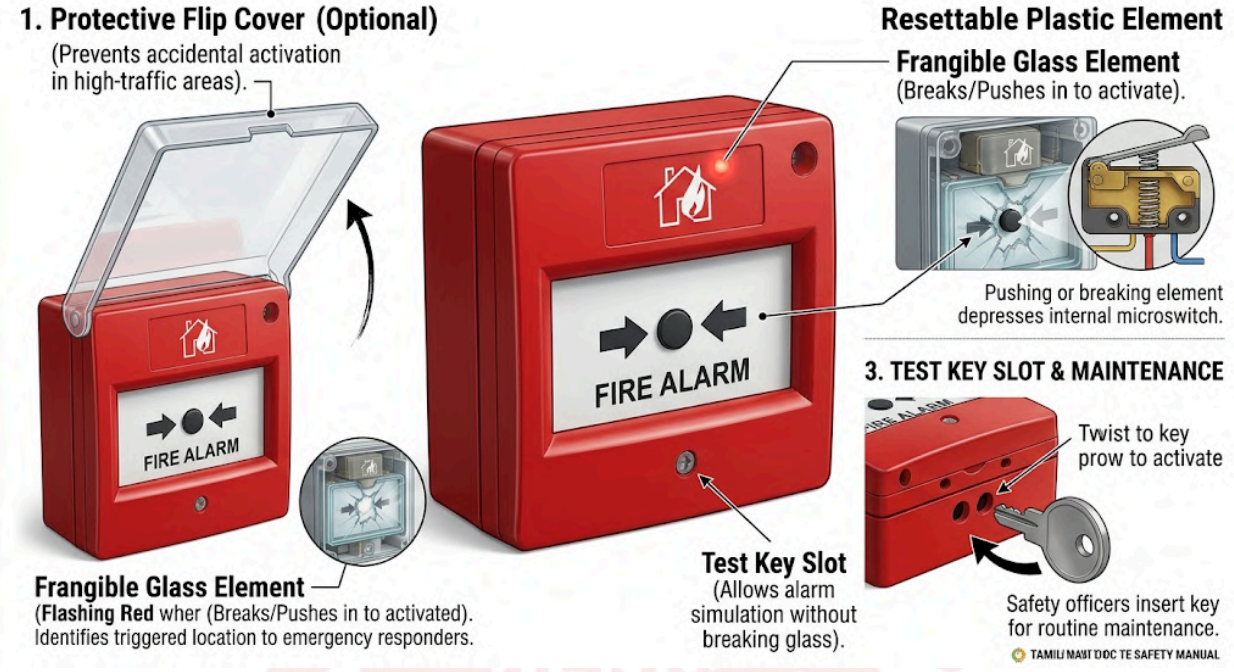


Real-World Physical Components & Operation

Manual Call Point System Components & Real Scenario

Key Operating Features (As Shown Above)

1. **Frangible Glass / Resettable Plastic Element**: Protects against accidental triggers. In an emergency, pushing or breaking the element depresses the internal microswitch.
2. **Test Key Slot**: Located at the bottom or side, allowing safety officers to insert a special two-prong test key to simulate an alarm condition during routine maintenance without breaking the glass.
3. **LED Status Indicator**: Emits a flashing red signal when activated to identify the triggered location to emergency responders.
4. **Protective Flip Cover**: Optional clear polycarbonate flap installed over the MCP in high-traffic or school areas to prevent false activation or accidental bumps.



Operation Sequence in Emergency Planning



Inspection, Testing, and Maintenance (ITM)

1. **Weekly Operational Test**: Operate at least one MCP weekly using a test key to confirm that the FACP correctly receives the signal and activates notification sirens.
2. **Visual Inspection**: Check weekly for physical damage, obstruction, missing glass elements, or painted-over housings.
3. **Resetting Procedure**: After testing or drill activation, insert the reset key to restore the internal microswitch and replace broken glass elements with standard spare panes.
4. **Logbook Record**: Maintain an entry of every MCP test detailing point location, panel zone address, response time, and inspector signature.

Fire Alarm and Automatic Fire Alarm

1. The Core Purpose: Detection and Notification
The fundamental objective of any fire alarm system is to detect a fire emergency as quickly as possible and notify occupants and emergency responders to initiate evacuation and suppression.
Systems are classified by how detection is initiated: Manual (requires human action) and Automatic (initiated by sensors).

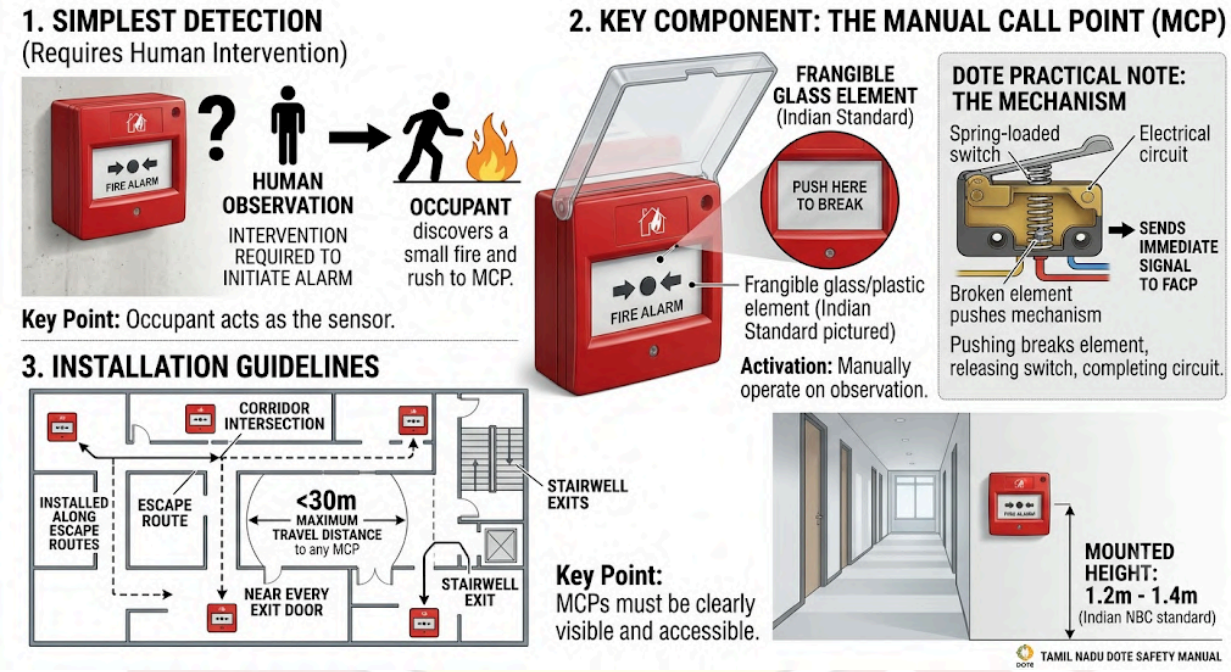
2. Manual Fire Alarm System (MCP)

This is the simplest form of detection, requiring human observation and intervention to initiate an alarm.

Key Component: The Manual Call Point (MCP)

How it works:

- Activation: Any occupant observing smoke or fire must manually operate the device. In India, these are typically frangible glass units (pictured above).
- The Mechanism (DOTE Practical Note): Pushing on the central element breaks a frangible glass or plastic pane, releasing a spring-loaded switch internally. This switch completes an electrical circuit, sending an immediate signal to the main control panel.
- Key Point: MCPs must be installed along escape routes, stairwell exits, and be clearly visible.



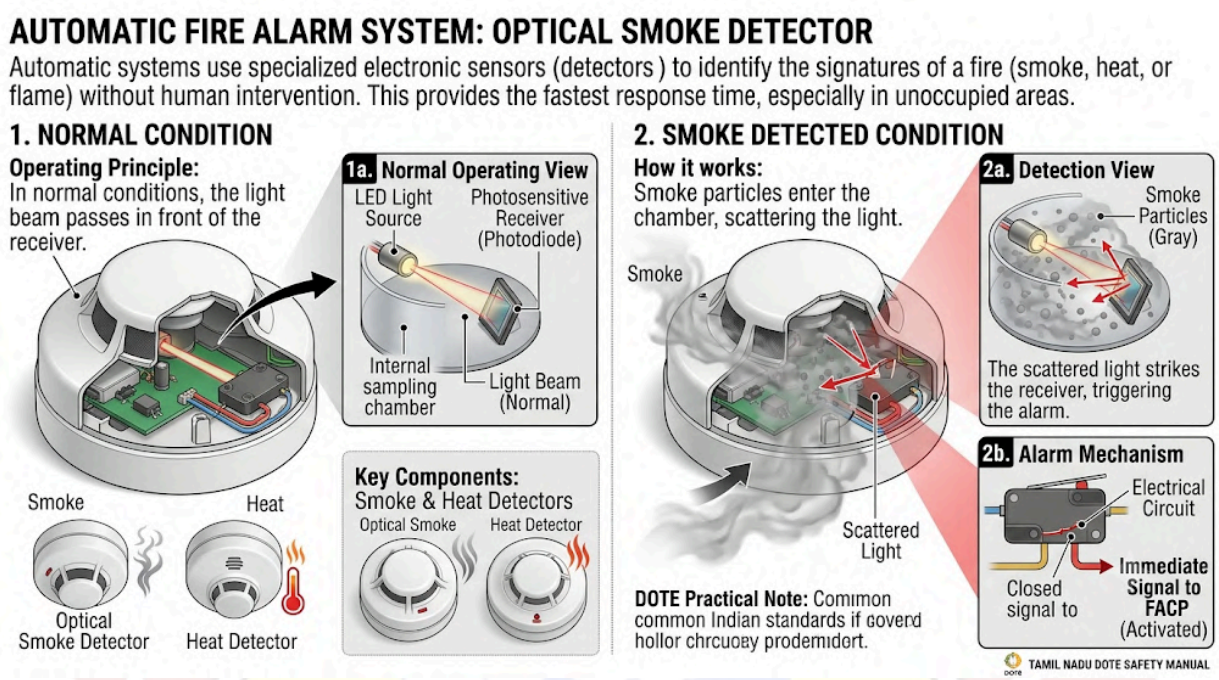
3. Automatic Fire Alarm System (detectors)

Automatic systems use specialized electronic sensors (detectors) to identify the signatures of a fire (smoke, heat, or flame) without human intervention. This provides the fastest response time, especially in unoccupied areas.

Key Components: Smoke and Heat Detectors

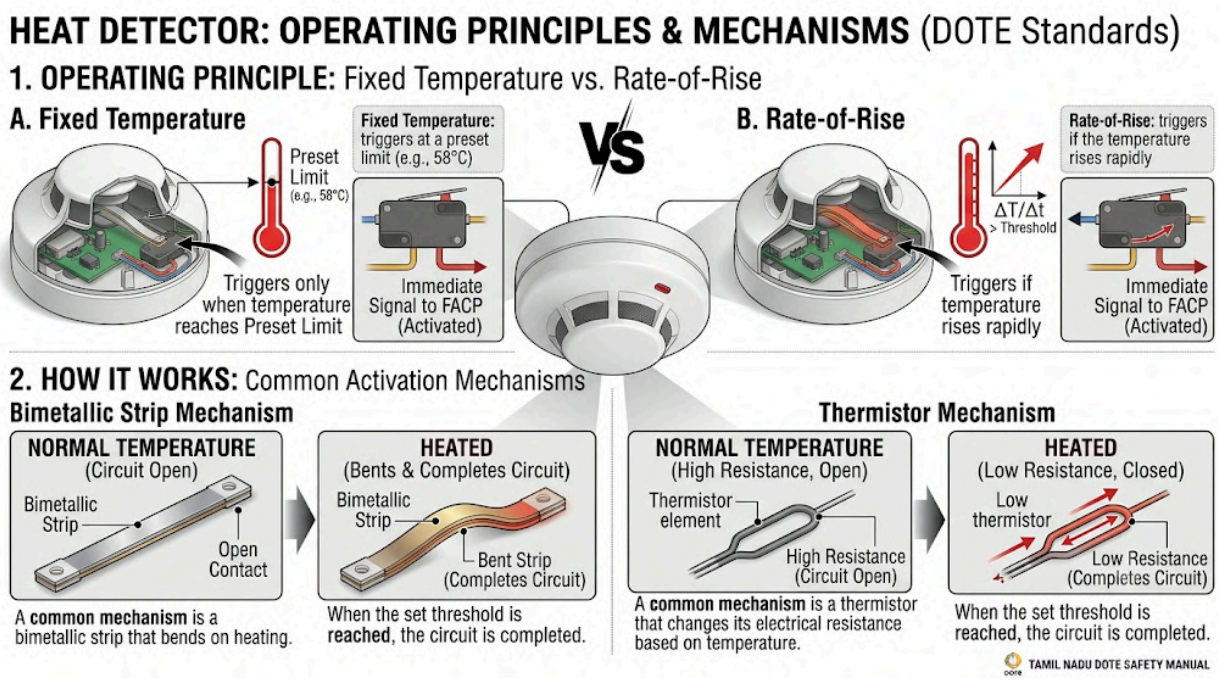
A. Optical Smoke Detector:

- Operating Principle (Inset View): Most common type. It contains an LED light source and a photosensitive receiver set at an angle inside a sampling chamber.
- How it works: In normal conditions, the light beam passes in front of the receiver. When smoke particles enter the chamber, they scatter the light. The scattered light strikes the receiver, triggering the alarm.



B. Heat Detector:

- Operating Principle (Inset View): Responds to thermal energy. There are two main types: Fixed Temperature (triggers at a preset limit, e.g., 58°C) and Rate-of-Rise (triggers if the temperature rises rapidly).
- How it works: A common mechanism is a bimetallic strip or a thermistor that changes its electrical resistance based on temperature. When the set threshold is reached, the circuit is completed.

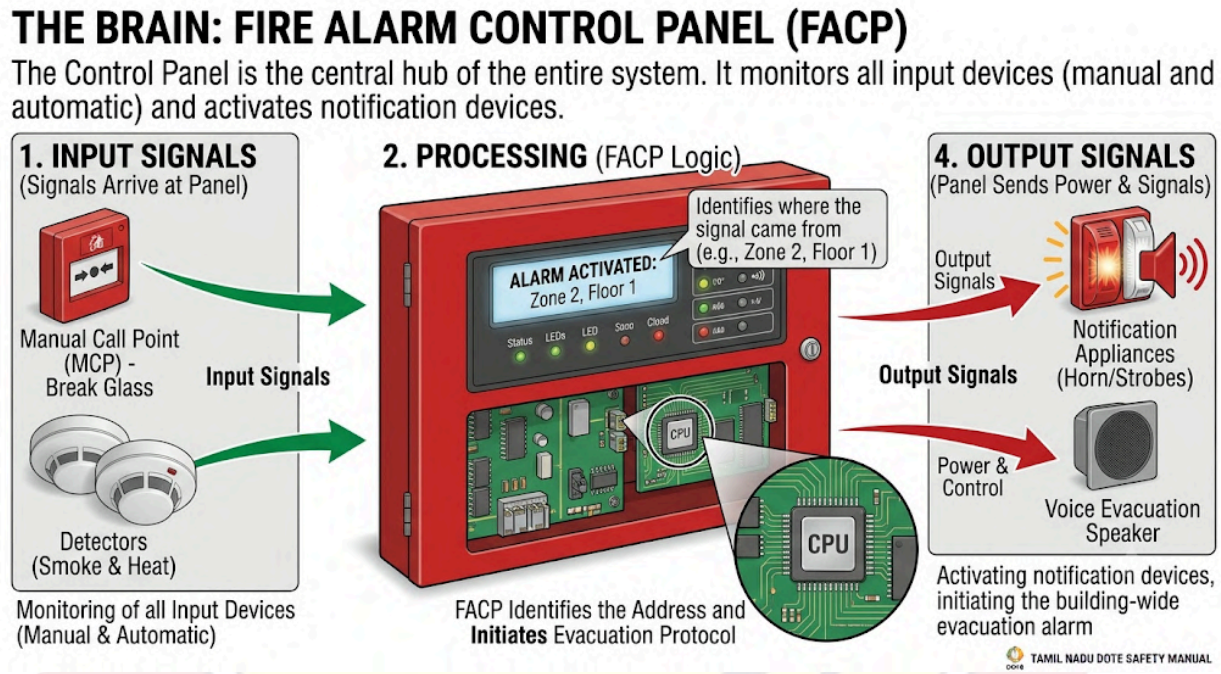


4. The Brain: Fire Alarm Control Panel (FACP)

The Control Panel is the central hub of the entire system. It monitors all input devices (manual and automatic) and activates notification devices.

How it works:

1. Input Signals: Signals arrive at the panel from MCPs or detectors (arrows entering the panel).
2. Processing: The FACP identifies where the signal came from (e.g., Zone 2, Floor 1).
3. Output Signals: The panel then sends power and signals to all notification appliances (arrows exiting the panel), initiating the building-wide evacuation alarm.



5. Notification Appliances (Horn/Strobes)

These devices provide the visual and audible warning to the building occupants.

How it works:

- Audible Warning (Horn): Produces a loud (100+ dB), distinctive temporal pattern sound to alert occupants and overcome background noise.
- Visual Warning (Strobe): A synchronized, high-intensity flashing light (ADA compliant) that provides warning to hearing-impaired occupants and provides signaling in smoky conditions.

<u>Gas Flooding System</u>

A Gas Flooding System (Total Flooding System) is a fixed fire suppression setup designed to rapidly discharge a gaseous extinguishing agent into an enclosed space. Its primary purpose is to protect high-value critical assets—such as server rooms, data centers, electrical control rooms, and archives—where water or chemical powder would cause irreparable equipment damage.

Key Gaseous Suppression Agents

1. **Clean Agents (Halocarbon Replacements)**:
    - **FM-200 (HFC-227ea) / Novec 1230 (FK-5-1-12)**: Extinguishes fire primarily by thermal energy absorption (cooling) without leaving any chemical residue or conducting electricity.
2. **Inert Gases**:
    - **IG-541 (Inergen) / IG-55 (Argonite)**: Mixtures of Nitrogen, Argon, and CO_2. Reduces oxygen concentration below the combustion threshold (typically below 15%) while keeping oxygen levels safe for short-term human exposure.
3. **Carbon Dioxide (CO_2) Total Flooding**:
    - Highly effective for Class B and C fires, but **life-threatening to personnel** due to extreme oxygen displacement. Used strictly in normally unoccupied or isolated areas.

