CBCS SCHEME

USN 1 C R 1 7 M E 4 1 6 15ME662

# Sixth Semester B.E. Degree Examination, June/July 2019
## Industrial Safety

Time: 3 hrs. Max. Marks: 80

**Note:** ***Answer any FIVE full questions, choosing ONE full question from each module.***



### Module-1

1 a. Define Industrial safety in context with OHS. What are the issues and topics it covers pertaining to Industry. **(08 Marks)**

b. How do you categorize workplace hazards? Explain briefly with suitable examples. **(08 Marks)**

**OR**

2 a. In construction, explain the hazards related to scaffolding and fall. What are the measures to be taken for protection? **(08 Marks)**

b. What is Material Safety Data Sheet (MSDS)? Explain the different sections of MSDS. **(08 Marks)**

### Module-2

3 a. What are the different classes of fire? Explain with examples. **(08 Marks)**

b. What is Fire Tetrahedron? Discuss various types of fire extinguishers and their applications. **(08 Marks)**

**OR**

4 a. List and explain common fire hazards and how they can be prevented. **(08 Marks)**

b. In case of fire accidents, what are the intervention methods and techniques to be adopted to control fire? **(08 Marks)**

### Module-3

5 a. What precautions are needed to avoid accident in material handling? **(08 Marks)**

b. What is Risk Assessment, Analysis and Evolution? How do you implent in case of welding operations? **(08 Marks)**

**OR**

6 a. Explain the various mechanical hazards associated with machines. **(08 Marks)**

b. Discuss the various safety control measures, with respect to machines. **(08 Marks)**

### Module-4

7 a. Define Electrical Safety. List the basic factors to be considered to ensure electrical safety in industries. **(08 Marks)**

b. What kind of injuries result from electrical current? Discuss briefly the preventive measures related to electrical hazards. **(08 Marks)**

**OR**

8 a. What safety precautions to be taken by electrical safety engineer and discuss the role and responsibility. **(08 Marks)**

b. List and explain various Personal protection equipment used in handling electrical equipments. **(08 Marks)**

### Module-5

9 a. What is Chemical Safety? List and explain various chemical hazards. **(08 Marks)**

b. Discuss what are guidelines to be followed when working with chemicals. **(08 Marks)**

**OR**

10 a. Explain the methods in implement for labeling of chemicals. **(08 Marks)**

b. With a suitable case study, explain implementation of chemical safety in a CNG plant. **(08 Marks)**

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# SOLUTION OF VTU QUESTION PAPER 2018-19

## MODULE 1

**1. a.**

Industrial safety is defined as policies and protections put in place to ensure plant and factory worker protection from hazards that could cause injury.

Topics OSH cover are

- Behavioral Safety
- Confined Spaces
- Construction Safety
- Disaster Preparedness
- Drug and Alcohol Testing
- Electrical Safety
- Emergency Response
- Enforcement
- Ergonomics
- Facility Security
- Fall Protection
- Fire Safety
- Food Safety
- Hazard Communication
- Hazmat
- Health Care
- Health and Medical Management
- Heat Stress and Thirst Quenchers
- Human Resources
- Incentives
- Indoor Air Quality
- Industrial Hygiene
- Infectious Diseases
- International Safety
- Plant Maintenance
- PPE
    - Foot Protection
    - Hand Protection
    - Head and Face Protection

    - Hearing Protection
    - Vision Protection
- Protective Apparel
- Protective Fabrics
- Regulations and Standards
- Respiratory
- Risk Management
- Showers and Eyewash
- Training and Software
- Transportation Safety

In developed countries, changes in the nature of work and the workforce may necessitate recalibrating the vision of occupational safety and health (OSH) researchers, practitioners, and policymakers to increase the focus on the most important issues. New methods of organizing the workplace, extensive labor contracting, expansion of service and knowledge sectors, increase in small business, aging and immigrant workers, and the continued existence of traditional hazards in high-risk sectors such as construction, mining, agriculture, health care, and transportation support the need to address: 1) broader consideration of the role and impact of work, 2) relationship between work and psychological dysfunction, 3) increased surveillance basis for research and intervention, 4) overcoming barriers to the conduct and use of epidemiologic research, 5) information and knowledge transfer and application, 6) economic issues in prevention, and 7) the global interconnectedness of OSH. These issues are offered to spur thinking as new national research agendas for OSH are considered for developed countries

**b.**

Safety Hazards:

Safety Hazards are unsafe working conditions that that can cause injury, illness, and death. Safety hazards are the most common workplace hazards.

THEY INCLUDE*:*

- Anything that can cause spills or trips such as cords running across the floor or ice
- Anything that can cause falls such as working from heights, including ladders, scaffolds, roofs, or any raised work area.
- Unguarded machinery and moving machinery parts that a worker can accidentally touch
- Electrical hazards like frayed cords, missing ground pins, improper wiring
- Confined spaces.

Biological Hazards:

Biological Hazards include exposure to harm or disease associated with working with animals, people, or infectious plant materials. Workplaces with these kinds of hazards include, but are not limited to, work in schools, day care facilities, colleges and universities, hospitals, laboratories, emergency response, nursing homes, or various outdoor occupations.

TYPES OF THINGS MAY BE EXPOSED INCLUDE:

- Blood and other body fluids
- Fungi/mold
- Bacteria and viruses
- Plants
- Insect Bites
- Animal and bird droppings

Physical Hazards:

Physical hazards can be any factors within the environment that can harm the body without necessarily touching it.

*THEY INCLUDE:*

- Radiation: including ionizing, non-ionizing (EMF's, microwaves, radio waves, etc.)
- High exposure to sunlight/ultraviolet rays
- Temperature extremes – hot and cold
- Constant loud noise

Ergonomic Hazards:

Occur when the type of work, body positions, and working conditions put a strain on your body. They are the hardest to spot since you don't always immediately notice the strain on your body or the harm that these hazards pose. Short-term exposure may result in "sore muscles" the next day or in the days following the exposure, but long-term exposure can result in serious long-term illness.

