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Anjugramam - Kanyakumari Main Road, Palkulam,Variyoor P.O. - 629 401, Kanyakumari District.

DEPARTMENT OF MECHANICAL ENGINEERING

INDUSTRIAL SAFETY (CODE: CME388)

SYLLABUS

UNIT – I INDUSTRIAL SAFETY

Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, washrooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.

UNIT – II MAINTENANCE ENGINEERING

Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

UNIT – III WEAR AND CORROSION AND THEIR PREVENTION

Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravity lubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

UNIT – IV FAULT TRACING

Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, i. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler,vi. Electrical motors, Types of faults in machine tools and their general causes.

UNIT – V PERIODIC AND PREVENTIVE MAINTENANCE

Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of:i. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, Advantages of preventive maintenance. Repair cycle concept and importance.

TEXT BOOKS:

1. L M Deshmukh, Industrial Safety Management, Tata McGraw-Hill Education, 2005.

2. Charles D. Reese, Occupational Health and Safety Management: A Practical Approach, CRC Press, 2003.

UNIT – I INDUSTRIAL SAFETY

Introduction

Accident is an undesired event. Accidents results in a physical injury or property damage or both, usually due to contact with a source of energy which is above the ability of the body or structure to withstand it. According to Ridley (1986), 99% of the accidents happen are due to either unsafe acts or unsafe conditions or both. Accidents are avoidable and should always be avoided irrespective of the level of damage or los they can cause. Each and every individual as well as industry as a whole should take all necessary steps to avoid and minimize the accidents in future. Recent studies suggest that around 2.3 million laborer mortalities occur due to work-related accidents and diseases. More than 474 million people endure chronic ailments, resulting from occupational activity, and non-fatal accidents. The fatality rate from construction accidents are among the highest compared to the overall industry. Studies suggest that hazardous working conditions contribute a meager 3 % among all other type of workplace accidents. Negligent attitude (unsafe act) of the worker account for 95 % of all workplace accidents. Uncontrollable acts add 2 % of all workplace accidents Safety is a responsibility, requirement and asset of all personnel in the industry. The accident caused is the action or the condition immediately preceding the accident. From this we can observe that accidents are caused by unsafe conditions and by unsafe acts.

Industrial Accident

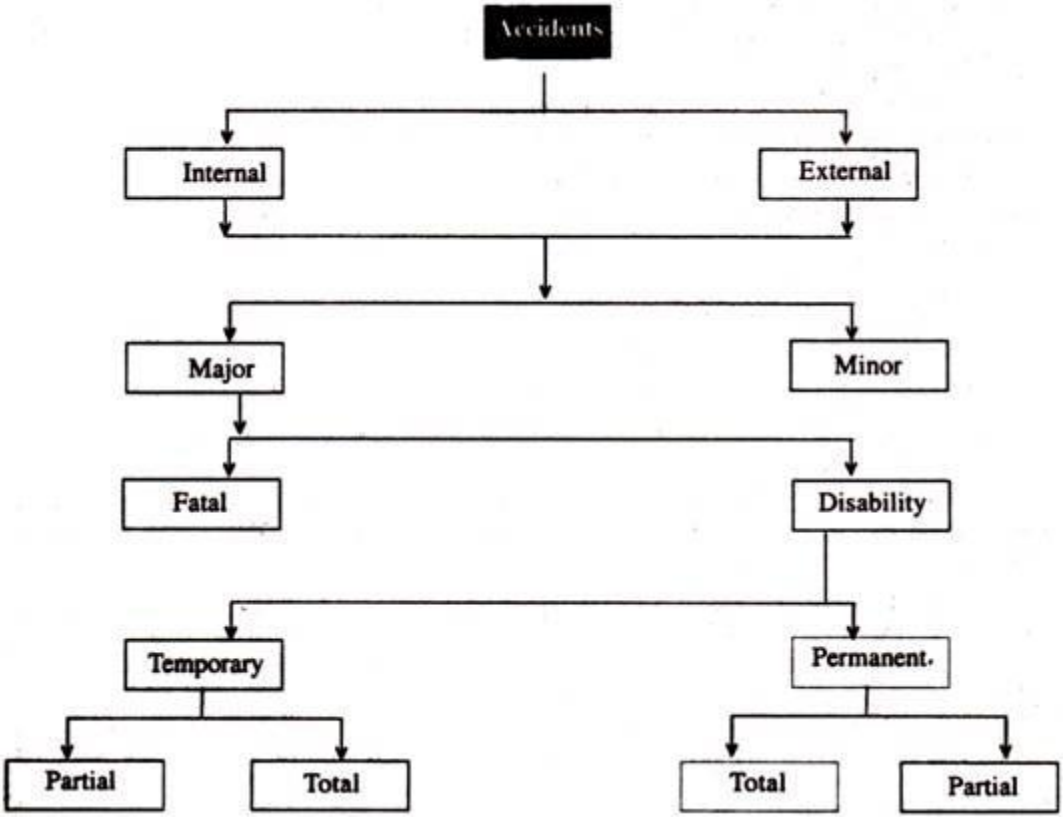
An accident (industrial) is a sudden and unexpected occurrence in the industry which interrupts the orderly progress of the work. According to the Factories Act, 1948: “It is an occurrence in an industrial establishment causing bodily injury to a person who makes him unfit to resume his duties in the next 48 hours”. In other words, accident is an unexpected event in the course of employment which is neither anticipated nor designed to occur. Thus, an accident is an unplanned and uncontrolled event in which an action or reaction of an object, a substance, a person, or a radiation results in personal injury. It is important to note that self-inflicted injuries cannot be regarded as accidents.