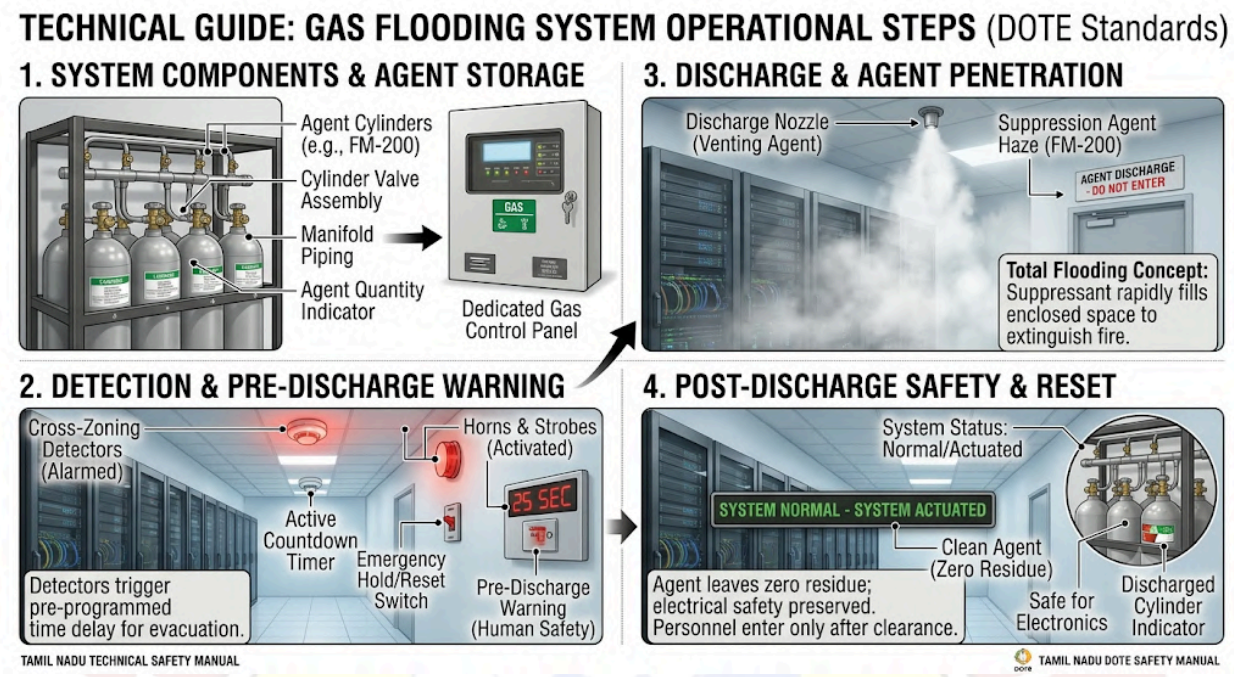
Core System Components

- **Storage Cylinder Bank**: High-pressure steel cylinders containing compressed or liquefied gas connected via a common manifold.
- **Actuation Mechanism**: Electric solenoid valve combined with a mechanical pneumatic actuator and manual pull station for manual override.
- **Discharge Nozzles**: Calibrated nozzles positioned near the ceiling level to achieve a uniform gas concentration across the protected enclosure within 10 seconds.

4. Operation Sequence and Safety Interlocks

Gas flooding systems operate on a strict **Cross-Zoning (Coincident Logic)** sequence to prevent accidental discharge:

1. **First Detector Tripped (Zone 1)**: Panel triggers local warning horns/strobes; alerts occupants.
2. **Second Detector Tripped (Zone 2)**: Panel confirms fire condition, initiates a **30-second Pre-Discharge Countdown Timer**, and trips safety interlocks:
    - Shuts down HVAC dampers to seal the room.
    - Trips power supplies to non-essential equipment.
    - Sounds high-decibel evacuation sirens.
3. **Discharge Phase**: Upon completion of the timer, the solenoid fires, opening cylinder valves to flood the room completely within 10 seconds.



5. Critical Practical Safety Devices

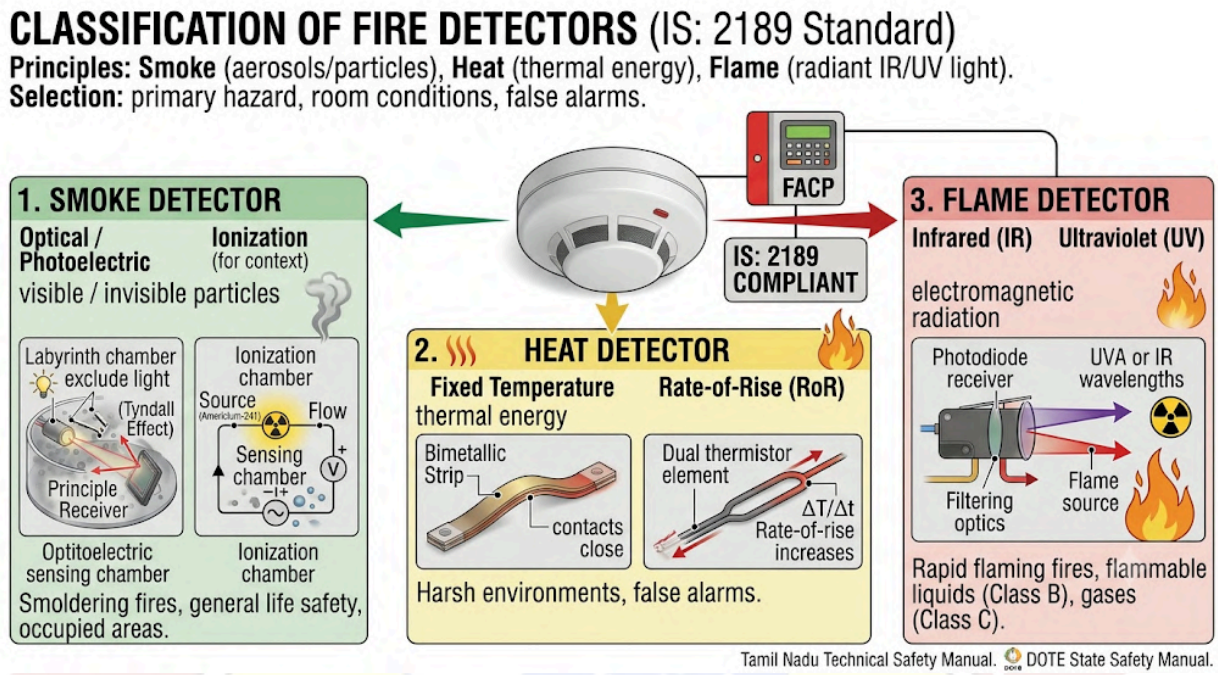
- **Abort Station (Emergency Hold)**: A manual push-button inside the protected space. Pressing and holding this switch pauses the countdown timer if a technician is inside or if a false alarm occurs.
- **Manual Pneumatic Actuator**: Mechanical lever at the cylinder manifold to manually release the agent if power or control panels fail.
- **Pressure Relief Vents (PRV)**: Wall-mounted dampers that open automatically during gas discharge to prevent structural over-pressurization of the room.

Sensors and Detectors

Automatic fire detection devices continuously sample the ambient atmosphere to identify physical changes produced by combustion: **Smoke (aerosols/particles)**, **Heat (thermal energy)**, and **Flame (radiant infrared/ultraviolet light)**.

Selecting the appropriate sensor depends on the primary fire hazard, ambient room conditions, and potential false alarm sources (e.g., steam, dust, or vehicle exhaust).

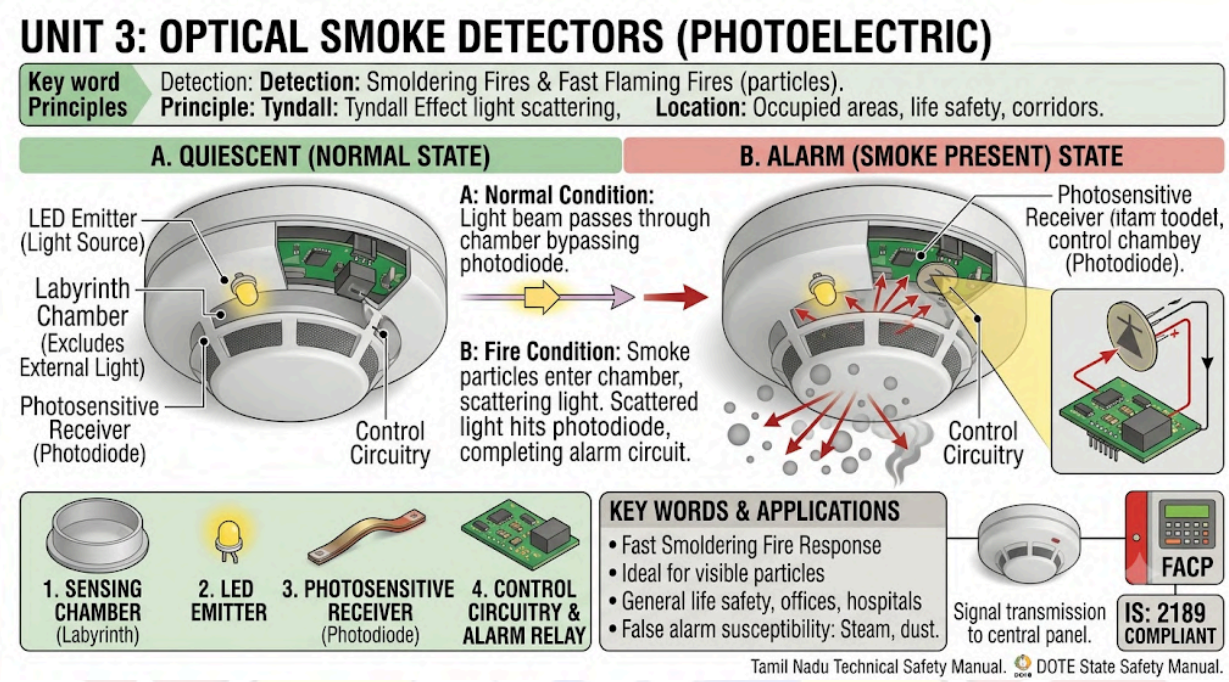
Classification of Fire Detectors (IS: 2189 Standard)



Optical Smoke Detectors (Photoelectric)

The optical smoke detector is the primary life-safety choice for general building zones (office spaces, escape corridors, hospital wards).

- **Operating Principle**: Employs the **Light Scattering Principle (Tyndall Effect)** inside a dark sensing chamber.
- **Key Components**: An Infrared LED transmitter, an angled Photosensitive Photodiode receiver, and a baffled labyrinth chamber designed to exclude ambient room light.
- **Working Mechanism**:
    1. *Quiescent State*: The LED projects a narrow light beam inside the chamber. Under normal conditions, the light beam passes straight ahead without striking the angled photodiode.
    2. *Alarm State*: When smoke particles enter the labyrinth, they scatter the light beam in all directions. A portion of the scattered light strikes the photodiode receiver, causing a voltage surge that sends an alarm signal to the Fire Alarm Control Panel (FACP).



Heat Detectors (Fixed Temperature & Rate-of-Rise)

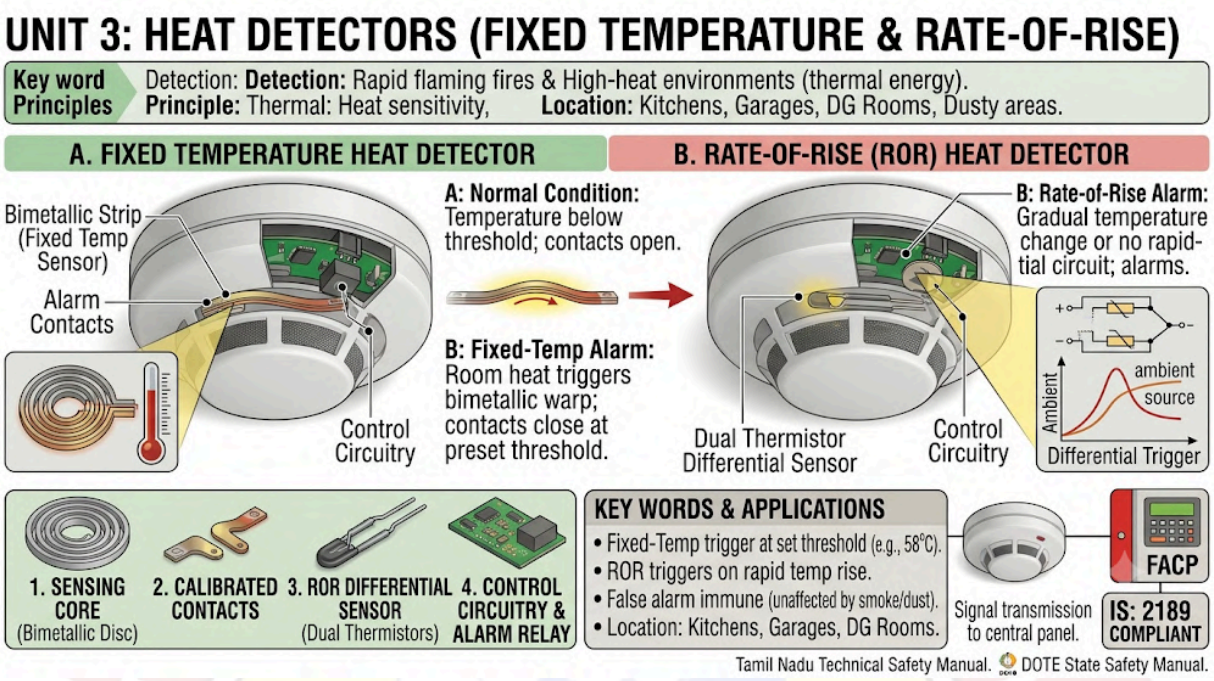
Heat detectors trigger directly from thermal energy. They are installed in harsh environments where smoke detectors would suffer from false alarms (e.g., kitchens, boiler rooms, workshops, and dusty warehouses).

A. Fixed Temperature Heat Detector

- **Mechanism**: Uses a precision **NTC Thermistor** or **Bimetallic Strip** calibrated to trigger at a specific temperature (typically **58°C** for standard ambient areas or **78°C–90°C** for high-temperature zones).
- **Operation**: When room heat raises the element's temperature past the threshold, thermistor electrical resistance drops rapidly, closing the alarm contact to the FACP.

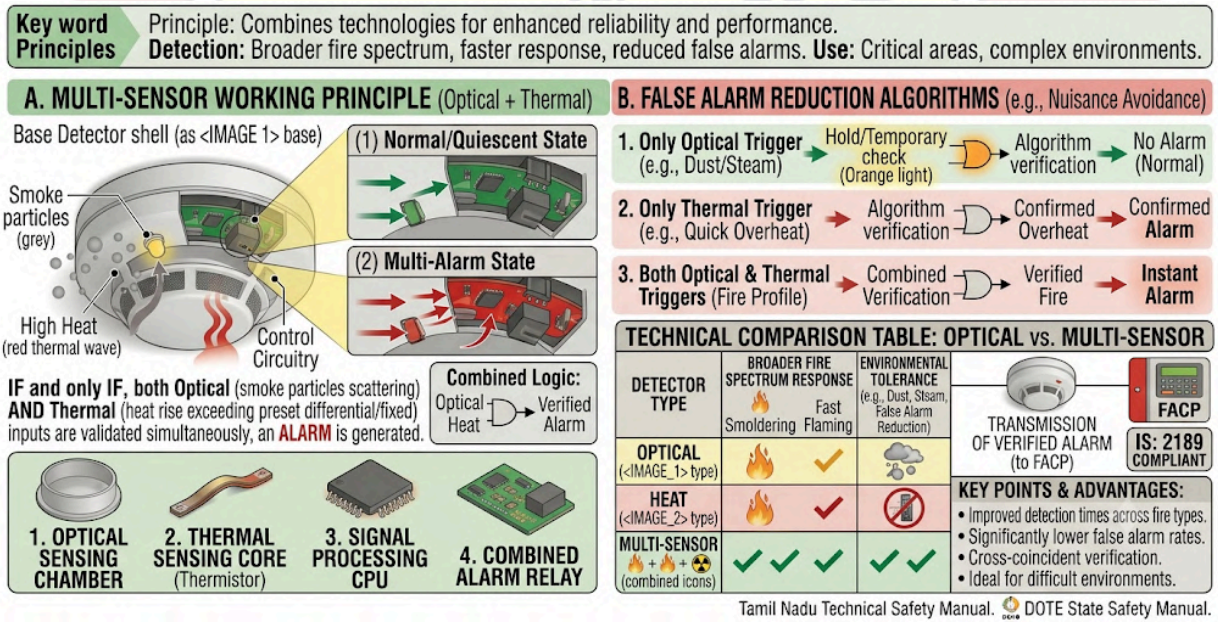
B. Rate-of-Rise (RoR) Heat Detector

- **Mechanism**: Responds to sudden, rapid bursts of thermal rise, regardless of starting temperature.
- **Operation**: Triggers if the surrounding air temperature rises faster than **8°C to 10°C per minute**, ensuring rapid notification during fast-burning liquid or paper fires before high absolute temperatures are reached.



Multi-Sensor Detectors & Technical Comparison

Modern IS: 2189 compliant systems frequently feature **Multi-Sensors (Optical + Thermal)**. These units combine both sensing elements into a single housing, analyzing smoke density and temperature rise simultaneously to eliminate false alarms from dust or moisture while maintaining rapid response times.



Philosophy of Accident

An **accident** is an unplanned, unexpected, and uncontrolled event caused by human error or technical failure that interrupts an activity and results in personal injury, property damage, or operational losses.

Modern safety philosophy operates on a fundamental principle: **Accidents do not just happen; they are caused, and therefore they can be prevented.**

Heinrich's Domino Theory (5 Dominoes Chain)

Proposed by H.W. Heinrich, this theory states that an accident results from a chain of sequential factors, like five standing dominoes aligned in a row:

1. **Ancestry & Social Environment**: Personal background and traits leading to undesirable behavior.
2. **Fault of Person**: Carelessness, ignorance, violent temper, or lack of safety awareness.
3. **Unsafe Act / Unsafe Condition**: The direct trigger (e.g., operating machinery without guards or oil spills on a shop floor).
4. **Accident**: The event itself (falling, crushing, or getting struck).
5. **Injury**: Fractures, lacerations, or disability resulting from the collision.

Core Concept: Removing the middle domino—**Unsafe Act or Unsafe Condition**—breaks the chain and prevents the accident entirely.

