FIRE

Technical explanation for fire is naturally occurring energy release in the form of heat and light when oxygen combines with a combustible or burnable material at a suitable high temperature. Three things must be present at the same time in order to produce fire.

i. Enough oxygen to sustain combustion.
ii. Enough heat to raise the material to its ignition temperature.
iii. Some sort of fuel or combustible material.

Fire or combustion is a chemical reaction between Oxygen and combustible fuel. It is a process by which fire converts fuel & Oxygen in to energy usually in the form of heat, by products of combustion includes light and smoke. For the reaction to start a source of ignition such as a spark or open flame or a sufficiently high temperature is needed.

Fire is a chain reaction, for combustion to continue these must be a constant source of fuel, Oxygen & heat which are in intimate contact with each other. This is explained by the fire triangle.

Fig: Fire Triangle

All chemical reaction involve forming and breaking of chemical bonds between atoms. In the process of combustion materials are broken down into basic elements, loose atoms forms bonds with each other to create molecules of substances that were not originally present. Therefore during burning deadly fumes are generated due to melting of plastics or synthetic polymers.

Remove the fires access to fuel or remove the Oxygen & fire dies. Although a spark may start a fire but the heat produced during fire is necessary to sustain it. Therefore, a fire may be put out by removing the fuel source starting it of Oxygen or cooling it below the combustion point. Even in Oxygen rich environment, fire can be avoided by controlling heat and breaking the bond between three elements of fire which is shown below in figure by broken triangle.

Fig: Broken Triangle.

CLASSES OR TYPES OF FIRE

There are six different types of fire classes which are based on the energy source that has caused them. Classifying a fire according to its energy source also makes it easier to choose the most appropriate method of fighting the fire. The classes of fire area as follows:

Class A – Ordinary combustible fires

Materials involved in these types of fires include paper, wood, textiles, rubber, some plastics and other organic carbon-based compounds.

Class A fires can be extinguished using appliances and fire extinguishers that spray water. The water cools the fire, removing the heat supply which is essential for the fire to burn.

Class B – Flammable liquids

Examples of liquids that are flammable include petrol, kerosene, alcohol, solvents and paints. Fires involving these volatile chemicals burn at a very high temperature give lots of heat and often spread quickly. These fires also produce toxic smoke and fumes, which can make situations involving these types of risks very difficult to control.

Class C – Flammable gases

Commercial premises used to store flammable gases such as butane, propane and petroleum gases can be very dangerous. Even a single spark has the potential to create an explosion consequently there are many laws to ensure flammable gases are stored securely in sealed containers and many insurers insist on having additional gas detection systems installed to provide an early signs of gas leakage.

Fires involving flammable gases are one of the hardest fires to put out as it can be hard to isolate the source of leakage and stop the release of gas or flammable liquid.

Class D – Metal fires

It requires a lot of heat to ignite most metals, but metals are good conductors and transfer heat away quickly to their surroundings so can be the cause of a fire. Powdered metals and metal shavings are easier to ignite than solid lumps of metal and therefore a much higher fire risk.

Standard fire extinguishers will not put out a class D fire and, if used on this type of risk, will almost certainly make the situation worse.

Class E – Electrical fires

Electrical fires can be caused by faulty equipment, damaged wiring, short circuits, and overloaded switchboards and sockets. Although electrical fires are not strictly a fire class of their own, electricity is classed as a source of ignition and has its own special fire safety requirements.

You should never try to extinguish a fire caused by electricity using water or foam as this acts as a conduit and could electrocute the person holding the appliance.

Class F – Cooking oil fires

Class F fires involve cooking oil and fats. These ignite at very high temperatures making them difficult to extinguish.

Standard fire extinguishers will not put out a class F fire and, if used on this type of risk, will almost certainly make the situation worse.

IDENTIFICATION OF FIRE

The national fire protection association (NFPA) has devised a system NFPA 704 for the quick identification of hazards presented when substances work, NFPA'S Red, Blue, Yellow & White diamond is used on the product labels & shipping cartons rating within each category are 0-4, where 0 represents no hazard, 4 represents most sever hazard.