*ERGONOMIC HAZARDS INCLUDE:*

- Improperly adjusted workstations and chairs
- Frequent lifting
- Poor posture
- Awkward movements, especially if they are repetitive
- Having to use too much force, especially if you have to do it frequently
- Vibration

Chemical Hazards:

Are present when a worker is exposed to any chemical preparation in the workplace in any form (solid, liquid or gas). Some are safer than others, but to some workers who are more sensitive to chemicals, even common solutions can cause illness, skin irritation, or breathing problems.

*BEWARE OF:*

- Liquids like cleaning products, paints, acids, solvents – ESPECIALLY if chemicals are in an unlabeled container!
- Vapors and fumes that come from welding or exposure to solvents
- Gases like acetylene, propane, carbon monoxide and helium
- Flammable materials like gasoline, solvents, and explosive chemicals
- Pesticides

Work Organization Hazards:

Hazards or stressors that cause stress (short-term effects) and strain (long-term effects). These are hazards associated with workplace issues such as workload, lack of control and/or respect, etc.

*EXAMPLES INCLUDE:*

- Workload demands

- Workplace violence
- The intensity and/or pace
- Respect (or lack thereof)
- Flexibility
- Control or say about things
- Social support or relations
- Sexual harassment

**2. a**

- **Falls**

Falls are attributed to the lack of guardrails, improper installation of guardrails and failure to use personal fall arrest systems when required. The OSHA standard requires fall protection must be used when work heights reach 10' or more. OSHA's standards represent the minimum level of protection; many general contractors require 100% fall protection at 6' or greater when working on scaffolds. These contractors are increasing safety margins by exceeding the minimum requirements of the OSHA standards.

- **Scaffold collapse**

The proper erection of a scaffold is essential in preventing this particular hazard. Before erecting the scaffold, a number of factors must be accounted for. The amount of weight the scaffold will be required to hold including the weight of the scaffold itself, materials, and workers must be considered. Foundation stability, placement of scaffold planks, distance from the scaffold to the work surface, and tie-in requirements are just a few of the other items that must be considered prior to building a scaffold.

- **Struck by falling materials**

Workers on scaffolds are not the only ones exposed to scaffold related hazards. Many individuals have been injured or killed due to being struck by materials or tools that have fallen from scaffold platforms. These people must be protected from falling objects. OSHA requires that this is done one of two ways. The first is to install toe boards or netting on work platforms to prevent these items from falling to the ground or lower level work areas. The other option is to erect barricades that physically prevent individuals from walking under work platforms.

- **Electrocution**

Once again we look to preplanning and the competent person to assure there are no electrical hazards present during scaffold use. A minimum of 10' must be maintained between the scaffold and electrical hazards. If this distance cannot be maintained, then the hazard must be de-energized or properly insulated by the power company. Coordination between the power company and the company erecting / using the scaffold cannot be over stated.

**Safety measures**

- When working on scaffolds more than 10 feet above a lower level, install guardrails, mid-rails, and toe boards along all open sides and ends of platforms.
- Install top rails so the top edge is between 39 and 45 inches.
- Install mid-rails halfway between the work platform and the top rail.
- Install toe-boards of a substantial material at least 4 inches high on all open sides and ends of platforms if there are workers below.
- Erect mobile scaffolds with cross, horizontal, or diagonal braces, as designed, to provide a rigid structure.

- Make sure scaffolds are plumb, level, and squared with all brace connections securely fastened.
- To prevent movement of the scaffold while it is being used in a stationary position, lock all scaffold casters and wheels with positive wheel and swivel locks.
- Check overhead clearance for power lines or other possible hazards before moving a mobile scaffold.
- Stay at least 10 feet away from all power lines. When using manual force to move the scaffold, apply the force as close to the base as possible, but not more than five feet above the supporting frame.
- Never move a mobile scaffold while you are on it. Inspect all scaffolds prior to use or at least on a daily basis.

**b.**

A **material safety data sheet (or MSDS)** is a document that provides workers with procedures for safely handling or working with a particular substance. It includes technical information like boiling points, toxicities, reactivities, and various numbers. And also, it includes instructions regarding necessary protective equipment, how to handle spills, first aid suggestions, storage and disposal, and the general health effects.

- SECTION 1: Identification of the substance/mixture and of the company/undertaking
  - 1.1. Product identifier
  - 1.2. Relevant identified uses of the substance or mixture and uses advised against
  - 1.3. Details of the supplier of the safety data sheet
  - 1.4. Emergency telephone number
- SECTION 2: Hazards identification
  - Classification of the substance or mixture
  - Label elements
  - Other hazards
- SECTION 3: Composition/information on ingredients
  - 3.1. Substances
  - 3.2. Mixtures
- SECTION 4: First aid measures
  - 4.1. Description of first aid measures
  - 4.2. Most important symptoms and effects, both acute and delayed
  - 4.3. Indication of any immediate medical attention and special treatment needed
- SECTION 5: Firefighting measures
  - 5.1. Extinguishing media
  - 5.2. Special hazards arising from the substance or mixture
  - 5.3. Advice for firefighters
- SECTION 6: Accidental release measure
  - 6.1. Personal precautions, protective equipment and emergency procedures
  - 6.2. Environmental precautions

- 6.3. Methods and material for containment and cleaning up
- 6.4. Reference to other sections

- SECTION 7: Handling and storage
  - 7.1. Precautions for safe handling
  - 7.2. Conditions for safe storage, including any incompatibilities
  - 7.3. Specific end use(s)
- SECTION 8: Exposure controls/personal protection
  - 8.1. Control parameters
  - 8.2. Exposure controls
- SECTION 9: Physical and chemical properties
  - 9.1. Information on basic physical and chemical properties
    - Appearance (physical state, color, etc.)
    - Upper/lower flammability or explosive limits
    - Odor
    - Vapor pressure
    - Odor threshold
  - 9.2. Other information
- SECTION 10: Stability and reactivity
  - 10.1. Reactivity
  - 10.2. Chemical stability
  - 10.3. Possibility of hazardous reactions
  - 10.4. Conditions to avoid
  - 10.5. Incompatible materials
  - 10.6. Hazardous decomposition products
- SECTION 11: Toxicological information
  - 11.1. Information on toxicological effects
- SECTION 12: Ecological information
  - 12.1. Toxicity
  - 12.2. Persistence and degradability
  - 12.3. Bioaccumulative potential
  - 12.4. Mobility in soil
  - 12.5. Results of PBT and vPvB assessment
  - 12.6. Other adverse effects
- SECTION 13: Disposal considerations
  - 13.1. Waste treatment methods
- SECTION 14: Transport information
  - 14.1. UN number
  - 14.2. UN proper shipping name
  - 14.3. Transport hazard class
  - 14.4. Packing group
  - 14.5. Environmental hazards
  - 14.6. Special precautions for user