Heinrich's 300-29-1 Triangle (Ratio Law)

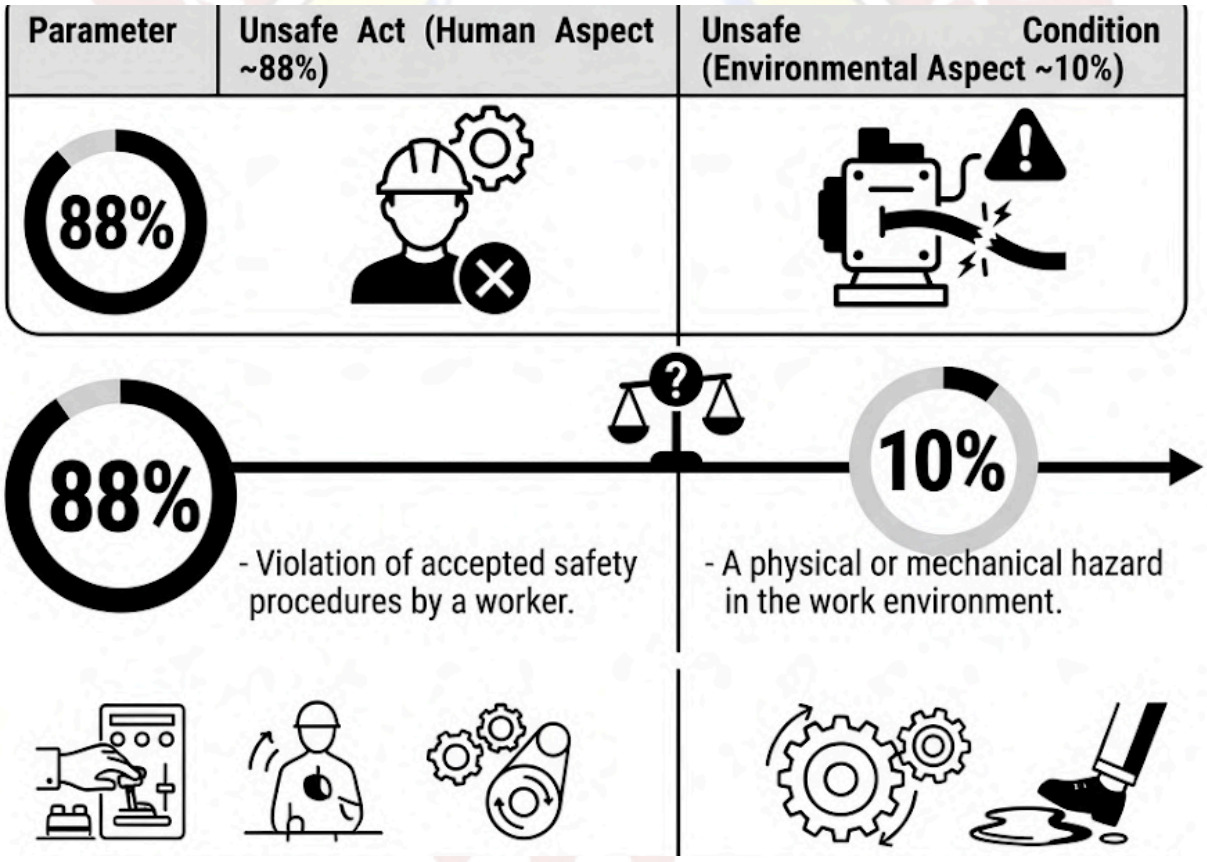
For every single **major injury / fatality**, there are **29 minor injury accidents** and **300 near-miss incidents** (no-injury incidents).

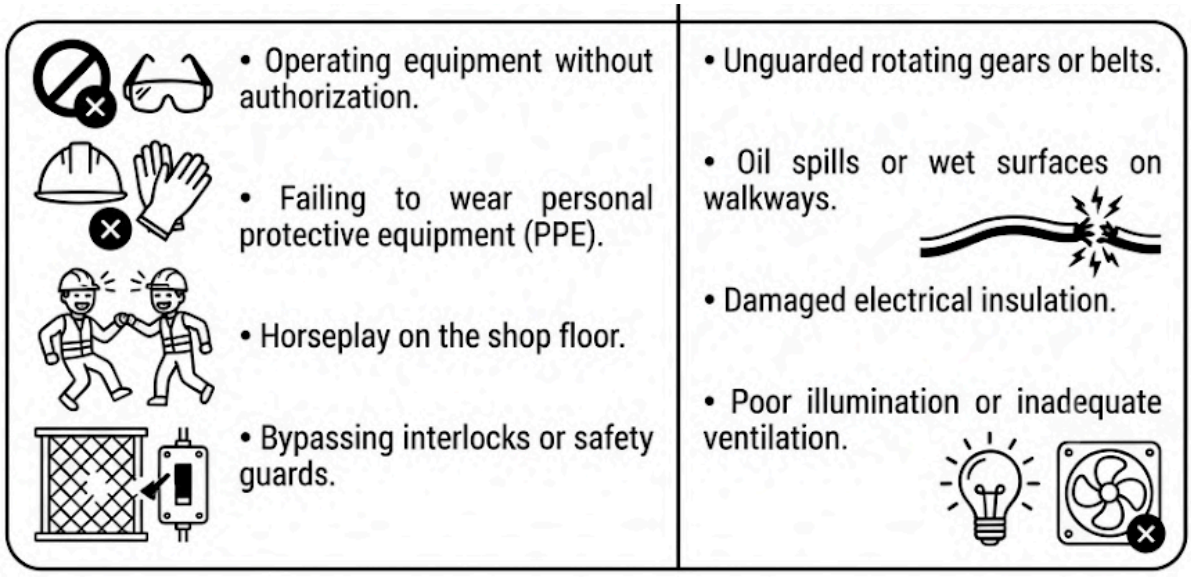
- **Focus of Safety Philosophy**: Safety management must focus on addressing the **300 near-misses** at the base of the triangle to prevent the single major fatality at the apex.

Unsafe Acts vs. Unsafe Conditions

Parameter	**Unsafe Act (Human Aspect ~88%)**	**Unsafe Condition (Environmental Aspect ~10%)**
Definition	A violation of accepted safety procedures by a worker.	A physical or mechanical hazard in the work environment.

Examples	• Operating equipment without authorization. • Failing to wear personal protective equipment (PPE). • Horseplay on the shop floor. • Bypassing interlocks or safety guards.	• Unguarded rotating gears or belts. • Oil spills or wet surfaces on walkways. • Damaged electrical insulation. • Poor illumination or inadequate ventilation.





Causes of Accidents & Safety Measures

Primary Categories of Accident Causes

Industrial accidents rarely stem from a single isolated failure. According to industrial safety engineering principles, causes are broadly classified into two categories:

- Human Factors (Unsafe Acts - approx. 88%): Caused by human error, behavioral deviation, lack of training, or failure to follow standard operating procedures (SOPs). Examples include:
    - Operating machinery or material handling equipment without proper authorization.
    - Removing, bypassing, or disabling machine guards and safety interlocks.
    - Adopting an improper posture or lifting heavy loads incorrectly, leading to ergonomic strain.
    - Engaging in horseplay, distraction, or working under the fatigue or influence of substances.
    - Omitting or refusing to wear mandated Personal Protective Equipment (PPE).

- Environmental & Mechanical Factors (Unsafe Conditions - approx. 10%): Caused by physical flaws in the workplace environment or equipment design. Examples include:
    - Exposed, unguarded rotating shafts, gears, pulleys, and nip points.
    - Defective tools, cracked machinery parts, or compromised structural integrity.
    - Slippery flooring due to oil spills, chemical leaks, or water accumulation.
    - Inadequate illumination, poor ventilation, or excessive noise and toxic gas buildup.

- Act of God (approx. 2%): Unpredictable natural phenomena (such as lightning strikes, severe earthquakes, or floods) that cause structural or industrial failures.

Engineering vs. Administrative Safety Measures

To eliminate or mitigate workplace hazards, industries implement a strict hierarchy of safety controls, prioritizing engineering solutions over behavioral compliance:

A. Engineering Controls (Design-Stage Safety)

- Inherent Safety Design: Redesigning equipment or processes to remove the hazard entirely (e.g., using non-toxic solvents instead of flammable hydrocarbons).
- Machine Guarding: Installing physical barriers (fixed, interlocking, or adjustable guards) that prevent any part of a worker's body from coming into contact with moving machinery parts.
- Emergency Stop Devices (E-Stops): Placing easily accessible push-buttons, pull-cords, or trip wires around high-risk automated machinery to instantly cut power during emergencies.
- Ventilation and Extraction Systems: Local exhaust ventilation (LEV) hoods placed directly over chemical processing units to remove toxic fumes and airborne dust.

B. Administrative Controls (Procedural Safety)

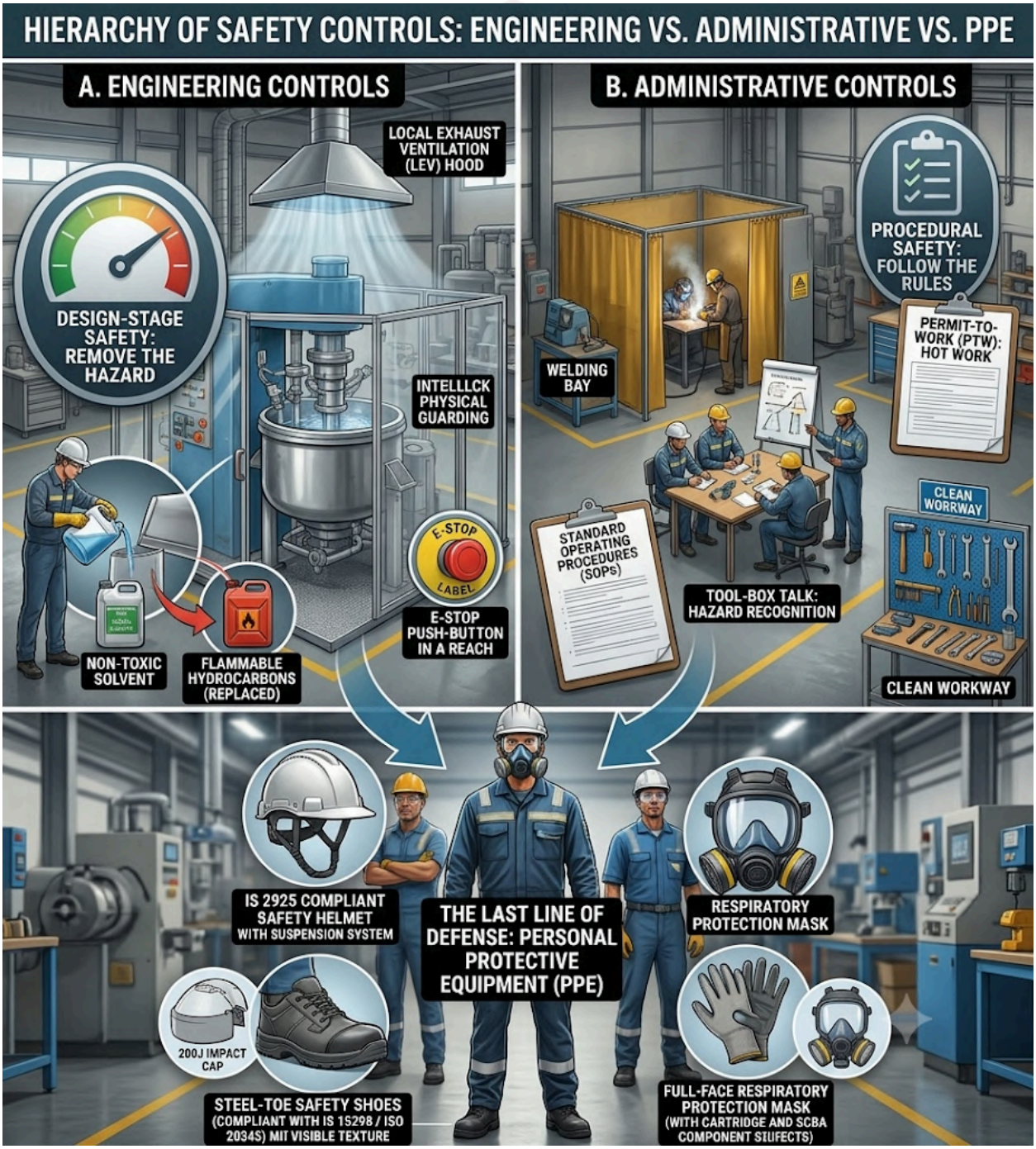
- Standard Operating Procedures (SOPs): Mandatory, step-by-step documentation detailing safe execution of high-risk tasks.
- Permit-to-Work (PTW) Systems: Formal written safety control documents required for hazardous activities such as hot work (welding), confined space entry, electrical high-tension maintenance, and working at heights.
- Safety Training and Tool-Box Talks: Routine educational sessions for diploma students and industrial workers to reinforce hazard recognition and emergency response protocols.
- Housekeeping Schedules: Routine cleaning protocols to clear walkways, eliminate oil spills, and prevent scrap accumulation.

The Last Line of Defense: Personal Protective Equipment (PPE)

When engineering and administrative controls cannot eliminate a hazard, PPE acts as the final barrier between the worker and injury:

- Head Protection: Industrial safety helmets (compliant with IS 2925) designed with High-Density Polyethylene (HDPE) shells and shock-absorbing suspension cradles.
- Foot Protection: Steel-toe safety shoes (compliant with IS 15298 / ISO 20345) featuring a 200J impact-resistant toe cap and anti-slip double-density PU soles.

- Respiratory Protection: Dust masks, chemical cartridge respirators, and Self-Contained Breathing Apparatus (SCBA) for toxic atmospheres or oxygen-deficient spaces.
- Fall Protection: Full-body safety harnesses, anchorage lines, and lifeline hooks mandatory for workers operating at heights exceeding 2 meters under national safety guidelines.



Do's & Don'ts while major fire & gas leaks.

Major Fire Outbreak: Do's & Don'ts

DO'S

- **Raise the Alarm Immediately**: Activate the nearest Manual Call Point (MCP) or shout "FIRE, FIRE!" to alert all occupants in the zone.
- **Evacuate Calmly via Stated Routes**: Follow green exit signs and designated escape routes toward the nearest designated assembly point.
- **Keep Low Under Smoke**: If smoke fills corridors, crawl or stay low where the air is cleaner and cooler, as toxic gases and smoke rise.
- **Close Doors Behind You**: As you evacuate a room, close (do not lock) doors behind you to slow down the spread of fire and smoke.
- **Check Doors for Heat**: Before opening any closed door, feel it with the back of your hand. If it is hot, do not open it—use an alternative escape route.
- **Use Extinguishers *Only* if Trained and Safe**: Tackle a small, incipient-stage fire using the correct extinguisher class (e.g., CO2 or Dry Powder) *only* if your back is clear to an exit.

DON'TS

- **DO NOT Use Elevators/Lifts**: Never use elevators during a fire emergency, as electrical power may fail trapping you inside, or shafts can act as chimneys for smoke.
- **DO NOT Stop to Collect Personal Belongings**: Valuables can be replaced; human life cannot. Evacuate immediately.
- **DO NOT Open Burning Rooms**: Introducing fresh oxygen into a starving or contained fire can cause a catastrophic **flashover** or **backdraft**.
- **DO NOT Panic or Run**: Running causes confusion, stampedes, and accidental injuries. Walk briskly and orderly.
- **DO NOT Re-enter the Building**: Once evacuated, never return inside for any reason until emergency services or the fire marshal declares the area 100% safe.



2. Major Gas Leak: Do's & Don'ts

DO'S

- **Evacuate Upwind and Crosswind**: Move away from the source of the leak immediately, traveling perpendicular to or against the wind direction to avoid toxic/flammable vapor clouds.
- **Wear Respiratory Protection (If Authorized)**: Put on Self-Contained Breathing Apparatus (SCBA) or appropriate chemical cartridge respirators if trained and designated for emergency response.
- **Isolate the Source (If Safe to Do So)**: If trained and accessible without hazard, shut off the main cylinder valve or emergency gas supply line.
- **Ventilate the Area**: Open doors and explosion-proof windows from the outside if it can be done safely to disperse lighter-than-air or heavier-than-air gases.
- **Inform Plant Safety Personnel**: Immediately notify the control room, plant safety officer, and local fire/disaster response authorities.

DON'TS

- **DO NOT Create Sparks or Flames**: Never strike matches, light lighters, smoke, or operate any open flame near a suspected gas leak.
- **DO NOT Operate Electrical Switches**: Do not turn lights on or off, plug in appliances, use mobile phones, or press doorbells. Electric arcs from switches can instantly ignite flammable gas-air mixtures.
- **DO NOT Inhale the Gas**: Never attempt to "sniff" or check gas leaks directly. Assume all unidentified gases are toxic, asphyxiating, or explosive.
- **DO NOT Hide in Confined Spaces**: Avoid basements, trenches, or low-lying areas if dealing with heavier-than-air gases (like LPG or CO_2), as they displace oxygen and accumulate in pits.
- **DO NOT Ignore Alarms**: Never treat gas odor or detector warnings as false alarms until fully investigated by professionals using gas-testing instruments.



On - Site & Off - Site Emergency Plan

Under the **Factories Act 1948** (specifically Section 41B regarding compulsory disclosure of information and emergency planning) and the Manufacture, Storage and Import of Hazardous Chemical (MSIHC) Rules 1989, high-risk factories handling hazardous chemicals must establish robust disaster management blueprints.

- **Primary Objective**: To localize the emergency, mitigate its effects, protect plant personnel and property, and facilitate seamless coordination with external public services during a catastrophic disaster.

On-Site Emergency Plan (Internal Plant Focus)

An **On-Site Emergency Plan** is designed to handle emergencies that occur entirely within the factory premises and can be managed using the plant's internal resources.

- **Key Elements**:
  - **Emergency Control Center (ECC)**: A designated secure command hub equipped with plant layouts, communication systems, wind direction indicators (wind socks), and emergency contact directories.
  - **Key Personnel & Responsibilities**: Clear identification of the **Site Main Controller (SMC)** (usually the Factory Manager or Plant Head) and **Incident Controller (IC)**, who direct tactical rescue operations.
  - **Emergency Response Teams (ERTs)**: Specialized internal teams trained for fire-fighting, search-and-rescue, hazardous material containment (HAZMAT), and first aid.
  - **Communication & Alarm Systems**: Distinct audio-visual sirens for fire outbreaks, toxic gas leaks, and plant-wide evacuation, paired with backup walkie-talkies and public address systems.

3. Off-Site Emergency Plan (External Community Focus)

An **Off-Site Emergency Plan** is activated when an industrial disaster escalates beyond the factory boundary, posing a direct threat to the surrounding public, property, and environment.

- **Key Elements**:
  - **Authority & Coordination**: Prepared by the District Collector, District Disaster Management Authority (DDMA), and local civil administration in consultation with factory management.
  - **Vulnerability & Hazard Mapping**: Detailed tracking of population density, schools, hospitals, and wind patterns within the vulnerable impact zone (radius determined by risk assessment studies).
  - **Public Warning and Notification Systems**: Sirens, public broadcast announcements, and SMS alert networks deployed to notify surrounding communities.
  - **Evacuation & Medical Triage**: Pre-planned evacuation routes, designated safe assembly zones, emergency shelter arrangements, and mobilization of nearby district hospitals, ambulances, and police forces.

