



Gujarat State Institute for Fire Safety  
Training (GSIFST)

## **Basic Course in Fire Prevention, Life Safety & Fire Protection Measures in Buildings**

**Category - Fire Safety Officer – General  
(FSO-G)**

**Participant's Workbook**

Gujarat State Fire Prevention Services  
Gandhinagar, Gujarat (India)





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**Participant's Workbook**

**Handbook Developed & Designed by:**



**Gujarat Institute of Disaster Management  
Gujarat, India.**







## Acknowledgement

In order to organize conscious, planned and determined efforts in order to improve fire prevention, life safety and fire protection measures in the buildings/ premises, Government of Gujarat under the able leadership of Hon'ble Chief Minister Shri Vijay Rupani took a significant decision to introduce an online citizen friendly end to end solution i.e. 'Gujarat Fire Safety Compliance Portal (Guj Fire Safety CoP)'. The portal is a landmark initiative of the Government of Gujarat which aims at strengthening the fire-safety framework across the state. Adequate training to the Fire Safety Officers (FSO) is one of the components under this initiative and a handbook on 'Basic Course in Fire Prevention, Life Safety & Fire Protection Measures in Buildings' is one of the outcome documents.

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**Principal**  
**Gujarat State Institute for**  
**Fire Safety Training (GSIFST)**



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## Abbreviation

SHALL	Indicates provision that is mandatory in nature
SHOULD	Indicates provision is recommendatory as per good Engineering practice
DCP	Dry Chemical Powder
MAP	Mono ammonium phosphate (Dry chemical powder)
DG	Diesel Generator
BIS	Bureau of Indian Standard
IS	Indian Standard
BIS	Bureau of Indian Standard, INDIA
HIRA	Hazard Identification and Risk Assessment
HSE	Health, Safety and Environment
ISO	International Organization for Standardization
TAC	Tariff Advisory Committee
MCP	Manual Call Point
NFPA	National Fire Protection Association, USA
PSV	Pressure Safety Valve
CO2	Carbon Dioxide
FAP	Fire Alarm Panel
MVWS	Medium Velocity Water Spray System
HVWS	High Velocity Water Spray System
FESH	Fire Escape Single Hydrant
QBD	Quartzoid Bulb Detector
SD	Smoke Detector
HD	Heat Detector
FP	Flash Point
FD	Flame Detector
MOC	Material of Construction
AFFF	Aqueous Film Forming Foam
GFR	Gujarat Factory Rule, 1963
TAC - FPM	Tariff Advisory Committee - Fire Protection Manual
OISD	Oil Industry Safety Directorate
FSO	Fire Safety Officer
NBC	National Building Code, 2016
FSPA	Fire Safety Plan Approval
FSC	Fire Safety Certificate
FSCR	Fire Safety certificate Renewal
FSCRn	Fire Safety certificate Regularization
RFO	Regional Fire Officer
CFO	Chief Fire Officer



## Terminology (As per National Building code – Part 4, 2016)

**Automatic Fire Detection and Alarm System:** A system comprising components and sub-systems required for automatically detecting smoke, heat or fire initiating an alarm and other actions as appropriate. This system also includes manually operated electronic fire alarm (MOEFA) system. NOTE — MOEFA system (with or without automatic fire detection and alarm system) includes all or some of the components such as manual call stations (initiating an alarm for fire and other actions as required), talk-back system and public address system.

**Building:** Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, Veranda, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents, Shamianahs, tarpaulin shelters, etc. erected for temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

**Down-comer:** An arrangement of firefighting within the building by means of down-comer pipe connected to terrace tank through terrace pump, gate valve and non-return valve and having mains not less than 100 mm internal diameter with landing valves on each floor/landing. It is also fitted with inlet connections at ground level for charging with water by pumping from fire service appliances and air release valve at roof level to release trapped air inside.

**Dry Riser:** An arrangement of firefighting within the building by means of vertical rising mains not less than 100 mm internal diameter with landing valves on each floor/landing which is normally dry but is capable of being charged with water usually by pumping from fire service appliances.

**Fire Barrier (or Fire Resisting Barrier):** A fire barrier is a vertically or horizontally aligned member such as a wall or a fire curtain, or a floor. These may be with discontinuities created by openings with a specified fire resistance rating, where such members are designed and constructed with a specified fire resistance rating to limit the spread of fire that also restricts the movement of smoke.

**Fire Compartment:** A space within a building that is enclosed by fire barrier or fire-resistant walls on all sides, including the top and bottom.



**Firefighting Shaft (Fire Tower):** An enclosed shaft having protected area of 120 min fire resistance rating comprising protected lobby, staircase and fireman's lift, connected directly to exit discharge or through exit passageway with 120 min fire resistant wall at the level of exit discharge to exit discharge. These shall also serve the purpose of exit requirement/ strategy for the occupants. The respective floors shall be approachable from fire-fighting shaft enabling the fire fighters to access the floor and also enabling the fire fighters to assist in evacuation through fireman's lift. The firefighting shaft shall be equipped with 120 min fire doors. The firefighting shaft shall be equipped with firemen talk back, wet riser and landing valve in its lobby, to fight fire by fire fighters (see Fig. 2 for a typical firefighting shaft of NBC 2016 Part 4).

**Fire Load:** Calorific energy, of the whole contents contained in a space, including the facings of the walls, partitions, floors and ceilings.

**Fire Load Density:** Fire load divided by floor area.

**Fireman's Lift:** A lift or a group of lifts invariably associated with all the features and requirements of a fire-fighting shaft. Such lift(s) are installed to enable fire services personnel to reach different floors with minimum delay and shall meet the additional features as required in accordance with this Part. This lift also serves the purpose of meeting the requirement of evacuation lift for assisted evacuation.

**Fire Stop:** A fire resistant material, or construction, having a fire resistance rating of not less than the fire separating elements, installed in concealed spaces or between structural elements of a building to prevent the spread/propagation of fire and smoke through walls, ceilings and the like as per the laid down criteria.

**Fire Suppression Systems:**

- a) **Gas based systems:** Systems that use gaseous agents as fire suppression media, such as, all agents alternate to Halon gases, listed and approved for use by relevant Indian Standards; other methods/types of gas based systems where their protection is equal to or better than what is suggested above for the type of application subject to the acceptance of Authorities concerned may also fall under such systems.
- b) **Water based systems:** Systems that use mainly water as firefighting media such as hydrant system, sprinkler system, water spray system, foam system and water mist system.

**High Rise Building:** A building 15 m or above in height (irrespective of its occupancy).



**Means of Egress:** A continuous way of travel from any point in a building or structure to a public way, consisting of three separate and distinct parts, that is, exit access, exit and exit discharge.

**Means of Escape:** A way out of a building or structure that does not conform to the strict definition of 'means of egress' but does provide an alternate way out.

**Mixed Occupancy:** A multiple occupancy where the occupancies are intermingled.

**Multiple Occupancy:** A building or structure in which two or more classes of occupancy exist.

**Occupancy or Use Group:** The principal occupancy for which a building or a part of a building is used or intended to be used; for the purpose of classification of a building according to the occupancy, an occupancy shall be deemed to include subsidiary occupancies which are contingent upon it.

**Occupant Load:** Maximum number of persons that might occupy a building or portion thereof at any one time.

**Refuge Area:** An area within the building for a temporary use during egress. It generally serves as a staging area which is protected from the effect of fire and smoke.

**Travel Distance:** The distance to be travelled from any point in a building to a protected exit or external escape route or final exit measured along the line of travel.

**Hydrant System:** A distribution system having a network of piping installed underground/aboveground around and/or through inside of a building with internal and/or external hydrants fitted with landing valves at regular intervals according to the occupancy. The distribution system is connected to water supply system for firefighting.

**Automatic Sprinkler System:** A system of water pipes fitted with sprinkler heads at suitable intervals and heights and designed to actuate automatically, control and extinguish a fire by the discharge of water.



**Automatic Water Spray Systems:** A special fixed pipe system connected to a reliable source of fire protection water supply and equipped with water spray nozzles for specific water discharge and distribution over the surface or area to be protected. The piping system is connected to the water supply through an automatically actuated deluge valve which initiates flow of water. Automatic actuation is achieved by operation of automatic detecting equipment installed along with water spray nozzles. There are two types of systems namely high velocity and medium velocity systems.

**Water Mist Systems:** A distribution system connected to a pumping and water supply system that is equipped with nozzles capable of delivering water mist to the part/entire enclosure or area, intended to control, suppress, or extinguish fire and is capable of meeting the specified performance requirements.

**Foam Protection System:** Firefighting systems where foam is made by mechanically mixing air with a solution consisting of fresh water to which a foaming agent (liquid concentrate) has been added. Firefighting foam is a stable aggregation of small bubbles of density lower than oil or water and shows tenacious qualities for covering horizontal surfaces. There are three types of foam applications that is, low, medium and high expansion foams depending upon the application.

**Wet Riser:** An arrangement for firefighting within the building by means of vertical rising mains not less than 100 mm nominal diameter with landing valves on each floor/landing for firefighting purposes and permanently charged with water from a pressurized supply

### **Classification of Buildings Based on Occupancy**

General Classification All buildings, whether existing or hereafter erected shall be classified according to use or the character of occupancy in one of the following groups:

Group A - Residential; Group B - Educational; Group C - Institutional; Group D – Assembly; Group E- Business; Group F – Mercantile; Group G – Industrial; Group H - Storage; Group J – Hazardous

**Building:** shall have the meaning assigned to it in the GDCR or relevant law or any law for the time being in force in the area in which this Act is in force; and includes places or premises comprising land or building, or part of a land or building, outhouses, if any, appertaining to such building or part thereof and petrol, diesel or gas lines, communication lines, power installations or pumps, whether authorized or otherwise.



**Building Bye-Laws:** means the building bye-laws, rules of regulations made under any relevant law and includes GDCR or regulations, by whatever name they are called, or any other building rules or regulations made under any other law for the time being in force and are in operation in the area in which this Act is in force.

**Chief Fire Officer:** means a person as classified under section 10.

**Commissioner:** shall have the meaning assigned to it in clause (9) of section 2 of the Gujarat Provincial Municipal Corporations Act, 1949 (Bombay LIX of 1949).

**Director:** means a person appointed under section 6.

**Disaster:** shall have the meaning assigned to it in clause (h) of section 2 of Gujarat State Disaster Management Act, 2003 (Gujarat 20 of 2003).

**Emergency Services:** means services required to be rendered in case of disaster or any eventuality where the life is at risk.

**Erector:** means a person or an association of persons, whether corporate or otherwise, who erects or makes a shamiyana or tents or mandap or any structure for occupation of people on a regular or temporary basis.

**Fess:** means fees levied under section 30.

**Fire Division:** means a territory comprising such number of fire sub-divisions as may be prescribed; and declared generally or specially by the State Government to be a fire division for the purpose of this Act.

**Fire Prevention and life safety measures:** means such measures as are necessary in accordance with the GDCR or as required by or under the provisions of any law or the National Building Code of India, for the time being in force, with regard to fire prevention, life safety and fire protection for containment, control and extinguishing of fire and for ensuring the safety of life and property in case of fire.



**Fire Region:** means territory comprising such number of fire divisions as may be prescribed and declared generally or specially by the State Government to be a fire region for the purpose of this Act;

**Fire Safety Officer:** means a person or an association of persons appointed under section 12 of this Act as the Fire Safety Officer by the owners and occupiers of certain premises and buildings as prescribed in this behalf for fire safety certificate renewal and such other related activities required to be carried out under this Act.

**Fund:** means fund constituted under section 32.

**GDCR:** means the Comprehensive General Development Control Regulations, 2017 made under the provisions of the Gujarat Town Planning and Urban Development Act, 1976 as revised from time to time.

**Licensed Agency:** means a person or an association of persons licensed under sub-section (1) of section 28.

**Housing Society:** includes all registered residential and non-residential or mixed housing societies, association of owners or co-owners of flat occupancy, building premises and associations of owners as defined under the Gujarat Ownership of Flats Act, 1973 (Gujarat 13 of 1973).

**Local Authority:** means a municipal corporation, nagar panchayat, municipality, district panchayat, taluka panchayat, gram panchayat, notified area committee or cantonment board constituted under relevant local authority law.

**Local Fire Service:** means the local fire service as may be notified by the State Government under section 3.

**National Building Code of India:** means the book or books containing Fire Prevention and Life Safety Measures to be implemented in the buildings, places, premises, workshops, warehouses and industries, published from time to time by the Bureau of Indian Standards.





**Nominated Officer:** means an officer possessing the prescribed qualifications and nominated by the Director or the Regional Fire Officer or the Chief Fire Officer to perform duties and functions laid down under this Act.

**Occupancy:** means the principal occupancy for which a building or a part of a building is used or intended to be used including subsidiary occupancies which are contingent upon it.

**Occupier:** shall have the meaning assigned to it in clause (xvi) of section 2 of the Gujarat Town Planning and Urban Development Act, 1976 (President Act No. 27 of 1976).