- 14.7. Transport in bulk

- SECTION 15: Regulatory information
  - 15.1. Safety, health and environmental regulations/legislation specific for the substance or mixture
  - 15.2. Chemical safety assessment
- SECTION 16: Other information: This section indicates when the SDS was prepared or when the last known revision was made. The SDS may also state where the changes have been made to the previous version. You may wish to contact the supplier for an explanation of the changes. Other useful information also may be included here.

## MODULE 2

**3. a.**

**Classes of fire**

- Class A Fires involving solid combustible materials of organic nature such as wood, paper, rubber and plastics where the cooling effect of water is essential.
- Class B Fires involving flammable liquids or liquefiable solids or the like where a blanketing effect is essential.
- Class C Fires involving flammable gases under pressure including liquefied gases, where it is necessary to inhibit the burning gas at fast rate with an inert gas, powder or vaporising liquid.
- Class D Fires involving combustible metals like magnesium, aluminium, zinc, sodium, and potassium where the burning metals are reactive to water containing agents and in certain cases carbon dioxide, halogenated hydrocarbons and ordinary dry powders. These fires require special media and techniques to extinguish.
- Class E Fire risks involving electrical apparatus/equipment.
- Class F/K Fires involving cooking oils, trans-fats or fats in cooking appliances. These typically occur in restaurant and cafeteria kitchens

**b.**

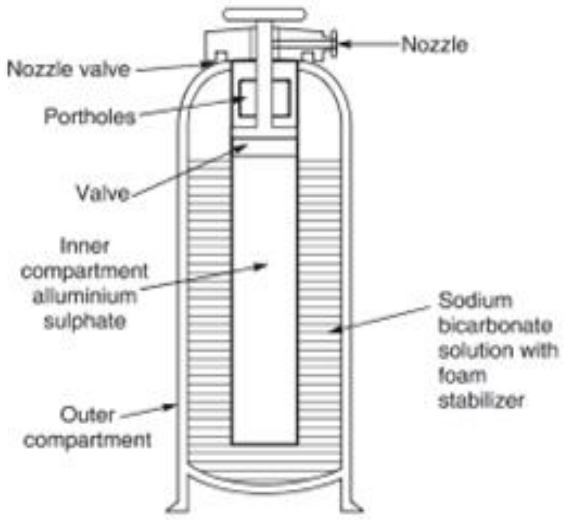
**Fire tetrahedron**

An alternative to the fire triangle model is the fire tetrahedron. The fire tetrahedron adds another element to the fire, which is chemical reaction. Fires involving metals such as titanium, lithium and magnesium have a chemical reaction that requires a different approach for fire fighters. This is called a class D fire and the application of water will exacerbate the combustion. Because of the chain reaction caused by the metals in class D fires, fire fighters must use a different approach involving the introduction of inert agents like sand to smother it. Learning about the fire triangle is a good way to understand the elements of fire and is an essential component of fire fighting education.

Types of fire extinguisher

- Water fire extinguisher (Soda water acid type and gas pressure type fire extinguisher)
- Carbon di-oxide fire extinguisher
- Halons fire extinguisher
- Foam fire extinguisher
- Dry chemical fire extinguisher

- Foam fire extinguisher



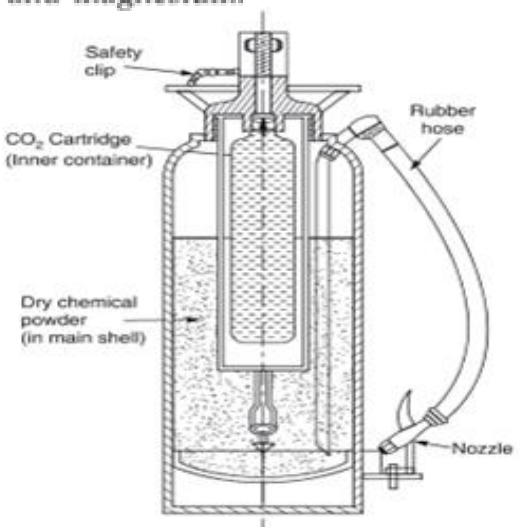

Portable extinguishers expelling foam are recommended for class B fires involving flammable liquids like oils, solvents, petroleum products, varnishes, paints, etc. The foam expelled by actuating the extinguishers forms a blanket over the surface.

- Dry chemical extinguisher

Dry Powder Fire Extinguishers are suitable for tackling petroleum fires, gas fires, fires in electrical equipments and for controlling surface fires in textile fibres. These extinguishers are noted for the speed with which they put out fires.

The chemical powders employed are usually sodium based and when applied to a fire, undergo chemical reaction. The free radicals which are responsible for sustaining any fire are out of action by the dry chemical powders and because of this, the fire dies out very fast.

Special dry powders containing sodium, potassium and barium compounds have been found useful in extinguishing fires in metals such as sodium and magnesium.



- Soda water acid type extinguisher

**Construction :** The various parts and contents of a soda acid extinguishers are shown in the Fig. 13.4.

The total liquid capacity of the body (or the solution containers) when filled to the specified level, should be 9 litres.

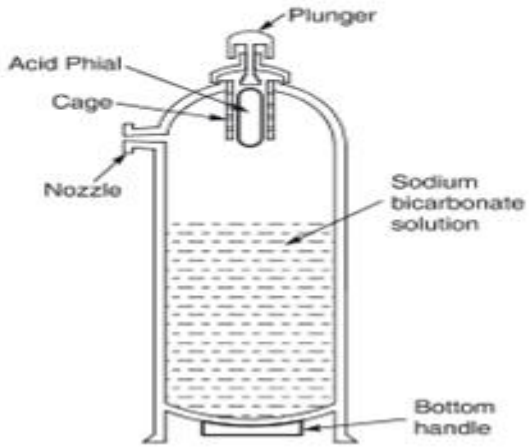
During manufacture, the body is required to be tested to an internal hydraulic pressure of 25 kgf/cm$^2$ for 5 minutes.