An industrial injury is defined as “a personal injury to an employee which has been caused by an accident or an occupational disease and which arises out of or in the course of employment and which could entitle such employee to compensation under Workers’ Compensation Act, 1923”.

Types of Accidents:

Accidents may be of different types depending upon the severity, durability and degree of the injury. An accident causing death or permanent or prolonged disability to the injured employee is called ‘major accident. A cut that does not render the employee disabled is termed as ‘minor’ accident. When an employee gets injury with external signs of it, it is external injury. Injury without showing external signs such as a fractured bone is called an internal one. When an injury renders an injured employee disabled for a short period, say, a day or a week, it is a temporary accident. On the contrary, making injured employee disabled forever is called permanent accident. Disability caused by accident may be partial or total, fatal or non-fatal.

The various types of accidents are now shown in Figure



No accident occurs automatically. Instead, certain factors cause accidents. It has been noticed that an accident does not have a single cause but a multiplicity of causes, which are often closely related. The same is discussed subsequently.

Causes of Accidents:

The industrial safety experts have classified the various causes of accidents into three broad categories:

1. Unsafe Conditions

2. Unsafe Acts

3. Other Causes

1. Unsafe Conditions (work-related):

Unsafe working conditions are the biggest cause of accidents. These are associated with detective plants, tools, equipment's, machines, and materials. Such causes are known as 'technical causes'. They arise when there are improper guarded equipment's, defective equipment's, faulty layout and location of plant, inadequate lighting arrangements and ventilation, unsafe storage, inadequate safety devices, etc. Besides, the psychological reasons such as working over time, monotony, fatigue, tiredness, frustration and anxiety are also some other causes that cause accidents. Safety experts identify that there are some high danger zones in an industry. These are, for example, hand lift trucks, wheel-barrows, gears and pulleys, saws and hand rails, chisels and screw drivers, electric drop lights, etc., where about one-third of industrial accidents occur.

2. Unsafe Acts:

Industrial accidents occur due to certain acts on the part of workers. These acts may be the result of lack of knowledge or skill on the part of the worker, certain bodily defects and wrong attitude.

Examples of these acts are:

(a) Operating without authority.

(b) Failure to use safe attire or personal protective equipment's,

(c) Careless throwing of material at the work place.

(d) Working at unsafe speed, i.e., too fast or too low.

(e) Using unsafe equipment, or using equipment's unsafely.

(f) Removing safety devices.

(g) Taking unsafe position under suspended loads.

(h) Distracting, teasing, abusing, quarrelling, day-dreaming, horseplay

(i) One's own accident-prone personality and behaviour.

3. Other Causes:

These causes arise out of unsafe situational and climatic conditions and variations. These may include excessive noise, very high temperature, humid conditions, bad working conditions, unhealthy environment, slippery floors, excessive glare, dust and fume, arrogant behaviour of domineering supervisors, etc. Of late, industrial accidents have become common happening in our country. A brief catalogue of major accidents in the recent past in India is produced here:

Major Accidents in the Last Decade:

Bhopal, December 1984: In world's worst chemical disaster, a methylisocyanate gas leak from the Union Carbide plant in the city killed over 4000 people. Thousands suffered irreversible health damage.

Delhi, December 1985: An oleum gas leak from the Sriram Foods and Fertilisers Plant in Delhi severely affected workers and those living in the neighborhood.

Rourkela, December 1985: Blast furnace accident in Rourkela Steel Plant. 18 workers affected.

Durgapur, June 1987: Chlorine leak at Durgapur Chemical Factory created panic all around. Long distance trains were halted. Over 100 were affected.

Bombay, November 1988: Fire at the Bharat Petroleum Refinery at Mahul, north-east Bombay, killed 32.

Ramagunaam, September 1989: Major gas leak at Fertilisers Corporation of India unit at Ramagundam, killed 7.

Nagothane, November 1990: Explosion at the Indian Petrochemicals, Nagothane complex, 35 persons killed, over 50 suffered 70 per cent bums.

Bombay, July 1991: Accident in a Hindustan Organic Chemicals unit near Bombay kills 7 workers.

Gwalior, December 1991: Blast at the dyeing department of GRASIM unit at Gwalior. 14 Killed and 22 severely injured.

Panipat, August 1992: Ammonia leak at the National Fertilizers Plant, Panipat killed 11, many injured.

Kahalgaon, October 1992: Boiler explosion in the National Thermal Power Corporation (NTPC), 11 killed and several injured.

It is reported that in every twenty seconds of every working minute of every hour throughout the world, someone dies as a result of an industrial accident. Industrial accidents cause losses to the employees and organizations as well. Table gives an idea about the enormous losses that accidents have caused to the industrial establishments in our country.

Accidents—Estimated Loss:

Date of Occurence	*Name of the Organisation*	*Estimated Loss (Rs in crore)*
29-01-87	Madras Ref. Manali	4.85
11-11-87	HPL Refinery, Vizag	3.40
09-01-88	JK Synthetics	6.92
20-09-88	Monica Electronics	3.86
05-05-88	Zenith Chem., Tarapur	4.00
30-08-88	IOC, Mathura	4.63
07-09-88	IEL, Gomia	5.00
09-11-88	BPCL	9.00
02-02-89	IPCL, Baroda	41.82
09-02-89	IAAI, Bombay	43.00
23-02-89	Voltas, Warora	5.00
08-01-95	ONGC, Pasarlapudi well blowout	41.44

Accidents causing losses to the industrial establishments need to be avoided. Adequate safety measures can avoid accidents.

