# CENTRAL POLYTECHNIC COLLEGE

## THARAMANI, CHENNAI

## Regulation 2023

## 1122 Diploma in Fire Technology and Safety

**1122233440 Safety Engineering Practicum - Manual**


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**UNIT 1 SAFETY INTRODUCTION**

Common rules that relate to almost every laboratory, Safety policies, First aid, Use of fire safety,Use of laboratory hood. Introduction, key concepts, terminologies, and safety quantification, safety by design, Hazard identification techniques (e.g., HAZOP, FMEA, etc.).

**UNIT 2 PERSONAL PROTECTION IN WORK ENVIRONMENT**

Personal protection in the work environment, Types of PPEs, Personal protective equipment respiratory and non-respiratory equipment. Standards related to PPEs. Monitoring Safety Performance: Frequency rate, severity rate, incidence rate, activity rate. Housekeeping: Responsibility of management and employees. Advantages of good housekeeping. 5 s of housekeeping. Work permit system- objectives, hot work and cold work permits. Typical industrial models and methodology. Entry into confined spaces.

**List of the Experiments**

1 Study of Personal Protective Equipments.
2 Design of safety training posters.
3 Identification of unsafe Acts, Unsafe condition.
4 Developing the Flowchart for reporting of accidents according to its severity.
5 Analysis of Data on Industrial Accidents.
6 Determination of accident rate and severity rate of an accident.
7 Determination of Cost and Man-hour Losses in an accident.
8 Performing evidence- based Accident Investigation for a mock accident.
9 Performing incident recall technique for an event.
10 Performing why-Why Analysis for a work/Task.

## UNIT 1 SAFETY INTRODUCTION

<u>Common rules that relate to almost every laboratory:</u>
Fire engineering labs carry unique hazards compared to standard chemical or wet labs: controlled open flames, massive thermal radiation, hot surfaces, toxic smoke gases, gas supply systems, and radiant heat sources like cone calorimeters or large burn hoods.

To manage these intense risks, fire testing environments strictly enforce a specific set of rules.

Specialized Personal Protective Equipment (PPE)

Standard cotton lab coats often aren't enough when working around high heat sources and thermal radiation.

- **Heat-Resistant & Flame-Retardant Clothing:** Synthetic fibers (like polyester or nylon) melt into the skin when heated; wear non-melting natural fibers (100% heavy cotton) or certified FR (flame-retardant) lab garments like Nomex.
- **Thermal Protection:** Keep high-temperature thermal gloves (e.g., Kevlar, aluminized, or heavy leather) nearby when handling hot sample holders or radiant cones.
- **Respiratory Protection:** Wear appropriate dust/particulate masks when preparing friable test specimens, and use approved air-purifying respirators (or SCBA for large-scale burns) where combustion gases might escape exhaust hoods.
- **Full-Face & Eye Shielding:** Use high-impact safety glasses or face shields, as intense radiant sources and thermal shock can cause glass or sample materials to explode.

Pre-Burn & Apparatus Protocols

**Check Exhaust Systems:**Ventilation verification.
Verify that primary fume exhaust hoods, scrubbers, and smoke extraction hoods are fully operational **before** sparking any flame or turning on radiant heaters.

**Inspect Gas Line Safety:**Piping & gas safety.
Inspect LPG, propane, methane, or oxygen lines for leaks using bubble-leak detectors or gas sensors. Check auto-shutoff safety valves (solenoids) before lighting burners.

**Clear the Burn Perimeter:**Containment setup.
Remove unnecessary combustibles, scrap materials, and solvent bottles within a designated radius of the test rig or radiant heater array.

**Assign Emergency Roles:**Personnel readiness.
Assign specific team members clear roles before starting large-scale tests (e.g., primary operator, safety officer, extinguisher runner, emergency stop controller).

**Burn Operations & Active Monitoring**

| Rule | Operational Practice |
|---|---|
| **Two-Person Rule** | **Never conduct active fire tests alone.** A minimum of two qualified individuals must be present during any ignition phase or high-temperature heating operation. |
| **Thermal Awareness** | Assume **all metal parts, sample holders, and radiant cones remain hot** for hours after testing. Treat them as burn hazards unless verified cool with a thermal camera or pyrometer. |
| **Combustion Air Control** | Monitor carbon monoxide (CO), hydrogen cyanide (HCN), and oxygen depletion levels using real-time atmospheric monitors in workspace zones. |
| **Sample Conditioning** | Ensure test samples (e.g., wood, polymers, insulation) are conditioned strictly according to humidity/temperature standards to avoid unexpected outgassing or erratic burning. |

**Emergency & Post-Test Procedures**

> **Fire Lab Rule:** Always have **secondary suppression** ($CO_2$ extinguishers, sand buckets, or deluge hoses) placed *outside* the heat radiation zone but *within immediate reach* of the operator.

- **Cooling Protocols:** Allow samples to cool completely under running exhaust hoods before moving them to waste storage to prevent re-ignition (thermal runaway/smoldering).
- **Safe Waste Disposal:** Soaking hot char and ash in water before placing them in designated non-combustible metal disposal bins.
- **Emergency Shutoff Awareness:** Every person in the lab must know the location of emergency gas shutoff buttons (E-stops) and electrical main breakers.

**<u>Safety policies</u>**

Safety policies in a **Fire Engineering Laboratory** go far beyond standard lab safety rules. Because these facilities routinely ignite controlled fires, generate high-flux thermal radiation, and handle pressurised fuel gases, their safety framework is strictly governed by institutional Environmental Health & Safety (EHS) divisions and national standards like **NFPA 45** (*Standard on Fire Protection for Laboratories Using Chemicals*) and **OSHA standards**.

**Governance & Administrative Safety Policies**

- **Pre-Burn Hazard Analysis:** Every non-standard or large-scale fire experiment requires a formal risk assessment (such as a Job Safety Analysis or Safety Review) approved by the Lab Safety Officer (LSO) before ignition.
- **Strict "Two-Person Rule":** Conducting active fire tests, operating burners, or running radiant heat panels alone is strictly forbidden. A dedicated safety observer must always be present.
- **Standard Operating Procedures (SOPs):** Every standard test rig (e.g., Cone Calorimeter, Single Burning Item, Smoke Density Chamber) must have written SOPs posted directly on or near the control console.
- **Access Control:** Active burn zones must be clearly cordoned off with warning lights, chains, or interlocked safety gates to prevent unauthorised personnel from entering during a test run.

**Personal Protective Equipment (PPE) Policies**

Unlike standard labs where cotton lab coats suffice, fire engineering environments demand heat- and flame-specific attire:

| Equipment | Policy Mandate |
|---|---|
| **Garment Materials** | Synthetic fibers (polyester, nylon, fleece) are **banned** due to melting risks. Personnel must wear non-melting 100% heavy cotton or certified FR (Nomex) lab coats. |
| **Thermal Protection** | High-temperature gloves (Kevlar/aluminized) must be worn when handling hot sample holders, radiant cones, or char residues. |
| **Face & Eye Protection** | High-impact safety glasses with side shields are required continuously; full-face shields are mandatory when working with pressurized burners or glass-fronted combustion chambers. |
| **Respiratory Gear** | Dust masks (N95/P100) are required during sample prep (sanding, cutting insulation/polymers), while SCBA or supplied-air systems are mandatory if entering large burn enclosures. |

**Fuel, Gas, & Chemical Storage Policies**

- **Pressurized Gas Safety:** Compressed gas cylinders (propane, methane, oxygen, standard gas mixtures) must be double-chained upright to structural walls and equipped with flashback arrestors and manual emergency shutoff valves.
- **Flammable Liquid Limits:** Flammable liquids must be stored in approved, grounded safety cans or flame-proof storage cabinets (complying with NFPA 30/45). Quantities kept on open benches must be minimized.
- **Distance Buffers:** Flammable storage cabinets and fuel cylinders must be located at a minimum safe distance from any open burn rigs, heat panels, or spark sources.

Ventilation & Fire Suppression System Policies

```
[Smoke & Effluent Source]
   |
   ▼
[Primary Extraction Hood] ──► [Gas Scrubber / Filter] ──► [Roof Exhaust]
   |
   ▼ (Backup Interlock System)
[Emergency Gas Shutoff] (Triggered if exhaust airflow drops below threshold)
```

- **Interlocked Exhaust Ventilation:** Radiant heaters and gas burners must be electrically interlocked with the extraction hood system—if airflow falls below the required threshold, fuel gas supply automatically shuts off.
- **Gas & Smoke Detection:** Continuous real-time detection systems for carbon monoxide, oxygen depletion, and flammable gas leaks must be calibrated monthly.
- **Dedicated Suppression Units:** Standard water sprinklers are often supplemented by local Clean Agent systems (e.g., Novec 1230, FM-200 over sensitive data-acquisition electronics to prevent equipment damage during unexpected flare-ups.

5. Waste Management & Post-Test Cooling Protocols

- **Smoldering & Char Handling:** Post-test samples (char, ash, melted polymers) must be fully quenched with water or cooled under an operating exhaust hood before disposal.
- **Self-Closing Metal Bins:** Oily, solvent-soaked, or char-contaminated rags must be disposed of exclusively in heavy-gauge, self-closing metal waste cans to prevent spontaneous combustion.
- **Thermal Decontamination:** Metallic specimen holders and tools must be tested with a pyrometer or thermal imaging camera to verify they have cooled below before being handled with bare hands.

## <u>First aid</u>

First aid in a **fire engineering laboratory** addresses unique injuries uncommon in standard labs, such as severe thermal burns, smoke and toxic gas inhalation, melted synthetic materials, and thermal shock injuries.

Understanding how to react immediately during the first few seconds can prevent permanent harm.


Thermal Burns (Flame, Radiant Heat, Hot Metals)

Thermal injuries are the most common hazard when handling test rigs like cone calorimeters or furnace frames.

**Cool the Burn Immediately:**20-minute cooling.
Hold the burned area under cool running tap water for **at least 20 minutes**. Do not use ice, ice water, or butter/ointments, as extreme cold can worsen tissue damage.

**Remove Tight Items Gently:**Swelling protection.
Quickly but gently remove rings, watches, belts, or tight clothing near the area before swelling starts.

**Handle Stuck Clothing Carefully:**Avoid tearing tissue.
If clothing or melted glove material is **stuck to the burn, do not pull it off**. Cut around the surrounding fabric and leave the adhered material for medical professionals.

**Cover Cover Lightly:**Sterile protection.
Cover the burn loosely with clean cling film (plastic wrap) or a sterile, non-adherent burn dressing. Do not pop any blisters.

**Smoke & Toxic Gas Inhalation**

Combustion of polymers, fire-retardant composites, and building materials generates hazardous gases like carbon monoxide , hydrogen cyanide , and acid gases .

- **Move to Fresh Air Immediately:** Evacuate the victim to an open, well-ventilated area away from combustion fumes.
- **Assess Airway & Breathing:** Look for signs of inhalation injury—singed nasal hair, soot around the nose or mouth, coughing, hoarseness, or difficulty breathing.
- **Administer High-Flow Oxygen:** If a trained lab first-responder is present, administer oxygen via a non-rebreather mask (cyanide and carbon monoxide interfere directly with cellular respiration).
- **Call Emergency Services :** Inhalation of toxic combustion products often causes delayed lung edema (fluid buildup) hours after exposure, making immediate professional evaluation vital.

3. **Chemical & Hot Liquid Spills**

Fire labs frequently use accelerants, solvents, or liquid fuels.

| **Scenario** | **Immediate First Aid Action** |
|---|---|
| **Chemical Burn on Skin** | Flush the area in a safety shower for a minimum of **15 to 20 minutes**. Remove contaminated clothing while showering. |
| **Chemical/Debris in Eye** | Flush eyes immediately at the eyewash station for **at least 15 minutes**, holding eyelids open. Roll eyes to rinse thoroughly. |
| **Flammable Liquid Exposure** | If clothes catch fire, **Stop, Drop, and Roll**, or use a safety shower/fire blanket to smother the flames. |

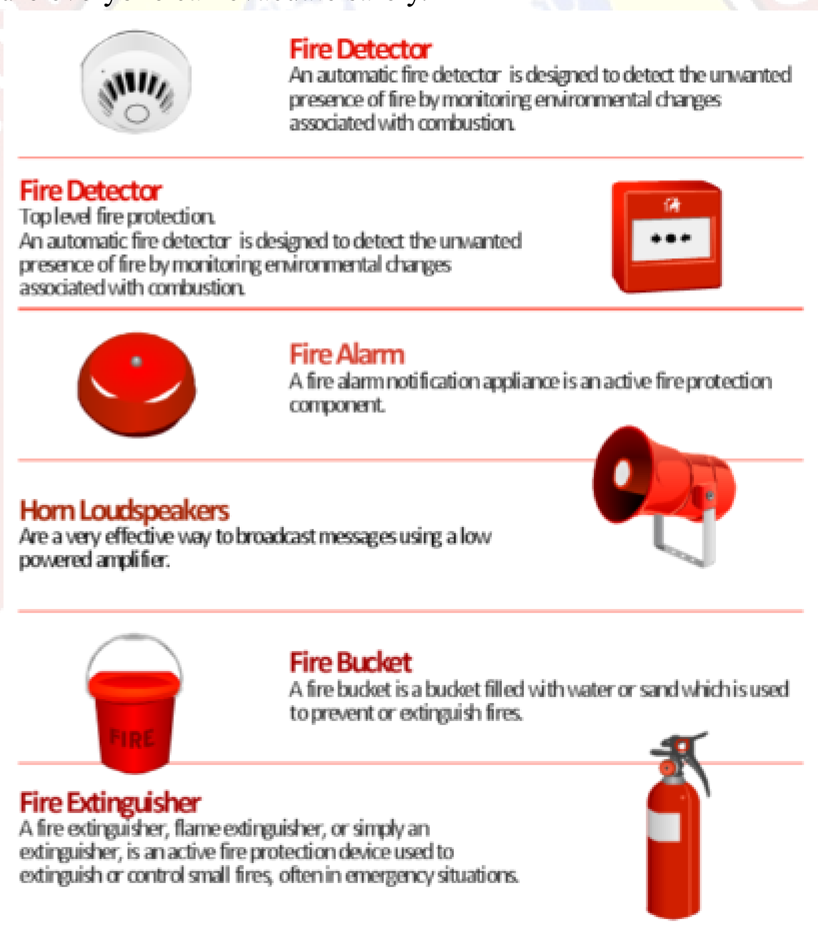
**Essential First Aid Kit Additions for Fire Labs**

Standard commercial first aid kits are usually insufficient for fire labs. Specialised kits in these facilities should include:

- **Sterile Burn Dressings & Sheets:** Non-adherent water-gel pads (e.g., BurnShield or Water-Jel) for rapid thermal cooling.
- **Cling Film / Plastic Wrap:** Ideal clean cover for large burn areas that won't stick to damaged skin.
- **Trauma Shears:** Heavy-duty scissors to cut away synthetic clothes or boots rapidly without disturbing underlying wounds.
- **Sterile Eyewash Bottles:** Portable wash units placed near fuel-mixing benches.
- **Emergency Medical Contact Card:** Displaying clear phone numbers for the nearest regional Burn Center and Poison Control.

**<u>Use of fire safety:</u>**

Fire safety serves a simple but critical purpose: to prevent fires from starting, limit their spread if they do, and ensure everyone can evacuate safely.



**Key Objectives of Fire Safety**

**Protection of Life**

The primary goal of any fire safety system is saving lives. This relies on early warning devices like **smoke detectors** and clear evacuation tools like **emergency lighting** and **unblocked exit routes** to ensure people can escape before toxic smoke builds up.

**Risk & Fire Prevention**

Preventative fire safety measures address fire hazards before they ignite:

- **Electrical Safety:** Inspecting wiring to avoid overload or short circuits.
- **Safe Storage:** Keeping combustible materials away from heat sources.
- **Maintenance:** Regularly servicing gas lines, kitchen vents, and heating systems.

**Rapid Suppression**

When a fire breaks out, active suppression tools limit the damage:

- **Fire Extinguishers:** Portable devices designed to control small, localized fires before they spread.
- **Fire Blankets:** Ideal for smothering pan fires in kitchens or clothing fires.
- **Automatic Sprinklers:** Heat-activated systems that douse fires in commercial and residential buildings automatically.

**Minimizing Property & Environmental Damage**

Beyond personal safety, proper fire doors, fire-rated walls, and quick suppression limit structural damage, preserving property and reducing air toxicity from burnt materials.

**Use of laboratory hood:** It is an atmospheric primary containment system designed to protect personnel from inhaling hazardous chemical fumes, vapours, dusts, and gases.


*Standard Laboratory Fume Hood. Source: jeangill / Getty Images*

**Introduction to laboratory hood:**

Unlike biosafety cabinets (BSCs)—which rely on HEPA filters to capture biological agents—a chemical fume hood primarily operates as a local exhaust ventilation (LEV) system. It captures contaminants at the source, dilutes them with room air, and exhausts them safely outside the building.