**Method of operation :** The operational instructions given on the body of the extinguishers should be read carefully. It should be confirmed whether soda acid extinguishers are of **up-right type** or **turn-over type** depending on their method of working. The type of the extinguishers provided at a given place must be known and method of operation must be practiced well in advance during training.

**Principle of Operation.** When the plunger is struck the acid phial (bottle) ruptures. The sulphuric acid and sodium bicarbonate solution react together to release carbondioxide ($CO_2$) gas.

The $CO_2$ generated creates internal pressure which forces the **water out of the extinguishers**.

**Note.** The $CO_2$ gas acts only as a propellant and the water extinguishers the **fire by cooling effect.** Such extinguishers are recommended only for class A fires.




**4. a.**

Common fire hazards

- Alcohol and fire are a deadly combination: It's a fact that many fire deaths are caused by people attempting to cook or smoke while under the influence of alcohol. There's more to responsible drinking than taking a cab. Don't put yourself or your family at risk to fire.
- Cooking: Fires can easily start in your kitchen.
- Electrical fire safety: Unsafe use of electricity can be a ticking time bomb! An electrical fire can happen at any time.

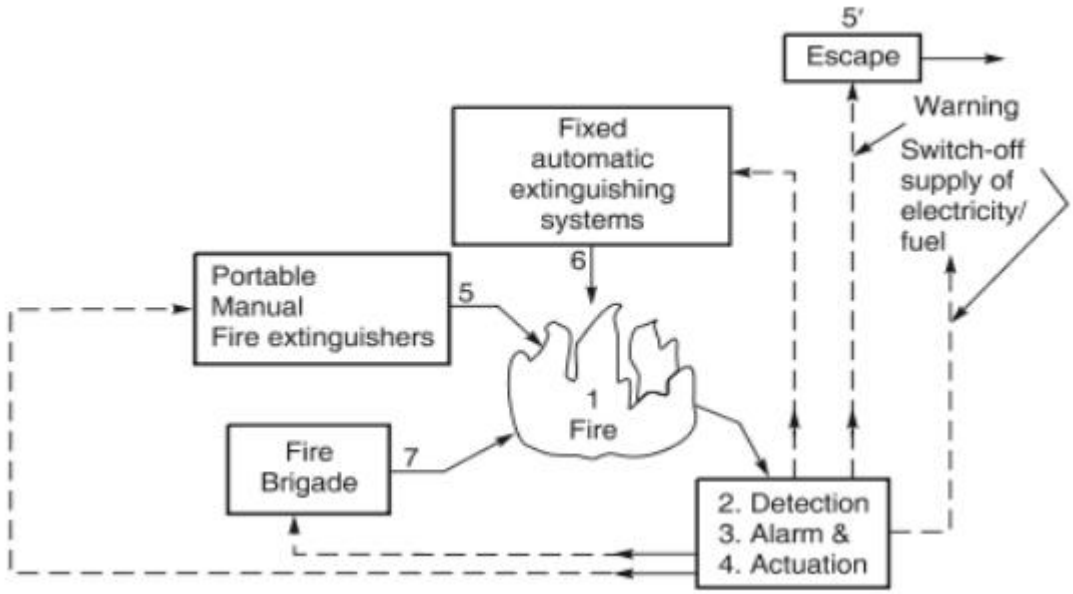
- Matches and lighters: can be lethal weapons in the hands of children.
- Smoking Safety

**Follow these safety precautions**

- Drink responsibly!
- After a party or gathering where alcohol has been consumed, check furniture to ensure cigarette ashes haven't fallen into the cushions where it can smolder.
- Avoid smoking when you have been drinking heavily.
- Never Leave Cooking Unattended! Never leave home when a microwave oven, stove burner, or oven is on. Keep a close eye on what you're cooking.
- Keep Your Cooking Area Clean. Many items in the kitchen can catch fire easily including pot holders, dish towels, and product packaging. Keep curtains away from the stove and clean up all spills on the stove top or near by counters.
- Clean your oven regularly. Many kitchen fires start because of built up grease.
- Follow-up when a fuse or circuit breaker blows. Don't just reset the breaker or replace the fuse. Find out what caused the problem.
- Purchase appliances that are approved by the Canadian Standards Association or ULC. Appliances without CSA/ULC approval could be unsafe.
- Put lamps on level surfaces, away from curtains or other flammable items.
- Teach younger children to take lighters and matches to tell an adult when they find lighters and matches.
- Be aware of items that appear burnt around the home.

**b.**

1. Fire Occurs
2. Fire is Detected by Observer or Detection System
3. Alarm is Sounded
4. Electric Power Supply and Other Fuel Supplies are Switched Off
5. Immediate Use of Portable Fire Extinguishers and Water/ Sand for Extinguishing Small Fires then and there
6. Automatic Fire Fighting System Gets Initiated
7. Call Fire Brigade.
8. Persons vacate the place.




**MODULE 3**

**5. a.**

- Avoid lifting materials from the floor or while seated.
- Make use of available handling aids.
- Refrain from using sudden or jerky movements.
- Never lift a load over an obstacle.
- Perform lifts in areas with adequate footing, space and lighting.
- Modify objects and redesign jobs to make moving easier.
- Seek assistance from co-workers.
- Stay in good physical shape.
- Begin lifts close to the body.
- Use containers made of lighter materials.
- Reduce load sizes when possible.
- Do not twist or bend while lifting objects.
- Ensure repetitive, heavy and bulky lifts are not performed.
- Keep lifts between shoulder and knuckle height.
- Use conveyors, slides or chutes to eliminate pushing or pulling.

**b.**

Risk assessment is a term used to describe the overall process :

- Identify hazards and risk factors that have the potential to cause harm (hazard identification).
- Analyze and evaluate the risk associated with that hazard (risk analysis, and risk evaluation).