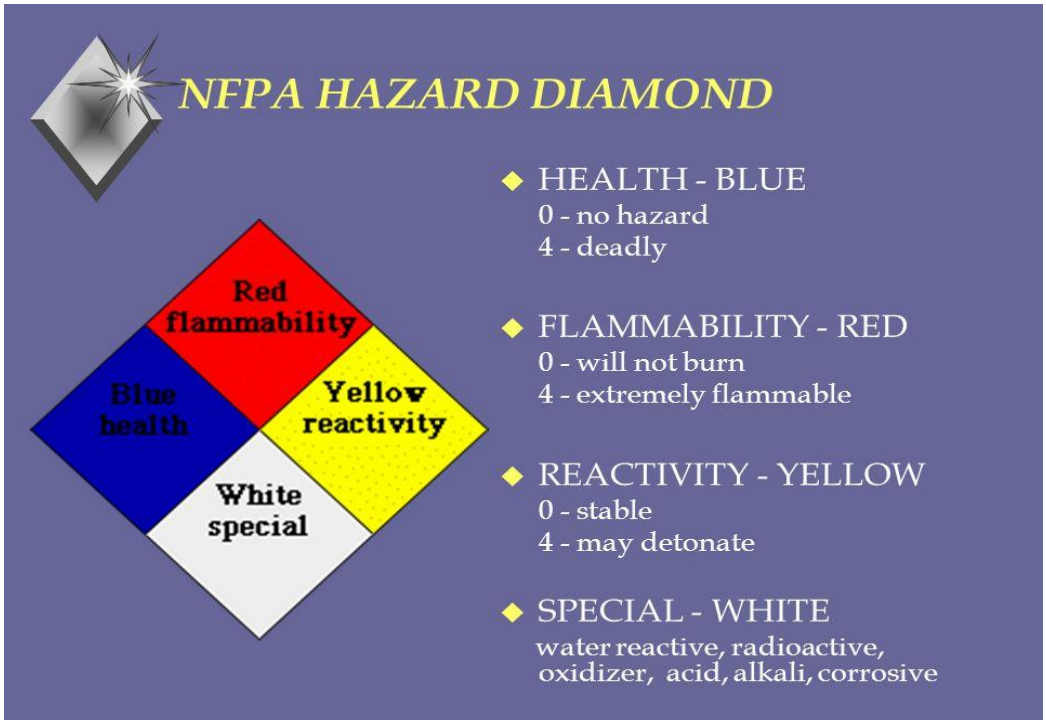

Fig: NFPA Hazard Diamond

1. Flammability has a red background & is the top quarter (1/4) of the diamond
   0 means no hazard; materials are stable during fires which do not react with water
   1- Slight hard, flash point well above normal ambient temperature.
   2- Moderate hazard, Flash point well above normal ambient temperature.
   3- Extreme Fire hazard, Gases or liquids can ignite at normal temperature..
   4- Extremely hazard flammable gases or liquids with very low flash point.
2. Health has a blue background & is the left quarter (1/4) of the diamond.
   0- No threat to health
   1- Slight health hazard respirator may be recommended.
   2- Moderate health hazard, respirator & high protection is required.
   3- Extremely dangerous to health, protective clothing's, Equipments is required.
   4- Eminent danger to health, Breathing or skin absorption may cause death. A fully encapsulating sooth is required.
3. Reactivity has a yellow background & the right Quarter of the diamond.
   0- No hazard
   1- Slight hazard material can become unstable at high temperature or react with water.

2- Moderate hazard material may undergo violent reaction that will not explode.
3- Extreme hazard material may explode if an ignition source is given/ violently react with water.
4- Constant extreme hazard materials may undergo other hazardous reaction on their own.

4. Special information has a white background & is the bottom quarter of the diamond. This area is used to note any special hazard presented by the material.