4. Comparison Between On-Site and Off-Site Plans

Parameter	On-Site Emergency Plan	Off-Site Emergency Plan
Operational Scope	Confined within factory boundaries / premises.	Extends outside the plant into local communities and district zones.
Preparedness Ownership	Factory Management & Plant Safety Officers.	District Collector, DDMA, and Local Administration.
Primary Resources	Internal fire tenders, plant ERTs, safety stock, and internal medical room.	District police, fire services, government hospitals, civil defense, and NGOs.
Activation Threshold	Any major incident or near-miss within the plant.	Disasters with potential off-site toxic release, massive explosion, or wide-scale blast wave.



Plant Layout

A Plant Layout refers to the optimum arrangement of industrial facilities, including machinery, equipment, raw material storage, workflow paths, and employee service stations, within the physical structure of a factory.

From an industrial safety perspective, an ideal plant layout aims to:

- Prevent Domino Effects: Isolate hazardous processes so that a localized fire, explosion, or toxic release does not escalate into a catastrophic plant-wide disaster.
- Ensure Smooth Workflow: Minimize material handling and cross-traffic to reduce physical collision and mechanical handling accidents.
- Facilitate Emergency Evacuation: Provide wide, unobstructed escape routes and clear access for external emergency vehicles (fire tenders and ambulances).

Key Safety Principles in Plant Layout Design

A. Principle of Isolation and Segregation

Hazardous Units Separation: High-risk units—such as boilers, furnaces, flammable liquid storage tanks, and gas manifolds—must be isolated downwind or at safe separation distances away from administrative offices, control rooms, and assembly areas.

Control Room Siting: Occupied buildings and central control rooms should be structurally fortified (blast-resistant) and located away from potential explosion or toxic vapor cloud paths.

B. Principle of Minimum Movement and Flow

Linear Workflow: Materials should move in a progressive, forward direction from raw material storage to processing and final dispatch, eliminating backtracking and traffic congestion.

Clear Walkways: Distinct pathways marked with yellow and black safety lines must separate pedestrian walkways from heavy material handling vehicle paths (forklifts and cranes).

C. Principle of Accessibility and Maintenance

Emergency Access Roads: Dedicated perimeter roads must allow fire engines unhindered 360-degree access to major process blocks and tank farms.

Equipment Clearance: Ample clearance space must be maintained around rotating machinery and electrical panels to allow safe operation, servicing, and emergency shut-off.

3. Statutory Safety Requirements in Layouts

Ventilation and Illumination: The layout must incorporate natural or mechanical cross-ventilation to prevent the accumulation of toxic or explosive gases, alongside uniform lighting across all task areas.

Emergency Exits: Production floors and workshops must feature multiple, well-lit, outward-opening emergency exit doors placed at strategic locations, ensuring no worker has to travel excessive distances to escape.

Storage Safety: Flammable chemical storage must be situated outdoors or in dedicated fire-rated open-air sheds equipped with natural ventilation and blast relief panels.

Handling & Storage of materials

Material handling—encompassing the movement, storage, and control of raw materials, components, and finished goods—accounts for a significant percentage of industrial

accidents. These typically involve musculoskeletal strains from manual lifting, or severe crushing and struck-by injuries from mechanical material handling (MMH) equipment.

- **Primary Safety Goal**: Eliminate manual lifting hazards through mechanical aids where possible, establish ergonomic posture limits, and ensure secure stacking and storage to prevent collapses.

Manual Material Handling (MMH) Safety

Manual lifting and carrying are major contributors to back injuries and sprains in industrial workshops.

- **Ergonomic Lifting Guidelines**:
  - **Keep the Load Close**: Hold heavy items close to the body's center of gravity to minimize spinal leverage and lumbar strain.
  - **Lift with the Legs**: Bend at the knees while keeping the back straight; use leg power rather than lower back muscles to lift loads.
  - **Avoid Twisting**: Do not twist the torso while lifting or carrying a load; pivot with the feet to change direction.
  - **Weight Limits**: Adhere strictly to safe working load limits per worker under factory safety regulations (typically restricted to safe thresholds based on gender and age groups).

Mechanical Material Handling (MMH) Safety

When using heavy equipment—such as overhead cranes, hoists, forklifts, and conveyors—strict operational protocols must be followed:

- **Forklift Safety (Industrial Trucks)**:
  - Operators must be trained, authorized, and certified.
  - Always travel with the load carried low (about 15 to 20 cm above the ground) to maintain stability.
  - Observe speed limits, sound the horn at blind corners and intersections, and never allow passengers to ride on the forks or body.
- **Cranes and Hoists**:
  - Inspect wire ropes, chains, hooks, and slings before every shift.
  - Never exceed the **Safe Working Load (SWL)** marked on the lifting equipment.
  - Ensure unauthorized personnel stay clear of the drop zone; never pass suspended loads over workers.

Safe Storage and Stacking Principles

Improper storage leads to falling object hazards, obstructed walkways, and fire risks.

- **Stability of Stacks**: Stack materials (bags, cartons, drums, or timber) in interlocking, stable tiers to prevent sliding or toppling. Observe safe height-to-base ratios.

- **Clearance and Aisles**: Maintain minimum clearance distances below overhead sprinkler heads (at least 45 cm to 90 cm) and keep primary escape aisles completely unobstructed.
- **Hazardous Material Segregation**: Store incompatible materials (such as flammable liquids separated from oxidizers or acids separated from bases) in designated, well-ventilated, fire-rated storage zones.

Safe Methods of Handling LPG Cylinder

Safe practices for handling and storing **Liquefied Petroleum Gas (LPG) Cylinders**, structured in accordance with the **Gas Cylinder Rules**, **IS 6044** codes of practice.

Core Properties & Associated Hazards

LPG (primarily a mixture of propane and butane) is stored as a liquid under pressure.

- **Heavier than Air**: LPG vapor is approximately 1.5 to 2 times heavier than air. If a leak occurs, the gas does not dissipate upward; instead, it settles, flows along the floor, and accumulates in low-lying areas, pits, or drains, creating an invisible explosive hazard over long distances.
- **Extremely Flammable**: It has a very wide explosive/flammable range when mixed with air, meaning even a minor spark can trigger a flash fire or detonation.
- **Odourant Added**: Mercaptan is added to LPG to give it a distinct pungent smell so that even minor leaks are detectable.

Safe Transportation and Handling Rules

- **Always Keep Upright**: Cylinders (both full and empty) must **always be transported, stored, and operated in a vertical (upright) position**. Laying an LPG cylinder flat allows liquid gas to enter the pressure regulator, causing high-pressure failure and severe hazards.
- **No Dragging or Rolling**: Never drag, slide, or roll cylinders across the floor. Move them using approved hand trolleys or gently tilt and roll them on their bottom rim only if short distances require it.
- **Avoid Impact and Dropping**: Never drop cylinders, subject them to mechanical shock, or use them as rollers, work supports, or makeshift anvils.
- **Use Protective Valve Caps**: Always screw on the safety valve cap/guard when the cylinder is not connected to a system or during transit to protect the valve stem from breaking if dropped.

Safe Operating Practices

- **Check for Leaks with Soap Solution**: Always test joints, connections, and hose fittings using a **soapy water solution**. **Never use an open flame (matchstick or lighter)** to check for gas leaks.
- **Keep Away from Heat Sources**: Position cylinders away from direct sunlight, open flames, stoves, radiators, or high-temperature industrial equipment.

- **Hose and Regulator Maintenance**: Use only ISI-certified rubber/synthetic low-pressure hoses (compliant with IS standards), secure them with proper hose clips, and inspect them regularly for cracks, wear, or rodent damage. Replace flexible hoses periodically.
- **Never Transfer Gas Illegally**: Decanting or transferring LPG from a commercial/domestic cylinder to another container or unauthorized setup is strictly illegal and extremely hazardous.

Safe Storage Guidelines (IS: 6044 Standards)

- **Well-Ventilated Outdoor Storage**: Cylinders should ideally be stored outdoors or in a dedicated, well-ventilated, open-air shed with a protective roof. Avoid fully enclosed, damp, or subterranean spaces.
- **Segregation from Incompatible Materials**: LPG cylinders (flammable gas) must be stored at a safe separation distance (minimum 3 meters) away from oxidizing or toxic gas cylinders like compressed oxygen.
- **Separation of Full and Empty Units**: Maintain a clear physical separation between **full** and **empty** cylinders to avoid operational confusion during an emergency.
- **Mandatory Signage**: Display clear safety notices such as **"DANGER – FLAMMABLE GAS"** and **"NO SMOKING / NO OPEN FLAMES"** around the storage perimeter.

Do's & Don'ts in case of LPG Leaks:

LPG Leak: DO'S

- **Put Out All Open Flames Immediately**: Instantly extinguish any bhuvan stoves, agarbattis, oil lamps, cigarettes, or nearby open flames.
- **Isolate the Gas Supply**: If it is safe to reach, immediately close the cylinder valve or main supply regulator (turn clockwise) to cut off the source of escaping gas.
- **Ventilate the Area Thoroughly**: Open all doors and windows wide. Because LPG vapor is heavier than air and sinks to the floor, create low-level ventilation to help sweep the gas out.
- **Evacuate the Hazard Zone**: Order all non-essential personnel and students to evacuate the area immediately, moving upwind and away from low-lying areas or basements.
- **Inform Safety Personnel / Fire Services**: Alert the plant safety officer, campus security, or local fire and rescue services immediately if the leak cannot be stopped.

LPG Leak: DON'TS

- **DO NOT Operate Any Electrical Switches**: Never turn lights, fans, exhaust fans, AC units, or electrical appliances **ON or OFF**. Operating a switch creates a

microscopic electrical spark inside the toggle mechanism, which can instantly ignite the gas-air mixture.

- **DO NOT Use Mobile Phones or Electronic Devices**: Avoid using mobile phones, walkie-talkies, or lighters near the leakage zone, as electronic circuitry can generate static or sparks.
- **DO NOT Strike Matches or Use Lighters**: Never attempt to check for the leak using a matchstick, candle, or lighter.
- **DO NOT Pull Plugs Out of Sockets**: Do not disconnect appliances or pull electrical plugs, as arcing at the socket can trigger an explosion.
- **DO NOT Enter Low-Lying Pits or Drains**: Avoid descending into cellars, maintenance pits, or trenches where heavier-than-air LPG vapor may have pooled and displaced life-sustaining oxygen.



Personal Protective Equipment & their Uses.

Personal Protective Equipment (PPE) refers to specialized clothing, gear, or appliances worn by workers to minimize exposure to hazards that cause serious workplace injuries and illnesses.

- The Hierarchy of Hazard Control: PPE represents the absolute last line of defense. It is used only when hazards cannot be eliminated through engineering controls (such as machine guarding or ventilation), substitution, or administrative policies.
- User Fit and Comfort: Equipment must fit the user properly, not introduce secondary ergonomic strains, and comply with national manufacturing standards.

A. Head Protection (Industrial Safety Helmets)

- Standard: IS 2925:1984
- Material: High-Density Polyethylene (HDPE) or polycarbonate shells.
- Purpose: Protects the skull and brain against falling tools, structural debris, overhead electrical hazards, and lateral impacts.
- Key Components: Features a shock-absorbing 4-point or 6-point inner suspension cradle and a ratchet fit adjustment to absorb and distribute impact force.

B. Eye and Face Protection

- Standards: IS 11783 (Goggles) / IS 852 (Face Shields)
- Purpose: Safeguards against flying metal/wood chips, chemical splashes, dust particles, and harmful optical radiation (such as UV/IR rays from welding).
- Types: Chemical splash goggles with indirect ventilation, clear safety spectacles with side shields, and heavy-duty welding face shields with dark filter shades.

C. Respiratory Protection

- Standards: IS 9623 / IS 14166
- Purpose: Prevents inhalation of toxic dusts, mists, metal fumes, chemical vapors, or oxygen-deficient air.
- Types:
    - Particulate Respirators: Filtering half-masks (like N95/FFP2) for dust and aerosols.
    - Chemical Cartridge Respirators: Half-face or full-face masks with replaceable filters for specific gases.
    - Self-Contained Breathing Apparatus (SCBA): Independent air supply for high-risk toxic leaks or confined space entry.

D. Foot Protection (Safety Shoes / Boots)

- Standard: IS 15298:2011 (Part 2)
- Purpose: Protects feet from heavy falling objects, puncture wounds from sharp debris, chemical corrosives, and electrical slip hazards.
- Key Features: Built with a 200-Joule impact-resistant steel toe cap, puncture-resistant steel midsole plates, oil-resistant, and anti-slip double-density PU soles.

E. Hand and Arm Protection

- Standard: IS 6994 / IS 2573
- Purpose: Protects against cuts, abrasions, thermal burns, and chemical absorption.
- Types: Leather gloves for welding/handling rough materials, chemical-resistant rubber/neoprene gloves for handling acids and solvents, and electrical insulating rubber gloves tested for high-voltage protection.

3. Statutory Responsibilities & Maintenance Rules

- Employer Responsibility: Under factory legislation, management must provide certified PPE free of cost to workers exposed to workplace hazards.
- Worker Responsibility: Workers must wear mandated PPE correctly during active shifts, inspect equipment prior to use, and report any structural damage immediately.
- Care and Inspection: PPE must be cleaned regularly, stored in clean, dry cabinets away from direct sunlight, and replaced immediately if compromised by wear, tear, or structural impact (such as a safety helmet taking a heavy blow).



EXPERIMENT NO. 1: DETERMINATION OF CALORIFIC VALUE OF A SUBSTANCE

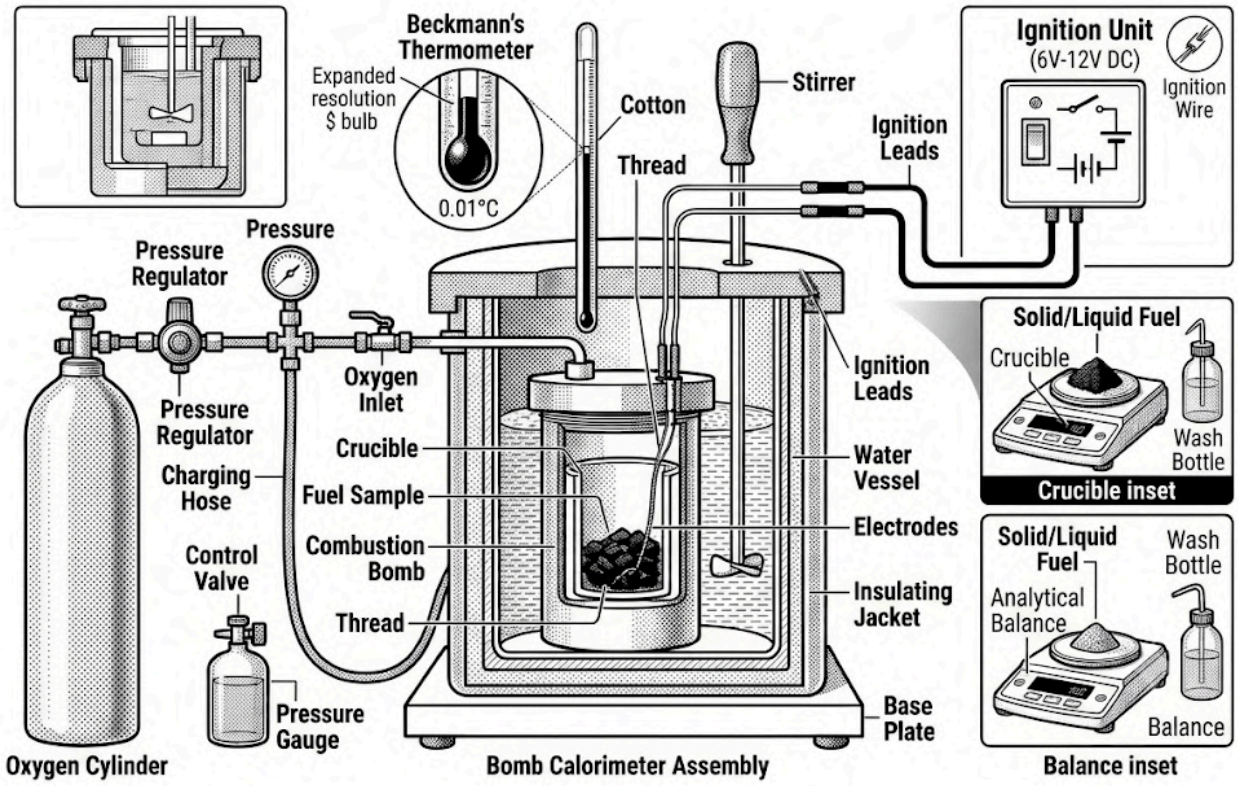
1. Aim (5 Marks)

To determine the gross and net calorific value of a given solid or liquid fuel sample (such as coal or fuel oil) using a standardized **Bomb Calorimeter** apparatus in accordance with standard testing practices.

2. Apparatus Required (5 Marks)

- **Bomb Calorimeter Assembly**: Consisting of a strong stainless-steel combustion bomb with a tightly sealable screw lid.
- **Oxygen Cylinder**: Equipped with a pressure regulator, high-pressure charging hose, and control valve.
- **Calorimeter Vessel & Water Jacket**: Copper or stainless-steel calorimeter container surrounded by an insulating air/water jacket to minimize heat loss by radiation.
- **Temperature Sensor / Beckmann's Thermometer**: Capable of reading temperature variations down to 0.01°C.
- **Motorized Stirrer**: To ensure uniform temperature distribution throughout the water bath.
- **Ignition Unit**: 6V–12V DC power supply unit with electrical leads connected to bomb electrodes.
- **Consumables & Tools**: Crucible (stainless steel or nickel-chromium), nickel/magnesium fuse wire, sewing cotton thread, analytical balance, and wash bottle.

EXPERIMENT NO. 1: DETERMINATION OF CALORIFIC VALUE OF A SUBSTANCE



3. **Procedure / Material Preparation / Arrangements (20 Marks)**

A. Sample Preparation & Bomb Assembly

1. Accurately weigh about $0.5g$ to $1.0g$ of the finely ground, dried fuel sample into a clean, pre-weighed crucible.
2. Stretch a clean piece of fuse wire (such as nickel or magnesium wire) across the two internal stainless-steel electrodes inside the bomb lid so that it dips down.
3. Tie a short length of clean cotton thread to the middle of the fuse wire, ensuring the loose end of the thread makes firm contact with the fuel sample inside the crucible.
4. Pour exactly $10mL$ of distilled water into the bomb body to absorb acid gases (H_2SO_4 and HNO_3) formed during combustion.
5. Carefully place the loaded crucible onto the support ring attached to the electrode, screw the bomb lid on tightly, and hand-seal it to ensure a gas-tight fit.