Safety:

In simple words, safety means freedom from the occurrence or risk of injury or loss. As regards, industrial safety, it means the protection of employees/workers from the danger or risk of industrial accidents. In other words, industrial safety refers to protection against accidents occurring in the industrial establishments.

Mechanical and Electrical Hazards: Types, Causes, and Preventive Steps

Understanding mechanical and electrical hazards is crucial for ensuring workplace safety. Below is a detailed overview of their types, causes, and preventive measures.

Mechanical Hazards

Types of Mechanical Hazards:

1. **Moving Parts**: Includes gears, belts, pulleys, and rotating machinery that can cause entanglement or crushing injuries.

2. **Sharp Edges:** Tools or machinery with exposed blades or sharp surfaces that can cause cuts or lacerations.

3**. In-Running Nip Points**: Created between two rotating parts or between rotating and fixed parts, posing risks of crushing or shearing.

4. **Falling Objects**: Tools or materials that can fall from heights, leading to injuries.

Causes of Mechanical Hazards:

- Improper machine guarding or missing guards

- Lack of Lockout/Tagout procedures during maintenance

- Unauthorized personnel operating machinery

- Poor housekeeping leading to cluttered workspaces

Preventive Measures:

- **Machine Guards**: Install fixed, adjustable, or interlocked guards to prevent access to moving parts.

- **Training**: Provide comprehensive training on machine operation and safety protocols.

- **Regular Inspections**: Conduct routine checks to ensure all safety devices are functional and guards are in place.

- **Emergency Procedures**: Establish clear emergency protocols for accidents involving machinery.

Electrical Hazards

Types of Electrical Hazards:

1. **Shock Hazards**: Occur when a person comes into contact with live electrical components.

2. **Arc Flash/Blast**: Explosive release of energy caused by an electrical fault.

3. **Overloaded Circuits**: Can lead to overheating and fires due to excessive current flow.

4. **Exposed Wiring:** Damaged insulation or exposed wires can lead to short circuits and shocks.

Causes of Electrical Hazards:

- Poorly maintained electrical equipment

- Improper use of extension cords and power strips

- Lack of proper grounding for electrical systems

- Unauthorized modifications to electrical systems by unqualified personnel

Preventive Measures:

- Regular Maintenance: Ensure all electrical equipment is regularly inspected and maintained by qualified personnel

- Proper Training: Train employees on electrical safety practices, including the use of personal protective equipment (PPE)

- Use of Circuit Breakers: Install circuit breakers or fuses to prevent overloads and reduce fire risks

- Lockout/Tagout Procedures: Implement these procedures during maintenance to ensure machines are properly shut off and cannot be started unexpectedly

Salient Points of the Factories Act, 1948 for Health and Safety

The Factories Act of 1948 is a critical piece of legislation in India aimed at ensuring the health, safety, and welfare of workers in factories. Here are the key provisions related to health and safety:

Health Provisions

1. Cleanliness: Factories must maintain cleanliness to safeguard workers' health. This includes proper waste disposal, cleanliness of work areas, and maintenance of sanitary facilities.

2. Ventilation and Temperature Control: Adequate ventilation must be provided to prevent overcrowding and ensure a comfortable working temperature. Factories are required to monitor air quality and temperature levels.

3. Drinking Water: Sufficient drinking water must be provided at convenient locations within the factory premises. This water should be clean and potable.

4. Sanitary Facilities: The Act mandates the provision of adequate latrines and urinals for both male and female workers, which must be easily accessible and kept clean.

5. Waste Disposal: Factories are required to implement effective waste disposal systems to manage effluents and other waste materials properly.

Safety Provisions

1. Machine Safety: All machinery must be properly fenced to prevent accidents. The Act prohibits young persons from operating dangerous machinery.

2. Emergency Protocols: Factories must have adequate emergency exits and safety measures in place, including manholes that allow for safe evacuation in case of emergencies.

3. Training and Competence: Employers are required to appoint safety officers and ensure that machinery is operated by trained personnel only. Regular inspections of lifting equipment, hoists, and other machinery are mandated to ensure their safe operation.

4. Prohibition of Hazardous Work: The Act restricts the employment of women and children in certain hazardous processes, thus providing additional protection for vulnerable workers.

Welfare Provisions

1. Rest Facilities: Employers must provide adequate restrooms, first aid facilities, and canteens for workers to ensure their well-being during working hours.

2. Welfare Officers: Factories employing a significant number of workers are required to appoint welfare officers to oversee the health and safety measures in place.

Washrooms

- Layout: Washrooms should be conveniently located and designed to accommodate the expected number of users. Separate facilities for men and women are essential. Accessibility features must be included for individuals with disabilities, such as grab bars and sufficient clearance for mobility devices.

- Facilities: Each washroom should provide adequate toilet cubicles, handwashing stations with soap dispensers, and hand-drying facilities (towels or air dryers). Regular cleaning is crucial to maintain hygiene.

- Durability: Materials used in washroom construction should be durable and resistant to frequent cleaning. Compact Grade Laminate (CGL) is recommended for cubicle panels.

Drinking Water Layouts

- Accessibility: Drinking water stations should be easily accessible to all employees. They must be strategically placed throughout the facility to encourage hydration.

- Quality: Water supply systems should ensure that the water is potable. Regular testing and maintenance of water quality are necessary to prevent contamination.