FIRE DEVELOPMENT: SEVERITY & DURATION

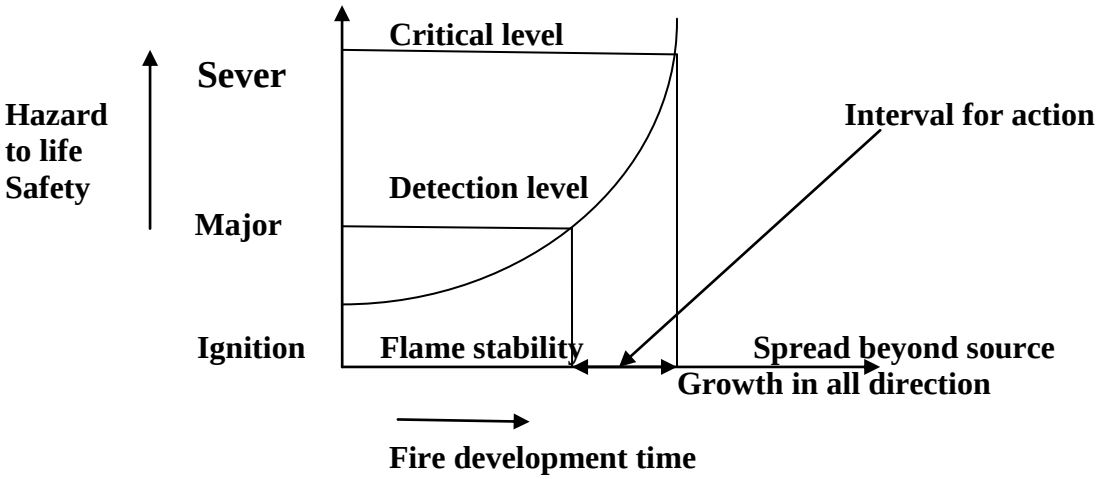

Fig: General Effects of Fire Development on Hazards to Life Safety

The protection of life is of primary importance in fire situation & therefore aware of the hazards & its development, fire developed over time & the environment detritions as smoke & heat build up to endanger life.
Initially, when fuel, Oxygen and heat combine there is little or no hazard when ignition occur, fires develops slowly & the rate of hazard increases as the fire develops.
The figure shows the general effect of fire development on hazards to life safety; from the figure we can say that there is a time interval between the first detection & the critical level of fire development which represents hazards to life cycle. All actions to preserve life safety must be undertaken in this interval to time.
Ignition: The ignition source along with the fuel first ignited will determine the initial fire development, the ignition source dependent on the fuel & presence of flammable vapors in the right mixtures.

Flames spread: Flame spreads along the surface of the original fuel which was ignited depends on the properties of the fuel & the supply of Oxygen. The moving flame heats adjacent un-burnt fuel, adding more flammable vapors & increasing the flame sites. In general flame spreads faster upwards than reduce little horizontally or downward due to heating by the combustion products flowing upwards & outwards from the fire.

THE EFFECTS OF ENCLOSURE

Once the fire is been started it spread beyond the source is determined by the enclosure within the building. In larger fire, the effect of enclosure will become a important factor as it controls the Oxygen source and it traps all combustion gases in the upper portion of the room. This is a result of heat transfer under fire conditions. Heat must be transferred to other materials for the fire to spread and takes place by convection, conduction or radiation.

Convection is the movement of heat by hot gases, conduction the transfer of heat through a material from hot to cold area and radiation is transfer of heat by electromagnetic waves from a source to a solid within line of site with the source.

When a fire is contained within a room where Oxygen supply is adequate, the fire will continue to grow until all the fuel is consumed, such a fire which is limited by amount of fuel is called fuel controlled fire. When all fuel is burning, but is slowed because it becomes starved of Oxygen then it is called ventilation controlled fire.

EARLY DETECTION OF FIRE

Life safety is the major concern in fire protection. From various examinations it is clear that life safety through early detection is the best way.

Detection permits fires to be extinguished easily and results in less damage to property. There are many types of detection system, these systems can warm off the pressure of smoke, radiation, elevated temp or increased light intensity.

The Four important fire detection systems are as follows:

1. **Thermal expansion detector**
   Use a heat sensitive metal link that melts at a predetermined temperature that make contact and ultimately sound an alarm or heat sensitive instrument can be used which will melt in a predetermined temperature there by initiating short circuit and activating the alarm.
2. **Photo electric fire sensors**
   It detects changes in infrared energy that is radiated by smoke, often by the smoke particles obscuring the photo electric beam. A relay is open under acceptable conditions and closed to complete the alarm circuit when smoke interferes.
3. **Radiation or ionization sensors**
   It losses the tendency of a radioactive substance to ionize when exposed to smoke. The substance becomes electrically conductive with smoke exposures and permits the alarm circuit to be completed.

4. **UV or infrared detectors**
   It sounds an alarm when the radiation from fire flames is detected. When rapid changes in radiation intensity and gives alarm signal.

REDUCING FIRE HAZARD

The best way to reduce fire is to prevent their occurrence.

- One means of reducing fire hazard is the isolation of triangle elements of fire.
- Fire may also be prevented by the proper storage of flammable liquids. Liquids should be stored in flame resistant buildings that are isolated from places where people work or in tanks below ground level or on the first floor of multi storage building.
- Substituting less flammable materials is another effective technique for fire reduction.
- A catalyst or fire inhibitors are employed to create an endothermic energy that will smother the fire.
- Several ignition sources can be eliminated or isolated from fuels. Smoking should be prohibited near any possible fuels; electrical spark from equipments, wiring and lighting should not be close to fuel, open flames should be kept separate from fuels, use of non sparking equipments has to be encouraged.
- Other strategies for reducing the risk of fires are as follows:
  - Clean up spills of flammable liquids as soon as they occur and properly dispose of the materials used in the clean up.
  - Keep work areas free from extra supplies of flammable materials, place electrical cords along wall rather than across.
  - Turn off the power and completely de-energize the equipment before conducting maintenance procedures.
  - Routine the test fire extinguishers.

FIRE EXTINGUISHERS

A fire extinguisher is an active fire protection device used to extinguish or control small fires, often in emergency situations. It is not intended for use on an out-of-control fire, such as one which has reached the ceiling, endangers the user (i.e., no escape route, smoke, explosion hazard, etc.), or otherwise requires the expertise of a fire department. Typically, a fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent which can be discharged to extinguish a fire.