B. Oxygen Charging and Calorimeter Setup

1. Connect the oxygen filling hose to the bomb inlet valve. Slowly open the oxygen cylinder valve and charge the bomb with pure oxygen up to a pressure of **25 to 30 atmospheres**. Close the valve and disconnect safely.
2. Measure a known quantity of water ($Wgrams$) into the copper calorimeter vessel such that the bomb, when submerged, is entirely covered.
3. Place the charged bomb inside the calorimeter vessel, check for any gas leaks (ensure no air bubbles escape), and fit the calorimeter into the insulated outer water jacket.
4. Position the Beckmann's thermometer and the motor-driven stirrer into the water jacket lid. Ensure the stirrer moves freely without touching the bomb.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram

[Sample Weighing & Crucible Setup] ⟶ [Bomb Assembly & Oxygen Charging (25 atm)]

↓

[Final Temperature Peak Recorded] ⟵ [Ignition via Firing Circuit (Stirrer On)]

↓

[Acid & Wire Corrections Applied] ⟵ [Post-Test Washout & Titration Analysis]

B. Observation & Data Logging

- Start the mechanical stirrer and let it run continuously.
- Record the initial temperature (t_1) of the water at 1-minute intervals for 5 steady minutes.
- Connect the firing unit leads to the bomb terminals and press the ignition switch momentarily to burn the sample.
- Continue recording water temperatures every 30 seconds to 1 minute until the peak maximum temperature (t_2) is reached and steady cooling is observed.

C. Formulae and Calculations

Let:

- Mass of fuel sample = mg
- Mass of water taken in calorimeter = Wg
- Water equivalent of the calorimeter, bomb, stirrer, and thermometer = wg
- Initial temperature = $t_1{}^0C$
- Final peak temperature = $t_2{}^0C$

- Gross Calorific Value (GCV or θ):

$$GCV = \frac{(W+w)(t_2 - t_1 + t_c) - (t_a + t_f + t_t)}{m} cal/g$$

Where:

- t_c = Cooling correction
- t_a = Acid correction (H_2SO_4 and HNO_3 formation)
- t_f = Fuse wire correction
- t_t = Cotton thread correction
- Net Calorific Value (NCV):

- $NCV = GCV - (0.09 \times Percentage of Hydrogen \times 587) cal/g$

5. Output / Result (10 Marks)

- **Gross Calorific Value (GCV)** of the given fuel sample = _____$kcal/kg$ (or kJ/kg)
- **Net Calorific Value (NCV)** of the given fuel sample = _____$kcal/kg$ (or kJ/kg)

6. Viva Voce Questions (10 Marks)

1. What is the primary purpose of a bomb calorimeter in industrial fuel testing?
2. Why is pure oxygen pressurized inside the bomb instead of normal atmospheric air?
3. What is meant by the "water equivalent" of a calorimeter, and how is it determined?
4. Why are acid and fuse wire corrections necessary in this experiment?
5. What is the fundamental difference between Gross Calorific Value (GCV) and Net Calorific Value (NCV)?

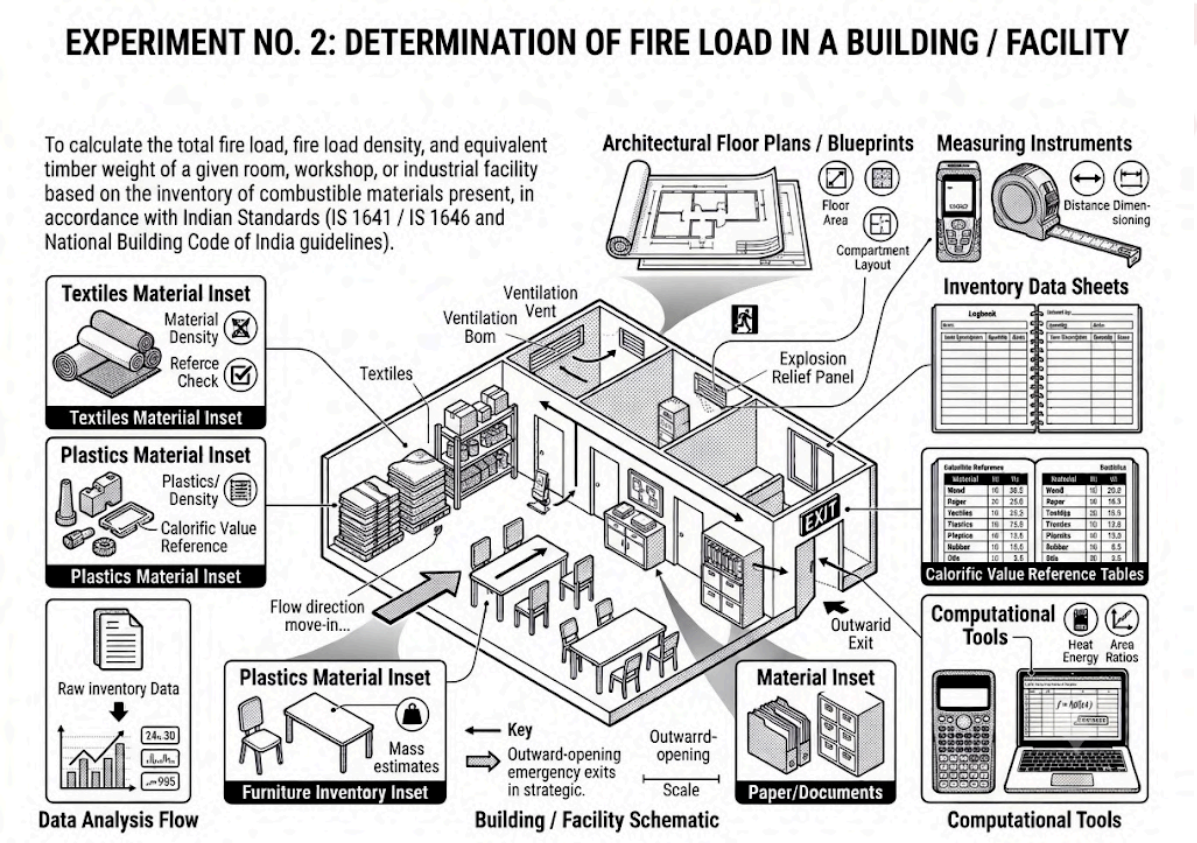
EXPERIMENT NO. 2: DETERMINATION OF FIRE LOAD IN A BUILDING / FACILITY

1. Aim (5 Marks)

To calculate the total fire load, fire load density, and equivalent timber weight of a given room, workshop, or industrial facility based on the inventory of combustible materials present, in accordance with Indian Standards (IS 1641 / IS 1646 and National Building Code of India guidelines).

2. Apparatus Required (5 Marks)

- **Architectural Floor Plans / Blueprints**: Showing room dimensions, floor areas, and compartment layouts.
- **Measuring Instruments**: Laser distance meter or steel measuring tape for accurate room and storage dimensioning.
- **Inventory Data Sheets**: Standardized logs for recording item descriptions, material types, quantities, and estimated masses.
- **Calorific Value Reference Tables**: Standard tables providing the calorific values (H_i) of common combustible materials (wood, paper, textiles, plastics, rubber, and oils).
- **Computational Tools**: Scientific calculator or spreadsheet software for calculating total heat energy and area ratios.



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. Compartment Selection & Area Measurement

1. Select a designated room, warehouse bay, or laboratory workshop for fire load assessment.
2. Measure the internal length (L) and width (B) of the compartment using a measuring tape or laser meter.
3. Calculate the total floor area ($A = L \times B$) in square meters (m^2).

B. Combustible Material Inventory Survey

1. Conduct a physical survey of everything inside the compartment capable of burning (e.g., wooden furniture, paper files, books, rubber mats, plastic storage bins, curtains, and packaging materials).
2. Weigh representative items or use standard manufacturing weight specifications to determine the total mass (m) in kilograms (kg) for each category of combustible material.
3. Record all data systematically in an inventory log table separating items by material type.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram

[Compartment Selection & Area Measurement (A)] ⟶ [Mass Inventory of Combustibles (m_i)]

↓

[Fire Load Density & Equivalent Timber Calculated] ⟵ [Calorific Value Lookup (H_i) Applied]

↓

[Classification of Fire Hazard]

B. Observation & Calculation Table

Item / Material Description	**Mass (mi in kg)**	**Calorific Value (Hi in kcal/kg or MJ/kg)**	**Total Heat Energy (Qi=mi×Hi)**
1. Wooden Tables & Chairs	m_1	$4,400 kcal/kg$	Q_1
2. Paper Files & Books	m_2	$4,000 kcal/kg$	Q_2
3. Plastic Storage Bins	m_3	$8,000 kcal/kg$	Q_3
Total Fire Load (Q)	—	—	$\sum Q_i$

C. Formulae

- **Total Fire Load (Q)**:

$$Q = \sum (m_1 H_1 + m_2 H_2 + m_3 H_3 + \dots) \text{ (in kcal or MJ)}$$

- **Fire Load Density (FLD)**:

$$FLD = \frac{Total\ Fire\ Load\ (Q)}{Total\ Floor\ Area\ (A)} (in\ kcal/m^2 or MJ/m^2)$$

- **Equivalent Timber Weight (W_{eq})**:

$$W_{eq} = \frac{Total\ Fire\ Load(Q)}{Calorific\ Value\ of\ Standard\ Wood\ (4{,}400kcal/kg)} kg$$

5. Output / Result (10 Marks)

- **Total Floor Area (A)** of the facility = _____m^2
- **Total Fire Load (Q)** = _____$kcal$ (or MJ)
- **Fire Load Density (FLD)** = _____$kcal/m^2$ (or MJ/m^2)
- **Equivalent Timber Weight (W_{eq})** = _____kg
- **Inference / Hazard Classification**: Based on the calculated Fire Load Density, the building category is classified as **[Low / Moderate / High]** Fire Hazard.

6. Viva Voce Questions (10 Marks)

1. What is meant by "Fire Load" and "Fire Load Density" in industrial building design?
2. Why is wood taken as the standard reference material for calculating equivalent timber weight?
3. How does fire load density influence the fire resistance rating required for structural elements (walls, floors, columns) of a factory?
4. What is the difference between low, moderate, and high fire load occupancies under IS building codes?
5. How does poor housekeeping and accumulation of combustible waste affect a building's overall fire load?

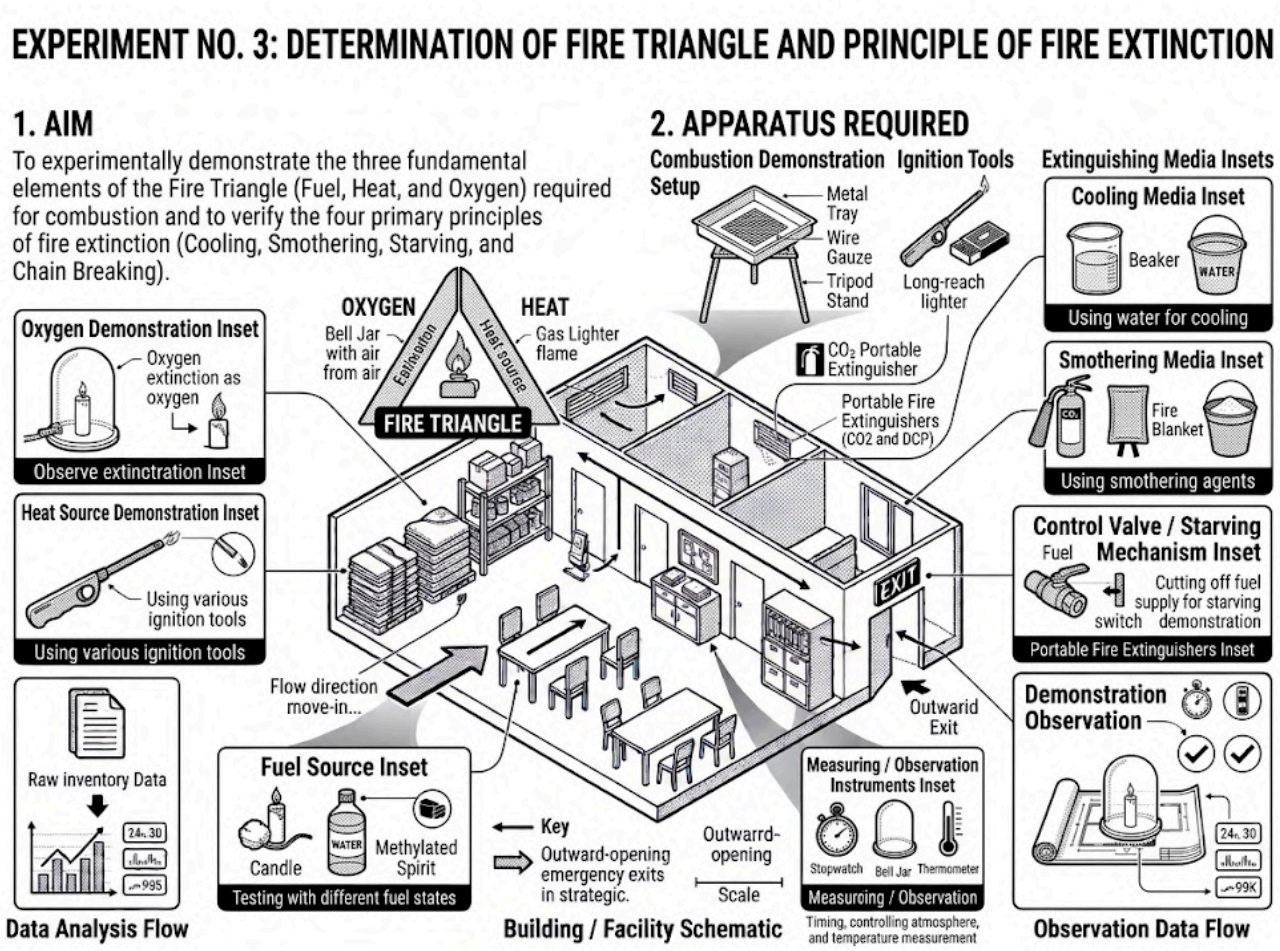
EXPERIMENT NO. 3: DETERMINATION OF FIRE TRIANGLE AND PRINCIPLE OF FIRE EXTINCTION

1. Aim (5 Marks)

To experimentally demonstrate the three fundamental elements of the Fire Triangle (Fuel, Heat, and Oxygen) required for combustion and to verify the four primary principles of fire extinction (Cooling, Smothering, Starving, and Chain Breaking).

2. Apparatus Required (5 Marks)

- **Combustion Demonstration Setup**: Metal combustion tray, tripod stand, and wire gauze.
- **Fuel Sources**: Paraffin wax candles, spirit/methylated spirit, and cotton waste.
- **Ignition Tools**: Long-reach gas lighter or safety matches.
- **Extinguishing Media & Equipment**:
    - Water beaker / bucket (for cooling demonstration)
    - Fire blanket / Sand bucket (for smothering demonstration)
    - Control valve / fuel cutoff mechanism (for starving demonstration)
    - Portable Fire Extinguishers (CO_2 and Dry Chemical Powder - DCP)
- **Measuring / Observation Instruments**: Stopwatch, glass cover/bell jar, and thermometer.



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. Part 1: Proving the Fire Triangle Elements

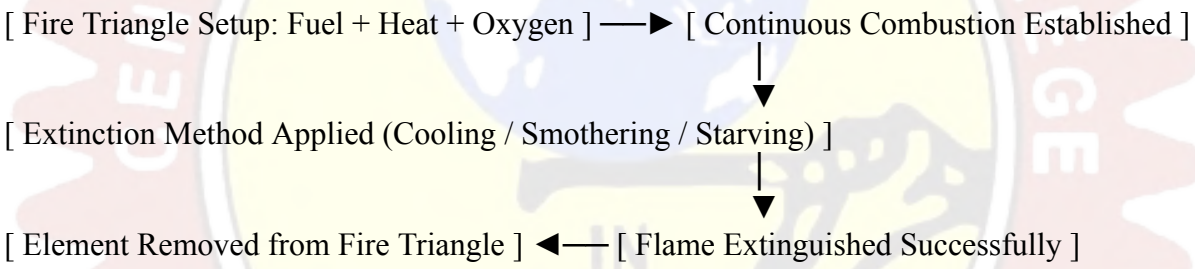
1. **Fuel Requirement**: Place a small piece of non-flammable stone on the tray and attempt to ignite it. Observe that without a combustible fuel, ignition does not occur. Now, place a wax candle or spirit in the tray and ignite it.
2. **Oxygen Requirement**: Light a candle fixed on a flat base. Carefully place a clear glass beaker or bell jar directly over the burning candle. Observe the flame as it gradually starves of oxygen and extinguishes when the internal oxygen concentration drops below the limiting oxygen index (*LOI*).
3. **Heat Requirement**: Ignite a combustible material using a heat source (lighter). Explain that the flash point/ignition temperature must be reached for continuous combustion.

B. Part 2: Demonstrating Principles of Fire Extinction

1. **Cooling (Removal of Heat)**: Ignite a small spirit pool fire or paper in the metal tray. Pour a controlled jet of water over the fire. Observe how the temperature drops rapidly below the ignition point, putting out the flame.
2. **Smothering (Removal of Oxygen)**: Cover a burning oil or spirit tray completely with a fire blanket or inverted metal container, or pour dry sand over it. Observe how cutting off the oxygen supply extinguishes the fire.
3. **Starving (Removal of Fuel)**: In a controlled gas burner setup, shut off the main supply valve. Observe how the flame dies out immediately once the fuel source is isolated.
4. **Chain Breaking (Chemical Inhibition)**: Discharge a Dry Chemical Powder (DCP) or CO_2 extinguisher across a small flaming surface to demonstrate free-radical chemical inhibition.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram



B. Observation & Extinction Mapping Table

Sl. No.	**Extinction Method**	**Principle Applied**	**Element Removed from Fire Triangle**	**Effective Fire Class**
1.	Water Jet Application	**Cooling**	Heat (Thermal Energy)	Class A (Solid combustibles)

2.	Fire Blanket / Foam / Sand	**Smothering**	Oxygen (Air Isolation)	Class B / Class C / Cooking oils
3.	Valve Isolation / Cut-off	**Starving**	Fuel Supply	Gas leaks & liquid fuel lines
4.	Dry Powder / CO_2	**Chain Breaking / Smothering**	Chemical Chain Reaction & Oxygen	Class B, Class C, & Electrical Fires

5. Output / Result (10 Marks)

- **Fire Triangle Verification**: Successfully proved that combustion requires the simultaneous presence of Fuel, Heat, and Oxygen, and the removal of any single element terminates the fire.
- **Extinction Principles**: Demonstrated that fires are successfully controlled and extinguished by applying the correct mechanisms of **Cooling, Smothering, Starving, or Chain Breaking** corresponding to the specific fire class.