**Owner:** shall have the meaning assigned to it in clause (xvii) of section 2 of the Gujarat Town Planning and Urban Development Act, 1976 (President Act No. 27 of 1976) and shall also include the housing society.

**Premises:** means any land or any building or part of a building and includes the garden ground and outhouse, if any, appertaining building or part of a building; and any land or any building or part of a building appurtenant thereto which is used for storing explosives explosive substance and dangerously inflammable substance.

**Prescribed:** means prescribed by rules made under section 57.

**Regional Fire Officer:** means a person appointed under section 8.

**Regulations:** means regulations made by the Director under section 58

**Shamiyana:** Shamiyana or tents or mandap" means a temporary structure with roof or walls made of straw, hay, ulu grass, golpatta, hogla, darma, mat, canvas, cloth or other like material which is not adopted for permanent or continuous occupancy.

Note: Words and expressions used in this Act but not defined shall have the meaning assigned to them in the Gujarat Town Planning and Urban Development Act, 1976 (President Act No. 27 of 1976) or the Gujarat State Disaster Management Act, 2003 (Gujarat 20 of 2003) or any other law relating to local authorities, as the case may be, and the rules made thereunder.

**Fire Safety Officer (General) Jurisdiction for the purpose of FSC renewals of new Building as per Schedule III of Gujarat Fire Prevention and Life Safety Rules, 2021**



Sr. No.	Type of Buildings for FSCR (As Per NBC Part 4)
1	Residential buildings (other than hotels and guest houses) having height more than 15 meters but not exceeding 35 meter in height.
2	Hotels up to 15 meters in height (exceeding 500 m <sup>2</sup> but not more than 1000 m <sup>2</sup> on each floor).
3	Hospitals and Nursing Homes less than 15 meter height with plot area up to 1000 m <sup>2</sup> , up to Ground plus one or more storeys with beds
4	Educational buildings having height more than 9 meters but not exceeding 15 meter in height
5	Custodial, Penal & mental institutions less than 10 meters in height
6	Assembly buildings less than 10 meters in height up to 300 persons, or above 10 meter but not exceeding 15 meter in height.
7	Business buildings above 15 m but not exceeding 24 m in height.
8	Mercantile occupancies less than 15 meter in height and Ground + one storey or more, having total floor area more than 500 m <sup>2</sup>
9	Low Hazard category building covered area more than 500 m <sup>2</sup> (for building height above 15 meter) as per ANNEX B, of the NBC 2016 – Part 4.
10	Mixed Use Occupancies, having height more than 9 meter up to 15 meter

### Requirements of Building for Practical and Project

Occupancy/ Main Category	Occupancy/ Main Category Type	AS PER NBC Part 4			Applicable FSO	Applicable Renewal Checklist NUMBER
		Occupancy Sub-Type	SN	Building Categories as per Table 7, NBC Part 4		
1	Residential	Dormitories (A-3) & Apartment Houses (A-4)	1	15 m and above but not exceeding 35 m in height	<b>FSO-G</b>	<b>C1R1</b>



Occupancy/ Main Category	Occupancy/ Main Category Type	AS PER NBC Part 4			Applicable FSO	Applicable Renewal Checklist NUMBER
		Occupancy Sub-Type	SN	Building Categories as per Table 7, NBC Part 4		
		Hotels (A-5)	2	Less than 15 m in height Floor area exceeding 500 m <sup>2</sup> but not more than 1000 m <sup>2</sup> on any of the floor	<b>FSO-G</b>	<b>C1R5</b>
2	Educational	Schools up to senior secondary level (B-1)	3	More than 9 m (but less than 15 m) in height (Ground + 1 or more storeys)	<b>FSO-G</b>	<b>C2ED1</b>
3	Institutional	Hospitals, Sanatoria and Nursing Homes (C-1)	4	Less than 15 m in height but with plot area up to 1000 m <sup>2</sup> - (ii) up to ground plus one storey with beds	<b>FSO-G</b>	<b>C3i1</b>
			5	Less than 15 m in height but with plot area up to 1000 m <sup>2</sup> - (i) Ground plus two or more storeys, with beds	<b>FSO-G</b>	<b>C3i2</b>
		Custodial (C-2), Penal & Mental (C-3)	6	Less than 10 m in height (up to 300 persons)	<b>FSO-G</b>	<b>C3i6</b>
			7	Less than 10 m in height (more than 300 persons)	<b>FSO-G</b>	<b>C3i7</b>



Occupancy/ Main Category	Occupancy/ Main Category Type	AS PER NBC Part 4			Applicable FSO	Applicable Renewal Checklist NUMBER
		Occupancy Sub-Type	SN	Building Categories as per Table 7, NBC Part 4		
4	Assembly	Buildings which include Theatres, community halls, auditoriums, convention centres, etc. (D-1 to D-5)	8	Less than 10 m in height (i) up to 300 persons	<b>FSO-G</b>	<b>C4A1</b>
			9	Above 10 m but not exceeding 15 m in height	<b>FSO-G</b>	<b>C4A3</b>
5	Business	Business (E-1 to E-5) - These buildings include Offices, banks, professional establishments (E-1), outpatient clinics, research establishments, libraries and test houses (E-2), Electronic data processing centres, computer installations, IT parks (E-3), Telephone exchanges (E-4), Broadcasting stations, T.V. stations and ATC towers (E-5)	10	Above 15 m but not exceeding 24 m in height	<b>FSO-G</b>	<b>C5B1</b>
6	Mercantile	Mercantile F-1 & F-2 - these include Shops, stores, markets having area < 500 m <sup>2</sup> (F-1) and area > 500 m <sup>2</sup> (F-2)	11	Less than 15 m in height and (i) Ground storey + one, having total floor area > 500 m <sup>2</sup>	<b>FSO-G</b>	<b>C6M1</b>



Occupancy/ Main Category	Occupancy/ Main Category Type	AS PER NBC Part 4			Applicable FSO	Applicable Renewal Checklist NUMBER
		Occupancy Sub-Type	SN	Building Categories as per Table 7, NBC Part 4		
7	Industrial	Low Hazard (G-1)	12	covered area more than 500 m <sup>2</sup> (for building height more than 15 m)	<b>FSO-G</b>	<b>C7iD1</b>
		Moderate Hazard (G-2)	13	covered area more than 500 m <sup>2</sup> up to 1000 m <sup>2</sup> (for building height above 15 m)	<b>FSO-G</b>	<b>C7iD2</b>
10	Mixed Use Occupancies	Commercial Complexes	14	Buildings above 9 m in height (or Ground plus three floors)	<b>FSO-G</b>	<b>C10MX1</b>

# **Chapter 1:**

## **Fire Science and Combustion**





# 1. Fire Science and Combustion

## 1.1. Physics and Chemistry of fire

Effective fire prevention and protection relies not only on applying rules, well designed systems and other means of protection but on understanding the physical science of fire. This section provides a snapshot of fundamental physics and chemistry of fire.

### 1.1.1. Background

In order to understand how fire behaves and how it can be extinguished, it is necessary to understand the physics and chemistry behind it.

Fires are chemical reactions governed by some fundamental processes, and extinguishing fires is a matter of interrupting one or more of these processes so that burning discontinues. Fire professionals will appreciate that it is therefore, of paramount importance to acquire a good understanding of what happens in a fire, in order to choose the best method available to control or extinguish fire and avoid escalating the situation and risk.

Good knowledge on physical and chemical properties of combustible and flammable fuels will help in understanding the behavior of fires and materials involved in the burning process. Once we understand the nature of fires and behavior of matters involved, the means to control and extinguish fires can be adopted aptly and easily.

### 1.1.2. Physical and chemical properties

#### a) Physical properties of matter

Matter refers to the name given to all material things, i.e., anything that has mass and occupies space. Mass and volume correlates with the third physical property of matter referred to as density. Mass, Volume and Density define the object's most basic physical properties.

The amount of matter is measured either in Mass or Space (volume), e.g. Mass of solids is measured in kilograms. Liquid, gases and vapors are measured by the amount of space they occupy, hence in volume. It should be noted that liquid, gases and vapors have mass which can be expressed in kilograms.

The following physical features are covered under this sub-heading:





(1)	(2)	(3)	(4)
Density	Specific gravity	Gas specific gravity	Buoyancy

### (1) Density:

Out of these three basic properties of matter, understanding density is extremely important for Fire professionals.

Density of a substance is its mass per unit volume.

$$\text{Density}(\rho) = \frac{\text{Mass}(m)}{\text{Volume}(V)}$$

If mass (m) is measured in kilograms (kg) and volume (V) in cubic meters (m<sup>3</sup>), the unit of density (ρ) will be kilograms per cubic meters (kg/m<sup>3</sup>). Similarly, if mass is in gram (g) and volume in cubic centimeters (cm<sup>3</sup>), the unit of density will be grams per cubic centimeters (g/cm<sup>3</sup>).

Water has a density of about 1000 kg/m<sup>3</sup> or 1 g/cm<sup>3</sup>. The term specific gravity or relative density is used to give measure of liquid's density.

$$\text{Relative Density} = \frac{\text{Density of the substance}}{\text{Density of water}}$$

Density of gas or vapor determines whether it will tend to rise or sink in air and be found in greatest concentrations at upper level or lower level. Density of burning liquid defines whether the fire professionals should use water to extinguish fire or use foam or the fire-fighting media.

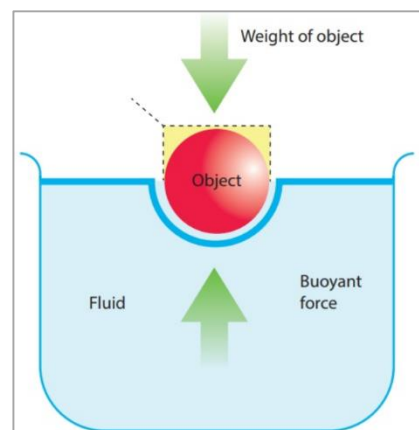
Gases and vapors have very low densities compared to liquids and solids and is measured as vapor density. At normal temperature and pressure (NTP), a cubic meter of water and air has mass of 1000 kg and 1.2kg, respectively. Because of this difference in mass at NTP, density of gas and vapor is given in relation to density of equal volume of hydrogen as H<sub>2</sub> is the lightest gas. The vapor density of air compared with hydrogen is 14.4, which means that a given volume of air is 14.4 times heavier than same volume of hydrogen.

### (2) Specific gravity

Specific gravity is the ratio of mass of a solid or liquid substance to the mass of an equal volume of water. (Note: At 15°C, the mass of 1 cm<sup>3</sup> of water is 1 g.)

### (3) Gas specific gravity

Gas specific gravity is the ratio of the mass of a gas to the mass of an equal volume of dry air at the same temperature and pressure. It is equal to its molecular weight divided by 29, where 29 is the effective molecular weight of dry air (approximately 21% oxygen + 79% nitrogen).



### (4) Buoyancy

Buoyancy is the upward force exerted on a body or volume of fluid by the ambient fluid surrounding it. If the volume of a gas has a positive buoyancy, then it is lighter than the surrounding gas and will tend to rise. If it has a negative buoyancy, it is heavier and will tend to sink. The buoyancy of a gas depends on both its molecular weight (see gas specific gravity) and its temperature.

If a flammable gas with a gas specific gravity greater than 1 leaks relatively slowly from its container, it will tend to sink to a low level. If the conditions are right, it can travel considerable distances and may be ignited by a remote source of ignition. If propane ( $C_3H_8$ , molecular weight 44) leaks from a cylinder, it will accumulate and spread at ground level with little dilution. In a confined space, such as a basement or a boat with poor ventilation, this situation presents a serious hazard.

The density of a gas decreases as its temperature is increased. Thus, hot products of combustion rise. On the other hand, immediately following a spillage of liquefied natural gas (LNG, mainly methane, which has a molecular weight of 16), the vapor is heavier than air because it is at a very low temperature (the boiling point of methane is  $-161.5^\circ\text{C}$ ). As with propane at ambient temperature, LNG spills can be very dangerous because the vapor can spread over a wide area. However, the gas specific gravity of methane is only 0.55 ( $16/29$ ) so that at ambient temperature the gas rises and disperses. In an enclosed area, it can create an explosion hazard very rapidly.

### b) Fire Chemistry

This section covers basic definitions and concepts relevant to fire chemistry. It does not attempt to be comprehensive but is intended to present some of the background material applicable to Fire chemistry. The following physical features are covered under this sub-heading:



(1) Atom	(2) Element	(3) Molecule	(4) Chemical formula	(5) Molecular weight of a compound
(6) Mole	(7) Chemical reaction	(8) Heat of chemical reaction	(9) Ignition	

**(1) Atom**

Atoms are the building blocks of chemistry. They form the basis of all matter with which we are familiar. Each atom has a dense, positively charged nucleus or core, which contains protons (positively charged) and neutrons (no charge), and around which negatively charged electrons swarm in a regularly structured pattern. The number of protons and electrons is equal, ensuring that the atom is electrically neutral. The precise structure of the electron “swarm” (or “cloud”) determines the chemical nature and reactivity of the atom.