The types of extinguishing agents how they function and how they can be distributed are summarized in below table.

Table: Types of extinguishing agents with mechanism and method of distribution for different class of fire

Extinguishing agents	Types of fire used for	Mechanism for extinguishment	Method of distribution	Problems encountered
Water	A, B, D	Cooling (heat absorbed in vaporization) smothering, emulsification, dilution	Automatic sprinklers, hose system	Freezing and pipe bursts in unheated areas
Carbon-di-oxide	C, A, B, D	Smothering, cooling	Portable extinguishers, total flooding	Re-ignition after dissipation
Halogenated agents (HALONS)	C, A, B, D	Chain breaking (chemical reaction which interferes with combustion)	Automatic sprinklers, Portable extinguishers	Toxic
Dry chemicals	A, B, C	Chain breaking, Smothering, cooling, radiation shielding	Automatic sprinklers, Portable extinguishers	
Foams	A, B, D	Smothering	Portable extinguishers, hose system	Horizontal fires only
Combustible metal agents	D	Smothering, cooling	Spread by hand Portable extinguishers	Expensive

TYPES OF FIRE EXTINGUISHERS

To deal with the multitude of different fire classes, a range of fire extinguishers have been developed. Types of fire extinguishers are as follows:

1. Water type fire extinguisher.
2. Foam type fire extinguisher.
3. Dry chemicals type fire extinguisher.
4. Carbon-di-oxide type fire extinguisher.
5. Halon type fire extinguisher.

1. WATER TYPE FIRE EXTINGUISHER

Water expelling fire extinguishers have water as an extinguishing agent which is released in the form of a jet by means of gas pressure in the upper part of the container. The gas pressure may be induced by chemical reaction or by mechanical means. Water expelling fire extinguishers is as shown in figure, are used mainly in Class 'A' fire, water when applied to burning material is converted to steam which reduces the percentage of available oxygen. Water expelling type extinguishers should not be used on fires involving electrical equipment without de- energing them.

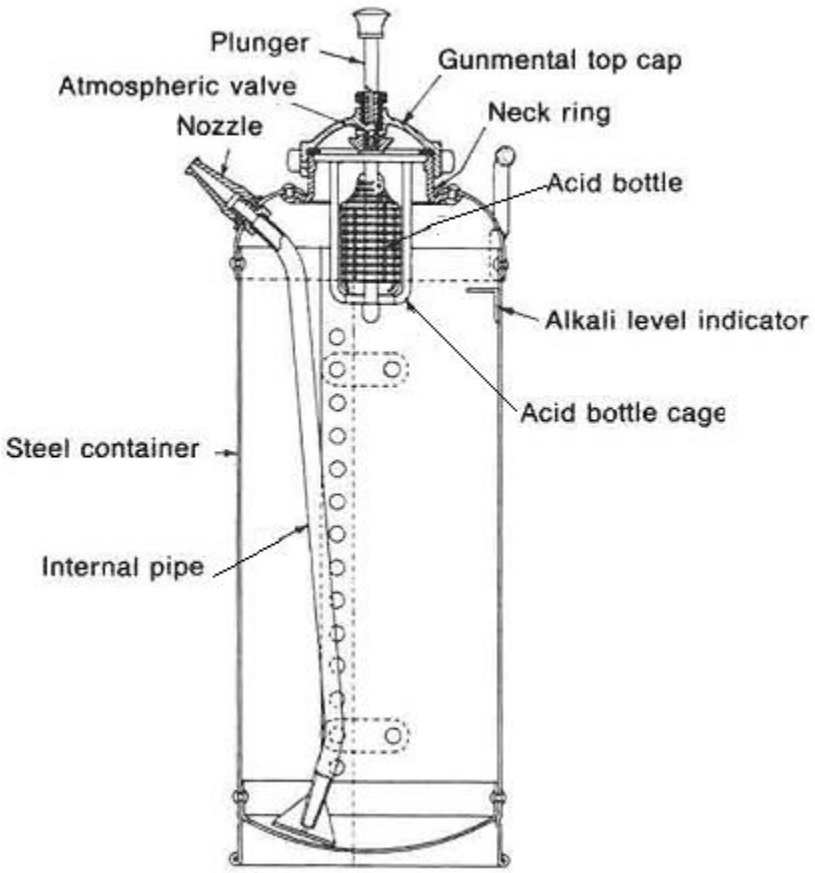

Fig: Water Type Fire Extinguisher

The various types of water expelling extinguishers are:

i. Soda acid type.
ii. Gas pressure activated type.
iii. Constant air pressure type.