- Determine appropriate ways to eliminate the hazard, or control the risk when the hazard cannot be eliminated (risk control).
- **Risk analysis** – a process for comprehending the nature of hazards and determining the level of risk.

**Notes:**

**(1)** Risk analysis provides a basis for risk evaluation and decisions about risk control.
**(2)** Information can include current and historical data, theoretical analysis, informed opinions, and the concerns of stakeholders.
**(3)** Risk analysis includes risk estimation.

- **Risk evaluation** – the process of comparing an estimated risk against given risk criteria to determine the significance of the risk.

Risk assessment should be specific to the required task. Factors to be considered in assessing risks associated with manual electric arc welding operation include:

(a) The type of arc welding equipment required and the electricity source available;

(b) The working environment, such as

(i) Ventilation and lighting of the workplace,

(ii) working in the presence of flammable vapours or airborne substances which would decompose into toxic materials at high temperature and in specific environments, such as confined space, pressurized or oxygen-rich environment, damp or slightly flooded workplaces,

(iii) Working space restricting body movement,

(iv) Working together with other welding workers,

(v) Working near combustible/ flammable materials, and

(vi) The possibility of slag or sparks reaching to or coming into contact with combustible materials;

(c) particulars of the work, such as

(i) Duration and frequency of the welding operation,

(ii) Operation on workpieces and vessels with possible combustible/ flammable residues,

(iii) Working at height,

(iv) Working posture, and

(v) Size, shape, weight and construction of the workpieces.

**6. a.**

- Pinch Points – Where two parts move together and at least one of the parts moves in a circle; also called mesh points, run-on points, and entry points. Examples include: belt drives, chain drives, gear drives, and feed rolls. When shields cannot be provided, operators must avoid contact with hands or clothing in pinch point areas. Never attempt to service or unclog a machine while it is operating or the engine is running.
- Wrap Points – Any exposed component that rotates. Examples include: rotating shafts such as a PTO shaft or shafts that protrude beyond bearings or sprockets. Watch components on rotating shafts, such as couplers, universal joints, keys, keyways, pins,

or other fastening devices. Splined, square, and hexagon-shaped shafts are usually more dangerous than round shafts because the edges tend to grab fingers or clothing more easily than a round shaft. However, round shafts may not be smooth and can also grab quickly. Once a finger, thread, article of clothing, or hair is caught it begins to wrap; pulling only causes the wrap to become tighter.

- Shear Points – Where the edges of two moving parts move across one another or where a single sharp part moves with enough speed or force to cut soft material. Remember that cutting devices cannot be totally guarded to keep hands and feet out and still perform their intended function. Recognize the potential hazards of cutting and shear points on implements and equipment that are not designed to cut or shear. Guarding may not be feasible for these hazards.
- Crush Points – Points that occur between two objects moving toward each other or one object moving toward a stationary object. Never stand between two objects moving toward one another. Use adequate blocking or lock-out devices when working under equipment.
- Pull-In Points – Points where objects are pulled into equipment, usually for some type of processing. Machines are faster and stronger than people. Never attempt to hand-feed materials into moving feed rollers. Always stop the equipment before attempting to remove an item that has plugged a roller or that has become wrapped around a rotating shaft. Remember that guards cannot be provided for all situations - equipment must be able to function in the capacity for which it is designed. Freewheeling parts, rotating or moving parts that continue to move after the power is shut off are particularly dangerous because time delays are necessary before service can begin. Allow sufficient time for freewheeling parts to stop moving. Stay alert! Listen and watch for motion!
- Thrown Objects – Any object that can become airborne because of moving parts. Keep shields in place to reduce the potential for thrown objects. Wear protective gear such as goggles to reduce the risk of personal injury if you cannot prevent particles from being thrown. All guards, shields or access doors must be in place when equipment is operating. Electrically powered equipment must have a lock-out control on the switch or an electrical switch, mechanical clutch or other positive shut-off device mounted directly on the equipment. Circuit interruption devices on an electric motor, such as circuit breakers or overload protection, must require manual reset to restart the motor.

**b.**

1. Workers must not remove or make ineffective any safeguards, unless authorized. Safeguards removed for repairs must be replaced promptly or temporary guards installed.
2. Machines and equipment shall be operated by authorized personnel only.
3. No machine shall be left unattended while it is in motion.

4. Cleaning, oiling or adjusting any machine shall not be done while the machine is in motion.
5. Materials to be machined shall be securely fastened or clamped to the working surfaces before starting the machine.
6. Keys or other adjusting tools must never be left so that they may creep, be thrown, or fall when machine is started.
7. Use a brush, special tool or hook to remove chips, shavings or other material from work. Flowing shavings shall not be handled with bare hands; metal hooks shall be used.
8. Revolving shafting, although apparently smooth, will catch loose or ragged clothing, hair or wiping rags. Proper clothes and caution are always necessary when working around any revolving machinery.
9. When tightening work in chuck jaws with chuck wrench, operator shall see that wrench fits properly; operator should take proper stance when tightening jaws to prevent falling if wrench slips.
10. When placing or removing heavy castings or billets from machines, operator shall get help or crane service to prevent injury.
11. Operators shall keep hands away from cutters and bars while operating machines. Operators shall keep hands off work while machine is in operation.
12. Operators shall stand so that they can easily reach the machine controls.
13. Cutters and tools shall be in the clear before machines are started.
14. Clean-up chips, spills, etc., on and around machinery after each use.

**7. a.**

**Electrical safety** is a system of organizational measures and technical means to prevent harmful and dangerous effects on workers from electric current, electric arc, electromagnetic field and static electricity.

The effects of electric shock on the human body depend on several factors. The major factors are:
1. Current and Voltage
2. Resistance
3. Path through body
4. Duration of shock

The muscular structure of the body is also a factor in that people having less musculature and more fat typically show similar effects at lesser current values.