**Key Concepts & Operational Principles- Laboratory Hood:**

**Negative Pressure Containment**

A chemical fume hood functions by creating negative relative pressure inside the enclosure compared to the laboratory. Air is constantly pulled through the front opening (face) into the hood interior and exhausted via ductwork, ensuring contaminants cannot spill out into the room.

**Capture and Containment Mechanisms**

- **Capture Zone:** The internal volume where chemical reactions or processes generate airborne contaminants.
- **Airfoil Design:** Curved surfaces along the bottom edge of the hood face reduce turbulence as room air enters, preventing eddy currents that pull vapors back out.
- **Aerodynamic Airflow:** Directional airflow pulls heavier-than-air or lighter-than-air gases smoothly toward internal exhaust slots.

**Fume Hoods vs. Biosafety Cabinets (Crucial Distinction)**

- **Chemical Fume Hood:** Protects **the user only** from chemical vapors by exhausting air outdoors. It does *not* filter air to protect the sample.
- **Laminar Flow / Biosafety Cabinet (BSC):** Protects **the sample or user** from biological contamination using HEPA filters. Standard BSCs do *not* protect against volatile toxic chemicals unless hard-ducted.

**Essential Terminologies - Laboratory Hood:**

| **Term** | **Definition** |
|---|---|
| **Sash** | The movable transparent window (vertical or horizontal) at the front of the hood used to adjust the face opening and serve as a physical blast/splash shield. |
| **Face Velocity** | The average speed of air moving perpendicular through the sash opening into the hood enclosure, typically measured in feet per minute (fpm) or meters per second (m/s). |
| **Baffles** | Moveable or fixed rear partitions inside the hood that create uniform airflow across the interior height, preventing dead zones where vapors collect. |
| **Airfoil** | A contoured edge along the bottom frame of the sash opening that minimizes boundary-layer air turbulence. |
| **VAV (Variable Air Volume)** | A smart ventilation system that adjusts exhaust airflow dynamically based on sash height to maintain a constant face velocity. |
| **CAV (Constant Air Volume)** | A system where exhaust volume remains constant regardless of sash height, causing face velocity to rise as the sash lowers. |

| | |
|---|---|
| **Working Height** | The designated sash opening height (typically 18 inches / 45 cm) marked on the frame for certified optimal containment. |

**Safety Quantification & Performance Metrics-Laboratory Hood**

Quantifying fume hood safety ensures the unit actively prevents chemical exposure. The primary standards governing hood performance are **ASHRAE 110** (Method of Testing Performance of Laboratory Fume Hoods) and **SEFA 1** (Scientific Equipment and Furniture Association).

**1. Face Velocity Quantifications**

Face velocity measures how effectively air is pulled into the hood:

Face Velocity (V) = Q/A

Where:

- Q = Total exhaust volumetric flow rate (CFM or m^3/s)
- A = Open area of the sash (ft^2 or m^2)

**Recommended Operating Ranges**

- **Standard Target: 80 – 100 fpm (0.4 – 0.5 m/s)** at maximum working sash height.
- **High-Performance / Low-Flow Hoods: 60 – 80 fpm (0.3 – 0.4 m/s)** using aerodynamic design.
- **Under-performance hazard (< 60fpm):** Thermal currents or room cross-drafts overcome face velocity, causing leakage.
- **Over-performance hazard (> 120 fpm):** Creates excessive turbulence and vortex eddies, paradoxically pulling vapours out toward the operator.

2. **Quantitative Containment Testing (ASHRAE 110 Protocol)**

To quantify containment beyond simple airflow speed, the **ASHRAE 110** testing suite evaluates three parameters:

[ASHRAE 110 Testing Suite]

├── 1. Face Velocity Profile (Grid testing across sash opening)

├── 2. Airflow Visualization (Smoke testing for turbulence/eddies)

└── 3. Quantitative Tracer Gas Containment (SF6 or Nitrous Oxide release)

During tracer gas testing, a sensor attached to a mannequin's mouth measures tracer gas leakage (ppm)

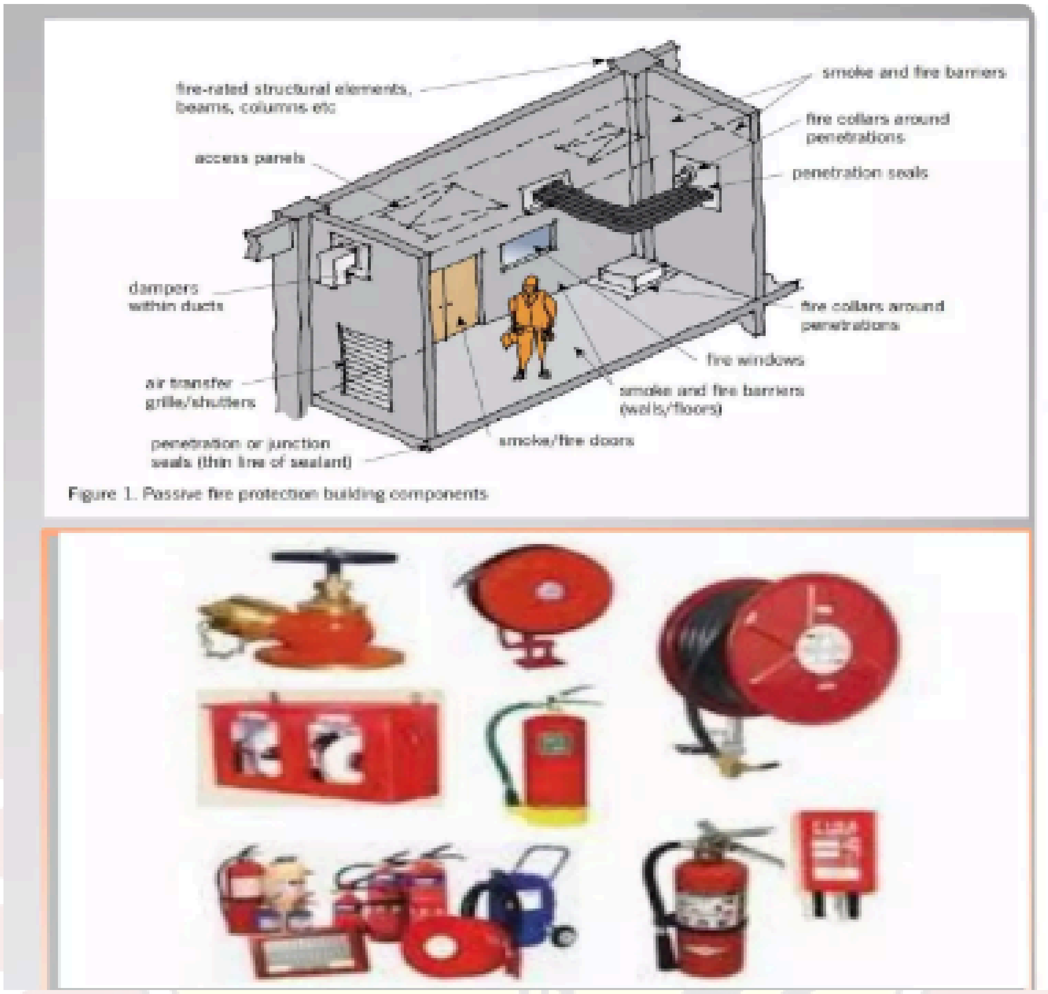
- **Control Level:** Acceptable exposure limits inside the operator's breathing zone are strictly set to $<0.05$ ppm or in as-installed field tests.

3. Operational Rules for Containment Safety
- **6-Inch Rule:** Always keep chemicals and equipment at least **6 inches (15 cm)** inside the hood sash plane to prevent eddy-current spillover.
- **Equipment Clearance:** Elevate large equipment 1–2 inches off the deck using blocks to allow airflow beneath it to reach rear baffles.
- **Sash Management:** Keep the sash as low as comfortably possible (and fully closed when unattended) to maximise safety and reduce HVAC energy consumption.

**Safety by design:**

**Safety by Design** (also known as Prevention through Design) in fire engineering means embedding fire safety directly into the conceptual, architectural, structural, and mechanical design phases of a project—rather than adding fire protection measures as an afterthought.

Instead of relying solely on fire extinguishers or alarms after a building is built, Safety by Design engineers the physical environment so that fires are hard to start, slow to spread, easy to escape, and straightforward for emergency crews to extinguish.




Integration of Passive and Active Fire Protection Systems

**Core Pillars of Safety by Design**

Fire safety engineering relies on five fundamental pillars integrated into the design phase:

1. **Fire Elimination & Prevention (Hazard Reduction)**

- **Material Selection:** Specifying non-combustible or flame-retardant cladding, insulation, and interior finishes (e.g., low-flammability index materials).
- **Ignition Control:** Designing electrical systems to prevent arcing, isolating high-risk machinery, and segregating fuel storage from potential heat sources.

2. **Passive Fire Protection (PFP)**

Passive elements are built directly into the structure to contain fire and smoke without requiring human or electrical activation:

- **Compartmentation:** Dividing buildings into fire-resistant zones using fire doors, fire-rated walls, and floors to stop fire propagation.

- **Structural Fire Resistance:** Protecting steelwork with intumescent coatings, concrete encasement, or board protection so the structure retains its load-bearing capacity during a fire.
- **Firestopping & Penetration Seals:** Sealing utility penetrations (pipes, cables, ducts) with intumescent materials to prevent flame leakage through walls and slabs.

3. **Active Fire Protection (AFP)**

Active systems detect, control, or suppress fires automatically:

- **Detection & Alarm:** Optical smoke detectors, beam detectors, and aspirating smoke detection (ASD) systems for early warning.
- **Suppression:** Automated fire sprinkler systems, water mist systems, or clean agent gas suppression (for server rooms/electronics).
- **Smoke Control:** Mechanical smoke extractors and stairwell pressurization systems to maintain clean air along escape routes.

4. **Means of Escape & Egress Architecture**

Designing the physical layout to ensure occupants can exit safely before conditions become untenable:

- **Travel Distance Limits:** Structuring layouts to limit how far a person must travel to reach a fire exit.
- **Protected Stairwells:** Enclosing egress stairs in fire-rated shafts with self-closing fire doors.
- **Width & Capacity Calculations:** Sizing exit doors and corridors relative to peak occupancy.

5**. Firefighter Access & Intervention**

- **Dedicated Fire Lifts & Risers:** Including dry or wet risers for high-rise buildings and firefighting elevators.
- **Site Layout:** Designing perimeter access roads capable of supporting fire engines and turntable ladders.

**Hazard identification techniques:**

**HAZOP**

Hazard Identification (HAZID) techniques are structured, systematic methods used to identify potential hazards, unsafe conditions, and operational problems in industrial processes, facilities, or activities before they cause harm.

1. **Overview of Common Hazard Identification Techniques**

- HAZOP (Hazard and Operability Study): A structured, team-based approach using guidewords to examine process deviations from design intent.

- What-If Analysis: A brainstorming technique using "What if...?" questions to evaluate the consequences of unexpected events or failure modes.
- Checklist Analysis: A systematic review against pre-established lists of requirements, standards, or past lessons learned.
- FMEA (Failure Mode and Effects Analysis): An inductive analysis focusing on individual component failure modes and their impact on the overall system.
- FTA (Fault Tree Analysis): A deductive, top-down technique that identifies combinations of hardware, software, and human errors leading to a specific unwanted event.
- Job Safety Analysis (JSA) / Job Hazard Analysis (JHA): A task-focused method that breaks a specific job down into steps to identify associated risks and mitigation measures.

2. **HAZOP (Hazard and Operability Study) in Detail**

What is HAZOP?

A HAZOP study is a formal, highly structured, and multi-disciplinary team execution method. It systematically breaks down a process facility into smaller sections to evaluate how deviations from the normal design intent can lead to hazards or operability problems.

Core Elements of a HAZOP Study

1. Nodes

A Node is a specific, manageable section of the process line or vessel chosen for detailed study (e.g., *"Suction piping from Storage Tank T-101 to Pump P-101"*).

2. Design Intent

The expected, normal operational parameter for the node

3. Parameters & Guidewords

HAZOP combines Parameters (physical or operational variables) with standard Guidewords to generate potential Deviations.

{Guideword} + {Parameter} = {Deviation}

- Parameters: Flow, Pressure, Temperature, Level, Viscosity, Composition, Phase, Addition, Reaction.
- Standard Guidewords:

| **Guideword** | **Meaning** | **Example Deviation** |
|---|---|---|
| NO / NONE | Complete negation of the intent | No Flow |
| MORE | Quantitative increase | More Pressure / More Temperature |

| | | |
|---|---|---|
| LESS | Quantitative decrease | Less Flow |
| AS WELL AS | Qualitative increase / additional activity | Contaminant present with feed |
| PART OF | Qualitative decrease / incomplete activity | Missing component in feed mixture |
| REVERSE | Logical opposite of the intent | Reverse Flow |
| OTHER THAN | Complete substitution | Wrong chemical added |

The HAZOP Step-by-Step Methodology

1. Node Selection: Define the node and establish its design parameters and intent.
2. Apply Guidewords: Select a parameter (e.g., *Flow*) and pair it with a guideword (e.g., *No*) to create a deviation (*"No Flow"*).
3. Identify Causes: Brainstorm potential causes for the deviation (e.g., *Pump trip, closed valve, line blockage*).
4. Determine Consequences: Identify the full consequences of the deviation without considering existing safeguards (e.g., *Pump overheating, dry running, loss of production*).
5. Evaluate Safeguards: Document existing engineered or procedural controls designed to prevent or mitigate the cause/consequence (e.g., *Low-flow interlock trip, relief valve, alarm*).
6. Formulate Recommendations: If existing safeguards are deemed insufficient for the risk level, action items/recommendations are assigned to specific team members with deadlines.
7. Repeat: Repeat the process for all parameters within the node, then move to the next node.

**Key Roles in a HAZOP Team**

- HAZOP Chairperson / Leader: An independent process safety expert who facilitates the discussion and enforces the methodology.
- Scribe / Recorder: Documents the findings, deviations, causes, safeguards, and action items in specialized software.
- Process / Chemical Engineer: Provides expertise on fluid mechanics, reaction kinetics, and mass/energy balances.

- Instrument & Control Engineer: Explains control loops, trips, interlocks, and alarm settings.
- Operations / Maintenance Personnel: Offers practical, hands-on insights on actual plant operations, startup, and shutdown routines.

**Advantages & Limitations of HAZOP**

- Advantages:
    - Highly structured, thorough, and minimizes overlooked hazards.
    - Captures both safety hazards and operational reliability issues.
    - Encourages dynamic cross-disciplinary team discussion.
- Limitations:
    - Time-consuming and resource-intensive.
    - Focuses heavily on single-failure events rather than complex multi-variable interactions.
    - Heavily reliant on the experience and competence of the team and session leader.

## UNIT 2 PERSONAL PROTECTION IN WORK ENVIRONMENT

**Personal protection in the work environment:**

Personal protection in the workplace involves a combination of organizational controls, equipment, and individual safety practices to prevent injuries, illnesses, and exposure to hazards.

### 1. Hierarchy of Hazard Controls

Before relying on personal protection equipment, workplaces follow the Hierarchy of Controls to eliminate or minimize risks at the source:

[ Elimination ] <-- Most Effective (Physically remove the hazard)
[ Substitution ] <-- Replace the hazard
[ Engineering ] <-- Isolate people from the hazard
[ Administrative ] <-- Change the way people work
[ P P E ] <-- Least Effective (Protect worker with equipment)

Elimination: Removing the hazard entirely (e.g., eliminating a dangerous step in a process).

Substitution: Replacing a hazardous material or process with a safer one (e.g., using water-based paint instead of solvent-based paint).

Engineering Controls: Installing physical safeguards (e.g., machine guards, local exhaust ventilation, noise barriers).

Administrative Controls: Implementing policies and training (e.g., job rotation, safety training, warning signs, standard operating procedures).

Personal Protective Equipment (PPE): Providing personal safety gear to protect workers from remaining residual hazards.

**2**. **Types of Personal Protective Equipment (PPE)**
When hazards cannot be fully controlled by engineering or administrative means, specific PPE is required based on the nature of the work environment:

Eye and Face Protection
Safety Glasses / Goggles: Protect against flying debris, impact, chemical splashes, and dust.

Face Shields: Provide full-face protection against major chemical splashes, high-impact sparks, or biological hazards (used in conjunction with safety glasses).

Welding Helmets: Protect against radiation (UV/IR light), heat, and sparks during welding.

Head Protection
Hard Hats (Class G, E, C): Protect against falling objects, overhead impacts, and electric shock depending on the rating.

Bump Caps: Used in tight spaces to protect against minor head bumps (not rated for falling objects).

Hearing Protection
Earplugs (Disposable or Molded): Inserted into the ear canal to reduce high-frequency noise.

Earmuffs: Cover the entire outer ear to attenuate sound in high-noise environments (e.g., construction sites, manufacturing plants).

Respiratory Protection
Dust Masks / N95 Filtering Facepieces: Protect against airborne particulates, dust, and non-oil aerosols.

Half-Face / Full-Face Elastomeric Respirators: Equipped with specific chemical cartridges to filter organic vapors, acid gases, or toxic particulates.

Supplied-Air Respirators (SAR) / SCBA: Provide clean breathing air in oxygen-deficient or immediately dangerous to life or health (IDLH) atmospheres.