**(2) Element**

Elements are substances that are composed of only one type of atom (e.g., pure carbon, C; nitrogen, N<sub>2</sub>; bromine, Br<sub>2</sub>).

**(3) Molecule**

Molecules are groups of atoms combined in fixed proportions. Substances composed of molecules that contain two or more kinds of atoms are called compounds. The molecules of a single compound are identical.

**(4) Chemical formula**

A chemical formula represents the number of atoms of various elements in a molecule. For example, water is H<sub>2</sub>O (two atoms of hydrogen and one of oxygen) whereas propane is C<sub>3</sub>H<sub>8</sub>, where C stands for carbon. A formula may be written to indicate the arrangement of the atoms in the molecule. Thus, propane is CH<sub>3</sub>CH<sub>2</sub>CH<sub>3</sub>.

### (5) Molecular weight of a compound

The molecular weight of a compound is the sum of the atomic weights of all atoms in its molecule. For example, from its chemical formula, the molecular weight of propane ( $C_3H_8$ ) is  $(3 \times 12 + 8 \times 1) = 44$ . The gram molecular weight of a substance is the mass of the substance equal to its molecular weight in grams.

### (6) Mole

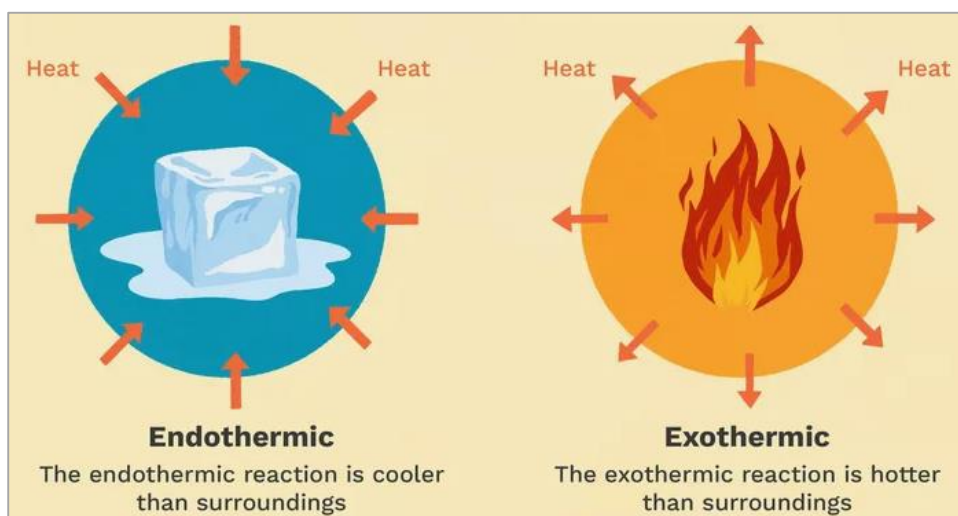
A mole of an element or compound is the amount that corresponds to the gram molecular weight. Thus, one mole of propane has a mass of 44 g. One mole of any element or compound contains  $6.022 \times 10^{23}$  molecules (see definition of atomic weight).

### (7) Chemical reaction

Chemical reaction is a process by which reactants are converted into products. More often than not, the equation that is used to describe a chemical reaction hides the details of the mechanism by which the change takes place.

### (8) Heat of chemical reaction

Heat of a chemical reaction is the energy that is absorbed or released when that reaction takes place. *Exothermic* reactions release energy when they occur whereas energy is absorbed when an *endothermic* reaction takes place. Combustion reactions are exothermic, implying that the products are more stable than the reactants. *Endothermic* reactions include the pyrolysis of solid fuels, as well as the decomposition processes that occur in concrete when chemically bound water is released at high temperature.





Chemistry of fire processes encompasses not only oxidation reactions in the gas phase but also thermal decomposition, or pyrolysis, reactions that are associated with the release of flammable vapors from combustible solids. Gas phase oxidation is an exothermic, self-sustaining reaction that is usually, not necessarily, is associated with the reaction of fuel vapors with atmospheric oxygen. In flaming combustion of solids and liquid fuels, vaporization is an essential part of the burning process. However, it should be remembered that some solids can undergo glowing combustion or smoldering in which oxygen reacts directly at the surface of the solids.

### (9) Ignition

Ignition is the process by which self-sustaining combustion is initiated. Thus, for a flammable vapor/ air mixture (i.e., the fuel concentration lies within well-defined flammability limits), introduction of the ignition source in the form of a spark or small flame will result in a flame propagating through the mixture. The relevance of this process to condensed fuels (liquids and solids) is best illustrated by considering the concept of flashpoint for liquid fuels, which is defined below:

**Flashpoint** defines the critical condition under which a fuel can be ignited and refers to the minimum temperature at which a flammable vapor-air mixture exists above the surface of the liquid. It can be measured in a closed cup apparatus. The open cup flashpoint is measured under conditions when the fuel vapor can diffuse away from the surface of the liquid. It is the lowest bulk liquid temperature at which a flash of flame is observed when an ignition source is present at the rim of the container that is specified in the standard test. The entire fuel vapor within the flammability limits is consumed momentarily, but flaming does not persist.

For ignition to be followed by continuous burning of the liquid, its temperature must be raised to the **fire point**. Introduction of an ignition source into the vapor-air mixture above the liquid surface will give a flash of flame, but this will be followed by sustained burning. The fire point temperature is higher than the flashpoint. To give an example, for ndecane ( $n\text{-C}_{10}\text{H}_{22}$ ), the closed cup and open cup flashpoints, and the fire point are 46°C, 56°C, and 64°C, respectively.

For both combustible liquids and solids, initiation of flaming occurs in the gas phase. Energy is required to convert sufficient fuel into the vapor phase to create a flammable vapor-air mixture in the vicinity of the surface.

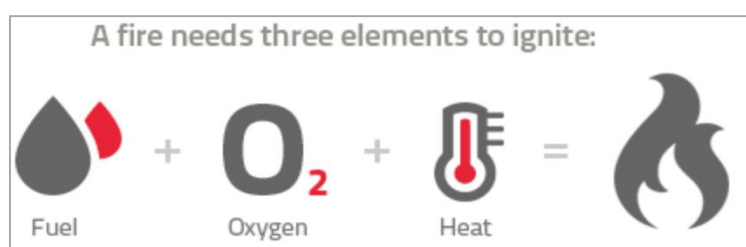
For most liquid fuels, this is simply a process of evaporation, but almost all solid fuels must undergo chemical decomposition (**pyrolysis**) before vapor is released.

**Spontaneous ignition temperature** is the temperature at which substance will ignite spontaneously without introduction of flame or source of ignition. This is sometimes referred to as auto-ignition temperature.

### 1.1.3. Fire triangle and fire tetrahedron - basic definitions

#### Fire triangle

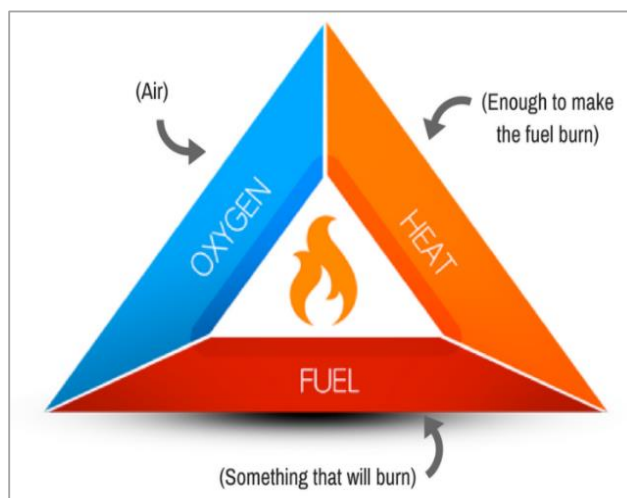
For combustion or burning to occur, oxygen, usually from air, must combine with a fuel.



A fuel may be in any one of the three states initially but for flaming combustion to occur, a solid to liquid fuel must be converted to vapor, which then mixes with air and reacts with oxygen. Smoldering combustion on the other hand, involves a reaction between oxygen and surface of the fuel. A flame is a region in which sustained heat releasing reaction takes place between fuel and oxygen. This region also emits light.

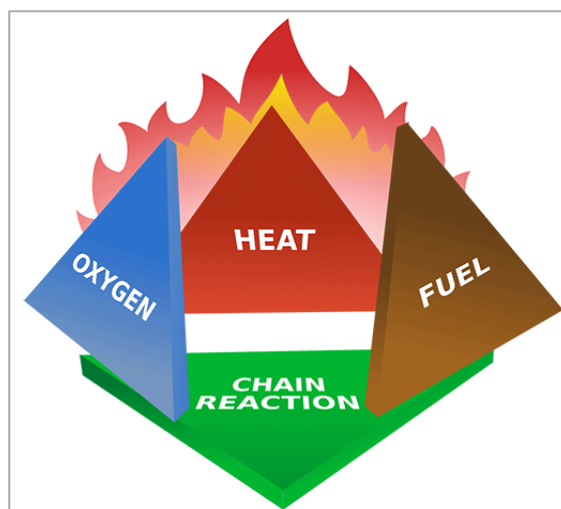
One way of discussion burning is on terms of Fire triangle (See figure).

For combustion to occur, three things are necessary: Heat, Fuel and Oxygen. Combustion will continue as long as these three things are present. Removing one of them leads to collapse of triangle and combustion stops.



## **Fire Tetrahedron**

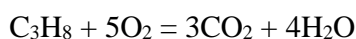
Fire triangle does not describe all the conditions for a flaming fire because it does not include the chemical chain reactions and reactive molecules in flame gases. Highly reactive molecular species, referred to as free-radicals, must be present in sufficient concentrations to insure the continuation of chemical chain reactions. Otherwise, flames are extinguished. A more complete visual image of



flammability is therefore provided by the fire tetrahedron, which recognizes that in order for flames to exist and not be extinguished, uninhibited chain reactions are necessary in addition to fuel (in a gaseous or vapor state), oxidizing agent, and heat. While the fire triangle identifies the conditions necessary to start a fire, the fire tetrahedron recognizes the conditions sufficient for a flaming fire. These conditions include the availability of gaseous fuel or fuel vapors, which can only be generated if there is sufficient heating from external sources or heat feedback from a burning material's own flames.

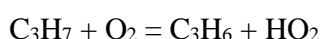
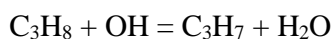
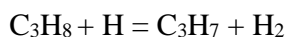
## **Chain reactions in flaming combustion**

Thus, for understanding, the equation for oxidation of propane is written conventionally as:



However, the mechanism is very complex and involves highly reactive species called free radicals. Free radicals include atomic hydrogen and oxygen, the hydroxyl radical (OH), and many more. The conversion of propane to carbon dioxide and water involves hundreds of intermediate steps (elementary reactions), which create a chain reaction.

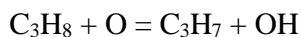
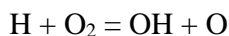
Typical elementary reactions are:







The radicals are highly reactive and very short-lived. The reaction of H atoms with molecular oxygen is particularly important because it leads to chain branching in which one free radical (the H atom) is replaced by three (two OH and one C<sub>3</sub>H<sub>7</sub>):



At high temperature, the reaction begins to dominate and the conversion rate (propane to products) increases dramatically. If species that remove hydrogen atoms (e.g., Halons, Halocarbons) are added to a flame, then the conversion rate (i.e., the rate of burning) falls dramatically and lead to fire extinguishment.

#### 1.1.4. Properties of fire, heat and energy sources

1. **Heat** is a form of energy. It can be produced by chemical means, i.e., by burning fuel or by mechanical means, i.e., friction. Heat can be converted into other form of energy, for example, pressure energy in steam boiler.

It is important to understand the difference between heat and temperature as heat transfer governs all aspects of fire, from ignition to a fully developed fire and beyond to the failure of structural elements.

Heat transfer is driven by temperature difference. Heat always flows from higher to lower temperature. Before considering various mechanisms of heat transfer, it is important to review the basic terms used, including the concept of temperature itself.

Temperature is a measure of how hot or cold a body is, not the amount of energy it contains. Rise in temperature of material depends on three factors: amount of heat transferred, mass of the body and Specific heat capacity of material.

2. **Specific heat capacity** is the amount of heat it absorbs as it's temperature increases. It is expressed as the amount of thermal energy required to raise unit mass of a substance by 1 degree, and its units are J/kg·K. Water has a specific heat of 4200 J/kg·K.

3. **Units of Heat and Temperature**

##### Heat Units



**(i) Joule (J)**

Joule is defined as the energy (or work) expended when unit force (1 newton) moves a body through unit distance (1 m). The joule is the most convenient unit of energy to use and can be related to the calorie, which is defined in terms of the heat energy required to raise the temperature of unit mass of water by 1°.

The joule (J) is an approved SI unit, as are kJ (kilojoule) and MJ (megajoule) where 1 kJ = 1000 J and 1 MJ = 1000 kJ.