6. Viva Voce Questions (10 Marks)

1. What are the three essential components that form the classic Fire Triangle?
2. How does a fourth element transform the Fire Triangle into the Fire Tetrahedron?
3. Why is water ineffective and dangerous when applied directly to Class B (flammable liquid) or Class C (electrical) fires?
4. What physical phenomenon occurs when a fire blanket is placed over a burning oil container?
5. Which extinguishing mechanism is primarily utilized by Carbon Dioxide (CO_2) fire extinguishers?

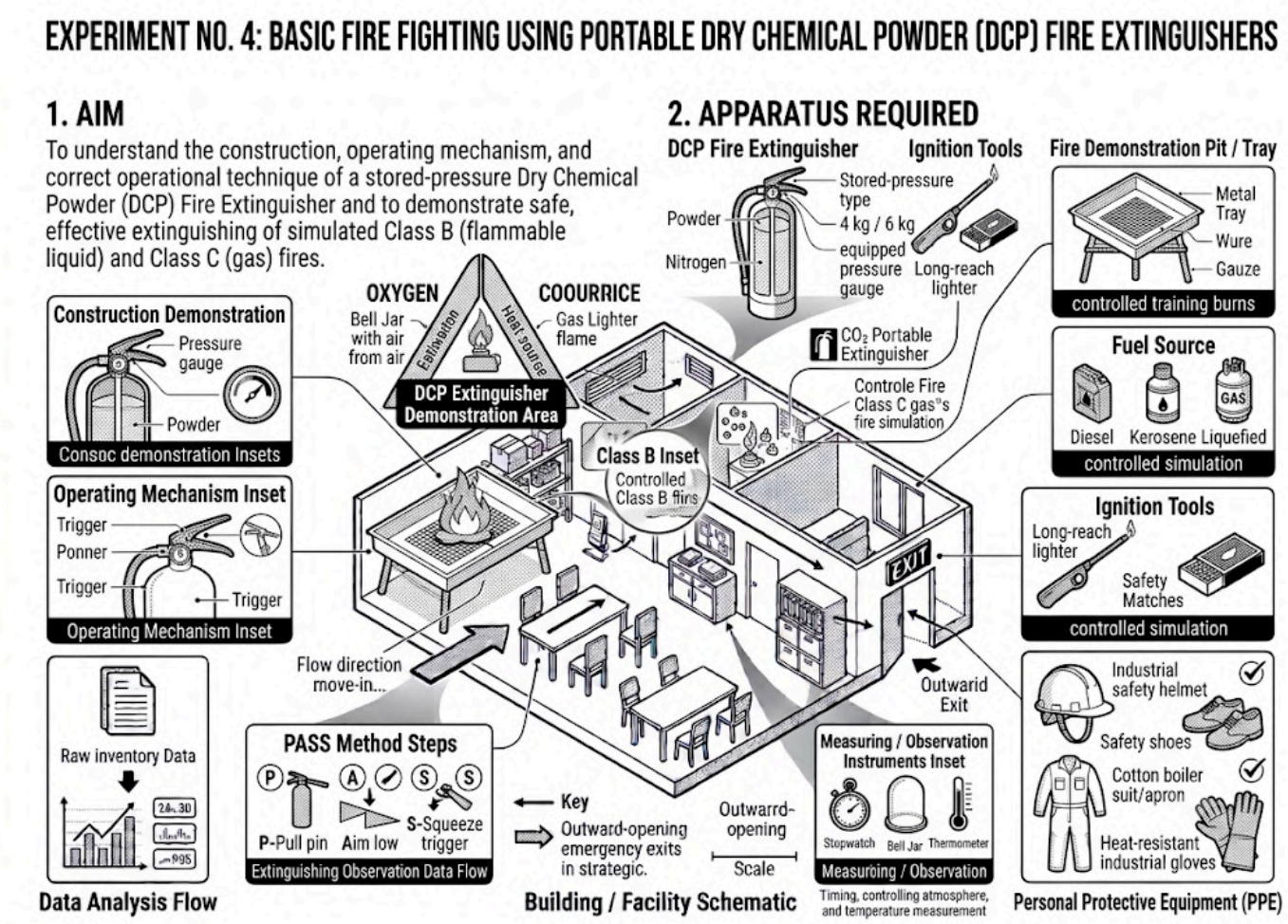
EXPERIMENT NO. 4: BASIC FIRE FIGHTING USING PORTABLE DRY CHEMICAL POWDER (DCP) FIRE EXTINGUISHERS

1. Aim (5 Marks)

To understand the construction, operating mechanism, and correct operational technique of a stored-pressure Dry Chemical Powder (DCP) Fire Extinguisher and to demonstrate safe, effective extinguishing of simulated Class B (flammable liquid) and Class C (gas) fires.

2. Apparatus Required (5 Marks)

- DCP Fire Extinguisher: Stored-pressure type (ABC or BC powder, typically 4 kg or 6 kg capacity) equipped with pressure gauge, discharge hose, and nozzle.
- Fire Demonstration Pit / Tray: Metal combustion tray for controlled training burns.
- Fuel Source: Diesel, kerosene, or liquefied petroleum gas (for controlled simulation).
- Ignition Tools: Long-reach gas lighter or safety matches.
- Personal Protective Equipment (PPE): Industrial safety helmet, safety shoes, cotton boiler suit/apron, and heat-resistant industrial gloves.



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. Pre-Inspection of the Extinguisher

1. Check the pressure gauge indicator to ensure the needle is in the **green zone** (indicating proper pressurization).
2. Inspect the safety pin and tamper-evident plastic seal to verify the unit has not been discharged.
3. Check the discharge hose and nozzle for cracks, blockages, or physical damage.

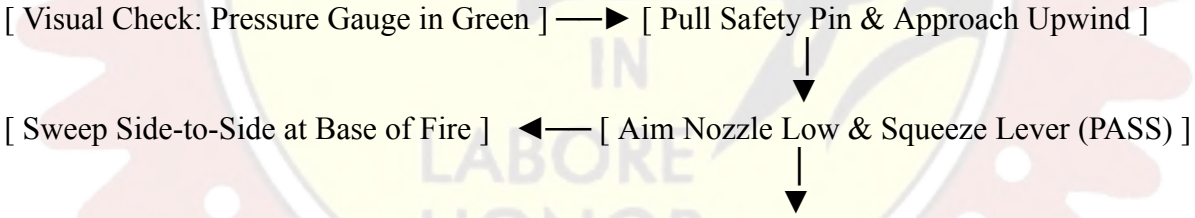
B. The PASS Operating Technique

Before approaching the fire zone, remember and apply the universal **PASS** acronym:

1. **P - Pull** the safety pin from the handle of the extinguisher.
2. **A - Aim** the nozzle or hose low, pointing directly at the **base** of the fire (not at the flames).
3. **S - Squeeze** the operating lever to release the pressurized extinguishing agent.
4. **S - Sweep** side-to-side across the base of the fire until the flames are completely extinguished.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram



B. Observation & Extinguishing Parameter Table

Parameter / Step	**Operational Guideline**	**Safety Significance**

Approach Direction	Always approach the fire from the **upwind** side.	Prevents smoke, toxic fumes, and radiant heat from blowing towards the operator.
Target Area	Direct discharge at the **base** of the fire, sweeping side to side.	Smothers fuel vapor and interrupts the chemical chain reaction at the burning surface.
Discharge Distance	Maintain a safe initial distance of **2 to 3 meters** from the fire.	Ensures effective coverage while preventing user burn injuries from sudden flashover.
Post-Use Action	Lay discharged or partially used extinguishers on their side.	Signals to others that the unit is empty and requires immediate recharging.

5. **Output / Result (10 Marks)**

- **Extinction Performance**: Successfully extinguished the simulated Class B/C fire using the correct **PASS** technique within the operational discharge time of the DCP unit.
- **Equipment Status**: Verified that the extinguisher functioned correctly, discharging free-flowing dry chemical powder to smother the flame front.

6. **Viva Voce Questions (10 Marks)**

1. What does the acronym **PASS** stand for in fire extinguisher operation?
2. Why must the extinguisher nozzle be aimed at the **base** of the fire rather than the upper flames?
3. What types of fires (Fire Classes) are effectively combated using a Dry Chemical Powder (DCP) extinguisher?
4. What does a pressure gauge needle dropping into the red zone indicate?
5. Why is it important to approach a fire from the upwind direction?

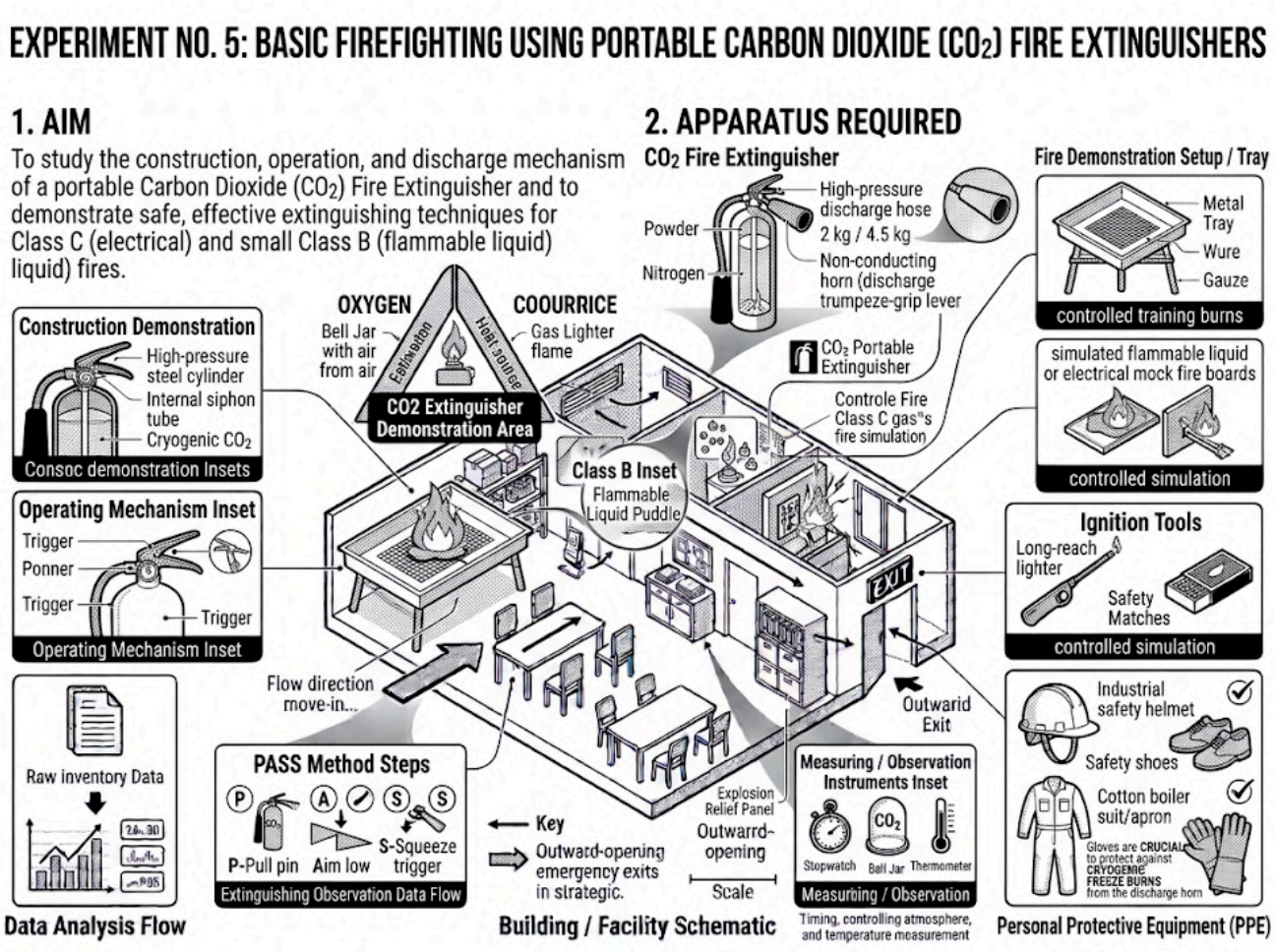
EXPERIMENT NO. 5: BASIC FIREFIGHTING USING PORTABLE CARBON DIOXIDE (CO_2) FIRE EXTINGUISHERS

1. Aim (5 Marks)

To study the construction, operation, and discharge mechanism of a portable **Carbon Dioxide (CO_2)** Fire Extinguisher and to demonstrate safe, effective extinguishing techniques for Class C (electrical) and small Class B (flammable liquid) fires.

2. Apparatus Required (5 Marks)

- CO_2 Fire Extinguisher: High-pressure steel cylinder (typically 2 kg or 4.5 kg capacity) equipped with a high-pressure discharge hose, a non-conducting horn (discharge trumpet), and a control valve or squeeze-grip lever.
- Fire Demonstration Setup / Tray: Metal tray for simulated flammable liquid or electrical mock fire boards.
- Ignition Tools: Gas lighter or safety matches.
- Personal Protective Equipment (PPE): Industrial safety helmet, safety shoes, cotton boiler suit, and insulated industrial gloves (crucial to protect against cryogenic freeze burns from the discharge horn).



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. Pre-Inspection of the Extinguisher

1. Check the physical condition of the high-pressure steel cylinder and verify its weight (as CO_2 extinguishers are weight-tested rather than pressure-gauged).
2. Inspect the discharge horn and hose for cracks, blockages, or thread wear. Ensure the anti-static discharge horn is securely attached.
3. Check the safety pin and tamper seal.

B. Operating Technique (CO_2 Specific Application)

1. **P - Pull** the safety pin from the handle assembly.
2. **A - Aim** the discharge horn low, directing it at the **base** of the fire. *(Caution: Hold the carrying handle and insulated grip of the horn only; never touch the metal discharge horn directly during use due to extreme sub-zero cooling reaching -78°C).*
3. **S - Squeeze** the operating lever or open the valve to release the compressed gas.
4. **S - Sweep** slowly from side to side across the base of the fire until the flames are smothered and fuel vapor is displaced.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram

[Weight & Horn Inspection (No Pressure Gauge)] ⟶ [Pull Safety Pin & Hold Insulated Grip]

↓

[Sweep Slowly Across Base of Fire] ⟵ [Aim Horn Low & Squeeze Lever / Valve]

↓

[Verify Complete Extinction (Smothering Effect)]

B. Observation & Extinguishing Parameter Table

Parameter / Step	**Operational Guideline**	**Safety Significance**

Primary Extinction Principle	**Smothering** (Displacement of atmospheric oxygen below 15%) and intense **Cooling**.	Leaves zero residue, making it ideal for delicate electronics and switchboards.
Handling Precaution	Hold the insulated handle/horn grip. **Never grab the metal trumpet.**	Prevents severe frostbite/cryogenic burns as expanding CO_2 drops to -78°C.
Enclosed Space Warning	Use with caution in unventilated or confined indoor spaces.	CO_2 displaces oxygen rapidly, posing an asphyxiation hazard to operators.

5. Output / Result (10 Marks)

- **Extinction Performance**: Successfully smothered and extinguished the simulated electrical/liquid fire using the CO_2 extinguisher without leaving any chemical or liquid residue.
- **Equipment Status**: Verified that the CO_2 cylinder discharged cleanly through the horn and requires professional refilling and weight verification.

6. Viva Voce Questions (10 Marks)

1. Why do CO_2 fire extinguishers lack a standard pressure gauge on their valve assembly?
2. Why is it dangerous to touch the metal discharge horn of a CO_2 extinguisher during or immediately after operation?
3. What is the primary mechanism by which CO_2 extinguishes a fire?
4. Why are CO_2 extinguishers preferred over DCP for electrical switchboard fires?
5. What is the major safety hazard of discharging a CO_2 extinguisher inside a small, tightly sealed room?

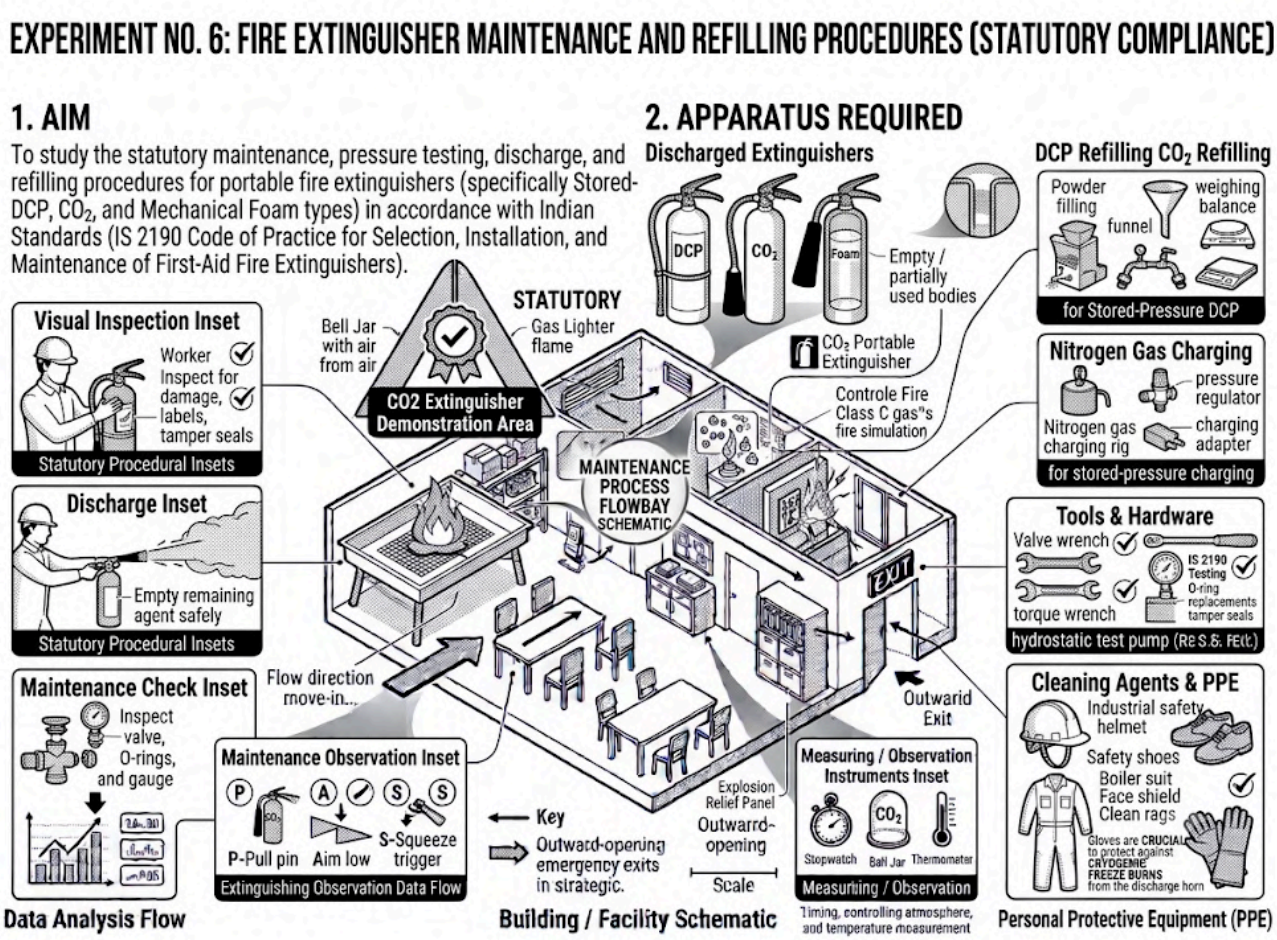
EXPERIMENT NO. 6: INSPECTION, MAINTENANCE, AND REFILLING OF FIRE EXTINGUISHERS

1. Aim (5 Marks)

To study the statutory maintenance, pressure testing, discharge, and refilling procedures for portable fire extinguishers (specifically Stored-Pressure DCP, CO_2, and Mechanical Foam types) in accordance with Indian Standards (**IS 2190** Code of Practice for Selection, Installation, and Maintenance of First-Aid Fire Extinguishers).