- Design: Drinking fountains or dispensers should be designed to minimize spills and ensure cleanliness. Consideration for ergonomic design can enhance usability for all workers.

Light

- Illumination Levels: Adequate lighting is essential for safety and productivity. Work areas should have sufficient illumination levels tailored to the tasks performed, typically ranging from 300 to 500 lux for general workspaces.

- Natural Light: Whenever possible, design layouts that maximize natural light exposure. This can improve employee well-being and reduce energy costs.

- Emergency Lighting: Ensure that emergency lighting systems are in place to guide personnel safely during power outages or emergencies.

Cleanliness

- Regular Maintenance: Establish a routine cleaning schedule for all areas, especially high-touch surfaces in washrooms and communal spaces. This helps prevent the spread of germs and maintains a hygienic environment.

- Waste Management: Provide adequate waste disposal facilities, including bins for recycling and general waste. Regular collection and disposal are necessary to avoid overflow and maintain cleanliness.

Fire Safety

- Fire Exits: Clearly marked fire exits must be easily accessible from all areas of the facility. Regular drills should be conducted to ensure all employees are familiar with evacuation procedures.

- Fire Equipment: Install fire extinguishers at strategic locations throughout the workplace, ensuring they are regularly inspected and maintained[8].

- Training: Conduct regular fire safety training sessions for employees to familiarize them with emergency procedures and the proper use of fire safety equipment[8].

Guarding

- Machine Guards: All machinery should have appropriate guards in place to protect workers from moving parts. These guards must be regularly inspected for effectiveness and compliance with safety standards.

- Safety Protocols: Implement lockout/tagout procedures during maintenance to prevent accidental machine start-up while servicing equipment.

Pressure Vessels

- Design Standards: Pressure vessels must comply with relevant design standards and regulations to ensure safety under pressure conditions. Regular inspections are required to detect any signs of wear or failure.

- Maintenance: Establish a rigorous maintenance schedule that includes testing for leaks, corrosion, and structural integrity of pressure vessels.

- Training: Provide training for employees who operate or maintain pressure vessels on safe handling practices and emergency response procedures related to pressure-related incidents.

Colour code of Safety

Red: Fire protection equipment, Danger, High risk of Injury or Death.

Orange: Moderate risk of injury, Guarding Devices.

Yellow: Caution statement, Minor risk of injury.

Green: Safety equipment or Information.

Blue: No immediate hazard

White: Poison or Toxic.

FIRE PREVENTION AND FIREFIGHTING

I. Chemistry of Fire

1.1. Mechanics of combustion

From casual observation of a simple wood fire, it seems that the wood itself is burning. Actually, only the vapors given off by it supply the fuel that feeds the flames. Nearly all combustible materials, whether in a liquid or solid state, give off vapors when heated. Even paper, which is not ordinarily regarded as vapor producing, when heated gives off vapors which can be burned at some distance from the paper itself. Most solids must first be converted into a liquid state before vaporization takes place paraffin, for example, as in the case of a candle burning. The ignited wick melts the paraffin into a liquid, and the liquid flows into the wick and gives off vapor to feed the flame.

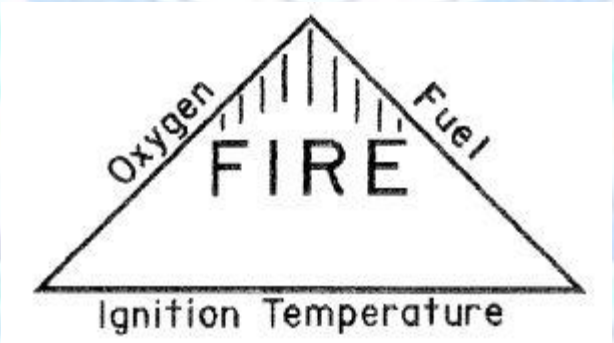
1.2. Flashpoint

Almost all oils must be heated until a vapor is given off before burning can take place. The temperature at which an oil begins to give off vapors that can be ignited is known as the flashpoint. Most lubricating oils must be heated to over 149 EC (300 EF) before they will flash. However, more highly volatile liquids such as gasoline, alcohol, naphtha, etc., have flashpoints so low they can be ignited readily at room temperature. The fire hazards that these liquids present are due to the fact that even at low temperatures they are constantly giving off highly flammable vapors. The flashpoint of gasoline is -43 EC (-45 EF), and while the ever-present vapors are not visible to the naked eye, they may be observed by means of a shadow image produced by a powerful light. The flashpoint of a liquid, however, should not be confused with the temperature necessary to ignite the vapors, for unless a source of heat considerably hotter than the flashpoint of the fuel comes into direct contact with the vapors, the fuel will merely continue to give off vapors without burning.

1.3. OXYGEN REQUIRED FOR COMBUSTION

The second essential factor in the process of combustion is oxygen. Without oxygen, even the most flammable vapors will not burn. Under normal conditions, a flame draws the amount of oxygen necessary to sustain combustion from the air. When the oxygen content of the air falls from normal 21 percent to below 15 percent, there is immediate extinguishment of practically all flames. The part that oxygen plays in supporting combustion is illustrated in a cutting torch. When only the acetylene gas is used, there is no cutting effect on the metal, but when the oxygen valve is opened the torch readily cuts through the metal on which it is being used. Under normal conditions, the oxygen in the air combines with the combustible vapor in the direct proportion to sustain combustion. With the regulated flow of vapor in an open space, the ready mixture of the two elements is evidenced. The greater the flow of vapor, the greater the mixture with oxygen and the larger the flame. This action is caused by the heat of the flame. The hot-air currents rising from the flame create a draft suction that draws a steady flow of oxygen into the flame area. With fuel at its flashpoint and vapors combining readily with air, the mixture may be regarded as in a state of readiness. Combustion, however, cannot occur until further heat is applied. An electric spark in some cases, or the heat of an open flame in others may furnish this needed heat.