Hand and Arm Protection
Chemical-Resistant Gloves: Nitrile, neoprene, or PVC gloves for handling corrosive substances or solvents.

Cut-Resistant Gloves: Kevlar or steel mesh gloves for handling sharp materials or blades.

Thermal / Electrical Gloves: Insulated gloves rated for extreme temperatures or electrical arc flash risks.

Body Protection
High-Visibility Clothing: Reflective vests or jackets for working near traffic, machinery, or low-light environments.

Chemical Protective Suits: Tyvek suits or heavy PVC aprons for protection against hazardous spills.

Flame-Resistant Clothing (FRC): Worn in environments with fire, thermal flash, or arc-flash hazards.

Foot Protection
Steel-Toe / Composite-Toe Boots: Protect feet from falling objects or compression.

Puncture-Resistant Soles: Prevent injuries from sharp objects like nails on construction sites.

Metatarsal & Chemical-Resistant Footwear: Protect the top of the foot and guard against chemical spills.

**3. Workplace Best Practices for Personal Safety**
Risk Assessment: Conduct a thorough hazard assessment of the work environment before starting any task.

Proper Fitting & Training: Ensure all PPE fits the worker correctly and that employees are trained on how to inspect, put on (don), take off (doff), clean, and store their equipment.

Maintenance & Inspection: Regularly check PPE for cracks, wear, tears, or degradation. Damaged PPE must be replaced immediately.

Ergonomics & Workstation Design: Ensure workstations reduce repetitive strain, poor posture, and physical fatigue.

Reporting Culture: Maintain an active system for reporting near-misses, unsafe conditions, and equipment failures.

Personal Protective Equipment (PPE) is broadly divided into respiratory and non-respiratory categories depending on how they protect the body from occupational hazards.

**1. Respiratory Protection Equipment**
Respiratory equipment is designed to protect workers from inhaling hazardous airborne contaminants, such as dusts, fumes, gases, vapors, mists, or oxygen-deficient atmospheres.

Filtering Facepiece Respirators (e.g., N95, P100): Lightweight, disposable masks that filter out solid and liquid particulates from the air.

Elastomeric Respirators (Half-Face / Full-Face): Reusable facepieces equipped with replaceable chemical cartridges, gas canisters, or particulate filters depending on the specific contaminant.

Powered Air-Purifying Respirators (PAPRs): Battery-powered systems that use a blower to pass contaminated air through a filter, delivering purified air to a hood, helmet, or facepiece with reduced breathing resistance.

Supplied-Air Respirators (SAR): Systems that deliver clean breathing air through a hose from a stationary source (such as compressed air cylinders or an air compressor) located in a safe atmosphere.

Self-Contained Breathing Apparatus (SCBA): Portable units featuring a high-pressure air cylinder worn by the user, providing complete independence from ambient air. Essential for entry into Immediately Dangerous to Life or Health (IDLH) environments, such as confined spaces or severe chemical leaks.

**2. Non-Respiratory Protection Equipment**

Non-respiratory PPE covers all other gear worn to protect specific external parts of the body from physical, mechanical, thermal, electrical, or chemical hazards.

Eye and Face Protection: Safety glasses, chemical splash goggles, full-face shields, and welding helmets designed to block flying debris, liquid splashes, optical radiation, and sparks.

Head Protection: Hard hats (classified by impact and electrical resistance ratings) and bump caps to protect against falling objects, overhead strikes, and minor bumps in tight spaces.

Hearing Protection: Disposable or reusable earplugs and over-the-ear earmuffs used to attenuate high-noise environments and prevent noise-induced hearing loss.

Hand and Arm Protection: Chemical-resistant gloves (nitrile, neoprene, butyl), cut-resistant gloves (Kevlar, wire mesh), thermal/cryogenic gloves, and electrical insulating rubber gloves.

Foot and Leg Protection: Steel-toe or composite-toe safety boots, puncture-resistant soles, metatarsal guards, electrical hazard (EH) footwear, and chemical-resistant boots.

Body Protection: High-visibility vests and clothing, chemical-resistant suits (Tyvek or hazmat suits), flame-resistant/arc-rated clothing, and heavy-duty aprons.

Fall Protection: Full-body harnesses, shock-absorbing lanyards, and lifeline systems designed to arrest falls safely when working at elevated heights.

**Standards related to PPEs:**

Personal Protective Equipment (PPE) standards define design specifications, testing criteria, and performance levels to ensure safety equipment protects workers from hazards. PPE standards are established by standard bodies across regions, primarily **ISO** (International), **EN** (European Union/Global), and **ANSI / ISEA** (United States).

**Primary Regulatory & Standards Bodies**

| Body / Organization | Scope & Region | Role |
|---|---|---|
| **ISO** | Global | International consensus standards for manufacturing, testing, and sizing. |
| **EN / CEN** | Europe (Widely used globally) | Standards required for the **CE mark** in European markets. |
| **ANSI / ISEA** | United States | Voluntary consensus standards defining PPE classes and performance levels. |
| **OSHA** | United States | Government regulatory agency that enforces the mandatory adoption of standards (e.g., ANSI). |

**PPE Standards by Body Category**

1. Head Protection (Helmets & Hard Hats)

- **EN 397:** Specification for industrial safety helmets (impact, penetration, and flame testing).
- **ANSI/ISEA Z89.1:** Industrial head protection classifying helmets by **Type** (Type I for top impact, Type II for top and lateral impact) and **Class** (Class G, E, C for electrical rating).
- **EN 12492:** Helmets for mountaineering and high-altitude industrial work.

2. Eye and Face Protection

- **ANSI/ISEA Z87.1:** American standard covering safety glasses, goggles, and face shields. Sets baseline requirements for high-impact protection (marked as **Z87+**) and liquid/splash exposure.
- **EN 166:** European basic standard for eye and face protection, defining optical quality, mechanical strength, and splash/dust resistance.

3. Respiratory Protection

- **EN 149:** Requirements for filtering half-masks (respirators), classifying them as **FFP1**, **FFP2**, or **FFP3** based on filtration efficiency.
- **NIOSH (42 CFR 84) / ANSI:** U.S. standards defining particulate filter ratings such as **N95, N99, N100**, and **P100** (oil-proof).

- **EN 140 / EN 136:** Reusable half-mask and full-face mask standards.

4. Hand Protection (Gloves)
   - **ANSI/ISEA 105:** U.S. standard evaluating mechanical risks (cut levels A1–A9, abrasion, puncture) and chemical resistance.
   - **EN 388:** European standard for protection against mechanical risks (abbreviated by a 4-digit/letter code for abrasion, cut, tear, puncture, and impact).
   - **EN 374:** Standard for chemical and micro-organism protective gloves.
   - **EN 407:** Protection against thermal risks (heat and/or fire).

5. Foot Protection
   - **ISO 20345 / EN ISO 20345:** Global standard for safety footwear, specifying requirements like 200-Joule toe-cap impact resistance, slip resistance, and puncture-resistant soles.
   - **ASTM F2413 / ASTM F2412:** American standards covering performance requirements and test methods for protective toe cap, electric shock hazard (EH), and metatarsal safety footwear.

6. High-Visibility Apparel
   - **ANSI/ISEA 107:** U.S. standard for high-visibility safety apparel (Class 1, Class 2, Class 3) based on background and retroreflective material area.
   - **ISO 20471 / EN ISO 20471:** International standard specifying requirements for high-visibility clothing designed to visually signal the user's presence.

7. Protective Clothing & Fall Protection
   - **ISO 13688:** General requirements for protective garments (ergonomics, sizing, labeling).
   - **EN ISO 11612:** Clothing to protect against heat and flame.
   - **ANSI/ASSP Z359:** Comprehensive U.S. standard family for fall protection systems (harnesses, lanyards, lifelines, and anchors).
   - **EN 361:** European standard for full-body harnesses for fall arrest.

Key Steps for Workplace Compliance

1. **Conduct a Hazard Assessment:** Identify physical, chemical, biological, thermal, or electrical risks present in the environment.
2. **Match Hazard to Standard:** Ensure purchased equipment clearly cites the applicable standard marking (e.g., Z87+ on glasses, ISO 20345 on boots, or CE EN 388 on gloves).
3. **Inspect Certification Markings:** Verify equipment possesses genuine certification marks (CE, ANSI, ISO, CSA, etc.) and vendor laboratory test certificates.

**Monitoring Safety Performance:**

Monitoring safety performance involves tracking key metrics that measure both **historical outcomes** (lagging indicators) and **proactive prevention efforts** (leading indicators).

The standard base multipliers used in calculations are typically:

- **200,000** — standard base for 100 full-time workers working 40 hours/week for 50 weeks (common under OSHA/US standards).
- **1,000,000** — standard base for 500 full-time workers (common in ILO/international standards).

1. **Frequency Rate (FR)**

Frequency Rate measures **how often** safety incidents or injuries occur relative to the total exposure hours worked. It reflects the probability of an incident occurring, regardless of its severity.

- **Formula:**

$$\text{Frequency Rate} = \left(\frac{\text{Number of Disabling / Recordable Injuries}}{\text{Total Man-Hours Worked}}\right) \times 1,000,000 \quad (\text{or } 200,000)$$

- **Key Focus:** Tracks incident quantity.
- **Type:** Lagging Indicator.

2. **Severity Rate (SR)**

Severity Rate measures the **seriousness of injuries** by evaluating the amount of lost work time caused by workplace accidents.

- **Formula:**

$$\text{Severity Rate} = \left(\frac{\text{Total Days Lost due to Injuries}}{\text{Total Man-Hours Worked}}\right) \times 1,000,000 \quad (\text{or } 200,000)$$

- **Key Focus:** Highlights operational impact and the human/financial cost per incident.
- **Type:** Lagging Indicator.

**Note:** Combining Frequency Rate and Severity Rate gives a comprehensive picture of incident patterns—high frequency with low severity indicates minor repetitive hazards, whereas low frequency with high severity indicates catastrophic risks.

3. **Incidence Rate (IR)**

Incidence Rate measures the **number of injuries/illnesses per fixed unit of workers** (typically per 100 full-time workers) rather than raw hours. It allows normalised comparisons across plants, business units, or standard industry benchmarks (e.g., OSHA TRIR/DART).

- **Formula (OSHA standard):**

$$\text{Incidence Rate} = \left(\frac{\text{Number of Recordable Cases}}{\text{Total Man-Hours Worked}}\right) \times 200,000$$

- **Key Focus:** Benchmarking company performance against regional or industry safety standards.
- **Type:** Lagging Indicator.

4. **Activity Rate (Safety Action Rate)**

Unlike the three lagging indicators above, the **Activity Rate** is a **leading indicator**. It evaluates the extent to which proactive safety measures and preventive actions are being actively executed across the workforce.

- **Formula:**

$$\text{Activity Rate (\%)} = \left(\frac{\text{Number of Safety Activities Executed}}{\text{Number of Planned / Required Safety Activities}}\right) \times 100$$

- **Examples of Tracked Activities:**
  - Safety inspections and audit completion
  - Near-miss reports submitted
  - Safety training session completion rates
  - Timely closure of corrective actions (CAPA)
- **Key Focus:** Drives worker behaviour and predicts future performance—higher proactive activity directly correlates with lower frequency and severity rates down the line.
- **Type:** Leading Indicator.

Summary Comparison

| **Metric** | **Measurement Type** | **Focus Question** | **Target Trend** |
|---|---|---|---|
| **Frequency Rate** | Lagging | How often do injuries happen? | Lower is better |
| **Severity Rate** | Lagging | How bad are the injuries when they happen? | Lower is better |

| | | | |
|---|---|---|---|
| **Incidence Rate** | Lagging | How does our workplace compare per 100 workers? | Lower is better |
| **Activity Rate** | Leading | Are we actively performing preventative actions? | Higher is better (100% compliance) |

**Housekeeping:**

Good industrial housekeeping is a foundational element of workplace safety, hygiene, and operational efficiency. It goes far beyond basic cleaning—it involves maintaining orderly work areas, clear walkways, proper material storage, and effective waste management to prevent slips, trips, fires, and chemical hazards.

Effective housekeeping requires shared commitment: Management provides the structure and resources, while Employees execute and maintain the standards daily.

1. **Responsibilities of Management**

Management holds the primary obligation to establish policy, allocate resources, and create a culture where cleanliness and order are prioritized.

Infrastructure & Resource Allocation

- Provide Storage & Equipment: Supply adequate storage facilities (racks, bins, cabinets), waste disposal containers, and suitable cleaning equipment/materials.
- Workplace Layout Design: Design safe layouts with designated, clearly marked aisles, walkways, emergency exits, and material storage zones.
- Waste Management Systems: Establish clear procedures and vendor channels for safe trash, hazardous material, and chemical waste disposal.

Systems, Policies & Standards

- Establish Written Standards: Define clear, standard operating procedures (SOPs) for workplace tidiness, tool storage, and chemical spill cleanups (e.g., implementing 5S Methodology: Sort, Set in Order, Shine, Standardize, Sustain).
- Assign Responsibilities: Incorporate housekeeping duties explicitly into shift schedules and individual job descriptions so accountability is transparent.

Training & Monitoring

- Provide Effective Training: Train workers during onboarding and refresher sessions on proper disposal, spill response, and safe storage techniques.

- Conduct Audits & Inspections: Execute regular housekeeping audits and safety walk-throughs to identify gaps, track performance, and correct deficiencies promptly.
- Lead by Example & Enforce: Model good housekeeping behavior and recognize/reward teams that maintain exemplary standards.

2. **Responsibilities of Employees**

Employees are the first line of defense. They execute housekeeping practices daily to keep themselves and their co-workers safe.

Clean-as-You-Go Practices

- Maintain Workstations: Keep immediate work areas clean, organized, and free from unnecessary clutter, scrap material, or personal belongings.
- Immediate Cleanup: Clean up minor liquid spills immediately (or report major spills) to prevent slip and fall accidents.
- End-of-Shift Cleanup: Return tools, equipment, and raw materials to their designated storage spaces before finishing work.

Safe Storage & Disposal

- Keep Aisles & Exits Clear: Never block walkways, fire extinguishers, electrical panels, eyewash stations, or emergency exits with boxes, pallets, or debris.
- Proper Waste Segregation: Dispose of scrap materials, oily rags, chemical waste, and general trash in designated, labeled bins (e.g., placing flammable rags in fireproof metal cans).
- Organize Materials Safely: Stack boxes and materials neatly on shelves or pallets, observing weight limits and keeping heavy items near the bottom to prevent collapses.

Reporting & Hazard Awareness

- Report Facilities Issues: Promptly notify management or maintenance about broken storage racks, damaged flooring, leaks, or inadequate light fixtures.
- Inspect Tools & Gear: Ensure personal protective equipment (PPE) and work tools are kept clean and stored properly when not in use.

Advantages of good housekeeping:

Good industrial housekeeping is essential for maintaining operational excellence and workplace safety. The **5S Methodology**—originating from Japanese lean manufacturing principles—serves as the foundational system to achieve and maintain these high standards.

1. Enhanced Workplace Safety

- **Prevents Slips, Trips & Falls:** Keeping aisles clear and floor surfaces dry directly reduces the primary causes of lost-time industrial injuries.
- **Fire Hazard Reduction:** Proper segregation and disposal of combustible trash, oily rags, and chemical waste mitigate fire propagation.
- **Clear Emergency Routes:** Unobstructed exits, pathways, and emergency equipment (extinguishers, eyewash stations) ensure swift evacuations during crises.

2. Higher Efficiency & Productivity

- **Reduced Search Time:** Workers waste significantly less time hunting for tools, parts, or documentation when shadow boards and labeled storage are used.
- **Optimized Workflow:** Eliminating clutter creates smoother material transport and reduces physical bottlenecks on the floor.

3. Equipment Reliability & Quality Control

- **Early Defect Detection:** Clean machinery makes oil leaks, cracks, and abnormal wear immediately noticeable before costly breakdowns occur.
- **Reduced Contamination:** Keeping work spaces dust- and debris-free minimizes product defects and rework rates.

4. Better Morale & Professional Image

- **Employee Well-Being:** A clean, organized environment reduces stress, fosters pride in work, and reduces absenteeism.
- **Positive Client Impression:** Clean facilities instill immediate confidence in auditors, clients, and regulatory inspectors.

**5 s of housekeeping**.

The 5S Framework of Housekeeping

| Step | Japanese Term | English Term | Objective | Core Action |
|---|---|---|---|---|
| 1st S | **Seiri** (整理) | Sort | Eliminate unnecessary items | Identify needed vs. unneeded items in the work area; dispose of or relocate clutter using "red-tagging." |
| 2nd S | **Seiton** (整頓) | Set in Order | Organize necessary items | Arrange tools, materials, and equipment logically so they are easy to find and return (*"A place for everything and everything in its place"*). |
| 3rd S | **Seiso** (清掃) | Shine | Clean and inspect | Regularly clean work areas, tools, and machinery to ensure equipment is functioning safely and to catch leaks/defects early. |
| 4th S | **Seiketsu** (清潔) | Standardize | Create systematic routines | Develop clear checklists, visual controls, and standard operating procedures (SOPs) to maintain the first 3 steps consistently. |

| | | | | |
|---|---|---|---|---|
| 5th S | **Shitsuke** (躾) | Sustain | Build long-term h | Foster a workplace culture of self-discipline through continuous training, regular audits, and management support. |

**Work permit system:**

A **Work Permit System**—commonly referred to as a **Permit to Work (PTW) System**—is a formal written safety management procedure used to authorize high-risk non-routine work in specified areas. It acts as an operational control to prevent workplace fatalities, injuries, and major asset damage.