- **CURRENT AND VOLTAGE:**

Although high voltage often produces massive destruction of tissue at contact locations, it is generally believed that the detrimental effects of electric shock are due to the *current* actually flowing through the body. Even though Ohm's law (I=E/R) applies, it is

often difficult to correlate voltage with damage to the body because of the large variations in contact resistance usually present in accidents. Any electrical device used on a house wiring circuit can, under certain conditions, transmit a fatal current. Although currents greater than 10 mA are capable of producing painful to severe shock, currents between 100 and 200 mA can be lethal. With increasing alternating current, the sensations of tingling give way to contractions of the muscles. The muscular contractions and accompanying sensations of heat increase as the current is increased. Sensations of pain develop, and voluntary control of the muscles that lie in the current pathway becomes increasingly difficult. As current approaches 15 mA, the victim cannot let go of the conductive surface being grasped. At this point, the individual is said to "freeze" to the circuit. This is frequently referred to as the "let-go" threshold. As current approaches 100 mA, ventricular fibrillation of the heart occurs.

Ventricular fibrillation is defined as "very rapid uncoordinated contractions of the ventricles of the heart resulting in loss of synchronization between heartbeat and pulse beat." Once ventricular fibrillation occurs, it will continue and death will ensue within a few minutes. Use of a special device called a de-fibrillator is required to save the victim. Heavy current flow can result in severe burns and heart paralysis. If shock is of short duration, the heart stops during current passage and usually re-starts normally on current interruption, improving the victim's chances for survival.

| Current level (milliamperes) | Probable Effect on Human Body |
|---|---|
| 1 mA | Perception level. Slight tingling sensation. |
| 5 mA | Slight shock felt; not painful but disturbing. Average individual can let go. |
| 6 – 16 mA | Painful shock. Loss of muscular control. Commonly referred to as the freezing current or "let-go" range. |
| 17 – 99 mA | Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go the source in contact with. Can cause ventricular fibrillation. |
| 100 – 2000 mA | Ventricular fibrillation (uneven pumping of the heart.) Muscular contraction and nerve damage begins to occur. Death likely. |
| > 2,000 mA | Cardiac arrest, internal organ damage, and severe burns. Death probable. |

- **RESISTANCE:**

Studies have shown that the electrical resistance of the human body varies with the amount of moisture on the skin, the pressure applied to the contact point, and the contact area. The outer layer of skin, the epidermis, has very high resistance when dry. Wet conditions, a cut or other break in the skin will drastically reduce resistance. Shock severity increases with an increase in pressure of contact. Also, the larger the contact area, the lower the resistance. Whatever protection is offered by skin resistance decreases rapidly with increase in voltage. Higher voltages have the capability of "breaking down" the outer layers of the skin, thereby reducing the resistance.

Body resistance (measured in ohms/cm2) is concentrated primarily in the skin and varies directly with the skin's condition. The resistance of dry well-keratinized intact skin is 20-30 kΩ /cm2. The resistance of moist thin skin is about 0,5kΩ/cm2. The resistance of punctured skin may be as low as 0,2-0,3 kΩ/cm2. The same resistance is in case of current applied to moist mucous membranes (e.g., mouth). If skin resistance is low, few, if any, burns occur, although cardiac arrest may occur if the current reaches the heart. If skin resistance is

high, much energy may be dissipated at the surface as current passes through the skin, and large surface burns can result at the entry and exit points.

Internal tissues are burned depending on their resistance; nerves, blood vessels, and muscles conduct electricity more readily than denser tissues (e.g., fat, tendon, bone) and are preferentially damaged.

- **PATH THROUGH BODY:**

The path the current takes through the body affects the degree of injury. A small current that passes from one extremity through the heart to the other extremity is capable of causing severe injury or electrocution. There have been many cases where an arm or leg was almost burned off when the extremity came in contact with electrical current and the current only flowed through a portion of the limb before it went out into the other conductor without going through the trunk of the body. Had the current gone through the trunk of the body, the person would almost surely have been electrocuted. A large number of serious electrical accidents in industry involve current flow from hands to feet. Since such a path involves both the heart and the lungs, results can be fatal.

- **DURATION OF SHOCK**

The duration of the shock has a great bearing on the final outcome. If the shock is of short duration, it may only be a painful experience for the person. If the level of current flow reaches the approximate ventricular fibrillation threshold of 100 mA, a shock duration of a few seconds could be fatal. This is not much current.

**b**.

Electric shock can result in anything from a slight tingling sensation to immediate cardiac arrest.

- **SHOCK.** Electric shock occurs when the human body becomes part of a path through which electrons can flow. The resulting effect on the body can be either direct or indirect.
    a. **Direct.** Injury or death can occur whenever electric current flows through the human body. Currents of less than 30 mA can result in death. A thorough coverage of the effects of electricity on the human body is contained in the section of this module entitled *Effects of Electricity on the Human Body*.
    b. **Indirect.** Although the electric current through the human body may be well below the values required to cause noticeable injury, human reaction can result in falls from ladders or scaffolds, or movement into operating machinery. Such reaction can result in serious injury or death.
- **BURNS.** Burns can result when a person touches electrical wiring or equipment that is improperly used or maintained. Typically, such burn injuries occur on the hands. Also burns are the result of the electric current flowing in the tissues, and may be either skin deep or may affect deeper layers (such as muscles and bones) or both. Tissue damage is caused by the heat generated from the current flow; if the energy delivered by the electric shock is high, the body cannot dissipate the heat, and the tissue is burned. Typically, such electrical burns are slow to heal.

- **ARC-BLAST.** Arc-blasts occur from high-amperage currents arcing through air. This abnormal current flow (arc-blast) is initiated by contact between two energized points. This contact can be caused by persons who have an accident while working on

energized components, or by equipment failure due to fatigue or abuse. Temperatures as high as 35,000F have been recorded in arc-blast research.