**(ii) Watt (W)**

Watt is a measure of power or the rate of energy release (or consumption). One watt is equal to 1 joule per second (1 W = 1 J/sec). The rate of heat release from a fire can be expressed in kilowatt (kW) or megawatt (MW). The watt, kilowatt, and megawatt are approved International System (SI) of units.

**(iii) Calorie**

One calorie is the amount of heat required to increase the temperature of 1 g of water by 1°C (measured at 59°F [15°C]). One calorie is equivalent to 4.183 J.

**(iv) British thermal unit (Btu)**

The amount of heat required to raise the temperature of 1 lb of water by 1°F (measured at 60°F [15.5°C]) is called the British thermal unit. One Btu equals 1054 J (252 calories) or 1.054 kJ. Btu and calories are not approved SI units.

**Temperature units*****Quick Celsius (°C) / Fahrenheit (°F) Conversion***

$$C = 5/9 \times (F - 32)$$

$$F = (C \times 9/5) + 32$$

**(i) Celsius**

A Celsius (or centigrade) degree (°C) is 1/100th of the difference between the temperature of melting ice and boiling water at standard atmospheric pressure (101.3 kPa). On the Celsius scale, zero (0°C) is defined as the melting point of ice, and 100°C as the boiling point of water. Celsius is an approved SI unit.

**(ii) Fahrenheit**



A Fahrenheit degree ( $^{\circ}\text{F}$ ) is  $1/180$ th of the difference between the temperature of melting ice and boiling water at standard atmospheric pressure (101.3 kPa). On the Fahrenheit scale, the melting point of ice ( $0^{\circ}\text{C}$ ) is taken as  $32^{\circ}\text{F}$ ; thus,  $212^{\circ}\text{F}$  is the boiling point of water ( $100^{\circ}\text{C}$ ).

#### (iii) Kelvin

A Kelvin degree or Kelvin (K) is the same size as the Celsius degree but the zero on the Kelvin scale is  $-273.15^{\circ}\text{C}$ . Zero on the Kelvin scale is the lowest achievable temperature, known as “absolute zero”; thus, the Kelvin scale provides us with so-called *absolute temperatures*. Kelvin is an approved SI unit. When expressing the units of a property such as specific heat, K is commonly used to indicate “degree” whether the Kelvin or Celsius scale is being referred to in the text. For example, the units of heat capacity are  $\text{kJ/kg}\cdot\text{K}$ .

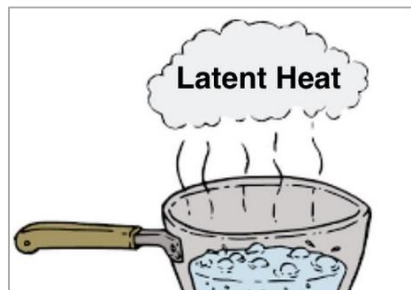
#### (iv) Rankine

A Rankine degree ( $^{\circ}\text{R}$ ) is the same size as the Fahrenheit degree, but on the Rankine scale, zero is  $-459.67^{\circ}\text{F}$  ( $-273.15^{\circ}\text{C}$ ). The Rankine scale provides us with absolute temperatures.

Note: Fahrenheit and Rankine degrees are not approved SI units and are hence not widely used.

### 4. Latent heat and heat of gasification

A substance absorbs heat when it is converted from solid to liquid or from liquid to gas. This thermal energy is called latent heat. Conversely, heat is released during conversion of a gas to a liquid or a liquid to a solid.



Latent heat is the quantity of heat absorbed by a substance passing between liquid and gaseous phases (latent heat of vaporization) or between solid and liquid phases (latent heat of fusion). A small number of compounds (e.g., naphthalene) go directly from the solid phase to the vapor phase without any chemical change, a transition known as sublimation. This is associated with a **latent heat of sublimation**.

Latent heats are measured in joules per unit mass ( $\text{J/kg}$ ). The latent heat of fusion of water (normal atmospheric pressure) at the freezing or melting point of ice ( $0^{\circ}\text{C}$ ) is  $333.4 \text{ kJ/kg}$ ; the latent heat of vaporization of water at its boiling point ( $100^{\circ}\text{C}$ ) is  $2257 \text{ kJ/kg}$ .

The large heat of vaporization of water is another reason for the effectiveness of water as an extinguishing agent. It requires 3 MJ to convert 1 kg of ice at 0°C to steam at 100°C. The latent heat of most other common substances are substantially less than that of water. Thus, the heat absorbed by water evaporating from the surface of a burning solid is a major factor in reducing its temperature and thus reducing the rate of pyrolysis and preventing flame spread to adjacent hot surfaces.

The term **heat of gasification** is used to describe the amount of energy that is required to produce unit mass of flammable vapor from a combustible solid that is initially at ambient temperature. Unlike sublimation, chemical decomposition (pyrolysis) of the parent molecules occurs during the process. Heat of gasification is very important because it determines the amount of flammable vapor supplied to a fire in response to a given supply of heat to the pyrolyzing surface.

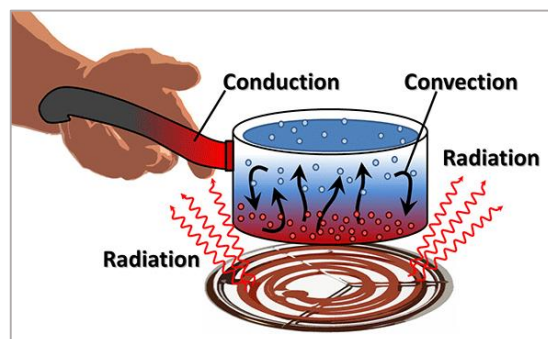
## 1.2. Heat Transfer

### 1.2.1. Modes of heat transfer – conduction, convection and radiation

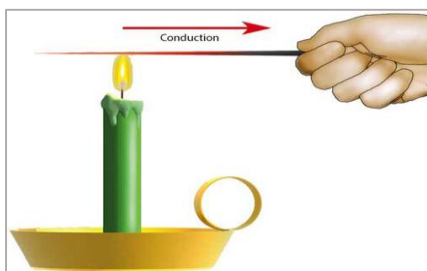
Heat energy always flows from region of high temperature to low temperature, no matter how small the temperature difference is.

Three basic mechanisms of heat transfer are listed below:

- i. Conduction
- ii. Convection
- iii. Radiation



These mechanisms must be considered together in any fire-related situation, although it is not uncommon for one to dominate the others.



#### 1. Conduction

Heat transfer through a solid (e.g., from a heated surface to the interior of the solid) is the process called conduction. The rate at which heat (energy) is transferred through a body under steady state

conditions is a function of the temperature difference and the conductance of the path involved.

Conductance depends on the thermal conductivity, the cross-sectional area normal to the flow path and the length of the flow path. The rate of heat transfer is simply the quantity of heat transferred per unit time, but it is convenient to normalize it to unit cross-sectional area and express heat transfer in terms of the heat “flux” (i.e., per unit surface area)

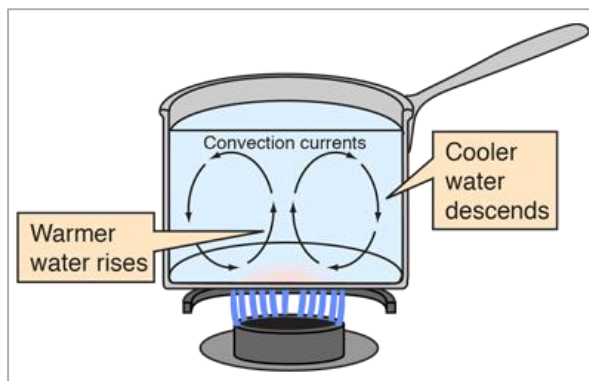
The best conductor of heat is silver and copper. Aluminum has about half the thermal conductivity of silver and iron has about one-eighth. Non-metallic solids are poor conductors, and besides mercury, which is metal, liquids and gases are very poor conductors of heat.

Thermal conductivity can be measured experimentally and is usually denoted by symbol  $K$ . Thermal conductivity in the SI system of unit is measured in Watt per meter per Kelvin ( $W/m\ K$ ).

## 2. Convection

Convection involves transfer of heat by a circulating fluid— either gas or liquid. Thus, heat generated in a stove is distributed throughout a room by heating the air in contact with the stove (by conduction across the stationary boundary layer in contact with the hot surface).

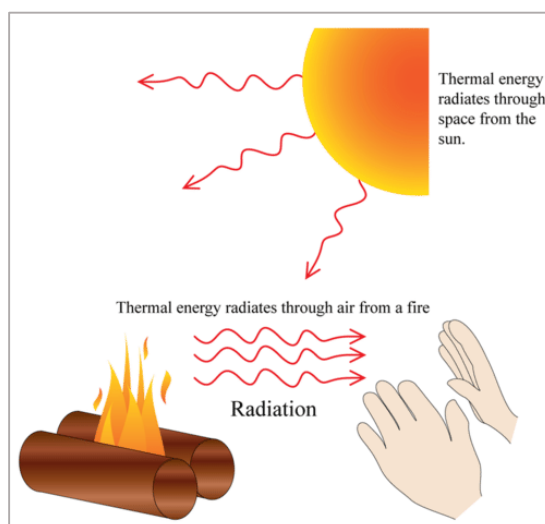
The hot, buoyant air then rises, setting up convection currents that transfer heat to distant objects in the room. Heat is transferred from air to these distant objects again by conduction across the boundary layer. Air currents can be made to carry heat by convection in any direction by use of a fan or blower (forced convection). Heat energy is carried out throughout the fluid by the molecules as they move until fluid has a uniform temperature.



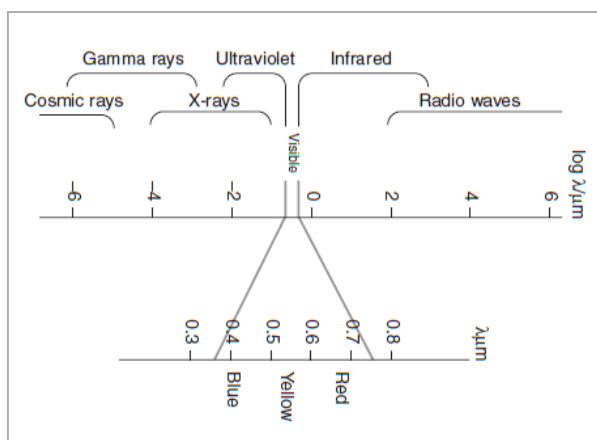
Convection causes the updraft in chimneys. When fire occurs in a building, convection currents can convey hot gases produced upwards through stairwells and open lift and service shafts, thereby spreading the fire to the upper parts of buildings.

## 3. Radiation

Thermal radiation is a form of energy that travels across space without any need for an intervening medium, solid or fluid. It travels as electromagnetic waves in straight lines, behaving similarly to light, radio waves, and X-rays. In a vacuum, all electromagnetic waves travel at the speed of light ( $3 \times 10^{10}$  m/sec). If these waves are directed onto the surface of a body, they can be absorbed, reflected, and/ or transmitted.



Visible light consists of wavelengths between  $0.4 \times 10^{-6}$  to  $0.7 \times 10^{-6}$  m, which correspond to blue and red ends of the visible spectrum respectively, whereas thermal radiation occurs principally in the infrared (and far-infrared) region (wavelengths greater than  $0.7 \times 10^{-6}$  m). A small fraction of radiation in the visible region is emitted by hot objects when the temperature is high enough. The visible radiation increases in intensity and changes in color as the temperature is raised.



The distinction between thermal radiation and convection can be illustrated by reference to a candle flame. The air that is required for combustion of the fuel vapors is drawn into the flame from the surrounding atmosphere by a process known as entrainment. The hot gases rise vertically upward as a plume that carries with it most of the heat (70%–90%) released by combustion (depending on the nature of the fuel). The rest of the heat is lost from the flame by radiation, which can be detected if a hand is held near the side of the flame. The sensation of warmth is caused by radiant heat transfer (i.e., thermal radiation), which is emitted from the flame in all directions. Up to 30 percent of the heat released in the flame is lost in this way, but the hand intercepts only a small proportion. If instead the hand is

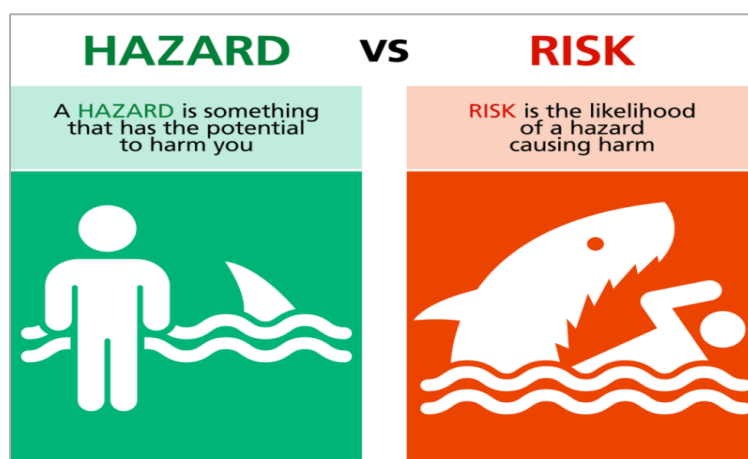
held over the top of the flame, in the plume of hot combustion products, it will intercept all of the “convected” heat and experience a much higher rate of heat transfer.