**Core Objectives of a Work Permit System**

1. Hazard Identification & Risk Assessment
    - **Pinpoint Non-Routine Risks:** Identify specific hazards associated with specialized tasks (e.g., hot work, confined space entry, working at heights, electrical isolation) before work starts.
    - **Define Safety Controls:** Specify exact control measures, such as gas testing, ventilation, LOTO (Lockout/Tagout), and mandatory Personal Protective Equipment (PPE).

2. Formal Authorization & Accountability
    - **Regulate Site Access:** Ensure high-risk work only proceeds with formal authorization from designated competent authorities (e.g., Area In-Charge, Safety Officer).
    - **Clear Ownership:** Establish clear responsibility for both the person issuing the permit (issuer) and the supervisor executing the work (performer/receiver).

3. Clear Communication & Coordination
    - **Define Exact Scope & Limits:** Specify the precise nature of work, exact location, equipment involved, allowed personnel, and strict validity timeframe.
    - **Prevent Conflicting Operations (SIMOPS):** Coordinate simultaneous operations (e.g., ensuring welding isn't authorized directly above a chemical drainage line or near flammable painting activities).
    - **Inform Affected Personnel:** Ensure operators, nearby teams, and emergency responders are aware of ongoing high-risk activities.

4. Verification of Precautions Before Work Starts
    - **Pre-Task Safety Checks:** Force a physical walkthrough to verify that isolations, atmospheric testing, and physical barriers are fully implemented prior to starting work.
    - **Toolbox Talks (TBT):** Brief the execution crew on task-specific risks, emergency response steps, and permit conditions before work commences.

5. Safe Work Suspension & Handover

- **Manage Changes:** Provide clear protocols to suspend work if site conditions change, alarms sound, or unforeseen hazards arise.
- **Formal Handover:** Ensure structured communication during shift changes or when work is temporarily paused.

6. Post-Job Closure & Housekeeping

- **Site Restoration:** Verify that the work area is left in a safe, clean, and stable state once the job is completed.
- **De-isolation:** Ensure temporary safety bypasses or LOTO points are safely removed and system integrity is restored before handing equipment back to operations.

**Common Types of Work Permits**

| **Permit Type** | **Covered Activities** | **Primary Hazards Controlled** |
|---|---|---|
| **Hot Work Permit** | Welding, cutting, grinding, open flames | Fires, explosions, toxic fumes |
| **Cold Work Permit** | Maintenance or construction not involving heat/sparks | Mechanical hazards, pressure releases |
| **Confined Space Entry** | Entering tanks, vessels, silos, pits | Toxic gas accumulation, asphyxiation, entrapment |
| **Height Work Permit** | Scaffolding, elevated platforms, roof work | Falls from height, falling objects |
| **Electrical / LOTO Permit** | Work on high-voltage equipment, panel maintenance | Electrocution, unexpected re-energization |
| **Excavation Permit** | Trenching, digging near buried lines | Cave-ins, striking underground utilities |

### Hot work and Cold work permits

In industrial safety management, **Hot Work** and **Cold Work** permits are the two primary categories used in a Permit to Work (PTW) system to control non-routine maintenance, construction, and repair activities.

The essential difference lies in the **presence of an ignition source or open flame**, which dramatically changes the risk profile and required controls.

### 1. Hot Work Permit

A **Hot Work Permit** is required for any activity that generates heat, sparks, or open flames capable of igniting flammable gases, vapors, dust, or combustible materials nearby.

Typical Activities Covered

- Welding (Arc, TIG, MIG, Gas)
- Flame cutting, brazing, and soldering
- Grinding and power disc cutting
- Blasting and thermal spraying
- Use of non-explosion-proof electrical tools in hazardous areas

Key Precautions & Safety Controls

- **Gas Testing:** Continuous or pre-job testing for Lower Explosive Limit (LEL), Oxygen (O2), and toxic gases (e.g., H_2S, CO) using calibrated gas detectors.
- **Fire Watch:** Assigning a dedicated, trained Fire Watch person equipped with a suitable fire extinguisher throughout the work and for at least **30 to 60 minutes after** work finishes.
- **Combustible Removal / Shielding:** Clearing all flammable materials within a **35-foot (10-meter) radius**, or covering them with fire-resistant blankets/tarps.
- **Drain & Vent Sealing:** Covering nearby floor drains, sewers, and process vents to prevent sparks from entering spark-sensitive areas.
- **Spark Containment:** Installing fire-retardant welding habitats or containment screens when working in live process units.

### 2. **Cold Work Permit**

A **Cold Work Permit** is required for non-routine activities that **do not produce sufficient heat, sparks, or flames** to cause ignition, but still carry physical, mechanical, or structural hazards to personnel and equipment.

Typical Activities Covered

- Routine mechanical maintenance (bolting, unbolting, flange management)
- Hand-tool work (scaffolding assembly using manual ratchets, pipe fitting)
- Cold cutting of piping or plate materials (using hydraulic or pneumatic shears)
- Painting, insulation work, and cleaning tasks (non-hazardous solvents)
- Rigging, hoisting, and heavy lifting operations

**Key Precautions & Safety Controls**

- **Energy Isolation (LOTO):** Ensuring mechanical, hydraulic, and electrical systems are depressurized, drained, isolated, and locked out/tagged out.
- **Personal Protective Equipment (PPE):** Task-specific PPE such as cut-resistant gloves, face shields, safety glasses, and hard hats.
- **Line Breaking / Depressurization:** Verifying that pipework is fully drained, flushed, and depressurized before breaking flanges or opening lines.
- **Physical Barriers & Barricades:** Setting up warning tape, tags, and physical barriers below overhead work or around lifting zones.

**Direct Comparison**

| **Feature / Criteria** | **Hot Work Permit** | **Cold Work Permit** |
|---|---|---|
| **Primary Ignition Hazard** | **High** (produces open flame, arcs, or sparks) | **Low to None** (no thermal/spark ignition sources) |
| **Atmospheric Gas Testing** | **Mandatory** (LEL, O2,, toxic gases) | Required only if working near process systems or line breaking |
| **Dedicated Fire Watch** | **Mandatory** during work & post-work | Not required |
| **Fire Suppression Readiness** | Fire extinguishers/hoses placed directly at work site | Standard building fire protection available |
| **Primary Risk Types** | Explosions, fires, thermal burns, flash hazards | Pinch points, falling objects, pressure release, chemical exposure |
| **Validity Period** | Short (typically 1 shift, maximum 8–12 hours) | Shift-based or multi-day (with shift-start re-validations) |

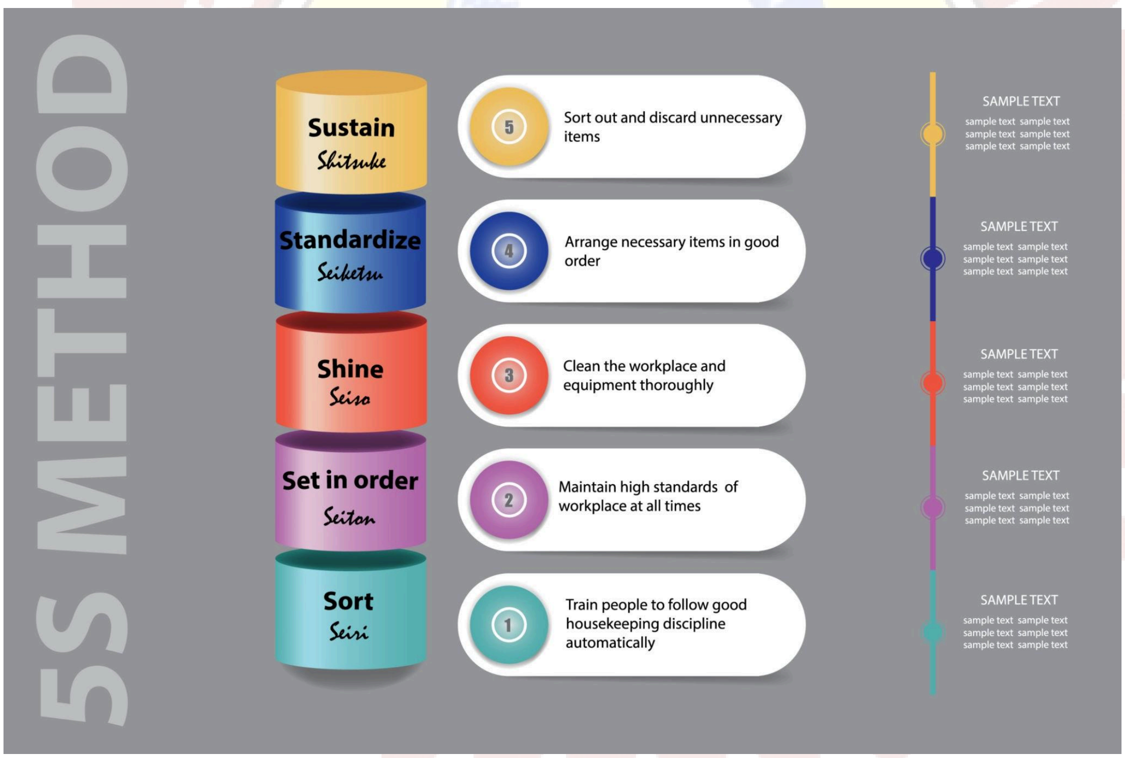
**Typical industrial models and methodology**.

Industrial models and methodologies provide structured frameworks to optimise manufacturing, quality, safety, process control, and maintenance across operations. They are categorized based on their primary operational focus.

1. Process Improvement & Quality Management

Lean Manufacturing

- **Core Philosophy:** Eliminating waste (**Muda**) to maximize customer value while using fewer resources.
- **Key Principles:** Value stream mapping, Just-In-Time (JIT) production, continuous flow, and pull systems (Kanban).
- **Core Sub-Tool: 5S Methodology** (*Sort, Set in Order, Shine, Standardize, Sustain*) for operational order.

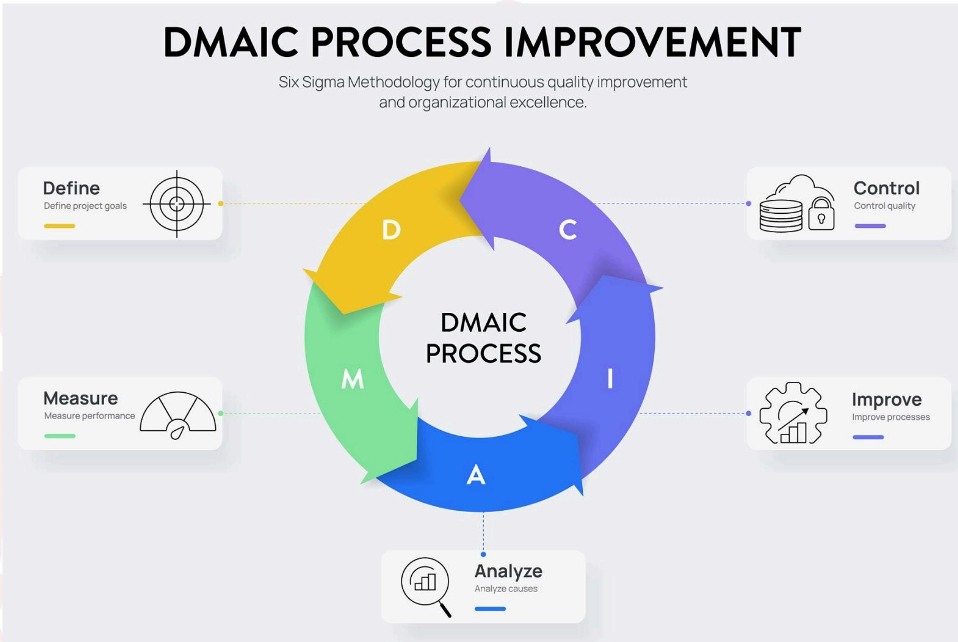



**5S Workplace Organization System.**

**Six Sigma (DMAIC)**

- **Core Philosophy:** Reducing process variation and defect rates using data-driven statistical methods.
- **Target Benchmark:** Achieving fewer than **3.4 defects per million opportunities (DPMO)**.
- DMAIC Framework:

1. **Define:** Identify the problem and project goals.
2. **Measure:** Collect baseline performance data.
3. **Analyze:** Identify root causes of defects (using tools like Ishikawa/Fishbone diagrams).
4. **Improve:** Design and test solutions to eliminate root causes.
5. **Control:** Implement standards and monitoring metrics to sustain gains.




DMAIC Process Improvement Cycle.

**Total Quality Management (TQM) & PDCA**

- **Core Philosophy:** Organization-wide focus on continuous quality improvement involving every employee.
- **PDCA Cycle (Deming Wheel): Plan** (identify goals), **Do** (implement pilot), **Check** (verify results against targets), **Act** (standardize or refine).


**Plan-Do-Check-Act (PDCA) Continuous Improvement Cycle. Source: Irina Samoylova / Getty Images**

2. Maintenance & Asset Management

Total Productive Maintenance (TPM)

- **Objective:** Eliminate downtime, equipment defects, and safety accidents by involving operators in daily maintenance.
- **Core Pillars:** Autonomous Maintenance (operators inspect/clean their own tools), Planned Maintenance, Focused Improvement (Kaizen), and Quality Maintenance.
- **Primary Metric: Overall Equipment Effectiveness (OEE)**:
  $OEE=Availability\times Performance\times Quality$

Reliability-Centered Maintenance (RCM)

- **Objective:** Determine the optimal maintenance strategy (predictive, preventive, or run-to-failure) for each physical asset based on risk and critical failure modes (FMEA/FMECA).

3. Safety & Environmental Management

ISO Management Systems

- **ISO 45001:** International standard for **Occupational Health and Safety (OH&S)** management systems, focusing on proactive hazard identification, risk mitigation, and management commitment.
- **ISO 14001:** International standard for **Environmental Management Systems (EMS)**, regulating waste reduction, emissions, and sustainable resource usage.

Hierarchy of Controls

A fundamental framework for systematically eliminating or reducing workplace risks:

1. **Elimination:** Physically remove the hazard (most effective).
2. **Substitution:** Replace the hazard with a safer alternative.
3. **Engineering Controls:** Isolate people from the hazard (e.g., guards, ventilation).
4. **Administrative Controls:** Change the way people work (e.g., procedures, training, work permits).
5. **PPE:** Protect the worker with Personal Protective Equipment (least effective, last line of defense).

**Summary Matrix of Major Industrial Models**

| **Model / Methodology** | **Focus Area** | **Primary Metric / Output** | **Best Used For** |
|---|---|---|---|
| Lean | Waste reduction & flow | Lead time, Lead time efficiency | Assembly lines, supply chain, logistics |
| Six Sigma | Defect reduction & variance | DPMO, Process Capability Index (Cpk) | High-volume manufacturing, precision engineering |
| TPM | Equipment reliability | Overall Equipment Effectiveness (OEE) | Heavy industry, automated manufacturing |
| PDCA / TQM | Continuous quality culture | Audit scores, customer satisfaction | Site-wide quality management systems |
| ISO 45001 | Safety & health management | Incident Frequency & Severity rates | Enterprise EHS compliance |

**Summary Matrix**

| **Responsibility Area** | **Management Role** | **Employee Role** |
|---|---|---|
| Facilities & Equipment | Provides cleaning gear, waste bins, storage racks | Uses and maintains provided equipment responsibly |
| Work Area Tidiness | Allocates time for daily cleanup during shifts | Practices "clean-as-you-go" and end-of-shift resets |
| Safety Hazards | Conducts audits and fixes infrastructural defects | Keeps exits, aisles, and emergency equipment clear |
| Chemical & Waste Disposal | Establishes disposal SOPs and supplies proper containers | Follows segregation rules and disposes waste correctly |

**Entry into confined spaces:**
Confined space entry is one of the most hazardous operations in industrial facilities. A confined space is defined as any location that is large enough for a worker to enter, has limited or restricted means of entry/exit, and is not designed for continuous human occupancy (e.g., storage tanks, vessels, silos, sewers, pits, pipelines, and reaction kettles).

**Key Hazards in Confined Spaces**

- Atmospheric Hazards:
    - Oxygen Deficiency: Less than $19.5\%$ oxygen level (causes asphyxiation).
    - Oxygen Enrichment: Greater than $23.5\%$ oxygen level (creates severe fire/explosion risk).
    - Toxic Gases: High concentration of chemicals like Hydrogen Sulfide ($H_2S$) or Carbon Monoxide ($CO$).
    - Flammable Vapors/Gases: High concentration reaching or exceeding the Lower Explosive Limit (LEL).
- Physical & Mechanical Hazards: Unexpected activation of agitators, mixers, or live electrical lines.