SODA ACID EXTINGUISHER

The operational instructions given on the body of the extinguisher should be read carefully .It should be ascertained whether it is of upright of turnover type. To operate the extinguisher, remove the cap and strike the plunger, direct the jet emerging from the nozzle on the fire.

WORKING PRINCIPLE

When the plunger is struck, it breaks the acid phial (bottle).The sulphuric acid and sodium bicarbonate solution react together to release CO_2. The CO_2 generated creates pressure which forces the water out of extinguisher. The CO_2 acts only as a propellant and the water extinguishes the fire by cooling effect.

GAS PRESSURE TYPE

The gas pressure type essentially has an outer container similar to that of the soda acid type. There is gas cartridge filled with CO_2 under pressure which forms the inner compartment. When the cartridge is priced open, CO_2 under pressure is released into the body of extinguisher driving water out through the discharge tube.

CONSTANT AIR PRESSURE TYPE

The constant air pressure type extinguisher is filled with water and dry air is introduced through air lines till the desire pressure is built up. When air lines are removed, the container is hermetically sealed. While activation safety pin is withdrawn and valve lever is depressed resulting in a jet of water through the hose, duration of discharge is 90 seconds to 120 seconds, effective jet length is 6m.

2. FOAM TYPE FIRE EXTINGUISHER

Foam type fire extinguisher is as shown in figure; this type is suited for class B fires. The foam expelled by actuating the extinguisher forms a blanket over the surface of the liquid on fire and gets over the contact of the burning liquid with air thus extinguishing the fire.

OPERATION

- Remove the extinguisher from the socket.
- Pull the plunger, rest it on the notch and turn the extinguisher over shaking well to ensure the mixing of the two liquids.
- Direct the foam jet above the level of turning liquid. This allows the foam to build up over the surface of the liquid. The jet from the foam extinguisher should have a length of atleast 6 m.

- Do not direct the jet directly into the liquid because this will drive the foam beneath the surface and render it ineffective. In addition it may splash burning liquid on to the surrounding and spread the fire.

Foam solution is electrically conductive and therefore is not recommended for use on electrical fires.