Effects of arc flash: Severe burns, broken bones, Vision damage, Hearing loss, Brain/internal injuries, Punctures and lacerations, Death

The three primary hazards associated with an arc-blast are:

a. **Thermal Radiation.** In most cases, the radiated thermal energy is only part of the total energy available from the arc. Numerous factors, including skin color, area of skin exposed, type of clothing have an effect on the degree of injury. Proper clothing, work distances and over current protection can improve the chances of curable burns.
b. **Pressure Wave.** A high-energy arcing fault can produce a considerable pressure wave. Research has shown that a person 2 feet away from a 25 Ka arc would experience a force of approximately 480 pounds on the front of their body. In addition, such a pressure wave can cause serious ear damage and memory loss due to mild concussions. In some instances, the pressure wave may propel the victim away from the arc-blast, reducing the exposure to the thermal energy. However, such rapid movement could also cause serious physical injury.
c. **Projectiles.** The pressure wave can propel relatively large objects over a considerable distance. In some cases, the pressure wave has sufficient force to snap the heads of 3/8 inch steel bolts and knock over ordinary construction walls. The high-energy arc also causes many of the copper and aluminum components in the electrical equipment to become molten. These "droplets" of molten metal can be propelled great distances by the pressure wave. Although these droplets cool rapidly, they can still be above temperatures capable of causing serious burns or igniting ordinary clothing at distances of 10 feet or more. In many cases, the burning effect is much worse than the injury from shrapnel effects of the droplets.

- **EXPLOSIONS.** Explosions occur when electricity provides a source of ignition for an explosive mixture in the atmosphere. Ignition can be due to overheated conductors or equipment, or normal arcing (sparking) at switch contacts. OSHA standards, the National Electrical Code and related safety standards have precise requirements for electrical systems and equipment when applied in such areas.

**FIRES.** Electricity is one of the most common causes of fire both in the home and workplace. Defective or misused electrical equipment is a major cause, with high resistance connections being one of the primary sources of ignition. High resistance connections occur where wires are improperly spliced or connected to other components such as receptacle outlets and switches.

## MODULE-4

**8. a.**

1 **Have only licensed electricians install, repair and dismantle jobsite wiring:** That way, everything will be completed according to electrical safety codes,

ensuring greater protection for the workers who will be using the wiring to power tools and equipment. Bringing in a professional electrician also prevents the injuries that result when less-qualified individuals attempt electrical jobs that they aren't properly trained to do.

2 **Always plug into a GFCI:** Ground Fault Circuit Interrupter protection is required at every plug-in point associated with your jobsite's temporary electrical supply - right down to extension cords. Make sure that only GFCI receptacles are installed, and that portable GFCIs are kept on hand in case additional grounding needs arise.

3 **Check each extension cord before use:** Ensure that insulation is completely intact (free from cracks, tears, or abrasion) and that power extension cables haven't been knotted, which can cause conductor damage and increase the risko fire

4 **Do a thorough check for electrical wiring before cutting through any wall, floor or ceiling:** Any time that a tool inadvertently makes contact with an unseen electrical line, the person holding that tool is likely to be shocked or electrocuted. Always size up the situation before you get started to reduce your risk of injury.

5 **Inspect power tools on a regular basis:** Look over the tools' power cords and plugs for any sign of damage to the insulation, blades, or grounding pin. If you find signs of excessive wear and tear, take tools out of commission until they've been properly repaired. Maintain awareness during electrical tool use as well; if a tool starts to overheat, smoke, give off a burning smell, or shock you on contact, discontinue use immediately.

6 **Check insulated tools for damage before each use:** Once the insulation layer of an insulated hand tool becomes nicked, cracked or cut, the tool is no longer effectively insulated - it actually becomes more of an electrical conductor, and can increase your risk of injury. If a tool has damaged insulation, it is no longer safe to use - destroy and replace it right away.

7 **Never modify electrical plugs:** Under no circumstances should you ever file down the blades, remove the ground pin, or otherwise modify an electrical plug so that it will fit into a socket - doing so only increases the likelihood of shock, electrocution, and fire. Either have a certified electrician change the device's plug, or replace outdated two-prong receptacles with grounded outlets that can accommodate a ground pin.

8 **Keep extension cords in a safe place where they won't be stepped on or driven over:** The force of a vehicle - or even repeated treading by pedestrians - can cause an extension cord's conductor to become misshapen or break, a problems that can lead to electrical fires. Because it occurs in the core of the

cable, conductor damage isn't always obvious to the eye, so play it safe from the start by guarding jobsite extension cords with heavy-duty cord covers.

**b.**

Basic *PPE* consists of:

- Cotton protective clothing with long sleeves
- Helmet or hard hat
- Goggles for eye protection
- Gloves (leather or rubber)
- Hearing protectors
- Safety footwear
    - Helmets normally need be worn only when working on outdoor switchgear, where they serve to protect against falling objects and collisions with solid objects at head height. Outdoor substations should always be considered ‘safety helmet’ areas and helmet wear made compulsory.
    - Hearing protectors are only required when the in a noisy situation, that can occur during construction works.
    - Eye protection should be worn when working with hazardous fluids, particularly mineral oil, to prevent splashes into the eye. They should always be worn when washing down the internal parts of oil circuit breakers.
    - Safety footwear should be routinely worn in all working areas and the shoes or boots should incorporate steel toe-cap and non slip soles.
    - Specific works require specific protective equipment.
    - Safety harness should be worn when working at any height greater than 1.5 m above ground level and a full harness equipped with a connector is preferred. Fall arrest equipment may be necessary when working at high level. Harnesses should be chosen that are suitable for their intended application and should be of a design that will support the user in the correct position. A harness should be comfortable, allowing adequate movement of the user and the unhindered operation of other devices within the system.
    - Depending on the conditions of the work a sit harnesses may be necessary; sit harness has lateral and central attachment points and are designed primarily to be used for work in suspension, although they may also be used for work restraint purposes.
    - Respirators can also be necessary when a leakage of *SF6* is suspected. Although *SF6* is not toxic, it degrades under the heat of arcing to gases.
    - When performing energized works *or* switching operations insulated gloves and dielectric shoes are required.

PPE for Arc Flash

When a risk of arc flash exists, the selection of *PPE* and its characteristics can be done as a consequence of the calculation of the incident arc energy or consulting a hazard category classification table, being one of those tables can be found at *NFPA* (National Fire Protection Association) .

Protective equipment for arc flash, as shown in Figure 3 consists of:

- Flame resistant protective clothing
- Arc Flash protection hood
- Hard hat
- Safety glasses
- Gloves

**MODULE-4**

**9. a.**

Airborne contaminants: Exposure to substances or mixtures in the workplace can occur through inhalation, absorption through the skin or ingestion. Most exposure occurs through the inhalation of vapours, dusts, fumes or gases. For some chemicals, absorption through the skin may also be a main source of exposure.