- Engulfment Risks: Free-flowing solids (grain, sand, powder) or liquids filling the space rapidly.
- Environmental Extreme: Heat stress, noise amplification, poor visibility, and limited mobility.

**Mandatory Prerequisites for Safe Entry**

1.Issue a Confined Space Entry Permit:Do not enter without formal authorization.
Obtain a signed Confined Space Entry Permit detailing the scope of work, duration, designated entrants, standby attendant, and safety controls.

2.Isolate Energy Sources (LOTO & Blinding):Prevent hazardous inflows.
Physically disconnect or insert spade/blind flanges into all connected piping lines. Perform Lockout/Tagout (LOTO) on electrical switches and mechanical agitators.

3.Purge, Vent, and Ventilate:Prepare a breathable environment.
Drain, flush, and steam or purge the space to remove residual chemicals or gases. Set up mechanical forced-air ventilation (blowers) and run continuously throughout the entry.

4.Perform Multi-Gas Atmospheric Testing:Test in order: Oxygen -.
Flammables -> Toxins">

A certified gas tester must test the air at top, middle, and bottom levels using a calibrated multi-gas detector. Record values on the permit:

- Oxygen ($O_2$): Must be between 19.5% and 23.5%
- Combustible Gas (LEL): Must be < 10% LEL (ideally 0%)
- Toxic Gases: $H_2S$ < 10 ppm},CO < 25 ppm

5.Position the Attendant & Rescue Equipment:Never leave the entrant unattended.
Position a dedicated, trained Standby Attendant (Hole Watcher) outside the entrance. Set up emergency retrieval equipment (tripod hoist, harness, and retrieval line) before entry.

**Crucial Roles & Responsibilities**

| **Role** | **Key Duties** |
|---|---|
| Authorized Entrant | Knows the hazards, uses required PPE/respirators, maintains continuous communication with the attendant, and evacuates immediately if alarms sound or hazards change. |

| | |
|---|---|
| Standby Attendant (Hole Watch) | Remains outside the entrance at all times, monitors entrant status, controls entry log/access, and never enters the space for rescue—calls emergency response instead. |
| Entry Supervisor | Verifies permit conditions, confirms all tests and isolations are complete, authorizes entry, and cancels/closes the permit upon task completion. |

Golden Rule of Confined Space Safety: Over 60% of fatalities in confined space accidents occur among untrained rescuers who rush in to save a fallen colleague without proper breathing gear. Emergency rescue must *always* be non-entry retrieval or performed by a certified rescue team wearing SCBA (Self-Contained Breathing Apparatus).

**EXPERIMENT NO. 1**

**TITLE Study of Personal Protective Equipment (PPE) & Identification of Components**

## 1. AIM

To study the classification, construction, standard specifications, and inspection methods of key Personal Protective Equipment (PPE) used in industrial operations.

## 2. APPARATUS / ITEMS REQUIRED

- Industrial Safety Helmet (EN 397 / ANSI Z89.1)
- Safety Glasses & Face Shield (ANSI Z87.1)
- Steel-Toe Safety Boots (EN ISO 20345)
- Ear Plugs and Ear Muffs (EN 352)
- Half-Mask Respirator with Cartridges (NIOSH / EN 140)
- Mechanical Cut-Resistant & Chemical Gloves (EN 388 / EN 374)
- Full-Body Harness with Fall Arrest Lanyard (EN 361 / ANSI Z359)

3. LINE SKETCHES FOR RECORD DRAWING (UNRULED PAGE)

The reference diagram below shows the complete set of protective equipment on a worker:

**Sketch 1: Industrial Safety Helmet (Cross-Section)**

```
             /-------------------------\   <--- Outer Shell (HDPE / ABS / Fiberglass)
            /    ____________________   \
           /   /                     \   \ <--- Crown Clearance Cushion Space (30-50mm
          (   (      [Head Top]       )   )
           \   \_____________________/   / <--- Internal Suspension Harness (4 to 6 Po
            \                           /
      =======`==========┬=============`=======  <--- Peak / Brim
             |           |             |
Chin Strap ->|           |             |<- Ratchet Adjustment Knob / Nape Strap
                         v
                     Sweatband
```

**Sketch 2: Steel-Toe Safety Footwear (Cross-Section)**

```
                  /-----------------\  <--- Padded Ankle Collar
                 /   /            \ \
                /   /              \ \ <--- Genuine Leather Upper
               /   /                \ \
Tongue ------>|   /                  | |
              |  /                   | | <--- Reinforced Heel Counter
Laces ------->| (                    | |
              \  \                  / /
Steel Toe Cap ->\__\_______________/ /
(200J Impact)   |____________________| <--- Puncture-Resistant Steel Midsole / Shank
                |vvvvvvvvvvvvvvvvvvvv| <--- Anti-Slip Rubber/PU Outsole with Deep Lugs
```

**Sketch 3: Full-Body Fall Arrest Harness**

```
                 [ Back View ]
                     \   /
                      \ /
                      (D)  <--- Dorsal Attachment D-Ring (For Lanyard connection)
                     / | \
Shoulder Straps -->/   |  \
                   /   |   \
                  |  [ X ]  | <--- Sub-Pelvic Webbing Cross-Plate
                  |   / \   |
   Leg Loops ---> (  )   (  ) <--- Quick-Release Leg Buckles
```

**Sketch 4: Half-Mask Respiratory Protection**

```
                   /‾‾‾‾‾‾‾‾‾‾\
                  /   _______   \   <--- Adjustable Head Straps
                 /  /         \  \
                (  (  Exhale )  ) <--- Central Exhalation Valve Flap
                 \  \ Valve /  /
[ Filter ] ——>|==\_____/==|<— [ Filter Cartridge / P100 ]
Cartridge     |   \___/   |
               \__________/    <--- Silicone/Rubber Facepiece Seal
```

## 4. THEORY & CLASSIFICATION

Personal Protective Equipment (PPE) represents the **last line of defense** in the Hierarchy of Controls. It does not eliminate hazards at the source, but minimizes human body exposure to physical, chemical, electrical, radiological, and mechanical risks.

Hierarchy of Controls
[ Elimination ]
(Most Effective) ——> [ Substitution ] ——> [ Engineering Controls ] ——> [ Administrative Controls ] ——> [ PPE ] (Last Line)

## 5. OBSERVATION TABLE

| Category | Equipment Name | Applicable Standard | Primary Risk Mitigated | Key Inspection Checkpoint |
|---|---|---|---|---|
| **Head** | Industrial Safety Helmet | EN 397 / ANSI Z89.1 | Overhead impact, falling objects, electrical contact | Shell hairline cracks, UV degradation, suspension harness elasticity |
| **Eye & Face** | Impact Safety Goggles | ANSI Z87.1 / EN 166 | Flying chips, chemical splashes, dust radiation | Lens clarity, impact rating (Z87+), frame seal integrity |

| | | | | |
|---|---|---|---|---|
| **Hearing** | Industrial Ear Muffs | EN 352-1 / ANSI S3.19 | Continuous noise exposure ($>85\text{ dBA}$) | Cushion seal softness, headband tension, foam dampening inserts |
| **Respiratory** | Half-Mask Filter Respirator | EN 140 / NIOSH N95 | Airborne toxic dusts, organic vapors, gases | Valve flap elasticity, cartridge expiration date, seal check |
| **Hand** | Cut-Resistant Gloves | EN 388 (4543C) | Mechanical cuts, punctures, abrasions | Weave integrity, chemical deterioration, palm grip coating |
| **Foot** | Steel-Toe Safety Boots | ISO 20345 / ASTM F2413 | Toe crushing ($200\text{ J}$ impact), sharp puncture hazards | Steel cap positioning, sole tread depth, oil resistance |
| **Fall Control** | Full-Body Safety Harness | EN 361 / ANSI Z359.11 | Falls from height ($>1.8\text{ meters}$) | Webbing fraying, stitching rot, D-ring deformation, latch lock |

**6. PROCEDURE & PRE-USE INSPECTION PROTOCOL**

1. **Visual & Tactile Inspection:** Inspect each piece of PPE for structural flaws, cracks, burn marks, fraying, or missing components.
2. **Standard Markings Verification:** Verify that certification codes (CE, ANSI, ISO, or NIOSH) are permanently stamped on the shell or fabric label.
3. **Fit Check & Adjustment:**
    - **Helmet:** Adjust the rear ratchet suspension to ensure the helmet sits level on the head without wobble.
    - **Respirator:** Perform **Positive and Negative Pressure Checks** to verify an airtight face seal.
    - **Harness:** Fasten leg and chest buckles snugly—allow two fingers to slide underneath straps.
4. **Defect Quarantine:** Any PPE showing signs of impact, fall loading, or chemical degradation must be tagged **"OUT OF SERVICE"** and scrapped immediately.

7. **RESULTS & INFERENCE**

1. All core industrial PPE types were physically identified and mapped against their relevant EN/ANSI standards.
2. Recognized that PPE effectiveness depends heavily on **proper fit**, **correct specification selection** (matching hazard levels), and **routine pre-use inspection**.
3. Understood that non-compliant or damaged PPE provides a false sense of security and must be removed from service immediately.

**EXPERIMENT NO. 2**

**TITLE Design and Evaluation of Industrial Safety Training Posters**

1**. AIM**

To study the principles of visual safety communication and design effective industrial safety training posters using standard color coding, signal words, ISO safety symbols, and structured layouts to enhance workplace hazard awareness.

2. **APPARATUS / MATERIALS REQUIRED**

- Drawing Sheet (A3/A4 size) / Computer Aided Graphic Software
- Drawing Instruments (Pencils, Scale, Eraser)
- Color Markers (Standard Safety Colors: Red, Yellow, Blue, Green)
- Standard Safety Symbol Stencils / ISO 7010 Reference Charts

3. **THEORY & PRINCIPLES OF SAFETY POSTER DESIGN**

A safety poster is an administrative tool used to reinforce safe behaviors, communicate hazard awareness, and remind workers of mandatory safety protocols. To be effective, a poster must follow the **AIDA Model**:

1. **A - Attention:** High-contrast header/signal word catches the worker's eye instantly.
2. **I - Interest:** Clear visual imagery/illustration relates directly to the target work area.
3. **D - Desire:** Concise text explains *why* compliance matters (risk vs. benefit).
4. **A - Action:** Simple, clear instruction stating exactly what action to take.


Standard Safety Header Levels. Source: Seetwo / Getty Images

Standard Safety Color Codes (ISO 3864 / ANSI Z535)

| Color | Meaning / Message | Example Application | Standard Symbol Shape |
|---|---|---|---|
| **RED** | **Danger / Prohibition** | Stop action, Fire equipment, Flammable hazard | Circle with diagonal cross / Red Header |
| **YELLOW / ORANGE** | **Warning / Caution** | Potential hazard, Trip risk, Pinch points | Equilateral Triangle pointing up |
| **BLUE** | **Mandatory Action** | Must wear PPE (Glasses, Helmet, Boots) | Solid Circle with white symbol |
| **GREEN** | **Safe Condition** | First aid station, Emergency exit route, Eyewash | Square or Rectangle |

4. LINE SKETCHES & LAYOUT DESIGNS FOR RECORD (UNRULED PAGE)

Copy these two sample poster layouts onto the blank (unruled) side of your lab notebook using pencil and color markers.

Poster Layout 1: Mandatory PPE Compliance Poster

Plaintext

```
┌──────────────────────────────────────────────────────────┐
│ [ BLUE HEADER ]                                          │
│                                                          │
│                    MANDATORY                             │
│                                                          │
├──────────────────────────────────────────────────────────┤
│                                                          │
│             PROTECT YOUR HEAD & EYES!                    │
│                                                          │
│               /‾‾‾‾‾‾‾‾‾‾\          ( O )  ( O )         │
│              /            \          \_______/           │
│             (   [HELMET]   )        [SAFETY GLASSES]     │
│              \____________/                              │
│                                                          │
│        ┌──────────────────────────────────────────┐      │
│        │ WEAR APPROVED PPE BEFORE ENTERING WORK   │      │
│        │ AREA. NO EXCEPTIONS!                     │      │
│        └──────────────────────────────────────────┘      │
│                                                          │
│ [ COMPANY SAFETY DEPT ]           [ LOCATION: PLANT 1]   │
└──────────────────────────────────────────────────────────┘
```

Poster Layout 2: Hazard Warning (Chemical / Hot Surface) Poster
Plaintext

```
Plaintext

┌──────────────────────────────────────────────────────────┐
│  [ RED / YELLOW HEADER ]                                 │
│                                                          │
│  ▲ DANGER ▲           HOT SURFACE HAZARD                 │
│                                                          │
├──────────────────────────────────────────────────────────┤
│                                                          │
│                       / \                                │
│                      /   \                               │
│                     /  !  \   <--- ISO Hazard Triangle   │
│                    /_______\                             │
│                                                          │
│                 [ SKETCH OF BURN RISK ]                  │
│                 ~~~~~~~~~~~~~~~~~~~~~~~                  │
│                                                          │
│      * DO NOT TOUCH WITHOUT THERMAL GLOVES *             │
│      * ALLOW PIPEWORK TO COOL BEFORE MAINTENANCE *       │
│                                                          │
│  RULE: Check temperature gauges before contact.         │
│                                                          │
└──────────────────────────────────────────────────────────┘
```

5. PROCEDURE & DESIGN STEPS

1. **Target Hazard Identification:** Select a specific high-risk workplace hazard (e.g., Working at Heights, Chemical Splashes, Noise Exposure, Lockout/Tagout).
2. **Header & Signal Word Selection:** Choose the appropriate severity header (**DANGER** for severe injury/death, **WARNING** for moderate risk, **MANDATORY** for required protective gear).
3. **Graphic Symbol Drafting:** Draw an easily recognizable ISO 7010 graphic symbol in the central frame. Keep lines clean and uncluttered.
4. **Actionable Message Formulation:** Draft a short, direct message using positive phrasing (e.g., *"WEAR YOUR HARNESS"* rather than *"DON'T FORGET YOUR HARNESS"*).
5. **Color Application:** Apply ISO standard safety color fills to the border, header, and symbols.
6. **Legibility Verification:** Verify that the poster title can be clearly read from a distance of **3 to 5 meters**.

6. OBSERVATION & DESIGN EVALUATION CHECKLIST

Evaluate your drafted poster against the safety communication standard parameters below:

| Parameter | Standard Criteria | Observation / Evaluation | Compliance |
|---|---|---|---|
| **Signal Word** | DANGER / WARNING / CAUTION / MANDATORY | Clearly visible at top header | **Yes** |
| **Color Scheme** | ISO 3864 compliant (Red/Yellow/Blue/Green) | Correct color applied for hazard class | **Yes** |
| **Graphic Symbol** | Universal ISO pictogram used | Easily understandable without text | **Yes** |
| **Readability** | High-contrast font, 3m viewing distance | Bold block letters used | **Yes** |
| **Action Message** | Positive, direct, short instruction | Action step clearly specified | **Yes** |

**7. RESULTS & INFERENCE**

1. Designed two industrial safety training posters adhering to ISO 3864 and ANSI Z535 communication guidelines.
2. Understood that effective safety posters rely on **minimal text**, **universal ISO pictograms**, and **standardized color coding** to bridge language and literacy barriers on the shop floor.
3. Recognized that safety posters serve as continuous visual reminders to reinforce formal safety training and reduce human-error incidents.

**EXPERIMENT NO. 3**
**TITLE: Identification of Unsafe Acts and Unsafe Conditions in the Workplace**

## 1. AIM

To identify, classify, and audit **Unsafe Acts** (behavioral hazards) and **Unsafe Conditions** (environmental/physical hazards) in an industrial facility, and to recommend corrective actions using Heinrich's Domino Theory and the Hierarchy of Controls.

## 2. APPARATUS / TOOLS REQUIRED

- Safety Inspection Checklist / Audit Form
- Measuring Tape / Distance Meter
- Camera / Hazard Observation Logbook
- Standard Industrial Workstation Scenario (Workshop / Laboratory)

3. LINE SKETCHES FOR RECORD DRAWING (UNRULED PAGE)

Copy these two visual risk classification diagrams onto the blank (unruled) side of your record notebook.

**Sketch 1: Cause Ratio Breakdown (Heinrich's Triangle Concept)**

```
      / \
     / 2% \   <--- Acts of God / Uncontrollable
    /------\
   /  10%   \  <--- UNSAFE CONDITIONS (Environmental Hazards)
  /----------\
 /    88%     \ <--- UNSAFE ACTS (Behavioral & Human Factors)
/--------------\
```

**Sketch 2: Hazard Identification Scenario (Act vs. Condition)**

```
                    [ WORKSHOP SCENARIO ]

  UNSAFE ACT                                   UNSAFE CONDITION
  (Worker Behavior)                            (Physical Hazard)

      O  <-- Working without Safety Helmet        [____] <-- Unguarded Spinning Flywheel
     /|\                                           ||
     / \ <-- Standing on Top Rung of Ladder      =====\\=====  <-- Oily / Slippery Floor
                                                      \\
                                                  [===X===] <-- Frayed / Exposed Wires
```

## 4. THEORY & DEFINITIONS

According to industrial safety engineering principles (Heinrich's Safety Model):

- **Unsafe Act (Behavioral Hazard):** Any action, performance, or deviation from safe working procedures carried out by a worker that increases the probability of an accident.
    - *Examples:* Bypassing safety interlocks, not wearing required PPE, horseplay, using defective tools, or operating machinery without authorization.
- **Unsafe Condition (Physical/Environmental Hazard):** A physical state or situation in the work environment that can directly lead to property damage or personal injury.
    - *Examples:* Missing machine guards, exposed high-voltage wiring, slippery or oily floors, inadequate lighting, or blocked emergency exits.