## 1.3. Hazards and Risk

### 1.3.1. Definition

#### About Hazard

A hazard is "a condition or changing set of circumstances that presents a potential for injury, illness or property damage." It is the potential or inherent characteristics of an activity, condition or circumstance which can produce adverse or harmful consequences. Hazard control is any means of eliminating or reducing the risk resulting from a hazard. Hazard recognition is perceiving or being aware that a hazard does or can exist.



Hazard is the presence of stored energy that, when released, can cause damage. Stored energy can occur in many forms, some are listed below:

- Chemical,
- Biological,
- Mechanical,
- Thermal,
- Radioactive,
- Electrical, etc.



Situations can also be hazardous, as for example confined or limited egress spaces, oxygen-depleted atmospheres, awkward positions, and repetitive motions, low-hanging or protruding objects, etc. They may also be classified as health or safety hazards by the populations that may be affected and the severity of the associated risk. In most cases a hazard may affect a range of targets and have little or no effect on others.

In particular, it is important to understand Flammability hazards of materials to identify control measures and methods of fire extinguishments. Further, NFPA 704 is widely used and recognized as the Standard for Identification of Hazards of Materials for emergency response.

### **Risk**

A fire risk is the likelihood of a fire occurring and the consequences of that fire incident. Risk expresses the likelihood/ chance/ probability that a person may be harmed or experience adversity from a particular hazard. Risk may be taken after careful consideration of the consequences or at times out of ignorance. The outcome of risk taking can be fortunate or disastrous or anything in between.

The process to manage risk is referred to as Risk Management. Risk Management comprises of culture, processes and structures that are directed towards realizing potential opportunities whilst managing the adverse effects/ outcomes.

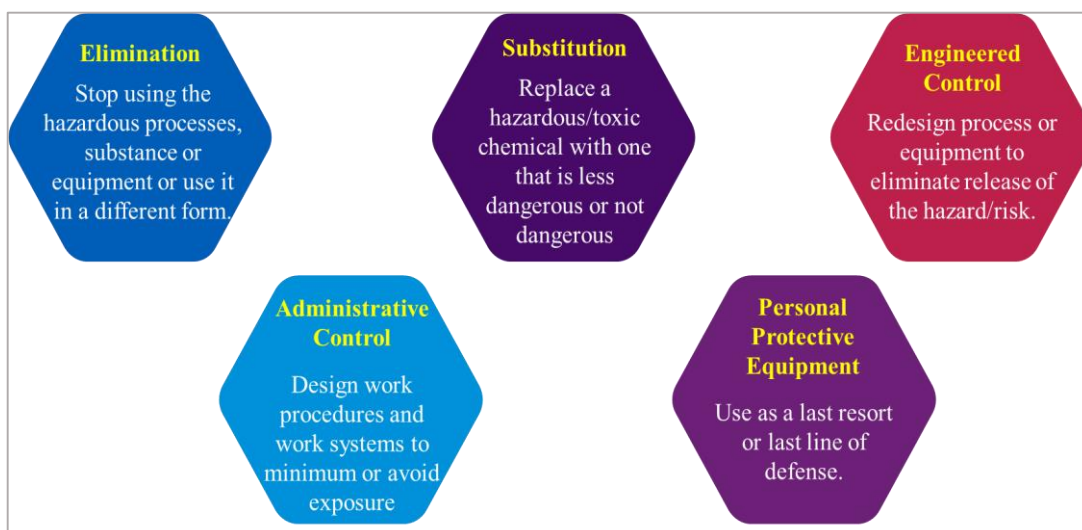
Risk management involves following distinct activities:

- **Risk identification**, e.g. by using inspections/ checklists, task analysis, SWOT, etc.
- **Risk evaluation** - derived based on economic, social, legal considerations with data on frequency of occurrence, severity of consequences, etc.
- **Risk elimination** and control – consists of avoidance, transfer, retention and reduction
- **Monitoring, audit and review.**

#### **1.3.2. Control measures**

In dealing with hazard/ risks, we must establish an order of treatment. There are many such orders of treatment available, a basic one is described below:





## 1.4. Combustion Process

### 1.4.1. Combustion Process

Combustion is a chemical process in which a substance reacts rapidly/ gradually with oxygen and gives off heat. The original substance is called the fuel and the source of oxygen is called the oxidizer.

When a material is heated, depending on its chemical composition and physical properties, it may respond in a variety of ways. Examples of such reaction are mentioned below:

### 1.4.2. What is combustion, Non-flaming and Flaming combustion

#### 1. Smoldering

Smoldering is a slow, exothermic surface reaction. Smoldering is usually characterized by glowing or incandescence, and smoke production. There is no flaming. Since smoldering is a surface effect it is strongly dependent on environmental conditions in addition to the properties of the fuel and the availability of oxygen.



Smoldering is a serious fire hazard for two reasons:

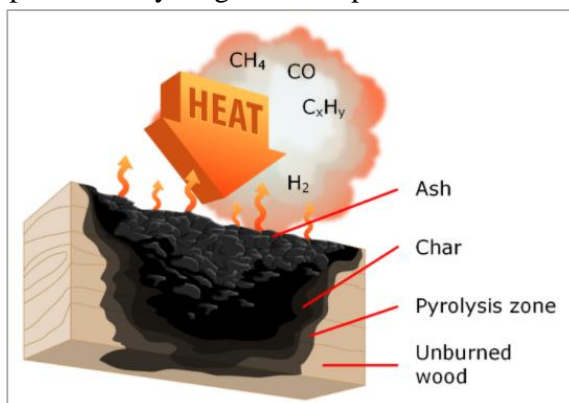
- It is an inefficient form of combustion so carbon monoxide will form a larger percentage of the combustion products relative to flaming fire conditions and,

- ii. Smoldering provides a means to flaming from heat sources normally too small to generate a flame.

## 2. Pyrolysis

Pyrolysis is the chemical decomposition of a material into one or more other substances due to heat alone. All solid combustibles must undergo pyrolysis in order to generate gaseous fuel vapors for flaming combustion. The process of converting a solid to gaseous vapors can take many physical paths depending on the chemical composition of the fuel.

Cellulosic materials, such as wood, decompose directly to gaseous vapors when heated, leaving behind a residue. Thermoplastics such as polypropylene undergo a two-step pyrolyzation process. As the thermoplastic is heated, it melts and turns into liquid and then this liquid is vaporized into a gaseous fuel. Other materials such as flexible polyurethane foams can decompose by different mechanisms which can produce liquid polyols and gaseous isocyanates.



The energy required to convert a solid material into a vapor through pyrolysis is termed as heat of gasification. The lower the heat of gasification, the greater will be the flammability hazard, since less heat will be required to produce fuel vapor that can react in a flame.

For a solid to burn, a portion of the solid must be at a high enough temperature so that pyrolysis occurs at a sufficient rate to maintain the flame. For most solids, this temperature is 300°C to 400°C and the pyrolysis rate must be a few grams per square meter per second.

Further, variety of physical changes result from pyrolysis, including char development, intumescence, melting, and vaporization.

## 3. Flaming combustion

In flaming combustion of solids and liquid fuels, vaporization is an essential part of the burning process. A flame represents a gas phase oxidation process.

The emissivity of flames is strongly linked to the quantity of soot particles present, which in turn will depend on the nature of the fuel and on the structure and behavior of the flame. The potential of a fuel to produce soot and smoke can be assessed by measuring the smoke point. For a given fuel, this is the minimum height of a laminar diffusion flame for which

there is a release of soot particles at the flame tip (i.e., the tip becomes luminous). Fuels that contain the aromatic ring, such as polystyrene, have a very small smoke point and consequently, yield a large amount of smoke. Polymethylmethacrylate and polyoxymethylene, on the other hand, produce relatively small amounts of smoke and have large smoke points.

Alcohol fires, particularly those of methyl alcohol, burn with blue flames containing no soot particles. The radiating species in such flames are the gaseous molecules of water and carbon dioxide. They radiate very weakly in comparison to soot particles and for this reason, the temperature of flames of alcohol fires are much higher than those of fires involving hydrocarbons.

The flame structure is highlighted below:

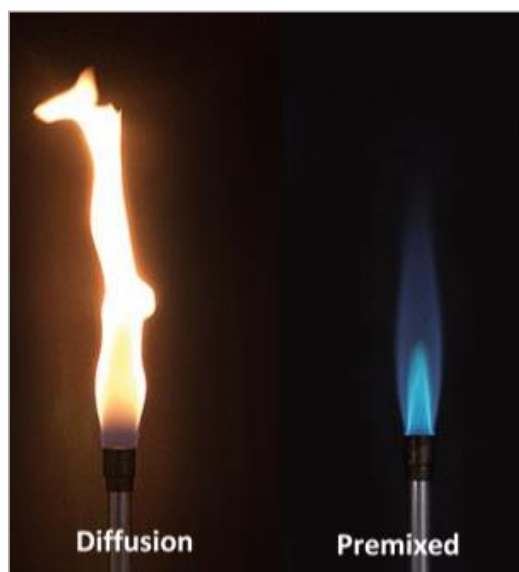
The following two types of flame are being considered:

- i. The premixed flame in which fuel and air are intimately mixed before ignition
- ii. The diffusion flame in which fuel and air are initially separate and burn in the region in which they mix

The premixed flame is much more efficient than a diffusion flame and the conversion of fuel into combustion products is very rapid.

#### 1.4.3. How combustion originates, spreads and terminates

The information gained so far, on the process of combustion is summarized below:



<p>A flammable substance, if in solid or liquid form, should be first converted into vapor (or should be in form of fine powder, if solid) before combustion can take place. In case of a liquid, sufficient <b>vaporization</b> must take place, or in case of carbonaceous solids, <b>pyrolytic distillation</b> must take place, for enough molecules to be available to react with oxygen of the atmosphere.</p>	<p>The flammable vapor/ gas should be intimately mixed with the oxygen of the atmosphere, and in the correct proportion, before combustion can take place i.e. the vapor concentration in air should be within certain limits, called <b>flammability limits</b>.</p>
<p>The mixture must be raised to a temperature where decomposition of molecules takes place (<b>Ignition temperature</b>) to yield smaller, more active fragments, which then begin to react. The chain reactions occurring in the flames provide further heat to increase vaporization, and to continue these reactions.</p>	<p>Combustion reactions will continue until one of the following takes place - the combustible material is consumed, or the oxygen concentration is lowered to a level where it cannot support combustion, or the temperature is lowered to below the ignition temperature, or flames are chemically inhibited.</p>



Perhaps the simplest description of a **fire classification** would be to divide the fire into three regimes:

- i. Pre-combustion
- ii. Smoldering combustion
- iii. Flaming combustion

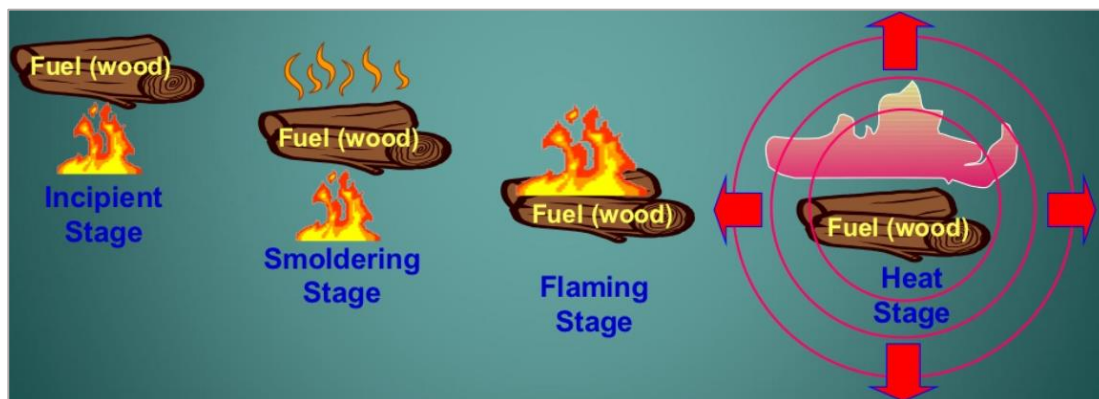
**Pre-combustion** is the process of heating fuels to their ignition point, during which time vapors and particulates are released from the fuel.

**Smoldering** is defined as glowing combustion on the fuel surface and may or may not be related in any way to the oxygen content in the vicinity of the smoldering process. What is implied here is that the fuel vapor production rate and temperatures involved may not be sufficient to support flaming combustion.

**Flaming combustion** - the production of sufficient energy and a fuel vapor mixture with air in a flammable range is the condition that underlies and supports the presence of flame.

Fire growth can be either positive (increasing growth rate) or negative (decreasing growth rate). A fire that increases its instantaneous energy output or heat release rate over time is said to be a growing fire. Typically, growing fires have more air available than is needed

for combustion of the fuel gases being generated and will continue to grow until limited either by the amount of fuel available or the amount of air for combustion.