Fire Triangle



The starting of a fire involves three elements - fuel, oxygen, and ignition temperatures. These elements may be compared to the three legs of a triangle (fig. 1), for fire cannot occur until all three are brought together.

The following is a common cause of fires in terms of the fire triangle. A cigarette is carelessly discarded and comes to rest on a scrap of paper. The heat of the glowing cigarette is sufficient to

cause the fuel - in this case, the paper (with a low ignition temperature)- to give off vapor. Oxygen is present, and when the vapors are given off in sufficient quantity the mixture ignites, the cigarette being hot enough to supply the ignition temperature. Because of the relatively large surface area, the fire spreads rapidly and grows in intensity, building up higher temperatures, causing more and more vapors to be given off. The heat of the flame causes the hot air to rise, drawing in additional oxygen to combine with the vapors and feed the flames. Referring to the fire triangle, to extinguish a fire, it is necessary to break up the triangle by taking away any one if its sides. This may be accomplished in various ways, as will be pointed out in the following sections.

II. Classification of Fires

2.1. Definition and Types.-

Classification of fires is the systematic arrangement in classes of the various substances that as fuels produce heat by combustion, as follows:

2.1.1. Class A: Ordinary combustible materials such as wood, cloth, paper, and some rubber and plastic materials.

2.1.2. Class B: Flammable liquids, gases, greases, and some rubber and plastic materials. Flammable or inflammable (identical in meaning) liquids do not themselves burn or explode, but, as pointed out previously, the gases or vapors formed when they are heated and evaporated explode; that is, the change of state from liquid to gas must first occur. As long as they are in a liquid state with no vapors being given off, there is little or no hazard. For the more volatile liquids, such as gasoline, storage in a closed container is a necessity. In order for any vapor to explode, it must have the correct vapor-air ratio, just as in the carburetor of a car. When the engine is flooded with gas, the mixture is too rich and fails to ignite. The same holds true in gasoline storage. The danger is when the gases being poured from one container to another, thus giving the vapors the change to mix with the correct amount of air to form an explosive moisture. The same circumstances hold true with all flammable oils when enough heat is present to release vapors from the liquid.

Keeping in mind that a flammable liquid is not hazardous as long as It is not hot enough to give off vapors which can mix with the oxygen in air and burn, two things can be done:

(a) The liquid can be cooled down to the point where no vapors are given off; and

(b) the supply of oxygen can be blanketed out. Some flammable liquids give off vapors at temperatures ordinarily considered cold. For example, gasoline vaporizes at -43 EC (-45 EF) or lower.

2.1.3. Class C: Live electrical equipment.

When equipment is deenergized, extinguishers for class A or B fires could be used safely; however, in fighting an electrical fire there are two important things to be taken into consideration: namely (a) damage to the equipment far beyond what the fire could do, and (b) danger to the Individuals fighting the fire. To avoid these two possibilities, deenergize the circuit and use only the types of extinguishment recommended for class C fires.

2.1.4. Class D:

Combustible metals such as magnesium, titanium, sodium, potassium, lithium, and zirconium.

SAFETY COLOR CODES

Safety color codes are standardized systems used to communicate hazards and safety information in various environments, particularly in workplaces. Here's a summary of the key safety color codes relevant to fire prevention and firefighting:

NFPA 704 Color Codes

The National Fire Protection Association (NFPA) uses a color code system to identify hazards associated with materials:

- **Red:** Indicates flammability (fire hazards).

- **Blue**: Represents health hazards (toxicity).

- **Yellow**: Denotes instability hazards (reactivity).

- **White:** Identifies specific hazards (e.g., corrosives, radiation).

OSHA and ANSI Safety Colors

The Occupational Safety and Health Administration (OSHA) and the American National Standards Institute (ANSI) have established color codes for safety signs:

- **Red:** Danger, fire-related hazards, emergency equipment.

- **Orange:** Warning of machinery that can cause injury.

- **Yellow:** Caution, indicating physical hazards.

- **Green:** General safety information and first aid.

- **Blue:** Information signs or instructions.

- **Brown:** Combustible fluids and gases.

ISO Color Codes

The International Organization for Standardization (ISO) also has color codes for various applications:

- Red: Firefighting equipment.

- Yellow: Flammable gases.

- Green: Safe materials (e.g., sea water).

- Black/White: Traffic movement and housekeeping.

FIRE PREVENTION AND FIREFIGHTING EQUIPMENT

Equipment

Firefighting equipment includes a range of tools designed to prevent and combat fires:

1. Fire Extinguishers: Portable devices filled with extinguishing agents suitable for various fire classes (A, B, C, D, K).

2. Fire Hoses: Used to deliver water or foam to extinguish fires.

3. Fire Blankets: Non-flammable materials that can smother small fires or wrap around individuals in case of flames.

4. Sprinkler Systems: Automated systems that release water when a fire is detected.

5. Smoke Detectors and Alarms: Devices that detect smoke and alert occupants of potential fire hazards.

Methods

Effective fire prevention and firefighting methods include:

- Regular Inspections: Ensuring all firefighting equipment is functional and accessible.