## 5. OBSERVATION & HAZARD AUDIT TABLE

Record the hazards observed during the workshop walk-through inspection:

| S.No. | Observed Hazard / Situation | Category | Primary Safety Risk | Recommended Control Action |
|---|---|---|---|---|
| **1** | Technician operating grinding wheel without safety goggles | **Unsafe Act** | Eye injury from flying high-speed sparks/chips | Enforce mandatory eye protection & issue safety warning |
| **2** | Machine drive belt exposed without protective metal guard | **Unsafe Condition** | Entanglement, pinch point crushing injury | Install fixed interlocking machine guard (Engineering Control) |
| **3** | Hydraulic oil spill on the main walkway floor | **Unsafe Condition** | Slip, trip, and fall hazards | Absorb oil with sawdust/degreaser; fix hydraulic line leak |

| | | | | |
|---|---|---|---|---|
| **4** | Worker standing on the top rung of an A-frame stepladder | **Unsafe Act** | Fall from height leading to severe trauma | Conduct height safety retraining; provide correct platform ladder |
| **5** | Blocked fire extinguisher and emergency exit door | **Unsafe Condition** | Delayed evacuation during a fire emergency | Clear obstructions immediately; paint yellow floor hatch markings |
| **6** | Using a screwdriver as a chisel with a hammer | **Unsafe Act** | Tool slippage causing hand puncture wounds | Supply correct tools; enforce tool inspection SOPs |

6. **PROCEDURE / AUDIT STEPS**

1. **Initial Walk-Through:** Conduct a systematic safety walk-through inspection across the designated shop floor or laboratory zone.
2. **Identification & Recording:** Note down all observed physical hazards (Unsafe Conditions) and unsafe worker behaviors (Unsafe Acts) on the observation log sheet.
3. **Classification:** Categorize each entry accurately as either an **Unsafe Act** or an **Unsafe Condition**.
4. **Risk Evaluation:** Determine the potential severity and likelihood of injury for each identified item.
5. **Formulate Controls:** Assign immediate administrative corrections or long-term engineering modifications based on the Hierarchy of Controls.

7. **RESULTS & INFERENCE**

1. Successfully conducted a workplace safety audit and identified **3 Unsafe Acts** and **3 Unsafe Conditions** on the shop floor.
2. Understood that **Unsafe Acts account for nearly $88\%$ of industrial accidents**, highlighting the importance of **Behavior-Based Safety (BBS)** training.
3. Reaffirmed that correcting Unsafe Conditions through engineering controls (such as machine guarding and proper housekeeping) significantly reduces human error hazards.

**EXPERIMENT NO. 4**
**TITLE: Developing the Flowchart for Reporting of Accidents According to Severity**

## 1. AIM

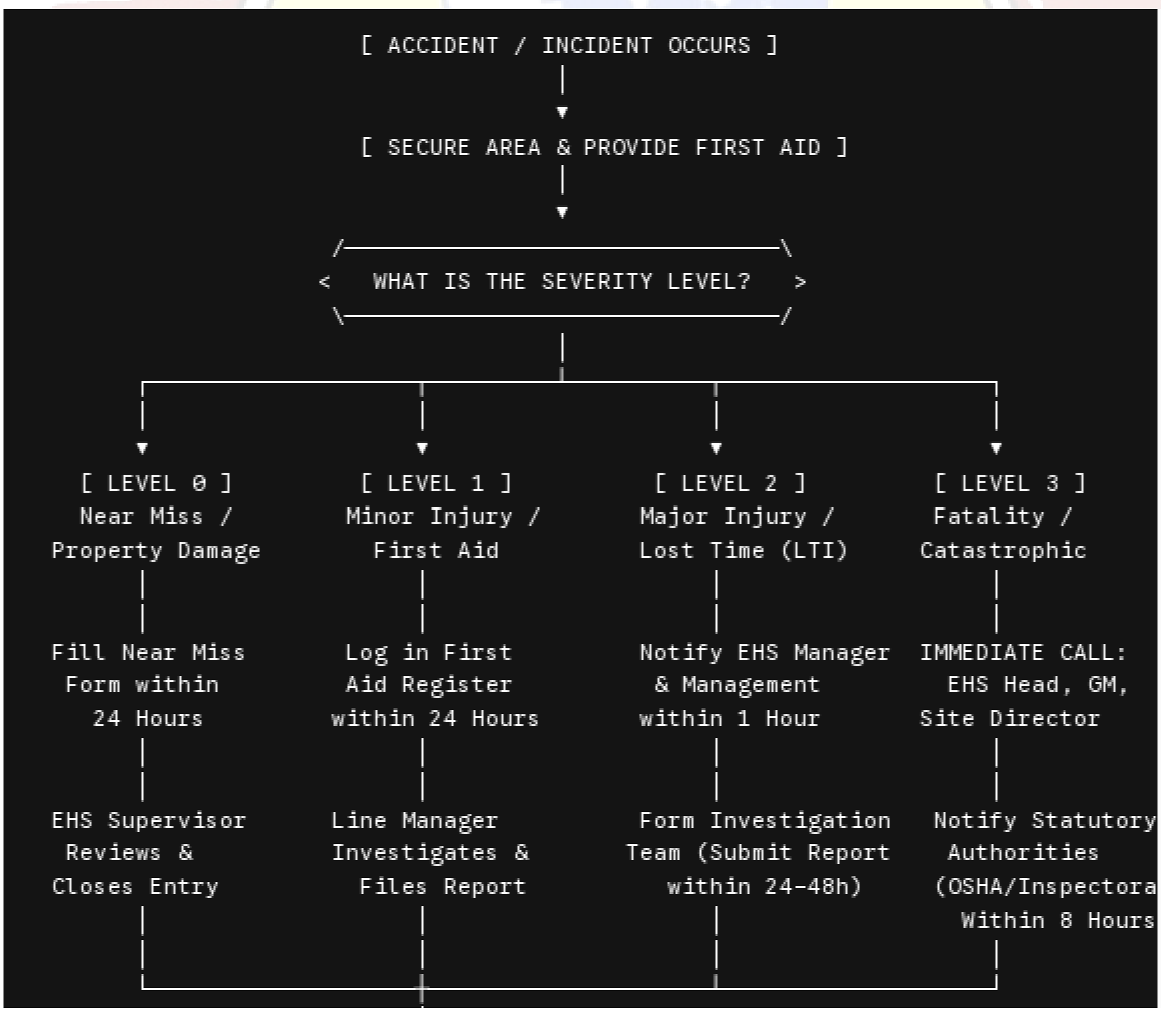
To design and evaluate a systematic reporting flowchart for workplace incidents, categorizing accidents by severity levels (Near Miss, Minor/First Aid, Major/Lost Time, and Fatality/Catastrophic) to ensure timely emergency response, statutory compliance, and root-cause investigation.

## 2. APPARATUS / TOOLS REQUIRED

- Flowchart Template / Graphic Software
- Drawing Sheet (A3/A4) & Drawing Instruments
- OSHA / Factories Act Severity Classification Guidelines

3. LINE SKETCHES FOR RECORD DRAWING (UNRULED PAGE)

Copy this complete **Accident Reporting Flowchart** onto the blank (unruled) side of your record notebook using pencil, ruler, and markers.



```
                    ▼
   [ ROOT CAUSE ANALYSIS (5-WHY / FTA) ]
                    |
                    ▼
   [ IMPLEMENT CAPA & LESSONS LEARNED ]
```

4. **THEORY & SEVERITY CLASSIFICATION LEVELS**

Accidents are categorized according to the severity of harm to personnel and operational impact:

- **Level 0 (Near Miss / Dangerous Occurrence):** An unplanned event that did not result in injury or damage, but had the potential to do so under different circumstances.
- **Level 1 (Minor / First Aid Case):** Minor injuries (e.g., small cuts, light burns, minor bruises) treated on-site using standard first-aid supplies. No lost work days beyond the shift.
- **Level 2 (Major / Lost Time Injury - LTI):** Severe injuries (e.g., fractures, deep lacerations, amputations) requiring external medical care and resulting in **days away from work ($>48\text{ hours}$)** or restricted work duty.
- **Level 3 (Fatality / Critical Event):** Work-related fatality, permanent total disability, or major structural collapse/explosion requiring immediate site shutdown and statutory notifications.

5. **STATUTORY REPORTING TIMELINES**

| **Severity Level** | **Internal Notification Window** | **External / Statutory Notification Window** | **Investigation Completion Target** |
|---|---|---|---|
| **Level 0 (Near Miss)** | Within 24 Hours | Not Applicable (Internal tracking only) | Within 3 Days |
| **Level 1 (First Aid)** | Within 24 Hours | Internal log entry | Within 2 Days |
| **Level 2 (Major / LTI)** | **Within 1 Hour** | Within **24 to 48 Hours** to Factory Inspectorate / OSHA | Within 5 Days |

| | | | |
|---|---|---|---|
| **Level 3 (Fatality)** | **IMMEDIATE (Within 15 mins)** | **Within 8 Hours** to Police, Factory Inspectorate, Pollution Board | Full formal inquiry within 7 Days |

6. **PROCEDURE / STEPS TO FOLLOW**

1. **Immediate Response:** Ensure scene safety and provide immediate first aid or emergency transport to the medical center.
2. **Initial Severity Assessment:** The line supervisor assesses the severity of the incident (Level 0 to Level 3).
3. **Internal Escalation:** Route notifications up the management hierarchy based on the required timeframe (e.g., Level 2/3 requires immediate phone call to EHS Head and Site Director).
4. **Statutory Reporting:** If required (Level 2 or 3), draft statutory Form 18 (under Factories Act) or OSHA Injury Report and send it within the legal window.
5. **Investigation & CAPA:** Assemble an investigation committee to perform Root Cause Analysis (5-Whys) and assign **Corrective and Preventive Actions (CAPA)** with fixed target completion dates.

7. **RESULTS & INFERENCE**

1. Successfully developed an accident reporting flowchart organized by severity levels (Level 0 through Level 3).
2. Understood that **Level 3 incidents require immediate statutory reporting within 8 hours**, whereas Level 2 cases require notification within 24 to 48 hours.
3. Recognized that systematic reporting of **Level 0 (Near Misses)** provides leading indicators that prevent catastrophic (Level 3) occurrences down the line.

**EXPERIMENT NO. 5**

**TITLE: Analysis of Data on Industrial Accidents & Safety Performance Metrics**

## 1. AIM

To collect, analyze, and evaluate workplace safety performance data by calculating standard accident statistics—including **Frequency Rate (FR)**, **Severity Rate (SR)**, **Incidence Rate (IR)**, and **Frequency-Severity Indicator (FSI)**—and to represent accident trends graphically for proactive risk management.

## 2. APPARATUS / TOOLS REQUIRED

- Monthly/Annual Workplace Safety Logbooks & Incident Reports
- Scientific Calculator / Data Spreadsheet Software
- Graph Paper / Drawing Instruments for Record Charting

3. LINE SKETCHES & DATA CHARTS FOR RECORD DRAWING (UNRULED PAGE)

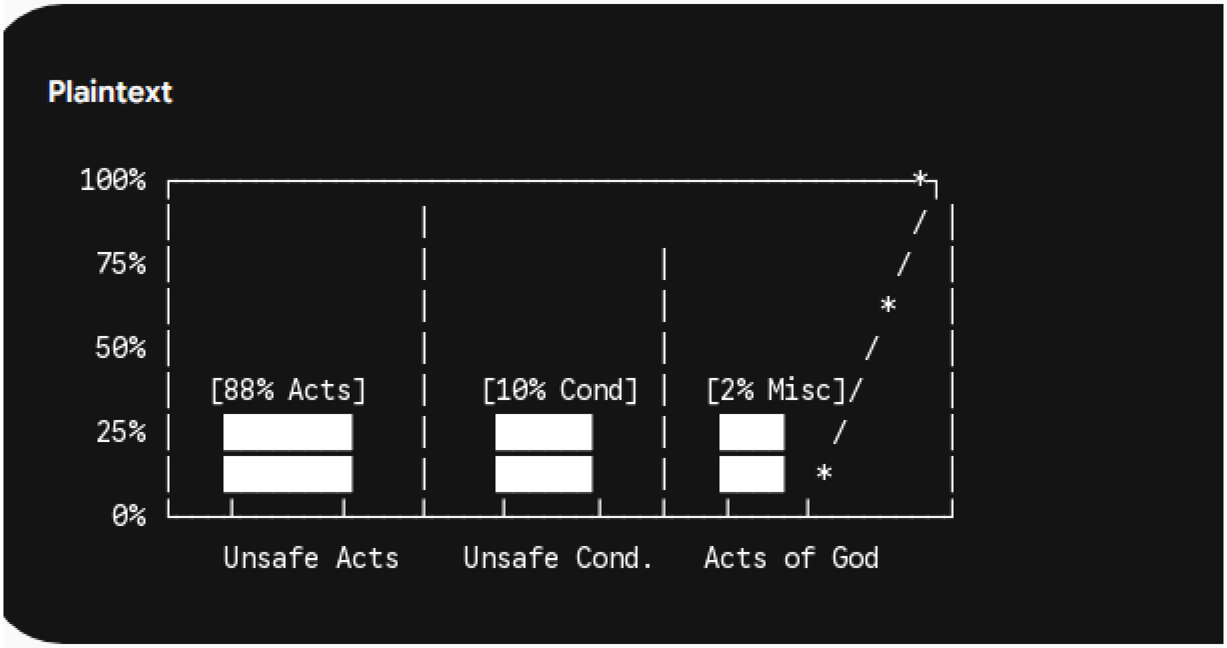
Copy these two safety metric visualization charts onto the blank (unruled) side of your record notebook using pencil and ruler.

### Sketch 1: Monthly Trend Chart (Frequency Rate vs. Severity Rate)

Plaintext

```
(FR)                                                      (SR)
25 ┌─────────────────────────────────────────────────────┐ 500
   │                                                     │
20 │   * [FR Line]                                       │ 400
   │    \                                                │
15 │     \         *                                     │ 300
   │      \       / \          o [SR Line]               │
10 │       *-----*   \        / \                        │ 200
   │                  *-----o    \                       │
 5 │                              \                      │ 100
   │                               o--------------------o│
 0 └─┬───────┬───────┬───────┬───────┬───────┬───────┬───┘ 0
    Jan     Feb     Mar     Apr     May     Jun     Jul
```

### Sketch 2: Accident Distribution by Root Cause (Pareto Chart Concept)




**4. THEORY & MATHEMATICAL FORMULAE**

Safety metrics quantify workplace risk exposure. Standard formulas used in safety engineering calculations are:

1. **Frequency Rate (FR)**

Measures the number of recordable disabling injuries per 1,000,000 man-hours worked.

$$\text{Frequency Rate (FR)} = \left(\frac{\text{Number of Disabling Injuries}}{\text{Total Man-Hours Worked}}\right) \times 1,000,000$$

2. **Severity Rate (SR)**

Measures the total number of workdays lost due to injuries per 1,000,000 man-hours worked.

$$\text{Severity Rate (SR)} = \left(\frac{\text{Total Days Lost Due to Injuries}}{\text{Total Man-Hours Worked}}\right) \times 1,000,000$$

3. **Incidence Rate (IR)**

Measures the number of injuries per 1,000 full-time workers.

$$\text{Incidence Rate (IR)} = \left(\frac{\text{Number of Disabling Injuries}}{\text{Total Number of Workers}}\right) \times 1,000$$

**4. Frequency-Severity Indicator (FSI)**
Combines both frequency and severity into a single benchmark indicator to rate safety performance.

$$\text{FSI} = \sqrt{\frac{\text{FR} \times \text{SR}}{1,000}}$$

# 5. SAMPLE DATA SET & CALCULATIONS

## Given Industrial Plant Data (Annual Audit)

- **Total Number of Workers:** $500$ workers
- **Working Hours per Worker per Year:** $2,000$ hours ($8 \text{ hrs/day} \times 250 \text{ days}$)
- **Total Man-Hours Worked ($H$):** $500 \times 2,000 = 1,000,000 \text{ hours}$
- **Number of Disabling Injuries ($N$):** $5 \text{ injuries}$
- **Total Days Lost ($D$):** $120 \text{ days}$

### Step-by-Step Calculation

1. **Calculate Frequency Rate (FR):**

$$\text{FR} = \left(\frac{5}{1,000,000}\right) \times 1,000,000 = \mathbf{5.00} \text{ injuries per million man-hours}$$

2. **Calculate Severity Rate (SR):**

$$\text{SR} = \left(\frac{120}{1,000,000}\right) \times 1,000,000 = \mathbf{120.00} \text{ days lost per million man-hours}$$

3. **Calculate Incidence Rate (IR):**

$$\text{IR} = \left(\frac{5}{500}\right) \times 1,000 = \mathbf{10.00} \text{ injuries per 1,000 workers}$$

4. **Calculate Frequency-Severity Indicator (FSI):**

$$\text{FSI} = \sqrt{\frac{5 \times 120}{1,000}} = \sqrt{\frac{600}{1,000}} = \sqrt{0.6} \approx \mathbf{0.77}$$

## 6. OBSERVATION & METRIC SUMMARY TABLE

| Parameter Metric | Calculated Value | Benchmark / Target Level | Safety Status / Evaluation |
|---|---|---|---|
| **Total Man-Hours Worked** | $1,000,000$ hours | N/A | Base Exposure Horizon |
| **Disabling Injuries Count** | $5$ | $0$ (Zero Harm Target) | Needs Behavioral Controls |
| **Total Workdays Lost** | $120$ days | $< 50$ days | High Severity per Injury |
| **Frequency Rate (FR)** | $5.00$ | $< 2.00$ | **Above Target** |
| **Severity Rate (SR)** | $120.00$ | $< 50.00$ | **High Impact** |
| **Incidence Rate (IR)** | $10.00$ | $< 5.00$ | Needs Intervention |
| **FSI Index** | $0.77$ | $< 0.50$ (Good) | **Moderate-High Risk** |

7. **RESULTS & INFERENCE**

1. Analyzed plant safety performance data and calculated key safety metrics: **{FR} = 5.00 ,{SR} = 120.0**and **{FSI} = 0.77**
2. An **FSI of 0.77** (> 0.50) indicates that while the total number of incidents is relatively low, the severity of each injury (days lost) is significant.
3. Recommended prioritizing high-severity risk areas—such as fall protection and machinery isolation (LOTO)—to reduce lost workday cases and lower the Severity Rate.