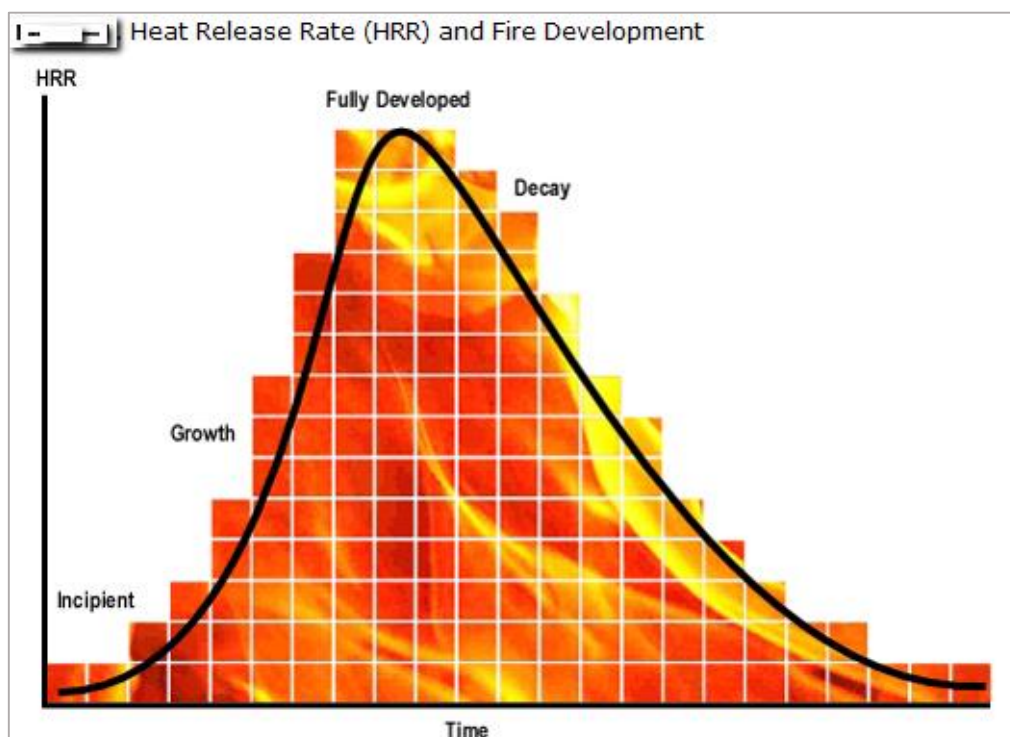


A second category based on growth rate is the steady-state fire. Under steady-state conditions, the fire's heat output or heat release rate remains relatively constant over time. This is not to say that there will not be variations, but there is no rapid continuing increase or continuing decrease in energy release rate. An example of this phenomenon is a flammable liquid pool fire of fixed diameter where, once the entire surface is involved in flame, the amount of energy produced is controlled by the surface area and will be essentially constant until the fuel is exhausted. Another example would be the production of energy from a fire becoming limited due to air supply. In situations where the air supply is increased, perhaps by breaking of windows, a steady-state fire may resume growing if there is sufficient fuel available.

A third category is the burnout or decay condition, where there is plenty of air for combustion but the HRR is decreasing, as fuel is consumed. See below figure for a graphical representation of growing fire, steady-state fire, and decay<sup>1</sup>.

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<sup>1</sup> Source: <https://journeytofirefighter.com/4-stages-of-a-fire/>



Growth rate, or the speed at which growth accelerates, is another way to classify fires. Such fires are considered “time dependent” fires.

## 1.5. Fire Extinguishment

### 1.5.1. Classification of fire

Based on the type of material burning, fires are categorized in 5 classifications:

1. Class A
2. Class B
3. Class C
4. Class D
5. Class F

**1. Class A Fires — Fires involving solid combustible materials of organic nature such as wood, paper, rubber, plastics, etc., where the cooling effect of water is essential for extinction of fires.**





**2. Class B Fires — Fires involving flammable liquids or liquefiable solids or the like where a blanketing effect is essential.**

**3. Class C Fires — 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 vaporizing liquid for extinguishment**

**4. Class D Fires — Fires involving combustible metals, such as magnesium, aluminum, zinc, sodium, potassium, etc. when the burning metals are reactive to water and water containing agents and in certain cases carbon dioxide, halogenated hydrocarbons and ordinary dry powders. These fires require special media and techniques to extinguish.**

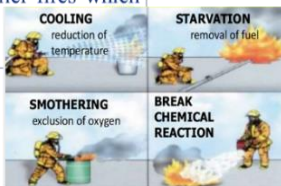
**5. Class F Fires — Fires involving cooking oils and fats. The characteristic of these fires is that the boiling point of these liquids is quite high (> 200 C) and as the heated oil reaches these temperatures, water cannot be applied as it will convert to steam and cause the burning oil to splash out and increase the fire. Special wet chemicals are required for extinguishing such fires.**

### **1.5.2. Fire Extinguishment**

Keeping in mind the fire tetrahedron explained earlier, it will be easy to understand the various methods/ actions by which these fire extinguishing agents act. To relate the fire tetrahedron with the various extinguishing actions, it should be kept in mind that the tetrahedron is a 3-dimensional figure with four sides, each in contact with and supporting the other sides. If even one of the sides is removed, the tetrahedron cannot be supported, and hence it collapses (which means that the fire will cease to exist).

The various extinguishing methods are depicted below:

<p><b>Starvation</b></p> <ul style="list-style-type: none"> <li>By removing potential fuel from neighborhood of fire</li> <li>By removing the fire from the mass of combustible material</li> <li>By dividing burning material into smaller fires which may be left to burn out</li> </ul>	<p><b>Smothering</b></p> <ul style="list-style-type: none"> <li>Reduce of oxygen supply will cease burning</li> <li>Prevent fresh air from reaching to the seat of fire</li> <li>Allow combustion to reduce the oxygen content in the confined atmosphere until it extinguishes itself</li> </ul>
<p><b>Cooling</b></p> <ul style="list-style-type: none"> <li>Rate at which heat is generated by combustion is less than the rate at which it is lost from the burning material, burning will not continue.</li> <li>Cooling the fuel is the main way in which water is used to extinguish the fires</li> </ul>	<p><b>Chemical inhibition of combustion chain reactions</b></p> <ul style="list-style-type: none"> <li>Process of Fire Chemistry cannot exactly be explained in the process of combustion</li> <li>Flaming combustion requires besides Fuel, Heat and Oxygen, a fourth factor, i.e., uninhibited chain reactions, to sustain it.</li> </ul>

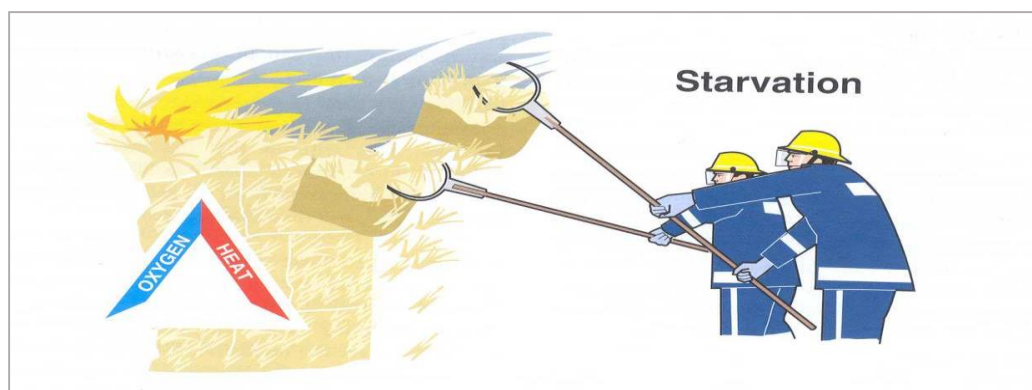


Detailed explanation of each of these methods is presented below:

## 1. Starvation

Fire can be starved in three ways:

- By removing potential fuel from neighborhood of fire. e.g. Draining out fuel from burning tank, counter burning in forest fire, etc.
- By removing the fire from the mass of combustible material for instance, pulling apart burning haystack.
- By dividing burning material into smaller fires which may be left to burn out or which can be extinguished more easily.



## 2. Smothering

If the oxygen supply to the burning material can be sufficiently reduced, burning will cease.



The general procedure in methods of this type is to try to prevent fresh air from reaching to the seat of fire, so to allow combustion to reduce the oxygen content in the confined atmosphere until it extinguishes itself. This is less effective where the burning material contains within itself a chemically combined form of oxygen.

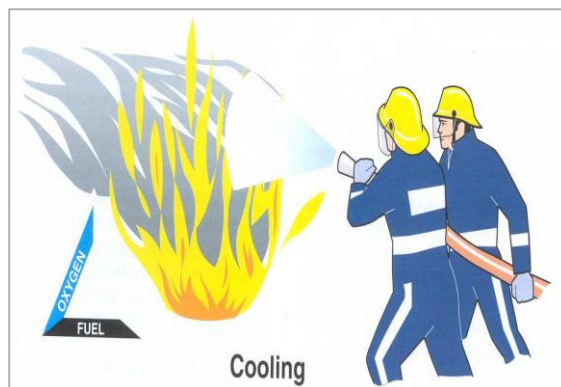


Fire can be smothered with foam, sometimes with fine particles of dry chemical powders or using some confinements which can prevent contact of burning material with oxygen.

### 3. Cooling

If the rate at which heat is generated by combustion is less than the rate at which it is lost from the burning material, burning will not continue.

Cooling the fuel is the main way in which water is used to extinguish the fires. When it is applied to a fire, the extinguishing medium, water itself undergoes changes as it absorbs heat from the fire:



- a) Its temperature will rise
- b) It may evaporate (boil)

Further, smothering effect of the steam produced during boiling process plays important part in fire extinguishment.

### 4. Chemical inhibition of combustion chain reactions

Though a lot of research has been done in the last 3-4 decades in the field of 'Fire' chemistry, scientists still cannot exactly explain the process of combustion. However, based on the available information, certain facts have been established. For instance, flaming combustion requires besides fuel, heat and oxygen, a fourth factor, i.e. uninhibited chain reactions, to sustain it. These chain reactions, are carried on by the presence of extremely active bodies, called '**active radicals**'. Hence, at each stage of combustion reactions, it is

important that enough number of active radicals are generated, so that further reactions are sustained.

If, however, combustion reactions fail to generate enough number of active radicals, the combustion process will slow down and eventually stop. If by the introduction of certain chemicals, these active radicals are somehow ‘arrested’, i.e., made to chemically react in such a way, that they do not further contribute to generation of further active radicals, the combustion reactions can be controlled. Fire can thus be extinguished. A number of chemicals are available today, which can help to achieve the above requirements, i.e., that of arresting the active radicals in the flames.

Amongst these are the Dry Chemical Powders, Halons and certain Halon alternatives<sup>2</sup>. These chemicals dissociate on entering the flame zone, and then cause the active radicals to react in such a way, that they are ‘chemically trapped’, i.e., unable to further contribute to the chain reactions occurring in the flames. However, for it to be effective, a certain minimum concentration of the chemical has to be introduced into the combustion zone. As this action is ‘chemical’ in nature (as opposed to cooling, oxygen dilution, etc. which are ‘physical’ actions), extinguishment by chemical inhibition of chain reactions is extremely fast.

## 1.6. Extinguishment Agents

### 1.6.1. Extinguishment Agents: Water, foams, inert gases and dry chemicals

Various fire extinguishing agents are in use in the world today. Simply stated, a fire extinguishing agent is a substance/ chemical which will extinguish a fire, and it may be in solid, liquid or gaseous form.

#### 1. Extinguishment with water

One might suppose that water is the most widely used extinguishing agent because of its low cost and ready availability, relative to other extinguishing liquids. However, quite aside from cost and availability, water is superior to any other known liquid for fighting majority of fires.



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<sup>2</sup> It should be noted that Halons are being phased out worldwide, due to their adverse impact on the ozone layer

Water has a very high heat of vaporization per unit mass, at least four times higher than that of any other nonflammable liquid. It is also nontoxic; even a chemically inert liquid, such as liquid nitrogen, can cause asphyxiation. Water can be stored at atmospheric pressure and normal temperatures. Its boiling point—212°F (100°C)—is well below the 482°F (250°C) to 842°F (450°C) range of pyrolysis temperatures for most solid combustibles and therefore evaporative cooling of the pyrolyzing surface is efficient. No other liquid, regardless of cost, can match these properties.

However, water is not an absolutely perfect extinguishing agent. It does freeze below 32°F (0°C). It does conduct electricity. It can irreversibly damage some items, although, in many cases, it is practical to salvage water damaged items. When applied in bulk or in sprays consisting of large droplets, water may not be effective for flammable liquid fires, especially flammable liquids that are insoluble in water and float on water, such as hydrocarbons. Water is not compatible with certain hot metals or certain chemicals.