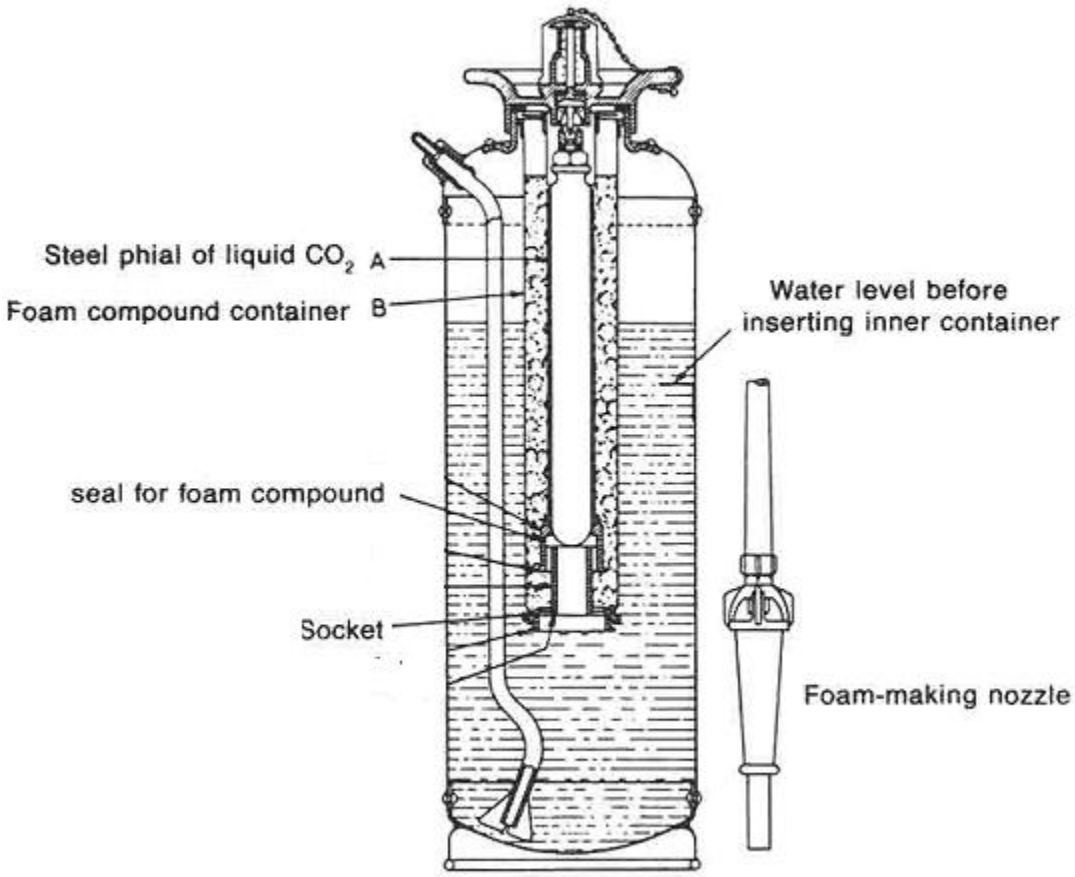

Fig: Foam type fire extinguisher

3. DRY CHEMICALS TYPE FIRE EXTINGUISHER

Dry chemicals type fire extinguisher is as shown in figure, this type is suitable for tracking gas fire, fires is electrical equipment. The chemical powder employed is usually sodium based and when applied to a fire undergoes chemical reaction. The free radicals which are responsible for sustaining any fire are put out of action by the dry chemical powders and because of this, the fire dies out very fast. Chemical dry powders containing mixtures of sodium, potassium and barium compounds have been found useful in extinguishing fires in metals such as sodium and magnesium.

The chemical powder is contained in the main shell and CO_2 gas is held under high pressure in a sealed cartridge. When the extinguisher is operated, the cartridge is broken allowing CO_2 gas to escape to the main shell and push out the powder in the form of fog.

OPERATION

Carry the extinguisher to the place of fire and keep it upright. Remove the safety clip and strike the knob located in the cap to activate the piercing mechanism which in turn breaks the sealing disc of the cartridge. Direct the stream of escaping powder at the base of the flame. For effective result stand about 5 to 8 feet away and direct the stream near the seat of the fire, progress forward, moving the nozzle rapidly with a side to side sweeping motion. When using on outdoor fires always operate extinguisher from the upwind side for the fire.

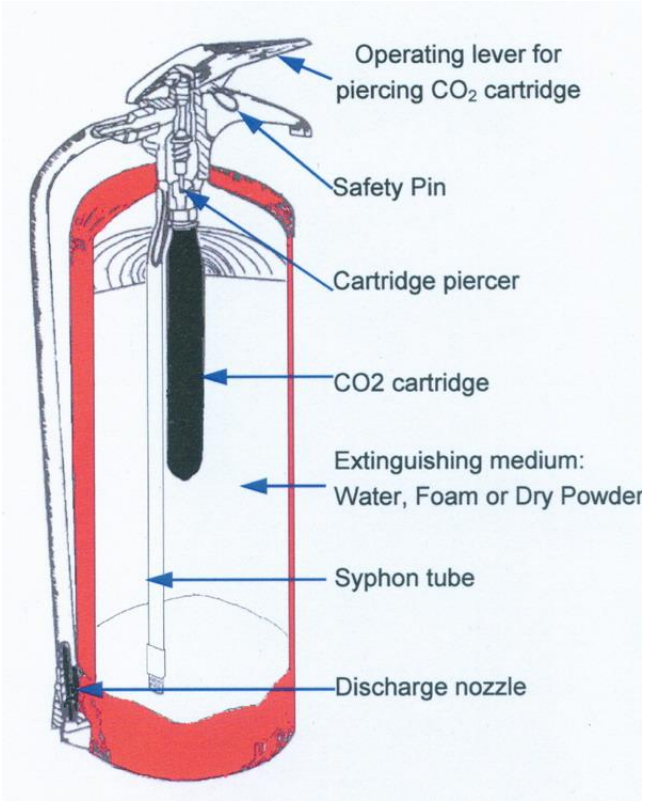

Fig: Dry chemicals type fire extinguisher

4. CARBON-DI-OXIDE TYPE FIRE EXTINGUISHER.

Carbon-di-oxide type fire extinguisher is as shown in figure; CO_2 is effective as an extinguishing agent primarily because it reduces the oxygen content of air to a point where combustion cannot continue. CO_2 is non-combustible and does not react with most substances. Being a gas it can penetrate and spread to all areas affected by fires.

Carbon-di-oxide fire extinguishers are used for putting out fires in petroleum products, gaseous substances under pressure and also in sophisticated electrical and electronic apparatus. Carbon-di-oxide extinguishers are not to be used in

- Fires involving chemicals that contain their own oxygen supply.
- Fires involving reactive metals such as sodium, potassium and magnesium.

OPERATION

Carry the extinguisher to the place of fire. Remove the safety pin and operate the discharge device or unscrew the valve depending on the design. CO_2 is delivered by means of discharging horn through a high pressure flexible hose. Direct the jet at the base of fire, starting at one edge and sweeping across the surface of the burning material. When used in open air, the operator should stand on the up-wind side of the fire and should apply the gas in a downwind direction as close as possible to the fire. On fires in electrical equipment first switch off the current then direct the jet or horn straight at the fire.