**EXPERIMENT NO. 6**
**TITLE Determination of Accident Rate and Severity Rate of an Accident**

## 1. AIM

To determine the **Accident Rate (Incidence Rate)**, **Frequency Rate**, and **Severity Rate** for an industrial facility over a specified operating period, and to evaluate workplace safety performance against statutory standard benchmarks.

## 2. APPARATUS / TOOLS REQUIRED

- Annual Workplace Incident Log & Attendance Register
- Scientific Calculator / Data Analysis Sheet
- Graph Paper / Drawing Instruments for Record Charting

3. LINE SKETCHES & DATA CHARTS FOR RECORD DRAWING (UNRULED PAGE)

Copy these two visual representation charts onto the blank (unruled) side of your record notebook using pencil and ruler.

**Sketch 1: Injury Severity Pyramid (Heinrich / Bird Concept)**

```
Plaintext

                /\
               /  \
              / 1  \   <--- FATALITY / MAJOR INJURY
             /------\
            /   10   \  <--- MINOR / FIRST AID INJURIES
           /----------\
          /     30     \ <--- PROPERTY DAMAGE INCIDENTS
         /--------------\
        /      600       \ <--- NEAR MISSES / DANGEROUS OCCURRENCES
       /------------------\
```

**Sketch 2: Monthly Severity Rate vs. Target Trend**

```
(SR)
300 ┌───────────────────────────────────────────┐
    |                                           |
250 |  * [Actual SR]                            |
    |   \                                       |
200 |    \                                      |
    |     *---------*                           |
150 |                \                          |
    |                 *---------*               |
100 |                            \              |
    |                             *-------------------*  |
 50 ├ - - - - - - - - - - - - - - - - - - - - - ┤ <--- Target Limit
  0
      Jan    Feb    Mar    Apr    May    Jun    Jul
```

# 4. THEORY & MATHEMATICAL FORMULAE

Accident statistics quantify the safety performance of an enterprise. They allow safety engineers to compare performance across different plants and time periods regardless of plant size.

### 1. Total Man-Hours Worked ($H$)

The total cumulative exposure hours of all employees:

$$H = N_w \times d \times h$$

*Where $N_w$ = Total number of workers, $d$ = Working days per year, $h$ = Daily working hours per worker.*

### 2. Accident Rate / Injury Incidence Rate (IR)

Measures the number of recordable accidents per $1,000$ workers over a period:

$$\text{Accident Rate (IR)} = \left( \frac{\text{Total Number of Accidents / Injuries}}{\text{Total Number of Workers } (N\_w)} \right) \times 1,000$$

### 3. Accident Frequency Rate (FR)

Measures the frequency of disabling injuries per $1,000,000$ man-hours worked:

$$\text{Frequency Rate (FR)} = \left( \frac{\text{Number of Disabling Injuries}}{\text{Total Man-Hours Worked } (H)} \right) \times 1,000,000$$

### 4. Accident Severity Rate (SR)

Measures the severity of accidents by calculating the number of lost workdays per $1,000,000$ man-hours worked:

$$\text{Severity Rate (SR)} = \left( \frac{\text{Total Workdays Lost Due to Accidents}}{\text{Total Man-Hours Worked } (H)} \right) \times 1,000,000$$

## 5. EXPERIMENTAL DATA & STEP-BY-STEP CALCULATIONS

### Given Facility Data (Annual Operating Period)

- **Total Employees ($N_w$):** $800$ workers
- **Working Days in Year ($d$):** $300$ days
- **Shift Duration ($h$):** $8 \text{ hours/day}$
- **Overtime / Extra Exposure Hours:** $80,000 \text{ hours}$
- **Number of Disabling Accidents ($A$):** $8 \text{ incidents}$
- **Total Days Lost / Absenteeism ($D$):** $240 \text{ days}$

### Step-by-Step Calculation

1. **Calculate Total Man-Hours Worked ($H$):**

$$H = (800 \times 300 \times 8) + 80,000 = 1,920,000 + 80,000 = \mathbf{2,000,000} \text{ hours}$$

2. **Calculate Accident Rate / Incidence Rate (IR):**

$$\text{IR} = \left(\frac{8}{800}\right) \times 1,000 = \mathbf{10.00} \text{ accidents per 1,000 workers}$$

3. **Calculate Frequency Rate (FR):**

$$\text{FR} = \left(\frac{8}{2,000,000}\right) \times 1,000,000 = \mathbf{4.00} \text{ injuries per million man-hours}$$

4. **Calculate Severity Rate (SR):**

$$\text{SR} = \left(\frac{240}{2,000,000}\right) \times 1,000,000 = \mathbf{120.00} \text{ days lost per million man-hours}$$

5. **Average Severity per Accident:**

$$\text{Average Days Lost per Injury} = \frac{\text{Total Days Lost}}{\text{Total Accidents}} = \frac{240}{8} = \mathbf{30.0} \text{ days/accident}$$

## 6. OBSERVATION & METRIC SUMMARY TABLE

| Parameter Metric | Measured / Calculated Value | Standard Threshold | Performance Assessment |
|---|---|---|---|
| Total Exposure Hours ($H$) | $2,000,000$ hours | N/A | Base Exposure Horizon |
| Accident Count ($A$) | 8 cases | 0 | Needs Behavioral Controls |
| Days Lost Count ($D$) | 240 days | $< 100$ days | High Production Time Loss |
| Accident Rate (IR) | 10.00 | $< 5.00$ | **Exceeds Baseline** |
| Frequency Rate (FR) | 4.00 | $< 2.00$ | **Needs Improvement** |
| Severity Rate (SR) | 120.00 | $< 50.00$ | **High Impact Severity** |
| Mean Lost Time per Case | 30.0 days | $< 10$ days | Major Traumatic Injuries |

**7. RESULTS & INFERENCE**

1. The Accident Rate (IR) was determined as **10.00 per 1,000 workers**, the Frequency Rate (FR) as **4.00**, and the Severity Rate (SR) as **120.00 per 1,000,000 man-hours**.
2. An average lost time of **30days per accident** indicates that the facility experienced high-severity injuries (such as fractures or deep lacerations) requiring prolonged recovery.
3. Recommended implementing mandatory machine guarding, job safety analysis (JSA) prior to maintenance tasks, and behavior-based safety audits to lower both frequency and severity metrics.

IN LABORE HONOR CHENNAI

**EXPERIMENT NO. 7**

**TITLE: Determination of Cost and Man-hour Losses in an Industrial Accident**

## 1. AIM

To calculate and evaluate the total financial cost (direct and indirect costs) and total human resource losses (direct and indirect man-hours lost) resulting from an industrial accident, using Heinrich's Iceberg Cost Model.

## 2. APPARATUS / TOOLS REQUIRED

- Accident Cost Estimation Worksheet / Incident Report Data
- Time & Attendance Records / Payroll Hourly Rate Data
- Scientific Calculator / Data Spreadsheet

3. LINE SKETCHES & DATA CHARTS FOR RECORD DRAWING (UNRULED PAGE)

Copy these two cost breakdown diagrams onto the blank (unruled) side of your record notebook using pencil and ruler.

**Sketch 1: Heinrich's Iceberg Cost Model (Direct vs. Indirect Costs)**

```
                        / \
                       /   \   <--- DIRECT COSTS (Visible: 1 Unit)
                      / 1x  \       (Medical Bills, Worker's Compensation)
~~~~~~~~~~~~~~~~~~~~~/~~~~~~~\~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
                    /         \  <--- SEA LEVEL
                   /           \
                  /  4x to 10x  \ <--- INDIRECT / HIDDEN COSTS (Invisible)
                 /               \     (Production delays, Equipment damage,
                /_________________\     Training replacements, Legal fees)
```

**Sketch 2: Total Man-Hour Loss Components**

| TOTAL MAN-HOUR LOSSES | |
|---|---|
| DIRECT MAN-HOURS LOST | INDIRECT MAN-HOURS LOST |
| • Injured Worker Recovery Time<br>• Hospitalization & Sick Leave | • Co-workers Stopping Work<br>• First Aiders & Rescue Response<br>• Supervisors Investigating<br>• Repair & Equipment Cleanup Time |

# 4. THEORY & MATHEMATICAL FORMULAE

An accident leads to two distinct types of losses: **Man-Hour Losses** and **Financial Cost Losses**.

## 1. Total Man-Hour Loss ($H_{\text{total}}$)

$$H_{\text{total}} = H_{\text{direct}} + H_{\text{indirect}}$$

- **Direct Man-Hours Lost ($H_{\text{direct}}$):** Hours lost directly by the injured worker due to absence from work.

$$H_{\text{direct}} = D_{\text{lost}} \times h_{\text{shift}}$$

*(Where $D_{\text{lost}}$ = Lost workdays, $h_{\text{shift}}$ = Daily shift hours).*

- **Indirect Man-Hours Lost ($H_{\text{indirect}}$):** Time lost by other personnel due to the incident:

$$H_{\text{indirect}} = H_{\text{witness}} + H_{\text{first\_aid}} + H_{\text{investigation}} + H_{\text{repair}}$$

### 2. Total Financial Cost ($C_{\text{total}}$)

$$C_{\text{total}} = C_{\text{direct}} + C_{\text{indirect}}$$

- **Direct Costs ($C_{\text{direct}}$):** Measurable out-of-pocket expenses directly paid due to the injury:

$$C_{\text{direct}} = C_{\text{medical}} + C_{\text{compensation}} + C_{\text{insurance\_claim}}$$

- **Indirect Costs ($C_{\text{indirect}}$):** Hidden expenses associated with downtime, repairs, and administrative tasks:

$$C_{\text{indirect}} = C_{\text{wages\_lost\_time}} + C_{\text{damage}} + C_{\text{overtime}} + C_{\text{training\_replacement}}$$

- **Heinrich's Iceberg Ratio Rule:**

$$\text{Indirect Cost } (C_{\text{indirect}}) \approx 4 \times \text{Direct Cost } (C_{\text{direct}})$$

## 5. EXPERIMENTAL DATA & STEP-BY-STEP CALCULATIONS

### Given Accident Incident Data (Workshop Machine Shop)

- **Average Hourly Wage Rate ($R$):** $\$20/\text{hour}$
- **Injured Worker Lost Time ($D_{\text{lost}}$):** $15$ working days $(8 \text{ hrs/day})$
- **Medical Expenses ($C_{\text{medical}}$):** $\$1,200$
- **Workers' Compensation Paid ($C_{\text{compensation}}$):** $\$1,800$
- **Co-Workers Work Stoppage (5 workers for 2 hours):** $5 \times 2 = 10$ hours
- **Supervisor Investigation & Reporting:** $12$ hours
- **Maintenance Repair & Cleanup Time:** $18$ hours
- **Property / Machine Repair Expenses ($C_{\text{damage}}$):** $\$2,500$
- **Overtime Wages to Cover Production Backlog:** $\$1,500$

## Step-by-Step Calculations

### A. Man-Hour Loss Calculations

1. **Direct Man-Hours Lost ($H_{\text{direct}}$):**

$$H_{\text{direct}} = 15 \text{ days} \times 8 \text{ hours/day} = \mathbf{120} \text{ man-hours}$$

2. **Indirect Man-Hours Lost ($H_{\text{indirect}}$):**

$$H_{\text{indirect}} = 10 \text{ (stoppage)} + 12 \text{ (investigation)} + 18 \text{ (repair)} = \mathbf{40} \text{ man-hours}$$

3. **Total Man-Hours Lost ($H_{\text{total}}$):**

$$H_{\text{total}} = 120 + 40 = \mathbf{160} \text{ man-hours}$$

### B. Financial Cost Calculations

1. **Direct Costs ($C_{\text{direct}}$):**

$$C_{\text{direct}} = C_{\text{medical}} + C_{\text{compensation}} = \$1,200 + \$1,800 = \mathbf{\$3,000}$$

2. **Indirect Costs ($C_{\text{indirect}}$):**

$$\text{Wages for Lost Indirect Time} = 40 \text{ hrs} \times \$20/\text{hr} = \$800$$

$$C_{\text{indirect}} = \$800 \text{ (wages)} + \$2,500 \text{ (repairs)} + \$1,500 \text{ (overtime)} = \mathbf{\$4,800}$$

3. **Total Cost of Accident ($C_{\text{total}}$):**

$$C_{\text{total}} = C_{\text{direct}} + C_{\text{indirect}} = \$3,000 + \$4,800 = \mathbf{\$7,800}$$

4. **Indirect-to-Direct Cost Ratio:**

$$\text{Ratio} = \frac{C_{\text{indirect}}}{C_{\text{direct}}} = \frac{\$4,800}{\$3,000} = \mathbf{1.6 : 1}$$

## 6. OBSERVATION & COST SUMMARY TABLE

| Parameter Loss Head | Direct Component | Indirect Component | Total Calculated Value |
|---|---|---|---|
| **Man-Hour Losses** | 120 hours (Injured) | 40 hours (Team / Repair) | 160 man-hours |
| **Financial Cost** | $3,000 (Medical/Comp) | $4,800 (Repairs/Wages) | $7,800 |
| **Cost Distribution Ratio** | 38.5% | 61.5% | 100% **(1.6 : 1 Ratio)** |

7. **RESULTS & INFERENCE**

1. The accident resulted in a **Total Man-Hour Loss of 160 hours** and a **Total Financial Loss of $7,800**.
2. Indirect costs ($4,800) exceeded direct costs ($3,000), demonstrating Heinrich's principle that the hidden costs of accidents represent the largest portion of financial loss.
3. Proved that investment in proactive safety controls (such as machine guarding and training) provides significant cost savings by eliminating hidden productivity and downtime losses.

**EXPERIMENT NO. 8**

**TITLE: Performing Evidence-Based Accident Investigation for a Mock Accident**

## 1. AIM

To conduct a systematic, evidence-based accident investigation for a simulated mock industrial accident using the **PEEPO (People, Equipment, Environment, Procedures, Organization)** framework, physical evidence preservation, 5-Why Analysis, and Root Cause Analysis (RCA).

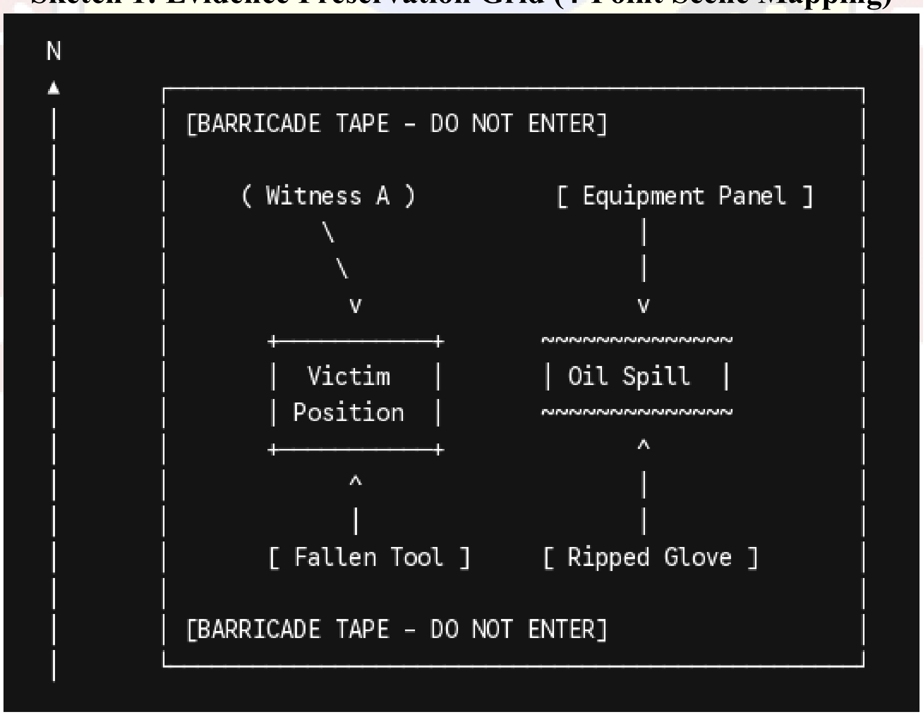
## 2. APPARATUS / TOOLS REQUIRED

- Evidence Collection Kit (Measuring Tape, Camera/Tablet, Evidence Tags, Sample Bags)
- Incident Investigation Form & Witness Interview Sheets
- Barricade Tape / Warning Flags (for scene preservation)
- Mock Accident Scenario Setup (Chemical Spill / Machine Entanglement Simulation)

3. LINE SKETCHES & DIAGRAMS FOR RECORD DRAWING (UNRULED PAGE)

Copy these two investigation diagrams onto the blank (unruled) side of your record notebook using pencil and ruler.

**Sketch 1: Evidence Preservation Grid (4-Point Scene Mapping)**



**Sketch 2: PEEPO Evidence Classification Model**