With fires in these materials, other agents, for example, aqueous foam, inert gases, environmentally-friendly halocarbons, and dry chemicals, are preferred. Water may extinguish a fire by a combination of mechanisms—cooling the solid or liquid combustible; diluting water-soluble flammable liquids; cooling the flame itself; generating steam that prevents oxygen access; and as fog, blocking radiative transfer. Although all these mechanisms may contribute to extinguishment, probably the most important is cooling a gasifying combustible.

## 2. Extinguishment with foam



Aqueous foam agents are principally used for fighting flammable liquid fires. If the flammable liquid is lighter than water and is insoluble in water, then application of water would simply result in the flammable liquid floating on it and continuing to burn. If the flammable liquid is an oil or fat, the temperature of which is substantially above the boiling point of water, then the water will penetrate the hot oil, turn into steam below the surface, and cause an eruption of oil that will accelerate the burning rate and possibly spread the fire.

Foams are the primary tools for fighting fires that involve substantial quantities of petroleum products, such as those found at refineries, tankers, and storage areas. If the flammable liquid is water soluble, such as alcohols, then the addition of sufficient water

will dilute the liquid to the point where it is no longer flammable, or alcohol resistance foam can be used. If there is a deep pool of water-soluble flammable liquid rather than a shallow spill, however, the time required to obtain sufficient dilution might be so great that aqueous foam would be a better extinguishing agent. If the nature of a liquid is unknown, aqueous foam might be chosen instead of the direct application of water.

Another important application of aqueous foam agents is on liquids or solids that are burning in difficult-to-access spaces, such as a room in a basement or the hold of a ship. The foam is used to flood the compartment completely.

### 3. Extinguishment with inert gases



Water acts to extinguish fires primarily by cooling, although the formation of steam helps to dilute the concentration of oxygen. On the other hand, inert gases act to extinguish a fire primarily by dilution. Carbon dioxide is the most commonly used inert gas, although nitrogen or steam could be used. Theoretically, helium, neon, or argon could be used, but they are expensive, and are used in certain special cases, such as magnesium fires.

On a volume basis, carbon dioxide is substantially more effective than nitrogen. Note, however, that a given volume of carbon dioxide is 1.57 times as heavy as nitrogen (44 to 28 molecular weight ratio), so the two gases have nearly equal effectiveness on a weight basis. Either gas in sufficient quantity will prevent the combustion of anything except certain metals or unstable chemicals such as pyrotechnics, solid rocket propellants, hydrazine, etc.

If available, steam also can be used as an inert extinguishing agent. The percentage by volume required is intermediate between that required for carbon dioxide and for nitrogen.

It is important to note that carbon dioxide or nitrogen reduces the oxygen level to a point at which exposed humans will suffer undesirable effects. In case of carbon dioxide, an additional serious physiological effect will occur at the concentrations required to extinguish a fire.

Application of an inert gas can extinguish the flame over a liquid or solid. However, if the inert gas dissipates after several minutes, because, for example, the enclosure is not airtight, it is possible that a glowing ember or hot metal could reignite the fire. Re-ignition is

common for a deep-seated fire, such as what might occur in upholstered furniture or in a carton of documents.

#### 4. Extinguishment with dry chemical agents

Sometimes water cannot be used over burning metals, the result of applying water can be



disastrous, often leading to an explosion. New methods of extinguishment have had to be evolved. The dry chemical powders are stored in metal containers under pressure or which can be released by pressured gas<sup>3</sup>. Most basic of these is

sodium bicarbonate with the addition of a metallic stearate as a water proofing agent. Dry powder is very effective at extinguishing flames. It is expelled from the container by gas pressure and directed at the fire in a concentrated cloud. Dry chemical powders are supplied in polyethene bag & it is better to bury metal fire under these bags for effective extinguishment – powder melts and smothers the flame. Dry chemical powders are also tested for their compatibility with foams.

Turnery eutectic chloride powders have been developed for some metal fires especially radioactive metals such as uranium and plutonium. These contain an ingredient which melts then flows a little and forms a crust over burning metal, effectively sealing it from surrounding atmosphere thereby isolating the fire.

### 1.7. Combustion Products

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<sup>3</sup> Source of image – Yamato Protec



### 1.7.1. Combustion Products - Heat, visibility & toxicity of fire products

The products of combustion at various stages of this process are fire gases (i.e. gases produced prior to and during the combustion process), flames, heat, and smoke. All these products have some or the other effect on the surroundings, including humans, for e.g. the smoke from fires affects the human ability to see and escape out of fire affected areas. It also affects the respiratory system, causing irritation of the respiratory tract, besides having other effects such as the development of a fear psychosis, nervous system depression, etc. The different gases generated during combustion can have different physical and physiological effects on the human body, some of which can be lethal.

The heat emanating from a fire causes thermal burns; scalding of the skin and respiratory tract. Similarly, the heat and smoke from fires also adversely affect humans, equipment and surroundings, causing damage. To minimize such effects and to keep damages during fires to a minimum, it is important to obtain sufficient knowledge of these factors.

Combustion is an exothermic reaction, and a large amount of energy is given out in the form of heat and light. This evolution of a large amount of heat during combustion reactions is mainly responsible for the growth of fire, and hence it becomes necessary to somehow control this development and spread of heat. The effect of heat on surroundings and humans is seen in detail later. The heat evolved in a fire spreads by three main methods – conduction, convection and radiation.

#### 1. Conduction

It is the transfer of heat due to direct contact, i.e., the heat flows from one body to another if they are in direct (physical) contact with each other. Hence, heat can travel through solid walls, or steel beams, and ignite combustibles which are in contact with it even at a distance, for e.g. the fire may heat a steel beam on one side of the room, while a waste cloth lying on the other end of the beam will get ignited after some time, as the heat is conducted from one end of the beam to another. Steel drums filled with liquid, if involved in a fire, will conduct the heat to the liquid inside, which will then expand and cause the container to burst.

#### 2. Convection

Convection is the method of heat transfer in case of liquids and gases. This concerns the motion of heated liquids, smoke, hot air, and heated gases produced by the fire. It is known that hot gases (and liquids) move in an upward direction, as they are lighter, while cold gases (and liquids) move downwards. This is the reason why smoke and hot air from the





fire rise in an upward direction. These hot gases transfer the heat to substances and combustibles in other areas, which they come in contact with and can raise the temperatures sufficiently to cause ignition and further burning. This is especially true for enclosed/ semi-enclosed spaces, where the hot smoke and gases cannot escape vertically to the atmosphere, they can move in a horizontal direction, thus spreading the fire from one area to another. Calculation of the amount of heat given out in the form of convection is a difficult task (especially for open freely burning or 'turbulent' fires), though some calculations and formulae have been put forward by scientists in the recent past, which can give us an approximate value.

### **3. Radiation**

Radiation involves transfer of heat across space without the aid of any medium. The energy travels in the form of electromagnetic waves, at the speed of light. Radiated heat travels in straight lines and in all directions. This heat is either absorbed, reflected or transmitted by objects on which the radiation falls, depending on the property of the object. Objects which are dark in color will absorb most of the heat, while objects which are white or shiny will reflect most of the heat<sup>4</sup>. Visible light waves stretch from red to violet color (visible wavelengths). The radiation given out from fires is broader than this and stretches from infrared (wavelength larger than red) to ultraviolet (wavelengths smaller than violet). Thus, besides visible light, energy is also given out in the form of invisible radiation.

Radiation is absorbed by objects in the path of the radiated waves if the temperature of the object is lower than the temperature of the emitting body. When we light small fires to warm ourselves in the winter, most of the convected heat goes up along with the hot gases and smoke (and cooler air goes into the fire from the bottom side). The heat that we experience from a fire is due to the heat which is given out in the form of radiation. Radiant heat thus causes combustibles on which it falls, to heat up, and can ignite heated vapors, thus spreading fires. As radiation doesn't need a medium to travel, there have been instances of fires spreading from one building to another even across a river, with seemingly no contact. As almost 30 to 35% of the heat given out from a well ventilated outdoor fire, is given out in the form of radiation, it is important to know as much as possible of this form of heat and how it can be controlled.

### **4. Gases generated during combustion**

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<sup>4</sup> This is why most storage tanks are painted with white or silver color paint externally



Many gases generated during combustion can remain even after the combustion products are cooled to normal temperature. These gases can have different effects of human life. Many fire gases are toxic, some of them lethal even in small doses. As carbon is generated during most of the solid fire as well as hydrocarbon liquid fires, carbon monoxide and carbon dioxide are two gases that are generated commonly. Other gases that are produced are hydrogen sulphide, sulphur dioxide, ammonia, hydrogen cyanide, nitrous and nitric oxides, hydrogen chloride and phosgene. Different types of gases are generated depending upon the composition of the fuel, amount of oxygen available and the temperature reached during combustion which are elaborated subsequently.

The nature and concentration of the smoke generated depends on a variety of factors. These include the quantity of the product that is burning, whether the product is flaming or pyrolyzing, the ventilation in the area and distance from the fire. Thus, smoke toxicity is not a singular property of a product.

The threat to people from the heat and smoke depends on additional factors including the entire ensemble of burning products, the location of people relative to the fire, the locations of exits from the burning enclosure and the paths to those exits, the time (in the fire growth history) at which people are in the vicinity of the fire-generated atmosphere, individual susceptibility of each person to the components of the smoke, etc. The particulates and aerosols produced affect the occupants' visibility as they attempt to escape from a fire. Following gases are commonly produced by fires:

**i. Carbon dioxide (CO<sub>2</sub>)**

Carbon dioxide is generated in fires involving carbon contents, such as wood, rubber and plastic fires or in liquid hydrocarbon fires. Being only 0.04% (by volume) in atmosphere in normal circumstances, the increase in concentration of this gas causes overstimulation in breathing. For e.g., the rate of respiration increases one and half times for 2% CO<sub>2</sub> concentration, and two times for 3% concentration. Though CO<sub>2</sub> by itself may not cause immediate death or damage for concentration up to 10%, the important fact is that as the breathing rate increases, the intake of other toxic gases, which are produced during combustion also increases which can pose an immediate threat to life.

**ii. Carbon monoxide (CO)**

We are aware that when combustibles containing carbon, and a large number of combustibles do contain carbon, are involved in combustion; carbon dioxide is





generated. However, if the amount of oxygen available is not enough, the formation of carbon monoxide takes place. This gas, though seemingly similar to carbon dioxide, is lethal, as it is toxic even in small concentration and can be fatal for human beings even with limited exposure. The danger of carbon monoxide is that it combines very easily with hemoglobin, which is the oxygen carrier of our blood. In fact, its affinity to combine with hemoglobin is much greater than oxygen, and hence it prevents oxygen from entering the blood and reaching different parts of the body. This has an immediate effect on our metabolism, as the required amount of energy cannot be generated for different body functions. In fact, a 0.4% concentration of CO is lethal within an hour's time and a concentration of 1.3% can cause death within a few minutes.

For open, well ventilated fires, generation of carbon monoxide is very less, as most of the carbon is converted to carbon dioxide. However, for enclosed, poorly ventilated fires such as most indoor fires, the proportion of carbon monoxide can be much higher and can reach lethal concentrations very easily.

### **iii. Nitrogen dioxide (NO<sub>2</sub>)**

This reddish brown gas, is normally produced in fires involving cellulose nitrates, ammonium nitrates and other inorganic nitrates. This gas is also extremely toxic and produces an anaesthetizing effect on the throat, thus preventing recognition and causes delayed effects on the lungs. Exposures in excess of 0.02% can be fatal.

### **iv. Hydrogen chloride (HCl)**

Polymer systems containing halogen atoms (fluorine, chlorine or bromine) result in the formation of halogen acids such as hydrogen fluoride (HF), hydrogen chloride (HCl), and hydrogen bromide (HBr), the production of which is largely material-dependent as long as thermal decomposition temperatures are reached. For e.g., whenever plastic products containing chlorine are involved in combustion, hydrogen chloride gas is evolved. The most common example is PVC (Poly Vinyl Chloride), which is used commonly for most electrical cabling applications today. It is also being used increasingly as conduits and pipes. Besides being fatal at low concentrations (0.15%), it is also corrosive because of which it can cause great damage to equipment as well as construction elements, like steel members.

### **v. Hydrogen cyanide (HCN)**



An extremely poisonous gas, it can be generated in large quantities in fires involving substances containing nitrogen e.g., wool, silk, urethane, acrylics, especially if incomplete combustion takes place. However, the quantity of gas generated may not be as high in normal, ventilated fires. Lethal concentration is as low as 0.3%.

**vi. Acrylic aldehyde (C<sub>3</sub>H<sub>4</sub>O)**

Also known as acrolein, it is produced, though in small quantities, in fires involving fats, oils and petroleum products. It is, however, highly toxic and concentrations of about 10 ppm can be fatal in a short time.

Note: Like chemicals, many of the above mentioned gases also affect materials that they come in contact with. As they are in gaseous form, however, the physical contact with surrounding materials may not be for long periods chemical.