Asbestos: Asbestos is a naturally occurring, fibrous silicate mineral. Exposure to asbestos fibres in the air can cause a range of lung diseases and diseases of related tissue, including asbestosis and mesothelioma, a form of cancer which is usually fatal.

Hazardous Chemicals: Hazardous chemicals in the workplace are substances, mixtures and materials that are classified according to their health and physicochemical risks and dangers. Hazards include skin irritants, carcinogens or respiratory sensitisers that have an adverse effect on a worker's health as a result of direct contact with or exposure to the chemical, usually through inhalation, skin contact or ingestion. Physicochemical hazards generally result from a substance's physical and chemical properties, as is the case with flammable, corrosive, oxidising or explosive substances.

Lead Risk Work: Work that involves the potential exposure to lead is regulated due to the potential long-term harmful effects that can occur at relatively low exposures to lead compounds. Lead risk work occurs when the blood lead level of a worker involved in a lead process might reasonably be expected to rise above 1.45 µmol/L (30 µg/dL) or 10 µg/dL (0.48 µmol/L) for a female worker of reproductive capacity.

Major Hazard Facilities: Major Hazard Facilities (MHFs) are sites that store, handle and process large quantities of hazardous chemicals and dangerous goods, including explosives that exceed specified threshold quantities. Examples include:

- chemical manufacturing
- gas processing plants
- LPG storage and distribution facilities
- Some warehouses and transport depots.

Spray painting and powder coating: Substances viewed as hazardous with spray painting are paints, solvents, lead, powders, lacquers, paint removers, resins, adhesives, degreasers, surface preparation products, rust converters, rust removers and dust. Many hazards include but aren't limited to; chemical exposure, fire and explosions, confined spaces, machinery and equipment, working at heights, manual tasks, electricity or static electricity, heat or high humidity and noise.

**b.**

- Lab coat, safety glasses/goggles and shoes are a minimum requirement for working inside labs.
- Open toed footwear must not be used in the lab, as it will not offer protection in case of a chemical spill.
- Personal protective equipment in addition to those mentioned above must be used based on the hazards involved in the task being carried out.
- While selecting the personal protective equipment the following points must be kept in mind. Must be appropriate to the hazards of the job being done.
- Must properly fit the user and be comfortable to use.
- Regularly maintained and replaced as per the manufacturer's recommendation.
- If reusable must be properly cleaned and disinfected.
- After use the personal protective equipment must be stored away from the work area at a designated place to prevent contamination and damage.

- All personal protective equipment must conform to relevant Indian or International Standards (European Union/American National Standards Institute). The standard number will be specified on the equipment.
- Never use damaged personal protective equipment.

**10. a.**

Chemicals when transferred to secondary bottles/cans must be provided with proper labels. Chemical formulae or short forms must not be used for labelling of the containers. The label must contain

- the full name of the chemical,
- its hazards,
- information for safe handling and
- the signage/pictogram indicating the hazard class.

Labels of bottles which got deteriorated or worn off must be replaced immediately. Chemical bottles without labels or improper labeling can result in the wrong chemical being used.

Further it will also cause difficulty in case of a spill or body contact or at the time of disposal of the chemical. The Lab Standard requires that all chemicals be labeled. If you transfer a chemical from the original container to a new container, you need to also label that new container with the name of the chemical. This is very important because in the event of an emergency you need to know the exact chemical name or chemical formulation you are working with so that you will know which MSDS to consult.

Containers must be labeled with:

- Chemical name
- Manufacturer's name
- Health hazards
- Physical hazards
- Long & short term health effects

For frequently used chemicals, you can create your own labels for secondary containers using

a word processing program and standard labels so that you can print them out as they are needed. All hazardous chemicals must be clearly labelled for the benefit of current users, emergency personnel, and future users. Unknown chemicals can be expensive to dispose of. Make sure all labels are legible and in good condition. Repair or replace damaged or missing labels. Manufacturers' Labels Cal/OSHA requires that manufacturers provide labels with the following information:

- Contents of the container
- Physical and health hazard information
- Name, address, and emergency phone number of the manufacturer or other responsible party
- Original manufacturers' labels must not be removed or defaced. Material Safety Data Sheets (MSDSs) must be accessible to anyone working with these chemicals.

**b.**

Compressed natural gases can be hazardous because each cylinder contains large amounts of energy and may also have high flammability and toxicity potential. The following is a list of recommendations for storage, maintenance, and handling of compressed gas cylinders:

- Make sure the contents of the compressed gas cylinder are clearly stenciled or stamped on the cylinder or on a durable label.

- Do not identify a gas cylinder by the manufacturer's color code.
- Never use cylinders with missing or unreadable labels.
- Check all cylinders for damage before use.
- Be familiar with the properties and hazards of the gas in the cylinder before using.
- Wear appropriate protective eyewear when handling or using compressed gases.
- Use the proper regulator for each gas cylinder.
- Do not tamper with or attempt to repair a gas cylinder regulator.
- Never lubricate, modify, or force cylinder valves.
- Open valves slowly using only wrenches or tools provided by the cylinder supplier directing the cylinder opening away from people.
- Check for leaks around the valve and handle using a soap solution, "snoop" liquid, or an electronic leak detector.
- Close valves and relieve pressure on cylinder regulators when cylinders are not in use.
- Label empty cylinders "EMPTY" or "MT" and date the tag; treat in the same manner that you would if it were full.
- Always attach valve safety caps when storing or moving cylinders.
- Transport cylinders with an approved cart with a safety chain; never move or roll gas cylinders by hand.
- Securely attach all gas cylinders (empty or full) to a wall or laboratory bench with a clamp or chain, or secure in a metal base in an upright position.
- Store cylinders by gas type, separating oxidizing gases from flammable gases by either 20 feet or a 30-minute firewall that is 5 feet high.
- Store gas cylinders in cool, dry, well-ventilated areas away from incompatible materials and ignition sources.
- Do not subject any part of a cylinder to a temperature higher than 125 °F or below 50 °F.
- Store empty cylinders separately from full cylinders.