```
          / \
         /   \
        /  P  \  <--- PEOPLE (Statements, Competency)
       /-------\
      /    E    \ <--- EQUIPMENT (Machine condition, Guards)
     /-----------\
    /      E      \ <--- ENVIRONMENT (Lighting, Noise, Spills)
   /---------------\
  /        P        \ <--- PROCEDURES (SOPs, Work Permits)
 /-------------------\
/          O          \ <--- ORGANIZATION (Training, Safety Culture)
/-----------------------\
```

## 4. MOCK ACCIDENT SCENARIO DESCRIPTION

- **Location:** Mechanical Maintenance Workshop (Machine Shop B).
- **Time:** 10:30 AM.
- **Event:** An operator sustained a severe hand laceration and fracture while polishing a shaft on a high-speed manual lathe machine using an emery tape strip held by hand.
- **Initial Observation:** Emergency stop was pressed, a torn cut-resistant glove was found near the chuck, and an oil slick was present around the lathe base.

## 5. EVIDENCE-BASED INVESTIGATION METHODOLOGY (PEEPO)

Evidence was gathered across five critical dimensions:

| Category | Evidence Gathered | Method of Collection |
|---|---|---|
| **P - People** | Operator was wearing loose cotton gloves (against SOP); Witness statement confirms operator was rushed to meet shift targets. | Witness interviews, training records audit |

| | | |
|---|---|---|
| **E - Equipment** | Lathe emergency brake worked; Chuck guard was swung open and bypassed; Emery tape was hand-wrapped around spinning workpiece. | Physical inspection, photographic evidence |
| **E - Environment** | Floor had a minor oil leak (200{ mL); Lighting was 350 Lux} (adequate). | Lux meter measurement, scene mapping |
| **P - Procedures** | SOP explicitly prohibits wearing gloves while operating rotating lathes and prohibits manual hand-polishing with emery tape. | SOP Document Review (SOP-MECH-014) |
| **O - Organization** | No regular supervisor checks observed during the morning shift; Job Safety Analysis (JSA) was not briefed during pre-shift talk. | Audit of Toolbox Talk (TBT) logs |

**6. ROOT CAUSE ANALYSIS (5-WHY METHOD)**

Problem Statement: Operator's hand was drawn into the spinning lathe chuck, causing severe injury.

Why 1? Why was the operator's hand pulled into the machine?
└─> Because the operator's glove caught on the spinning workpiece/chuck.

Why 2? Why was the operator wearing gloves near rotating machinery?
└─> Because the operator felt uncomfortable handling raw metal parts without grip protection and was unaware of the snag risk.

Why 3? Why was the operator unaware of the snag risk of wearing gloves on lathes?
└─> Because the operator did not receive machine-specific hazard training during onboarding.

Why 4? Why was the safety SOP bypassed during hand-polishing?
└─> Because using hand-held emery tape was the informal standard practice accepted on the shop floor to speed up finishing.

Why 5? (Root Cause):

└─> Absence of mandatory machine safety induction training and failure of supervisory oversight to enforce safe operating procedures (SOPs).

7. **RECOMMENDED CORRECTIVE & PREVENTIVE ACTIONS (CAPA)**

| Action Type | Recommended Action | Responsible Party | Target Completion |
|---|---|---|---|
| Immediate (Corrective) | Isolate the lathe machine; provide medical aid; clean oil spill. | Workshop Supervisor | Immediate |
| Engineering Control | Install an interlocking chuck guard that prevents lathe startup when open; provide mechanical emery tape holding tools. | Maintenance Manager | 7 Days |
| Administrative Control | Conduct mandatory retraining on rotating machinery hazards; update SOP-MECH-014; enforce "NO GLOVES on Lathes" rule. | Safety Officer | 3 Days |
| Organizational Control | Implement daily supervisory walk-through audits and pre-shift Toolbox Talks (TBT) logs. | Plant Manager | 14 Days |

8. **RESULTS & INFERENCE**

1. Conducted an evidence-based accident investigation for a mock lathe machinery incident using the PEEPO evidence collection model.
2. Derived the root cause using 5-Why Analysis, revealing that the incident resulted from a lack of machine-specific safety training and inadequate supervisory enforcement.
3. Proved that focusing on evidence gathering rather than assigning personal blame leads to systemic safety improvements through the Hierarchy of Controls.

**EXPERIMENT NO. 9**

**TITLE: Performing Incident Recall Technique (IRT) for Near-Miss and Unreported Events**

## 1. AIM

To conduct an **Incident Recall Technique (IRT)** interview session to uncover near-miss events, unsafe practices, and unreported dangerous occurrences in the workplace, and to develop proactive corrective controls before loss-producing accidents occur.

## 2. APPARATUS / TOOLS REQUIRED

- Confidential Incident Recall Questionnaire / Interview Form
- Audio Recorder / Interview Logbook
- Safe & Neutral Interview Room (Psychologically Safe Setting)
- Risk Assessment Matrix (for evaluating recalled near-misses)

3. LINE SKETCHES & DIAGRAMS FOR RECORD DRAWING (UNRULED PAGE)

Copy these two Incident Recall diagrams onto the blank (unruled) side of your record notebook using pencil and ruler.

**Sketch 1: Incident Recall Process Flowchart**

```
[ SELECT EXPERIENCED OPERATORS / WORKERS ]
                      |
                      ▼
[ ESTABLISH NO-BLAME / CONFIDENTIAL ENVIRONMENT ]
                      |
                      ▼
[ CONDUCT STRUCTURED INTERVIEW (IRT PROMPTS) ]
                      |
                      ▼
[ UNCOVER UNREPORTED NEAR-MISSES & HAZARDS ]
                      |
                      ▼
[ EVALUATE RISK SEVERITY & FREQUENCY (MATRIX) ]
                      |
                      ▼
[ IMPLEMENT PROACTIVE CAPA BEFORE ACCIDENTS OCCUR ]
```

**Sketch 2: Safety Information Pyramid (Hidden Near-Miss Base)**

```
                /\
               /  \
              / 1  \   <--- REPORTED MAJOR ACCIDENT (Visible)
             /------\
            /   10   \  <--- REPORTED MINOR INJURIES
           /----------\
          /     30     \ <--- PROPERTY DAMAGE INCIDENTS
         /--------------\
        /      600       \ <--- UNREPORTED NEAR-MISSES & HAZARDS
       /------------------\     (Uncovered via Incident Recall)
```

## 4. THEORY & INCIDENT RECALL TECHNIQUE (IRT) METHODOLOGY

The **Incident Recall Technique (IRT)** is a proactive safety investigation tool developed by William G. Johnson. It uses structured, confidential interviews with experienced workers to recall "near-misses," "near-accidents," and operational errors that **did not result in injury or damage**, but had the potential to do so.

Key Principles of IRT

1. **No-Blame Policy:** Interviews focus on process and systemic flaws rather than personal fault.
2. **Confidentiality:** Worker identity is protected to encourage full disclosure.
3. **Structured Questioning:** Prompts encourage workers to remember situations where they felt unsafe, hesitated, or "got lucky."
4. **Proactive Hazard Elimination:** Fixes hazards at the bottom of the Safety Pyramid before they turn into lost-time injuries.

## 5. INCIDENT RECALL INTERVIEW QUESTIONNAIRE & CASE STUDY

A. Sample Interview Prompts Used

- "Can you recall a time in the last 6 months when a tool, machine, or component almost fell or slipped?"
- "Have you ever felt forced to bypass a safety step to complete a job on time?"
- "Has a machine ever started unexpectedly or behaved strangely during maintenance?"

B. Recalled Near-Miss Case Study

- **Work Area:** Chemical Processing Unit (Pump Station 3).
- **Recalled Event:** A maintenance technician recalled that while changing a pressure gauge on a live hot water pump line (80C}), a brief spurt of hot water escaped because the isolation valve did not seal completely. The technician jumped back in time and was wearing safety glasses, avoiding thermal burns.
- **Why it went unreported:** The technician was not injured and considered it a "routine operational annoyance."

## 6. RISK ASSESSMENT & CORRECTIVE CONTROL (CAPA)

Evaluating the recalled near-miss using the Risk Assessment Matrix:

| **Hazard Category** | **Assessment Details** |
|---|---|
| **Recalled Hazard** | Passing/Passing-through thermal isolation valve during live gauge replacement. |
| **Potential Severity** | **High** (Severe thermal steam burns / eye injury). |
| **Occurrence Probability** | **Medium** (Performs gauge maintenance monthly). |
| **Initial Risk Level** | **HIGH RISK** Requires Immediate Action. |

**Recommended Action Plan**

1. **Immediate Action:** Tag out isolation valve V-204 for mechanical seat overhaul and seal replacement.
2. **Engineering Control:** Install double block and bleed (DBB) valve arrangements for liquid line maintenance points.
3. **Administrative Control:** Re-brief team that valve passing/leakage **must be logged as a Near-Miss** immediately; issue zero-energy verification protocols.

## 7. RESULTS & INFERENCE

1. Successfully conducted an **Incident Recall Technique (IRT)** session and uncovered a high-risk, unreported near-miss involving thermal isolation valves.
2. Proved that near-misses represent valuable **leading safety indicators** that prevent major loss-producing accidents.
3. Recognized that establishing a confidential, non-punitive reporting culture is essential for effective proactive safety management.

**EXPERIMENT NO. 10**
**TITLE: Performing 5-Why Analysis for a Work / Task Incident**

## 1. AIM

To perform a structured **5-Why Root Cause Analysis (RCA)** for a workplace incident during a specific operational task, systematically tracing problem symptoms back to underlying organisational and physical root causes to prevent recurrence.

## 2. APPARATUS / TOOLS REQUIRED

- Incident Fact-Finding Worksheet / Task Observation Log
- Fishbone (Ishikawa) Diagram Template
- Scientific Calculator / Scientific Writing Material

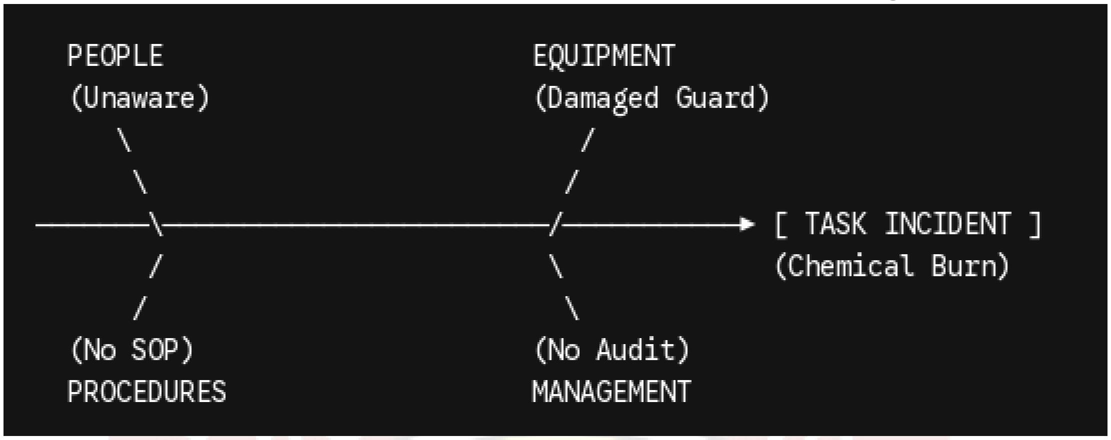
## 3. LINE SKETCHES & DIAGRAMS FOR RECORD DRAWING (UNRULED PAGE)

Copy these two root cause analysis diagrams onto the blank (unruled) side of your record notebook using pencil and ruler.

**Sketch 1: 5-Why Tree Drill-Down Structure**

```
[ PROBLEM STATEMENT: Visible Symptom ]
                    |
                    ▼
[ WHY 1? Direct Cause ]
                    |
                    ▼
[ WHY 2? Contributory Mechanical / Physical Cause ]
                    |
                    ▼
[ WHY 3? Procedural / SOP Failure ]
                    |
                    ▼
[ WHY 4? Training / Competency Failure ]
                    |
                    ▼
[ WHY 5? ROOT CAUSE: Systemic / Management Failure ]
```

**Sketch 2: Cause-and-Effect (Fishbone / Ishikawa) Diagram**




## 4. THEORY & METHODOLOGY OF 5-WHY ANALYSIS

The **5-Why Analysis** is an iterative interrogative technique developed by Sakichi Toyoda (Toyota Production System). It explores the cause-and-effect relationships underlying a particular industrial problem or safety incident.

Key Rules for Effective 5-Why Analysis

1. **Focus on Processes, Not People:** Avoid placing personal blame; focus on system failures.
2. **Base Steps on Evidence:** Every "Why" must be supported by verifiable physical or documented evidence.
3. **Trace the Causal Chain:** Each answer forms the basis for the next "Why" question until a controllable root cause is reached.
4. **Actionable Root Cause:** The analysis stops when the root cause identified can be controlled by system or management intervention.

## 5. CASE STUDY SCENARIO & STEP-BY-STEP 5-WHY DRILL-DOWN

Task Scenario

During a routine pipe flange bolt-tightening task on an acid transfer line, a maintenance technician sustained a chemical burn on the forearm from residual sulfuric acid ($H_2SO_4$).

Step-by-Step 5-Why Interrogation

- **Problem Statement:** Maintenance technician received a sulfuric acid chemical burn on the forearm during flange tightening.
- **Why 1? Why did acid contact the technician's forearm?**
  - *Answer:* Residual acid under pressure sprayed out from the flange interface when the bolts were loosened.
- **Why 2? Why was there pressurized residual acid in the pipe line?**
  - *Answer:* The pipe line had not been fully drained and depressurized prior to starting mechanical maintenance work.

- **Why 3? Why was the line not fully drained and verified depressurized?**
    - *Answer:* The line drain valve was plugged with chemical sediment, and the technician assumed the line was empty because the upstream isolation valve was closed.
- **Why 4? Why did the technician assume the line was safe without physical verification?**
    - *Answer:* The technician did not perform a line breaking check or review the **Permit to Work (PTW)** / isolation certificate before starting work.
- **Why 5? (ROOT CAUSE): Why was work started without verifying PTW isolation checks?**
    - *Answer:* **Lack of supervisory pre-job audit and failure to conduct mandatory pre-task Toolbox Talks (TBT)** to verify energy isolation and line-breaking precautions.

## 6. CORRECTIVE AND PREVENTIVE ACTION (CAPA) PLAN

Based on the root cause identified, corrective actions are developed across the Hierarchy of Controls:

| Level | Action Item | Target Completion | Responsibility |
|---|---|---|---|
| **Immediate** | Neutralize spill, flush affected area with emergency shower, provide medical care | Immediate | First Aid Team |
| **Engineering** | Install splash guards around all chemical pipe flanges and clear drain line blockage | 3 Days | Maintenance Team |
| **Administrative** | Revise line-breaking SOP (Mandatory zero-energy verification & chemical-resistant sleeves) | 5 Days | Safety Officer |

| | | | |
|---|---|---|---|
| **Systemic (Root Cause)** | Enforce pre-job Toolbox Talks (TBT) and supervisory sign-off on all PTW line-breaking permits | Continuous | Plant Manager |

**7. RESULTS & INFERENCE**

1. Successfully performed a **5-Why Root Cause Analysis** for a chemical exposure task incident.
2. Traced the incident from an immediate physical symptom (acid spray) to its fundamental root cause (**failure of pre-task PTW verification and supervisory oversight**).
3. Demonstrated that addressing root causes through administrative and engineering controls prevents incident recurrence far more effectively than merely penalizing the affected worker.

--------XXX-------