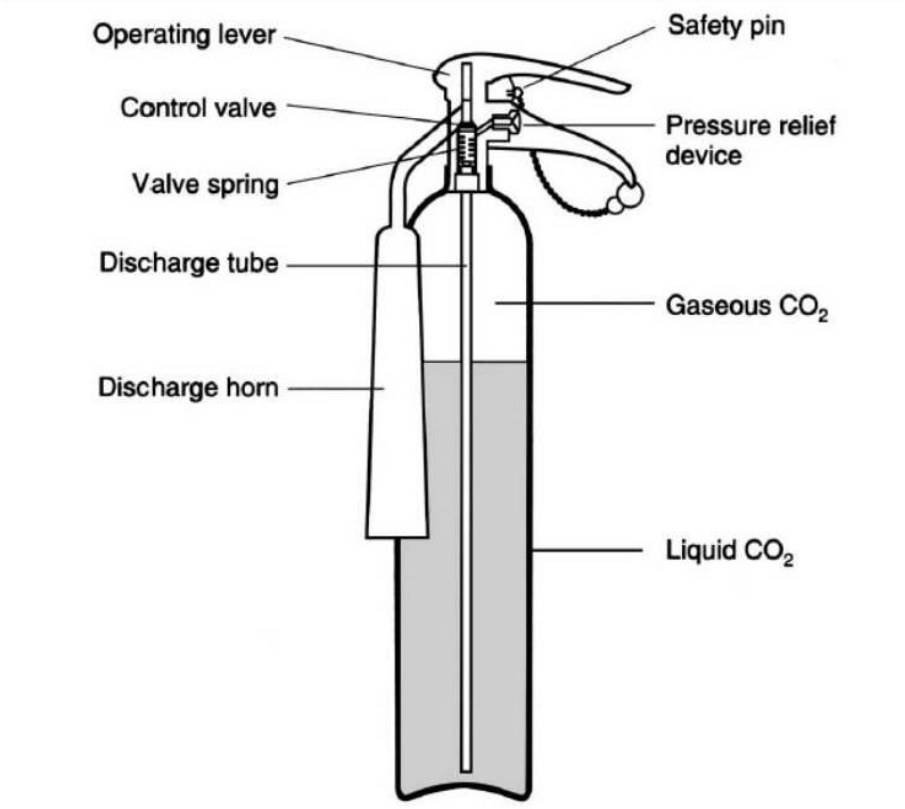

Fig: Carbon-di-oxide type fire extinguisher

5. HALON TYPE FIRE EXTINGUISHER

Halon is the most effective extinguishing agent than any other extinguishing agent. It is ideal for intense and rapid flammable fires. Halon is non-conductive and leaves no traces, when applied. So it is also suitable for electrical fires, computer rooms etc. Halon extinguishing the fire by interrupting the chain reactions which takes place at the flame zone for continuance of fire. Halon is twice as effective as carbon-di-oxide on a weight basis and five times as effective as carbon-di-oxide on volume basis.

OPERATION

Carry the extinguisher to the place of fire, remove the safety pin and operate the discharge device. Halon is discharged by means of the discharge nozzle or hose. When operated it is discharged as a semiliquid jet at a high velocity and evaporate rapidly to cover a fire in a blanket of mist. The halogenated extinguishing agents are known as Halons. Halogenated extinguishing agents are hydrogen in which one or more hydrogen atoms have been replaced by atoms from the halogen series i.e., fluorine, chlorine, bromine and iodine. There are many halogenated but only two are most effective and less toxic. They are Halons 1301nand Halon 1211.

ELECTRICAL SAFETY

Electrical faults ranks highly, along with careless smoking, heating and cooking. Electrical causes include distribution wiring, appliances and portable tools and other electrical processes which produce ignition sources such as welding. Fire can be ignited by over heating or by sparks created by arcing.

Electrical equipment's operate because electrical energy flows through a circuit. The potential of energy of circuit that is voltage is given by the relation.

$$E= IR$$

Where E is voltage or potential (in volts), I is the current measured in amperes, and R is resistance measured in ohms. The power P in any circuit is measured in watts and is given by the relation:

$$P=IE$$

$$P=I^2E$$

Heat is generated within the wires of circuit when current flows and can be described by the relation

$$H=I^2Rt$$

Where, t = time

All materials conduct electricity if the conditions are right. Resistance is important while determining the effects of electricity. It is the current which injures people in contact with electricity.

The hazards of electrical appliances is due to resistance of our skin for conduction of current, once skin resistance is over come current flows readily through blood and body tissues the effect can vary from slight sensations through painful muscle contractions, burns and death. Death can result from asphyxiation caused by respiratory interference either from muscular contraction or paralysis of central nerves system and affect the heart. Electrical burns are usually deep very painful and slow to heat.