2. Apparatus Required (5 Marks)

- **Discharged Extinguishers**: Empty or partially used fire extinguisher bodies (DCP, CO_2, and Foam).
- **Refilling & Charging Equipment**:
    - Powder filling machine / funnel and weighing balance (for DCP).
    - CO_2 decanting pump, transfer manifold, and high-precision electronic scale (for CO_2).
    - Nitrogen gas charging rig with pressure regulator and charging adapter.
- **Tools & Hardware**: Valve wrench, spanners, torque wrench, hydrostatic test pump, O-ring replacements, tamper seals, and safety pins.
- **Cleaning Agents & PPE**: Clean rags, drying air compressor, industrial safety helmet, safety shoes, boiler suit, and face shield.



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. Disassembly and Internal Inspection

1. Ensure the extinguisher is completely depressurized before attempting to remove the valve assembly. For stored-pressure units, slowly loosen the valve to vent any residual pressure safely.
2. Unscrew and remove the valve assembly from the cylinder body.
3. Inspect the internal siphon tube, discharge valve stem, springs, and rubber O-rings for wear, corrosion, or clogging.
4. Clean the interior of the cylinder shell thoroughly and dry it with compressed air. Perform a hydrostatic pressure test if the vessel is due for its statutory periodic re-testing (typically every 3 to 5 years).

B. Refilling Procedures by Extinguisher Type

1. **Dry Chemical Powder (DCP) Extinguisher**:
    - Weigh the empty cylinder shell. Using a funnel or powder filling machine, pour the exact specified quantity of dry powder (e.g., ABC or BC grade) matching the manufacturer's rated capacity.
    - Clean the valve threads, lubricate or replace the O-ring, and screw the valve assembly back on securely.
    - Connect the nitrogen charging hose to the valve, pressurize the cylinder to the designated working pressure (e.g., $15bar$ at 20°C), and check for leaks using a soap solution.
2. **Carbon Dioxide (CO_2) Extinguisher**:
    - Verify the empty weight (tare weight) stamped on the cylinder shoulder.
    - Transfer liquid CO_2 from a master storage cylinder into the extinguisher using a decanting scale until the exact rated charge weight is reached. Do not overfill.
    - Reattach the discharge horn and valve assembly securely.
3. **Mechanical Foam / Water Extinguisher**:
    - Empty and rinse the cylinder. Measure and fill with clean water mixed with the precise proportion of aqueous film-forming foam (AFFF) concentrate.
    - Reassemble the valve and pressurize with compressed air or nitrogen to the rated operating pressure.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram

[Depressurize & Disassemble Valve] ──► [Internal Inspection & Hydrostatic Testing]

▼

[Recharge with Exact Agent & Weight] ◄── [Clean Shell & Replace Worn O-Rings]

▼

[Pressurize / Seal & Affix Inspection Tag]

B. Observation & Maintenance Parameter Table

Extinguisher Type	**Filling Agent / Medium**	**Statutory Pressure / Weight Check**	**Hydrostatic Pressure Test Interval (IS 2190)**
Stored-Pressure DCP	Monoammonium Phosphate / Sodium Bicarbonate	Pressure gauge in green zone ($12 -- 15bar$)	Every 3 to 5 years
CO_2 **Gas Type**	Liquefied Compressed CO_2 Gas	Annual weight verification (loss > 10% requires refilling)	Every 5 to 10 years
Mechanical Foam (AFFF)	Water + Foam Concentrate	Pressure gauge check & annual liquid replacement	Every 3 years

5. Output / Result (10 Marks)

- **Refilling & Maintenance**: Successfully inspected, cleaned, recharged, and re-pressurized the selected fire extinguisher back to its statutory operating standards.
- **Readiness Verification**: Verified that the refilled unit is leak-free, properly sealed, tagged with inspection dates, and fully operational for emergency deployment.

6. Viva Voce Questions (10 Marks)

1. Why is it mandatory to completely depressurize a fire extinguisher before unscrewing its valve assembly?
2. How do you determine whether a CO_2 fire extinguisher requires refilling since it does not have a pressure gauge?

3. What is the purpose of conducting a hydrostatic pressure test on an extinguisher cylinder shell?
4. What happens if a DCP extinguisher is over-pressurized beyond its rated working limit?
5. According to IS 2190, what is the frequency for routine external maintenance checks of portable fire extinguishers?

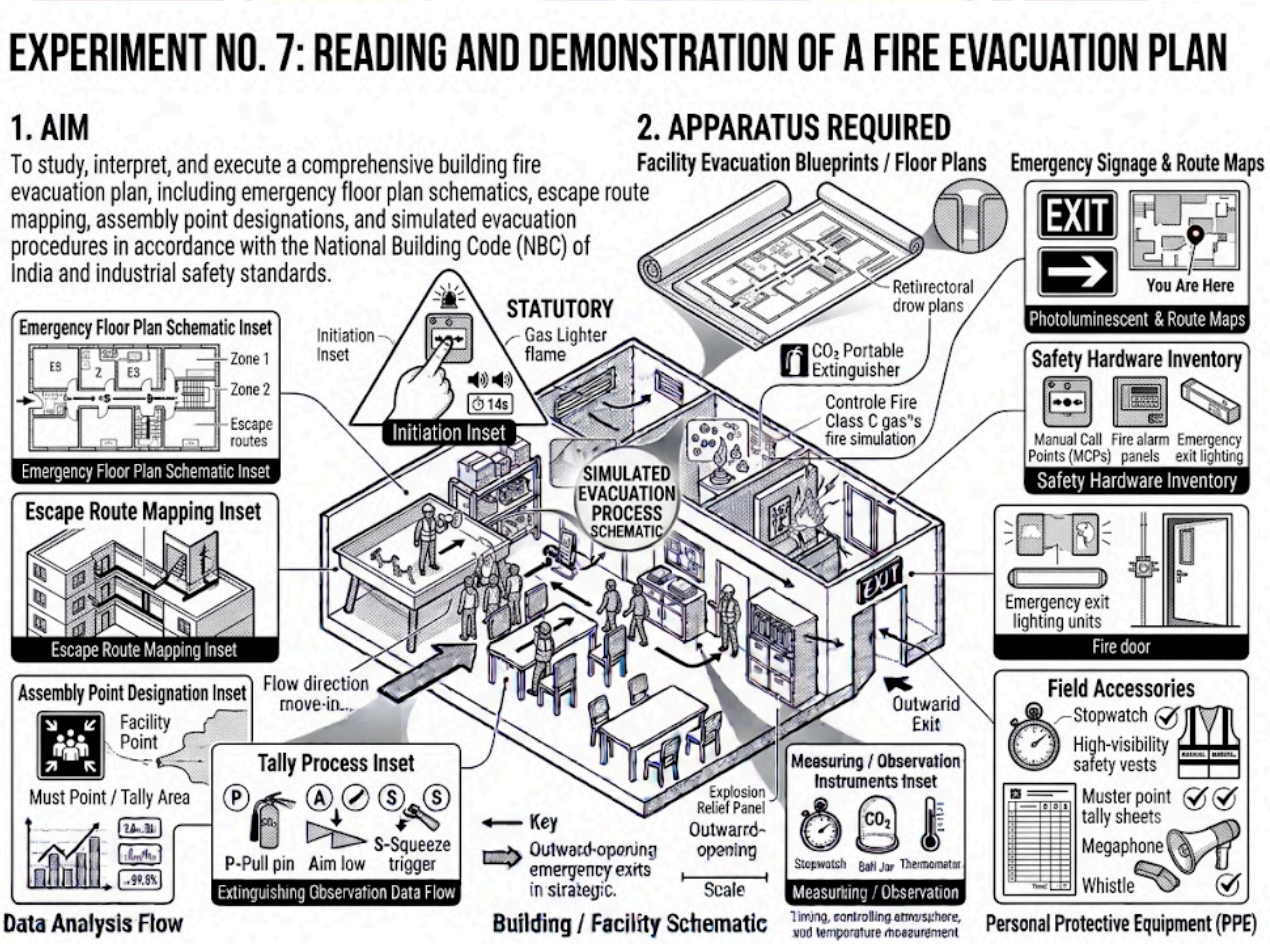
EXPERIMENT NO. 7: READING AND DEMONSTRATION OF A FIRE EVACUATION PLAN

1. Aim (5 Marks)

To study, interpret, and execute a comprehensive building fire evacuation plan, including emergency floor plan schematics, escape route mapping, assembly point designations, and simulated evacuation procedures in accordance with the National Building Code (NBC) of India and industrial safety standards.

2. Apparatus Required (5 Marks)

- **Facility Evacuation Blueprints / Floor Plans**: Detailed architectural layouts displaying room zones, exit corridors, stairwells, and emergency exit doors.
- **Emergency Signage & Route Maps**: Photoluminescent "EXIT" signs, directional arrows, and "You Are Here" facility maps.
- **Safety Hardware Inventory**: Manual Call Points (MCPs), fire alarm panels, emergency exit lighting units, and fire doors.
- **Field Accessories**: Stopwatch, high-visibility safety vests, muster point tally sheets, and a whistle/megaphone for marshals.



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. Blueprint Study & Route Mapping

1. Obtain and examine the facility floor plan, noting the location of all hazardous process areas, electrical switch rooms, and chemical storage zones in relation to exit pathways.
2. Identify **Primary Escape Routes** (shortest, most direct paths to safety) and **Secondary Escape Routes** (alternative paths to be used if primary routes are blocked by fire or smoke).
3. Locate all designated **Emergency Assembly Points (Muster Stations)** situated at a safe distance upwind or clear of the building structure.

B. Physical Walk-Through & Verification

1. Conduct a physical walkthrough of the mapped escape routes to check that corridors, stairwells, and emergency exits are entirely free from obstruction, storage boxes, or locked barriers.
2. Verify that panic hardware (push-bars) on emergency exit doors operate smoothly and open outward in the direction of escape.
3. Check the visibility and operational status of emergency lighting and photoluminescent exit signage along the route.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram

[Alarm Activation / Discovery of Hazard] ⟶ [Sound General Alarm & Notify Control Room]

↓

[Assembly at Designated Muster Point] ⟵ [Follow Green Exit Signs via Safe Routes]

↓

[Roll Call & Headcount Verification]

B. Observation & Evacuation Audit Table

Zone ID	Distance to Exit	Primary Route	Obstruction Status	Assembly Point
Zone A (Workshop)	25 meters	Corridor East & Stairwell 1	Clear / Unobstructed	Muster Point Alpha
Zone B (Laboratory)	18 meters	Main Corridor & South Exit	Clear / Unobstructed	Muster Point Beta
Zone C (Store Room)	30 meters	Fire Escape Iron Ladder	Clear / Unobstructed	Muster Point Alpha

5. Output / Result (10 Marks)

- **Plan Interpretation**: Successfully read, analyzed, and mapped the facility fire evacuation plan, identifying all critical escape pathways, exits, and assembly zones.
- **Evacuation Simulation**: Performed a timed evacuation walk-through, confirming that occupants can safely exit the building within statutory time limits.

6. Viva Voce Questions (10 Marks)

1. What is the primary objective of an Emergency Evacuation Plan in an industrial facility or educational institution?
2. Why must emergency exit doors always open outward in the direction of travel?
3. What is the difference between a primary escape route and a secondary escape route?
4. Why are elevators strictly prohibited for use during a fire evacuation emergency?
5. What is the role of a floor warden or safety marshal during a building evacuation?

EXPERIMENT NO. 8: DEMONSTRATION ON THE WORKING OF SMOKE, BEAM, AND FLAME DETECTORS

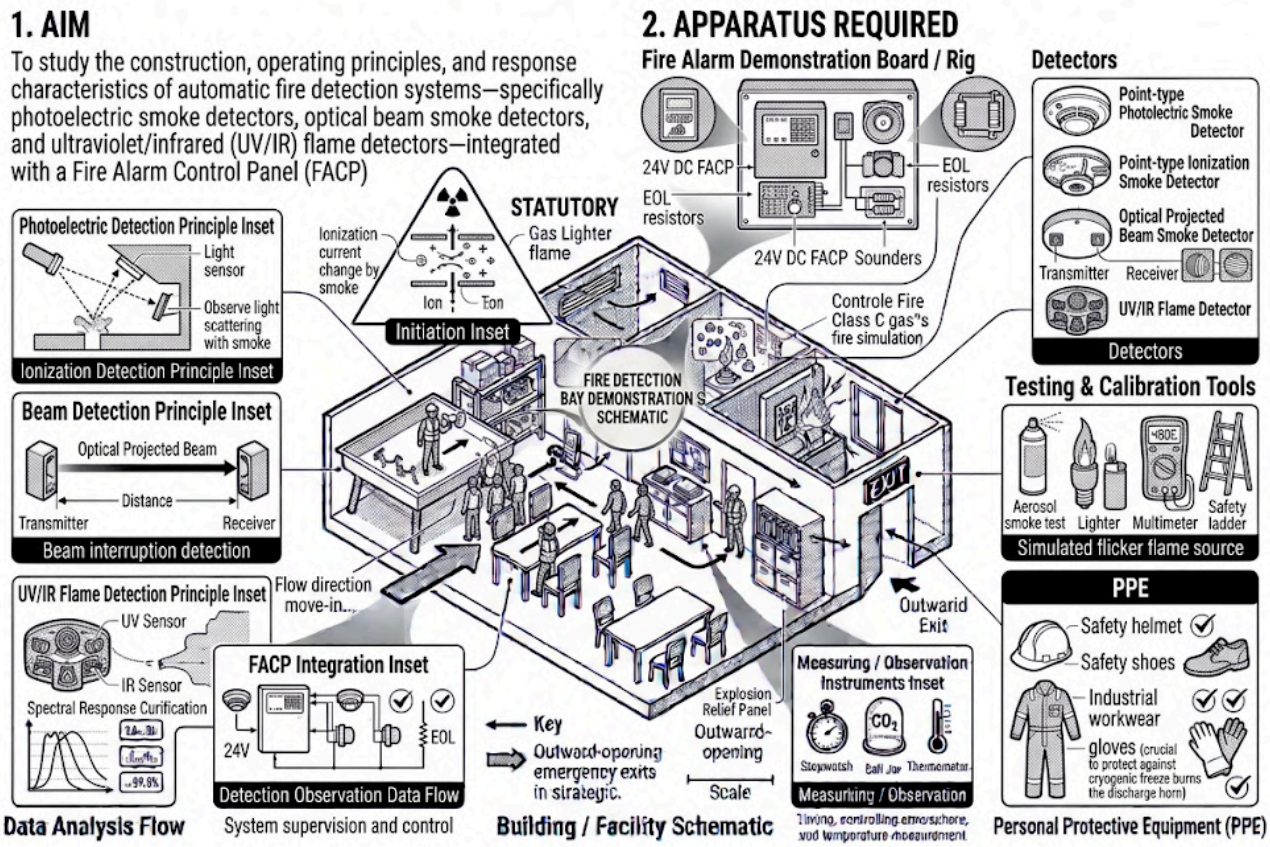
1. Aim (5 Marks)

To study the construction, operating principles, and response characteristics of automatic fire detection systems—specifically photoelectric smoke detectors, optical beam smoke detectors, and ultraviolet/infrared (UV/IR) flame detectors—integrated with a Fire Alarm Control Panel (FACP).

2. Apparatus Required (5 Marks)

- Fire Alarm Demonstration Board / Rig: Complete with a 24V DC Fire Alarm Control Panel (FACP), sounders/strobes, and end-of-line resistors.
- Detectors:
    - Point-type Photoelectric Smoke Detector
    - Point-type Ionization Smoke Detector
    - Optical Projected Beam Smoke Detector (Transmitter and Receiver units)
    - Ultraviolet (UV) / Infrared (IR) Flame Detector
- Testing & Calibration Tools: Aerosol smoke test spray, simulated flicker flame source (such as an electronic flickering lamp or butane lighter), multimeter, and safety ladder.
- PPE: Safety helmet, safety shoes, and industrial workwear.

EXPERIMENT NO. 8: DEMONSTRATION ON THE WORKING OF SMOKE, BEAM, AND FLAME DETECTORS



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. System Setup & Circuit Verification

1. Mount the detector units on the demonstration board or ceiling test rig and connect them to the 24V DC loop of the Fire Alarm Control Panel (FACP).
2. Verify that the FACP power indicator is green, indicating normal standby condition with no faults or alarms.

B. Testing Smoke and Flame Detectors

1. Photoelectric / Ionization Smoke Detector Test:
    - Spray a controlled burst of test smoke aerosol approximately 30 cm away from the smoke chamber inlet.
    - Observe the internal LED status indicator on the detector (shifting from blinking standby to steady red alarm) and the corresponding zone alarm trigger on the FACP.
2. Optical Beam Smoke Detector Test:
    - Align the transmitter and receiver heads across the test span.

- Slowly insert a neutral density filter or opaque card halfway across the optical beam path to simulate smoke obscuration. Verify that the receiver senses signal attenuation and triggers a trouble/alarm signal at the panel.