- Training Programs: Educating employees on fire risks and proper use of firefighting equipment.

- Emergency Plans: Developing clear evacuation routes and procedures in case of a fire.

- Fire Drills: Conducting regular drills to prepare occupants for real emergencies.

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III. PORTABLE FIRE EXTINGUISHERS

3.1. Types and Usage.- All extinguishers of a portable type act as a "first-aid" appliance for extinguishing fires in their incipient stage, and they cannot be expected to be effective after a fire has spread to involve a large amount of combustible material. The action of all extinguishers is by cooling the burning substance below its ignition temperature and by excluding the air supply (blanketing out the oxygen), or by a combination of these methods. Also, some types tend to inhibit oxidation by chemical action.\

There are several types of fire extinguishers, each designed for specific classes of fires. Understanding these types is crucial for effective fire safety and prevention. Here's a breakdown of the main types of fire extinguishers:

1. Water Extinguishers

- Use: Effective for Class A fires (ordinary combustibles like wood, paper, and textiles).

- Limitations: Not suitable for Class B (flammable liquids), Class C (electrical), or Class D (combustible metals) fires as water can spread flames or conduct electricity.

2. Foam Extinguishers

- Use: Suitable for Class A and Class B fires, particularly effective on flammable liquids.

- Limitations: Not recommended for electrical fires or combustible metals.

3. Dry Powder Extinguishers

-Types:

- Standard Dry Powder: Effective for Class B and C fires.

- Multipurpose Dry Powder: Can handle Class A, B, and C fires.

- Limitations: May leave a residue that can damage sensitive equipment.

4. Carbon Dioxide (CO_2) Extinguishers

- Use: Effective for Class B and C fires; ideal for electrical equipment as it leaves no residue.

- Limitations: Less effective on Class A fires and can cause frostbite if misused.

5. Wet Chemical Extinguishers

- Use: Specifically designed for Class K fires (cooking oils and fats) but also effective on Class A fires.

- Limitations: Not suitable for other classes of fires.

6. Specialist Dry Powder Extinguishers

- Use: Designed for Class D fires (combustible metals like magnesium and sodium).

- Limitations: Not suitable for other classes of fires.

7. Water Mist Extinguishers

- Use: Effective on Class A fires and safe for use on electrical equipment due to their misting action.

- Limitations: Not suitable for flammable liquids or combustible metals.

8. Water Spray Extinguishers

- Use: Similar to water extinguishers but with a spray mechanism to reduce the risk of electric shock.

- Limitations: Not suitable for flammable liquids or combustible metals.

3.1.1. Extinguishers for Class A Fires.-

Multipurpose dry chemical Foam extinguishers

Loaded stream extinguishers

3.1.2. Extinguishers for Class B Fires.-

Multipurpose dry chemical

Foam

Carbon dioxide (CO_2)

Dry chemicals

Loaded stream extinguishers

Bromotrifluoromethane - Halon 1301

3.1.3. Extinguishers for Class C Fires.-

Multipurpose dry chemical

Bromotrifluoromethane - Halon 1301

Carbon dioxide (CO_2)

Dry chemicals

3.1.4. Extinguishers for Class D Fires

Extinguishers or extinguishing agents for class D fires shall be types approved for use on the specific combustible metal.

3.2. OPERATION

The complete operation of each individual fire extinguisher, as the directions for operation will be found on the equipment. All persons who may have to use an extinguisher should carefully read and adhere to the instructions placed on the extinguisher by the manufacturer. Upon initial assignment and at least annually thereafter, all employees designated to use fire extinguishers will be provided training in the use of such equipment. All other employees will be educated in the general principles of fire-extinguisher use and the hazards with incipient-stage firefighting at least annually.

3.3. INSPECTION AND MAINTENANCE

3.3.1. General

Portable extinguishers shall be maintained in a fully charged and operable condition, and kept in their designated placed at all times when they are not being used. Each extinguisher shall be equipped with a tag for registering inspection date. Aluminum tags on which the date can be punched are preferred for a lasting record.

3.3.2. Inspection

Inspection is a quick check that an extinguisher is available and will operate. Extinguishers shall be inspected monthly, and the following items shall be checked:

(1) The extinguisher shall be in its designated place.

(2) Access to, or visibility of, the extinguisher shall not be obstructed.

(3) The operation instructions on the extinguisher nameplate shall be legible and face outward.

(4) Any seals or tamper indicators that are broken or missing shall be replaced.

(5) For water types without gauges, their fullness shall be determined by "hefting."

(6) Any obvious physical damage, corrosion, leakage, or clogged nozzles shall be noted.

(7) Pressure-gauge readings when not in the operable range shall be noted. The date the inspection was performed and the initials of the person performing the inspection shall be recorded. When an inspection reveals that tampering has occurred, or that the extinguisher is damaged, impaired, leaking, under- or overcharged, or has obvious corrosion, the extinguisher shall be subjected to applicable maintenance procedures.

3.3.3. Maintenance

Maintenance is a "thorough check" of the extinguisher intended to give maximum assurance that an extinguisher will operate effectively and safely. It includes a thorough examination and any necessary repair or replacement. Maintenance shall be performed at regular intervals, not more than 1 year apart or when specifically indicated by an inspection. Any extinguishers removed from the premises to be recharged shall be replaced by spare extinguishers during the period they are gone. Refill all extinguishers as soon as they are used. Stored pressure-dry chemical extinguishers that require a 12-year hydrostatic test will be emptied and subjected to applicable maintenance procedures every 6 years. Dry chemical extinguishers having non-refillable, disposable containers

are exempt from this requirement.