SAFE ELECTRICAL CIRCUITS

The consequences of electrical hazard are fire and injuries; the engineering methods with which electrical consequences control are also different. The equipment can be protected by eliminating fires and protect people by over load protecting and by grounding. Over load protection includes fuses or circuit breakers which trip at predetermined current load by de-energizing the circuit before damage can occur. There are many instances where the grounds are improperly installed or fault does not lead to current overload, thus leading to raise voltage which causes extreme hazards to personnel, so for this reason GFCI (ground fault circuit interrupters) are required that provides better personnel protection.

PRODUCT SAFETY

A quality product is one that meets or exceeds customer standards and expectations. Product safety is intimately associated with consumers. Therefore safety of the consumers from faulty product is very much important, for this purpose product liability law was introduced. According to this law one who sells any product in a effective condition and unreasonably dangerous to the users or consumers or to his property is subjected to liability.

As product liability law was developing a parallel increasing of public concern for the safety was also developed, this has lead to the passage of consumers product safety act (CPSA) in 1972, the purpose of the act are:

- To protect public against unreasonable risks of injury associated with consumer problem.
- To assist consumer in evaluating the comparative safety of consumer products.
- To promote research and investigation into the causes and prevention of product related death, illness and injuries.

Technical requirement of product safety program

The product safety program is carried out in five steps:

1. Design review.
2. Documentation & change Control.
3. Purchase product control.
4. Manufacturing & quality control.
5. Packaging & Marketing.

1. Design review

Products design is rarely the effort of a single individual; rather, the process of development involves a wide range of technical & Managerial skills. This product design process is divided into 3 stages conceptual Stage, intermediate Stage, and the final preproduction stage.

Stage	Tasks to be considered
*Conceptual stage	Function performance features cost to produce, life expectancy, environment for use, special characteristics such as safety, instructions.
*Intermediate stage	Preparation of layouts, electrical schematics specifications and needs of initial tooling.
*Final preproduction stage	Detailed schematics & drawings with tolerances, materials, manufacturing processes.

The consumer product safety commission (CPSC) suggests that persons representing production, quality control, consumer services & management personnel comprise the design review committee. This committee addresses product design safety which also takes preliminary hazard analysis (PHA) into account. Once PHA has been completed then the beginning of the formal design review process takes place.

2. Documentation & Change control

Accounting is a financial documentation essential for effective management. Technical record keeping is necessary for effective management. Records of product development have to be produced in litigation matters, when specifically requested & can be used as evidence.

Any changes in design, production & distribution have to be controlled & incorporated into all documentation. It is particularly important that drawing manufacturing changes quality control tests & inspections be current with the design.

3. Purchase product control

The control of the quality of purchased parts is equally important to the quality control of the final product. It is necessary, therefore, that control over vendors to a degree consistent with the potential safety impact of the parts they supply. This control is often over the purchase specifications, which may include dimensions and tolerances or might be related to material properties. The CPSC has established some purchase product control actions which is applicable as follows:

1. Purchased documents should be clear & concise with respect to design material & safety specifications.
2. Select proven vendors.
3. Verify conformance of supplies to contractual requirements.
4. Attend to promote corrective action when necessary.
5. Agreement on responsibility of suppliers for reporting hazards to the manufacturers.

4. Manufacturing & quality control

Concern for manufacturing safe products is not different from safely manufacturing products. This considers the task, the machinery & the worker. Machinery and procedures should confirm to all safety regulations & workers should be certified for critical tasks such as welding or brazing.

Equal interest should be given in detecting any manufacturing defects to prevent user injury. Whereas designed defects can affect the safety of all the units of a product. In order to prevent manufacturing defects, incorporate quality control procedures. Such procedures include various inspection and testing procedures, selected depending on the nature of the specific product & based upon random sample test procedure & statistical analysis of results. Analyze the test result fairly with respect to user safety.

5. Packaging & Marketing

Packaging is normally thought of as the protection for products during shipment. Packaging also includes instructions for assembly use & maintenance. In most cases packaging can be important as there are some instructions & warnings. These arise as a duty to warn of hazards which cannot be eliminated or reduced, but the product is desirable for societal needs.

QUESTION BANK

1. Define fire and explain various types of fire.
2. Classify the different types of fires and list the causes for each type of fire.
3. Name the different types of fire based on fuel and also list different types of fire extinguisher for dousing the fire.
4. What are fire extinguishers? List various fire extinguishing techniques and explain any two of them.
5. Define product safety. Give the technical requirements for product safety.
6. Write a note:
   i. Fire development and its severity.
   ii. Effects of enclosures.
   iii. Early detection of fire.
   iv. Electrical safety.