3. Flame Detector Test:
   - Expose the UV/IR flame detector to a simulated flickering flame source or UV test lamp within its field of view.
   - Observe the rapid response time as the sensor's optical filters and microprocessor validate the flicker frequency before initiating an alarm on the FACP.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram

[Sensor Activation / Obscuration by Smoke or Flame] ──► [Microprocessor Signal Validation]

▼

[Alarm Sounders & Strobes Triggered] ◄── [Central Control Panel (FACP) Signal Processing]

B. Observation & Detector Comparison Table

Detector Type	**Sensing Technology / Principle**	**Primary Application Area**	**Typical Response Time**
Photoelectric Smoke	Light scattering via infrared LED and photodiode.	Offices, corridors, and sleeping quarters (slow smoldering fires).	10 to 30 seconds
Optical Beam Detector	Attenuation of light beam across an open span.	Large open spaces, warehouses, atriums, and aircraft hangars.	15 to 45 seconds

UV / IR Flame Detector	Detection of specific radiation frequencies (ultraviolet/infrared flicker).	High-risk fuel storage, chemical plants, and turbine enclosures.	1 to 5 seconds

5. Output / Result (10 Marks)

- Detector Demonstration: Successfully demonstrated the operation, signal transmission, and alarm activation of smoke, beam, and flame detectors connected to the FACP.
- System Response: Verified that all detectors correctly identified their respective physical stimuli (smoke particles, light obscuration, and flame radiation) and communicated the emergency status to the control panel.

6. Viva Voce Questions (10 Marks)

1. What is the fundamental operational difference between an ionization smoke detector and a photoelectric smoke detector?
2. In what type of industrial environment is an optical beam smoke detector preferred over point-type detectors?
3. How do UV and IR flame detectors prevent false alarms caused by sunlight or ordinary incandescent lighting?
4. What does a "trouble" or "fault" signal mean on a Fire Alarm Control Panel (FACP)?
5. Why are automatic fire detectors critical for early-stage life safety in unpopulated industrial zones?

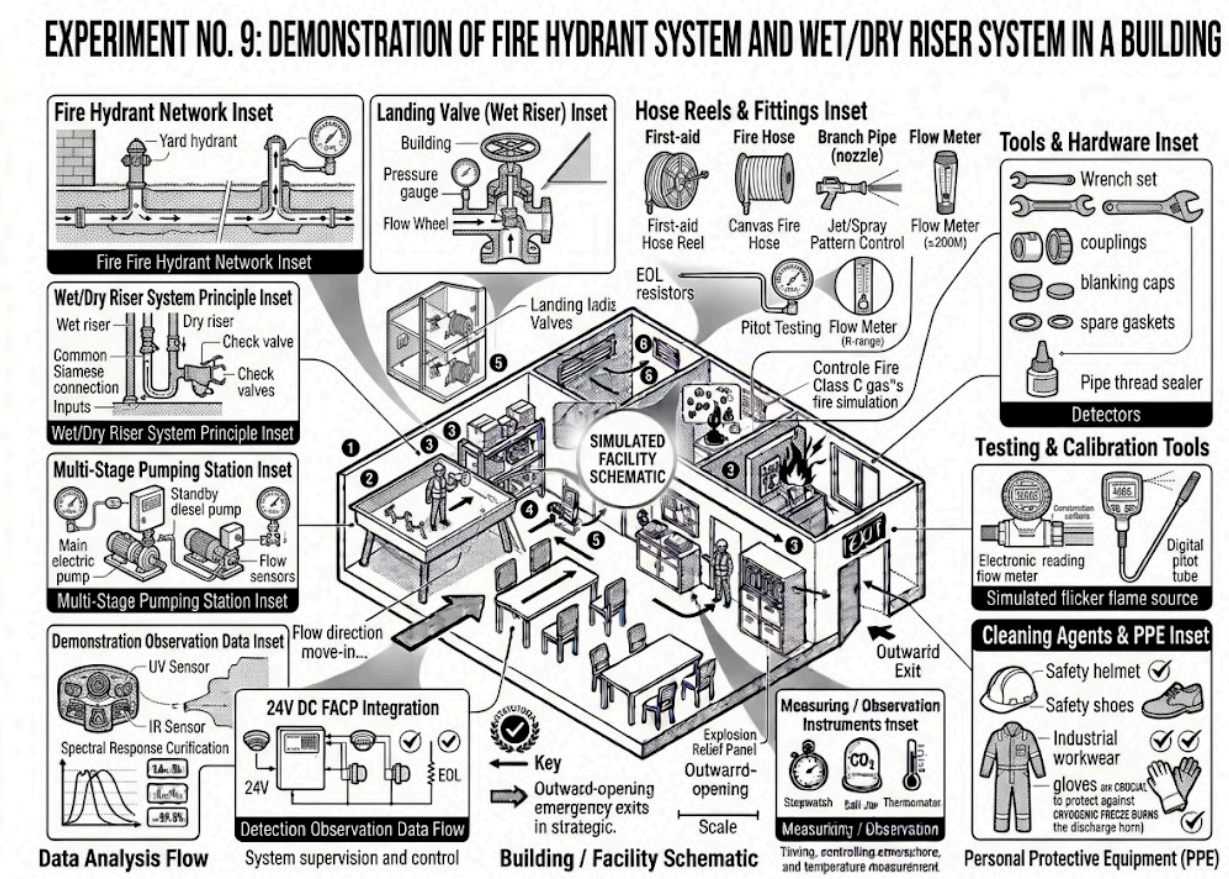
EXPERIMENT NO. 9: DEMONSTRATION OF FIRE HYDRANT SYSTEM AND WET/DRY RISER SYSTEM IN A BUILDING

1. Aim (5 Marks)

To study the layout, operation, water supply network, and pressure characteristics of an external/internal **Fire Hydrant System** and building **Riser Systems (Wet and Dry Risers)** in accordance with National Building Code (NBC) and IS 13039 / IS 3844 standards.

2. Apparatus Required (5 Marks)

- **Fire Hydrant Network**: Yard hydrants, landing valves (hydrant outlets), hose reels, and branch pipes with nozzles.
- **Pumping Station**: Main fire pump (electric motor-driven), standby diesel engine-driven pump, and automatic jockey pump.
- **Riser Piping**: Vertical wet/dry riser pipes running up multi-story building shafts with Siamese connections (fire brigade inlets) and landing valves on each floor.
- **Testing Tools**: Pressure gauges at pump discharge and riser terminals, pitot tube / flow meter, heavy-duty canvas/synthetic rubber hoses, and spanner wrenches.
- **PPE**: Industrial safety helmet, safety shoes, boiler suit, and high-visibility vest.



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. Pre-Inspection of Pumping Station & Hydrant Network

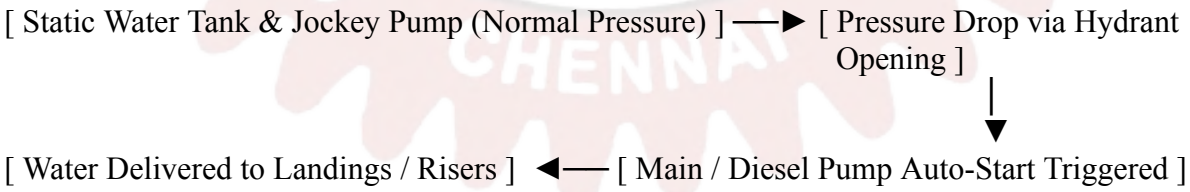
1. Inspect the main fire pump, jockey pump, and diesel engine pump controllers. Ensure selector switches are in "AUTO" mode and fuel/battery levels for the diesel pump are optimal.
2. Check the static water storage tank (underground/overhead reservoir) to verify that water levels comply with statutory fire safety reserve capacity.
3. Inspect external yard hydrants and internal landing valves (usually housed in Fire Hydrant Cabinets/Hose Boxes) to ensure handwheels, threads, and rubber washers are intact and unobstructed.

B. Operational Testing & Demonstration

1. **Jockey Pump Pressure Test**: Slowly bleed water pressure from the test valve to simulate a minor pressure drop. Verify that the automatic jockey pump starts immediately to maintain system pressure ($7 \text{ -- } 10 bar$).
2. **Main Fire Pump Cut-In Test**: Further bleed the system pressure to simulate an open hydrant valve. Observe the pressure drop trigger threshold that automatically starts the main electric fire pump and sounds the alarm.
3. **Riser Demonstration**:
    - Connect a fire hose to a landing valve on an upper floor connected to the **Wet Riser** system. Open the landing valve to verify continuous pressurized water supply.
    - For the **Dry Riser** system (intended for fire brigade use), connect a mobile fire tender pump discharge to the ground-level **Siamese connection (inlet)** and verify water delivery up to the upper-floor landings.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram



B. Observation & System Parameters Table

Component / System	Operating Pressure Range	Statutory Standard	Primary Function in Fire Emergency
Jockey Pump	$7.0 -- 8.5 kg/cm$	IS 12469	Maintains constant standing pressure in the network against minor leaks.
Main Fire Pump	$3.5 -- 7.0 kg/cm$	IS 1520	Delivers high-volume, high-pressure water during active fire fighting.
Wet Riser	Charged with water at all times	IS 3844	Provides immediate water supply to upper floors in high-rise buildings.
Dry Riser	Empty pipe; charged by fire brigade	IS 1648	Allows external fire engines to pump water directly to upper levels.

5. Output / Result (10 Marks)

- **System Demonstration**: Successfully demonstrated the automatic cut-in sequence of jockey and main fire pumps, water flow through yard hydrants, and pressurization of wet/dry riser networks.
- **Operational Readiness**: Verified that the hydrant and riser system maintains requisite pressure and delivers adequate water jet throw for effective fire suppression across building zones.

6. Viva Voce Questions (10 Marks)

1. What is the difference between a Wet Riser system and a Dry Riser system in a high-rise building?

2. What is the specific purpose of an automatic jockey pump in a fire hydrant installation?
3. What is a "Siamese Connection" (two-way or four-way inlet), and where is it located?
4. What minimum residual water pressure must be maintained at the highest/furthest landing valve during operation?
5. Why is a diesel engine-driven standby pump mandatory alongside the main electric fire pump?

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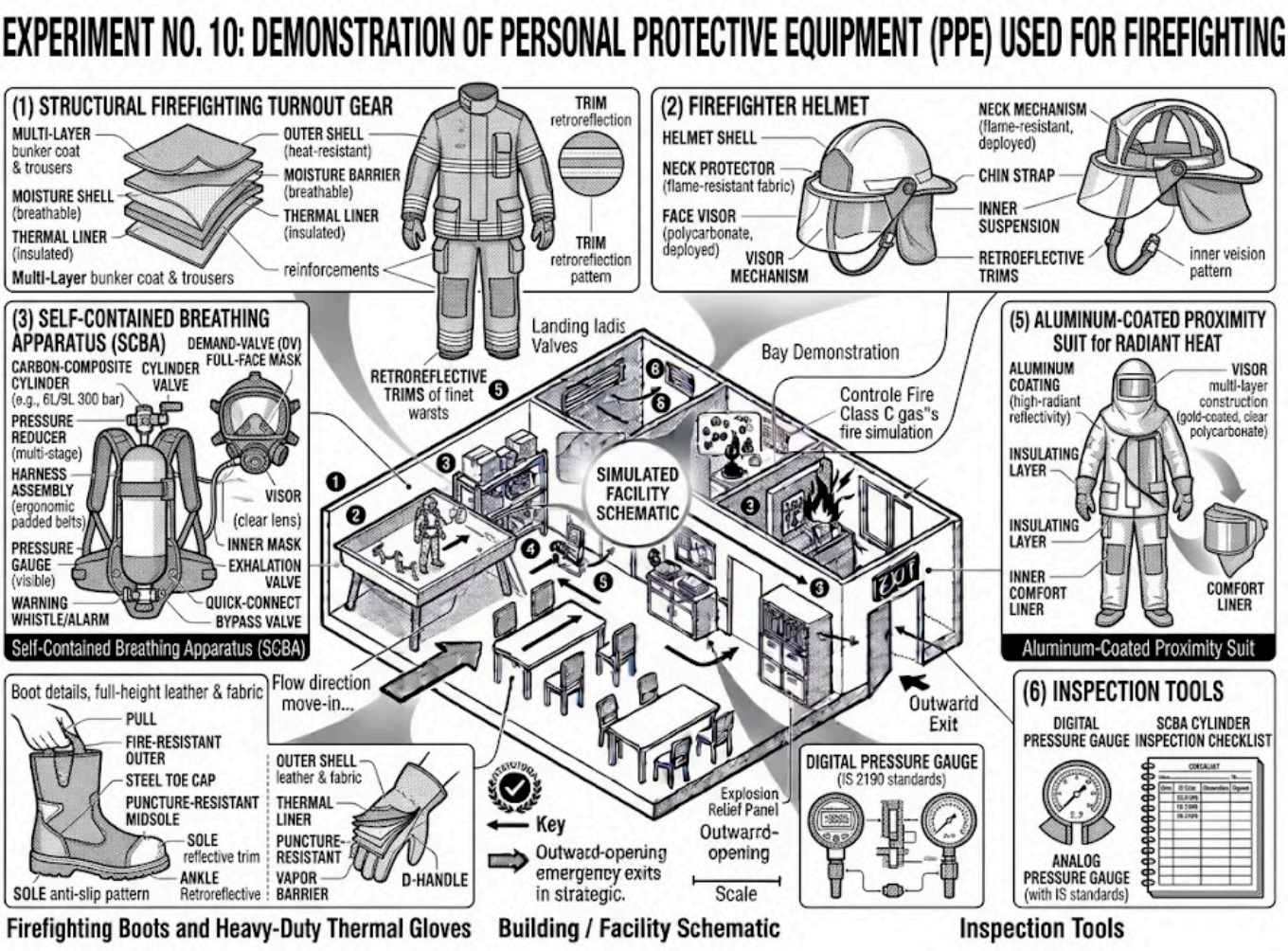
EXPERIMENT NO. 10: DEMONSTRATION OF PERSONAL PROTECTIVE EQUIPMENT (PPE) USED FOR FIREFIGHTING

1. Aim (5 Marks)

To study, inspect, and demonstrate the correct selection, wear, and operational utilization of specialized Personal Protective Equipment (PPE) used by firefighters—specifically structural turnout gear (bunker gear), Self-Contained Breathing Apparatus (SCBA), and heat-resistant protective garments in accordance with Indian Standards and international safety codes (EN / NFPA / IS).

2. Apparatus Required (5 Marks)

- **Structural Firefighting Turnout Gear**: Includes fire-resistant bunker coat and bunker trousers with thermal liners and moisture barriers, fitted with high-visibility reflective trims.
- **Firefighter Helmet**: Composite or thermoplastic shell with a neck protector, chin strap, and clear/gold-tinted face visor (conforming to IS 2925).
- **Self-Contained Breathing Apparatus (SCBA)**: Compressed air cylinder (carbon-composite or steel, 300 bar), carrying harness, pressure reduction regulator, demand valve, and positive-pressure full-face mask.
- **Footwear & Handwear**: Firefighting rubber/leather boots with steel toe caps and puncture-resistant soles (IS 15298), alongside heavy-duty thermal/chemical-resistant gloves.
- **Specialized Suits**: Aluminum-coated proximity suit or fire entry suit for radiant heat protection.
- **Inspection Tools**: SCBA cylinder pressure gauge, soap solution for leak checks, and donning station checklist.



3. Procedure / Material Preparation / Arrangements (20 Marks)

A. Pre-Donning Inspection

1. Inspect the structural turnout coat and trousers for rips, charring, damaged thermal liners, or compromised reflective tapes.
2. Check the SCBA air cylinder pressure gauge to ensure it is fully charged (minimum 270–300 bar) and verify that the low-pressure warning whistle functions correctly.
3. Check the full-face mask for elastic strap elasticity, visor clarity, and proper sealing edge integrity.
4. Inspect boots and gloves for tears, chemical degradation, or structural wear.

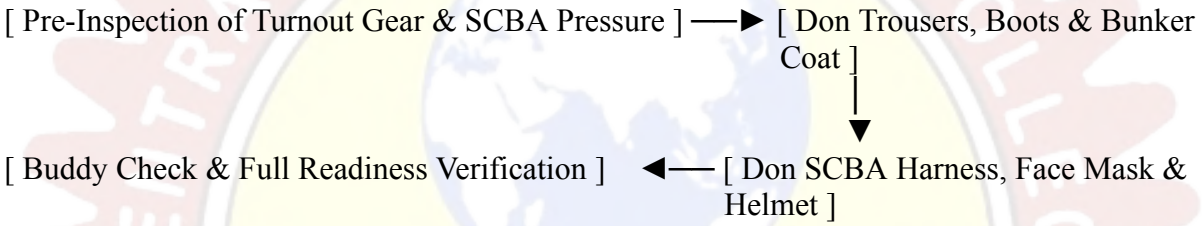
B. Step-by-Step Donning Sequence (Rapid Deployment)

1. Lower Body: Step into bunker trousers, pull up braces, adjust secure fasteners, and put on firefighting boots with trousers pulled down securely over boot cuffs.

2. Upper Body: Don the heavy bunker coat, secure all front closures (zippers, Velcro flaps, and heavy-duty snaps), and pull down the Nomex protective hood over the head and neck.
3. Breathing Apparatus (SCBA): Slip arms through the SCBA harness straps, adjust and lock the waist belt and shoulder straps so the cylinder rides comfortably on the back.
4. Face Mask & Regulator: Put on the full-face mask, tighten the head net straps symmetrically, and perform a negative pressure seal test (inhale and hold breath to ensure the mask seals tightly against the face). Connect the demand valve to the mask inlet.
5. Final Gear: Put on the firefighting helmet, secure the chin strap, put on heat-resistant gloves, and conduct a final "buddy check" with team members.

4. Demonstration / Flow Chart / Data Analysis (25 Marks)

A. Operational Flow Diagram



B. Observation & PPE Specification Table

PPE Component	**Material / Standard Specification**	**Primary Protection Function**
Bunker Coat & Pants	Nomex / Kevlar outer shell with moisture and thermal barriers	Protects against intense convective and radiant heat, cuts, and water ingress.
SCBA System	Compressed breathing air (EN 137 / IS standards)	Provides independent, clean breathing air in toxic, smoke-filled, or oxygen-deficient environments.

Firefighter Helmet	High-temp thermoplastic / fiberglass with face shield	Protects against falling debris, lateral impact, and head/face burns.
Proximity Suit	Aluminized fiberglass fabric	Reflects up to 95% of radiant heat during aircraft or fuel spill rescue operations.

5. Output / Result (10 Marks)

- **PPE Demonstration**: Successfully demonstrated the complete physical inspection, correct donning sequence, and functional testing of structural firefighting turnout gear and SCBA.
- **Readiness Verification**: Confirmed that the operator can fully kit up within statutory time limits and verify air supply integrity for safe entry into hazardous fire zones.

6. Viva Voce Questions (10 Marks)

1. What are the three primary layers that make up a standard structural firefighting bunker coat?
2. Why is a positive-pressure full-face mask critical when using an SCBA in a toxic gas environment?
3. What is the difference between a proximity suit and a fire entry suit?
4. How do you test the low-pressure warning whistle on an SCBA unit before entering a hazard zone?
5. Why must structural bunker gear be kept clean and free of flammable chemical residues or oil stains?

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