4.2. FOAM EXTINGUISHING SYSTEMS

4.2.1. General

Firefighting foam is a mass of gas-filled bubbles which is lighter than flammable liquids. The foam can float on all flammable liquids and produces an air-excluding, cooling, continuous layer of vapor sealing, water-bearing material for purposes of halting or preventing combustion. Two main types of foam are available. These are low- and high-expansion foam as discussed below. The following general rules apply to the application and use of ordinary air foams:

(1) Most foams are adversely affected by contact with vaporizing liquid extinguishing agents and by many dry chemical agents. These materials should not be used simultaneously with air foams. Gases from decomposing plastic materials have a similar breakdown effect on foams.

(2) Foam solutions are not recommended for use on electrical fires as the foam is conductive.

(3) High-expansion foam can seem to completely submerge and apparently extinguish fires, while the fire continues to burn quietly beneath it, This can occur when burning vapors beneath the foam support the foam blanket on heated air.

4.2.2. Low-Expansion Foam

The normal expansion ratios for Iow-expansion foam range from 4:1 to 12:1. The expansion ratio is the volume of foam generated, divided by the volume of solution used. The primary method of extinguishment with low-expansion foam is smothering, although cooling is a factor. The minimum foam depth for extinguishing a fire is about 6 mm (1/4 in) with an average depth of 76 mm (3 in) or more.

4.2.3. High-Expansion Foam

The normal expansion ratios for high- expansion foam range from 100:1 up to 1000:1. The primary method of extinguishment is the smothering and cooling effect of water. High-expansion foam is particularly suited as a flooding agent for use in confined spaces, for transporting wet foam masses to inaccessible places, and for volumetric displacement of vapor, heat, and smoke.

4.2.4. Limitations of Foam

Foams are primarily used for control and extinguishment of fires involving flammable or combustible liquids, and the following criteria must usually be met for the foam to be effective:

(1) The liquid must be below its boiling point at the ambient condition of temperature and pressure.

(2) If foam is applied to liquids with a bulk temperature higher than 100 EC (212 EF), the foam forms an emulsion of steam, air, and fuel. This may produce a fourfold increase in volume.

(3) The foam must not be highly soluble in the liquid to be protected, and the liquid must not be unduly destructive to the foam.

(4) The liquid must not be water reactive.

(5) The fire must be a horizontal surface fire as falling fuel fires cannot be extinguished by foam unless the fuel has a relatively high flashpoint and can be cooled to extinguishment by the water in the foam. However, some foams are capable of following a flowing fuel fire.

4.3. CARBON DIOXIDE EXTINGUISHING SYSTEMS

4.3.1. Principle

The use of CO_2 as an extinguishing agent is based on the principle of using an inert gas to reduce and displace the oxygen content of the air. Most fires where there are no flowing embers to maintain a high degree of heat for reignition can be extinguished by a reduction of the oxygen content from the normal 21 percent to 15 percent. Since CO2 is heavier than air, it has the ability to penetrate into loose material and confined spaces where water or foam might not. The rapid expansion of the gas on discharging produces a refrigerating effect, as indicated by the CO2 snow, which has a temperature of minus 79 EC (-110 EF). This snow turns into gas and in the process absorbs heat from the surrounding atmosphere.

4.3.2. Uses

CO_2 may be used on a large variety of fires, such as: flammable liquids in practically any type container, all types of electrical machinery and apparatus, and any situation where water would be damaging to the material after the fire is extinguished. CO2 is not suitable for use on pyroxylin plastics (photographic film).

4.3.3. Precautions in Using CO_2

The characteristics of carbon dioxide are such that certain precautionary measures are necessary. So far as safety to life is concerned, CO2, if not breathed in excessive amounts, is not dangerous; however, a concentrated atmosphere inhaled for several minutes will produce suffocation. Breathing a higher concentration than 9 percent CO2 can render a person helpless almost immediately. As CO2 design concentrations for fire extinguishing generally exceed 25 percent, it Is potentially dangerous for personnel to be in an area protected by a CO2 system. Also, the release of carbon dioxide into an enclosure causes a blinding storm of small crystals and builds up CO2 concentration so rapidly that escape becomes nearly Impossible. All employees entering such areas must obtain clearance on the stationary extinguishing system and make it inoperative by mechanical and/or electrical means. A test release of a bank of CO2 concentrations from atmospheric normal to above 45 percent in less than 10 seconds. It also increased CO2 concentrations in turbine pits to 15 percent, and hazardous concentrations in both locations remained for approximately 1 hour.

4.3.4. Entering Enclosures After CO_2 Discharge

Concentrations for the proportions listed in paragraph 4.3.3 are not likely to be encountered when portable CO2 equipment is being used to fight fires in an open area; however, they will be obtained when CO2 is used to smother a fire in an enclosure such as a generator housing on oil storage or oil purifier room. It is desired to maintain a minimum concentration of at least 25 percent for a period of time to extinguish fires in enclosures of this kind. Therefore, the following precautionary measures for personnel safety are required. In entering a generator housing after CO2 has been discharged, proper clearance of the generator should be obtained and enough time should elapse so that the CO2 application has served its intended purpose in extinguishing the fire. This period should be determined by a CO2 concentration test. Two employees equipped with self-contained breathing apparatus will open generator housing door and vents to permit the CO2 and smoke to escape by natural draft and to determine if all fire has been extinguished. Fans can also be used to clear the unit of smoke and CO2. After this has been accomplished and atmospheric tests for carbon dioxide and carbon monoxide concentrations are found to be below safe limits, other personnel may enter the powder is nonconducting and, in some housing. In the case of the oil storage and types, nonabrasive. However, the powder oil purifier rooms, proper airing out of the

remaining after the fire is extinguished is area should also be obtained before difficult to clean from motor or generator personnel are allowed to enter. windings. These extinguishers are effective on fires of flammable liquids in CO2 is stored in a liquid state under very vats and pools, spilled fires on floors, or in high pressure; and when discharged, the any situation where the compound stream rapid expansion produces a refrigerating can be swept across the burning surface. effect to the extent that one may obtain a "burn," or frostbite from coming in contact

4.4. CARBON TETRACHLORIDE IN FIRE EXTINGUISHERS

- **Historical Use**: Carbon tetrachloride was widely used in portable fire extinguishers starting from 1910. It was effective in smothering fires by vaporizing and displacing oxygen when sprayed on flames. However, due to its toxicity, it has been banned for use in fire extinguishers since 1987.

- **Mechanism:** When carbon tetrachloride comes into contact with fire, it vaporizes rapidly, creating a cloud that suffocates the flames by driving off oxygen. This mechanism is effective but poses significant risks if used in confined spaces, as it can lead to oxygen deprivation for anyone inside.

- **Health Risks:** The chemical is extremely toxic, linked to liver damage and potential carcinogenic effects. Additionally, it is a potent greenhouse gas and contributes to ozone depletion.

CHLORO-BROMOMETHANE

- **Properties**: Chloro-bromomethane is another chemical that has been utilized in fire extinguishers. Like carbon tetrachloride, it works by interrupting the combustion process.

- **Usage:** It is often found in halon extinguishers, which are designed for Class B (flammable liquids) and Class C (electrical) fires. Halons are effective because they disrupt the chemical reactions occurring during combustion without leaving residue.

INVERTING-TYPE EXTINGUISHERS

- **Design:** Inverting-type extinguishers are designed to be used upside down. This feature allows for the complete discharge of the extinguishing agent, which is particularly useful for certain types of fires.

- **Application:** These extinguishers are often filled with chemicals like carbon tetrachloride or halon, enabling them to effectively combat various classes of fires while ensuring that the entire content can be expelled quickly.

4.5. DRY CHEMICAL EXTINGUISHERS

Principle of Dry Chemical Extinguishers

Dry chemical extinguishers operate on the principle of interrupting the chemical reactions that sustain a fire. They achieve this by discharging a fine powder that coats the burning material, effectively cutting off its access to oxygen and disrupting the combustion process. The key components involved in this mechanism include:

- **Fine Powder Discharge:** When activated, dry chemical extinguishers release a fine powder, typically composed of substances like monoammonium phosphate, sodium bicarbonate, or potassium bicarbonate. This powder is propelled by a gas, often nitrogen or carbon dioxide, which helps to disperse it effectively over the fire.

- **Smothering Effect**: The powder forms a barrier over the fuel source, preventing oxygen from reaching it. This smothering action is crucial as it deprives the fire of one of its essential components—oxygen—thus extinguishing the flames.

- **Cooling Effect**: In addition to smothering the fire, some dry chemical agents also absorb heat from the flames, further reducing the fire's intensity and ability to reignite.

USES OF DRY CHEMICAL EXTINGUISHERS

Dry chemical extinguishers are versatile and can be used on various classes of fires, making them suitable for multiple environments. Their primary applications include:

1. **Class A Fires**: Effective against ordinary combustibles such as wood, paper, and textiles. The powder coats these materials to cut off oxygen and suppress flames.

2. Class B Fires: Highly effective for flammable liquids and gases (e.g., gasoline, oil). The powder forms a barrier on the liquid's surface, preventing vapor release and disrupting combustion.

3. Class C Fires: Safe for use on electrical fires since they are non-conductive. They can extinguish fires involving energized electrical equipment without posing additional risks.

4. Class F Fires: Some dry chemical extinguishers are also suitable for kitchen fires involving cooking oils and fats, although specific wet chemical extinguishers are generally preferred for these types.

IMPORTANCE OF FIRE DRILLS

Fire drills are essential for ensuring the safety of individuals in various environments, such as workplaces, schools, and public buildings. They prepare occupants for a swift and orderly evacuation in the event of a fire or other emergencies. Regular practice can save lives by familiarizing everyone with evacuation procedures and reducing panic during real incidents.

Steps to Conduct a Fire Drill

1. Planning the Fire Drill

- Define clear goals, such as ensuring quick evacuation and testing alarm systems.
- Choose a time that minimizes disruption while allowing maximum participation.
- Inform fire wardens, safety officers, and emergency services about the drill.

2. Conducting the Drill

- Trigger the fire alarm to start the drill.
- Monitor how quickly and effectively individuals evacuate, noting any issues with exits or alarm systems.
- Ensure fire wardens assist those needing help and direct everyone to the designated assembly point.

3. Post-Drill Evaluation

- Note the total evacuation time and any problems encountered during the drill.
- Discuss any issues with supervisory staff and refine evacuation procedures based on feedback.
- Complete a fire drill report and keep it on file with your fire safety plan.

Frequency of Fire Drills

Different environments have specific requirements for how often fire drills should be conducted:

- High-Rise Buildings: Every 2 months

- Laboratories: Every 3 months

- Schools: Three times each term

- Day-Care Centers: Monthly

- Other Occupancies: Annually