**vii. Other gases and Aerosols:**

Depending on the composition of the combusting products, additional toxic components of smoke can be produced in a fire. For example, phosphorus-containing fire retardants can result in phosphoric acid aerosol, and sulfur-containing polymers can generate sulfur oxides.

**5. Visibility effects of smoke**

Smoke consists of suspended, solid particles, consisting of carbon and other unburned substances, as well as vapors of water, acids and other gases which can have toxic effects if inhaled. In some instances, i.e., clean burning fires, smoke may not be visible, but in general, it is an indication and evidence of a fire.

As the hot buoyant fire gases move upwards, they cause mixing with the air, which gets entrained during the upward movement. This resultant mixture of hot, toxic gases and entrained air also causes condensation of the hot gases, resulting in formation of some particulate matter called soot. This mixture, which rises from the fire is known as ‘**smoke plume**’ and can vary in color from light color to black.

The visibility problems of smoke are well known; as the solid particles and aerosols block light, they impair vision and persons unable to view exits, or exit passages, can develop a panic psychosis. The fact that smoke induces tears in the eyes further complicates the problem of visibility.



## **Chapter 2:**

# **Fire Service Setup, Fire-Fighting Procedures & Fire Brigade Features in Buildings**



## 2. Fire Service Setup, Fire-Fighting Procedures & Fire Brigade Features in Buildings

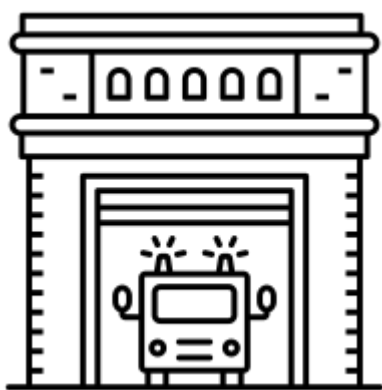
### 2.1. Introduction

Fire service is one of the most important emergency response services in the country, which comes under the 12th schedule of the constitution dealing with Municipal functions. At present, fire prevention and firefighting services are organized by the concerned states and Union Territories (UTs) and Urban Local Bodies (ULBs). Directorate of National Disaster Response Force and Civil Defense (NDRF & CD, Fire Cell), Ministry of Home Affairs (MHA) render technical advice to the states, UTs and central ministries on fire protection, prevention, and legislation. Fire services in Chhattisgarh, Gujarat, Haryana, Madhya Pradesh (excluding Indore), Maharashtra and Punjab are under the respective Municipal Corporations. In the remaining states, it is under the respective Home Department.

Varying risk scenarios need different types of firefighting equipment and training for responding to incidents. Risk varies with geographical location such as hilly area, coastal area, desert area and with residential (high-rise, medium, and low rise buildings), industrial, commercial area or a combination of these.

### 2.2. Function of fire service in government setup

#### 2.2.1. Background<sup>5</sup>



The primary role of fire services has been to attend to fire incidents. Besides firefighting, fire department also attends to other emergencies such as structure collapse, road traffic accidents, human and animal rescue and other special service calls. Some fire services also attend medical emergencies for transportation of casualties through ambulances maintained by them. Similarly, some states/UTs like Delhi and Goa have separate flood department with rescue boats and trained divers (in such cases, the Fire Services maintain

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<sup>5</sup> Source of icon – The Noun Project



skeletal facilities to act as “first responders” and waits until assistance from the flood department arrives). It is therefore, considered appropriate that the specialized facilities for such jobs is maintained and operated by the concerned department.

As indicated in the National Disaster Management Authority (NDMA) guidelines, Fire Service is one of the Emergency Support Functions (ESF). Based on DM Act 2005, various states have also formulated State Disaster Management Authorities (SDMAs) and District Disaster Management Authorities (DDMAs) both of which consider Fire Service as an ESF. It is, therefore, evident that the role of Fire Services has become multi-dimensional that includes not only attending fire incident calls but also various other emergencies. Accordingly, fire services in the jurisdiction of the respective fire stations are required to be prepared with suitable types of equipment to deal with various emergencies.

The role of fire services also includes effective fire prevention, creating awareness on fire safety and enforcing the inbuilt fire protection arrangements for various types of occupancies in line with National Building Code:2016 (NBC) Part 4. However, some of the States/Municipal Fire Services are unable to enforce the fire safety provisions due to a lack of appropriate directives from the authorities controlling the function of fire services. Some of the Fire Services do not adhere to NBC and have created their own fire-safety building byelaws, e.g., Mumbai Fire Brigade. It may be noted that in-built fire safety arrangements and escape facilities are much more important than having a fire service within the premises without the above facilities. It is, therefore, necessary to enforce the fire-safety provisions through appropriate directives to all the States/UTs by the Ministry of Home Affairs (MHA) directly or through DG, NDRF & CD office.

In addition to the regular fire services, various other organizations/ industries such as ports, airports, defense, power, oil and gas, steel, heavy engineering, fertilizers, chemicals, etc. have their own fire service set-ups (including their own captive resources), in order to provide fire protection to their facilities and some of them at times provide support to local fire services on request. All of them have their rules and regulations concerning fire safety. For example, Oil India Safety Directorate (OISD) norms for oil and gas industries, International Civil Aviation Organization (ICAO) norms for airports, Tariff Advisory Committee (TAC) regulations (now discontinued), various Indian standards for industries etc. and Electricity Rules for power sector.

Safety of highly hazardous processing and storage industries requires 100 percent round the clock built-in and functional fire protection arrangements with trained fire fighters as



well as on-site and off-site disaster management plans. Fire services are not expected to create the infrastructure to independently tackle such emergencies within the industry, as it may be not be possible to do so. However, they are expected to support any on-site and off-site firefighting to protect surrounding population and handle such incidents during transportation through civil areas. Moreover, local fire services should have mutual-aid schemes with all the industries in their jurisdiction and must be aware of the various arrangements available with them in order to provide efficient support, in case of an emergency.

### **2.2.2. Concept of fire station requirement and location based on response time, population, etc.**

**(Reference to SFAC guidelines)**

Presently, Fire & Emergency Services in Gujarat have 214 operational Fire Stations (combined with Municipal Corporations and Municipalities), a Gujarat State Institute for Fire Safety Training (GSIFST) and 5 Emergency Response Centres (ERCs) at Gandhinagar, Gandhidham, Rajkot, Surat, and Vadodara.

### **2.3. Current fire service setup in urban and non-urban areas in Gujarat**

At present, there is a lack of a comprehensive centralized database on the distribution of fire service infrastructure and the stock of existing fire fighting vehicles, manpower and specialized equipment, their types, and their quantities. Most of the information is either disaggregated or requires updation.

As stated earlier, the fire service was expected to focus on fighting fires and the law constrained what they could do. However, with time, the importance of promoting fire safety increased and the type of incidents the Fire Service responded to also changed. As a result, under the new act, Fire and rescue authorities now have a range of statutory duties to:

- |   |
|---|
| <b>1) Promote fire safety</b>   |
| <b>2) To prepare for:</b> <ul style="list-style-type: none"><li>(i) Fighting fires and protecting people and property from fires;</li><li>(ii) Rescuing people from road accidents(vehicle collision)</li></ul> |



- (iii) Dealing with other specific emergencies such as rescuing people and animals from floods
- (iv) Handling emergencies such as Earthquake
- (v) Rescuing people from building (structure collapse)
- (vi) Providing emergency services during gas leakage
- (vii) Providing services during chemical related emergencies
- (viii) Providing ambulance services
- (ix) Protocol related duties, providing standby duties for VIP movement
- (x) Water tanker facilities(in some departments)

### 2.3.1. Current Fire Service setup in urban and non-urban areas in Gujarat – Infrastructure, vehicles and manpower availability

Fire service in the state of Gujarat is mainly divided into 3 parts

1) Fire service operating under state department in accordance to the new formed act (Gujarat state fire prevention and life safety measures act, rules and regulations)	2) Fire service operating under the various municipal corporations under GPMC act (Gujarat provincial municipal corporation act, 1949- GPMC act 2019)	3) Fire Brigade set up in Government, PSU and Private Factories
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### 2.3.2. Gujarat state government setup

Currently the prime focus of the state fire service department is on prevention related services and development & upliftment of the whole cadre including basic infrastructure, vehicle procurement and recruitment process for various posts and also framing and amendments of rules and act to bring the whole Fire service under 1 umbrella (developing of a state cadre with single department headed by the Director of Fire service)

### 2.3.3. Municipal corporation setup

Even before the independence, a fire service was working under municipal corporations.

Currently there are 8 municipal corporations in the state of Gujarat and 162 municipalities.



Areas pertaining to urban development authorities is looked after by municipal corporations and municipalities both (whichever is near and has less response time is responsible to deploy its man and machine). Rural areas are looked after by various municipalities.



Along with that, there are 5 specially made fire stations ERC (Emergency Response Centres). These ERC's have been allotted with specially procured vehicles and machinery by GSDMA (Gujarat state Disaster Management Authority). Its prime focus is to provide services in the rural areas and also industrial belts in rural areas. These ERCs are being operated by various municipal corporations of each zone through tripartite MoU between Commissioner of Relief, GSDMA and concerned Municipal Commissioner/ District Collector.

#### 2.3.4. Fire brigade set up in government, PSUs& private factories

Along with state and local bodies fire set up, there is also a third segment which effectively operates the fire services with sufficient man & machines in their organizations independently and associated in the form of Mutual aid program as a part of the district disaster management plan of respective districts.

Following are the examples of such fire services set up.

<b>Government</b>	GIDC, Port Authorities, Airport authority of India, GEB, etc.
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<b>PSUs</b>	ONGC, OPAL, other refineries, GoG companies, etc.
<b>Private</b>	It includes private industries which have their own fire department having 24x7 manned and vehicles

### 2.3.5. Details of region-wise fire stations & staff in Gujarat

SN	Regions	Headquarter	Territory	District
1	Ahmedabad Municipal Corporation	Ahmedabad	Area of Ahmedabad Urban Development Authority (Except Municipality Area of Dehgam, kalol, Bareja, Sanand and Mehamdabad)	—
2	Surat Municipal Corporation	Surat	Area of Surat Urban Development Authority (Except Municipality Area of Sachin and Kanakpur, Kansad) including Surat Municipal Corporation	—
3	Vadodara Municipal Corporation	Vadodara	Area of Vadodara Urban Development Authority including Vadodara Municipal Corporation	—
4	Rajkot Municipal Corporation	Rajkot	Area of Rajkot Urban Development Authority including Rajkot Municipal Corporation	—
5	Jamnagar Municipal Corporation	Jamnagar	Area of Jamnagar Urban Development Authority including Jamnagar Municipal Corporation	—



SN	Regions	Headquarter	Territory	District
6	Gandhinagar Municipal Corporation	Gandhinagar	Area of Gandhinagar Urban Development Authority including Gandhinagar Municipal Corporation	—
7	Bhavnagar Municipal Corporation	Bhavnagar	Area of Bhavnagar Urban Development Authority including Bhavnagar Municipal Corporation	—
8	Junagadh Municipal Corporation	Junagadh	Area of Junagadh Urban Development Authority including Junagadh Municipal Corporation	—
9	Ahmedabad	Ahmedabad	Limits of Districts Shown in Column-5 excluding any area included in sr.No1 to 8 above	(i) Ahmedabad (ii) Kheda (iii) Surendranagar (iv) Botad
10	Gandhinagar	Gandhinagar	Limits of Districts Shown in Column-5 excluding any area included in sr.No1 to 8 above	(i) Gandhinagar (ii) Banaskantha (iii) Mehsana (iv) Sabarkantha (v) Aravali (vi) Patan
11	Surat	Surat	Limits of Districts Shown in Column-5 excluding any area included in sr.No1 to 8 above	(i) Surat (ii) Narmada (iii) Navsari (iv) Bharuch (v) Valsad (vi) Tapi (vii) Dang
12	Vadodara	Vadodara	Limits of Districts Shown in Column-5 excluding any area	(i) Vadodara (ii) Mahisagar (iii) Dahod



SN	Regions	Headquarter	Territory	District
			included in sr.No1 to 8 above	(iv) Panchmahal (v) Anand (vi) Chhota-Udepur
13	Rajkot	Rajkot	Limits of Districts Shown in Column-5 excluding any area included in sr.No1 to 8 above	(i) Rajkot (ii) Jamnagar (iii) Devbhumi-Dwarka (iv) Morbi (v) Kutchh (vi) Porbandar
14	Bhavnagar	Bhavnagar	Limits of Districts Shown in Column-5 excluding any area included in sr.No1 to 8 above	(i) Bhavnagar (ii) Amreli (iii) Gir-Somnath (iv) Junagadh

### 2.3.6. Details of municipal corporation-wise fire stations & staff in Gujarat

SN	Regions	Number of fire stations	Fire manpower
1	Ahmedabad	16	<ul style="list-style-type: none"> <li>Chief Fire officer</li> <li>Add. Chief Fire officer</li> <li>Dy. Chief Fire officer</li> <li>Divisional Fire officer</li> <li>Fire officer/ Sub fire officer</li> <li>Leading Fireman</li> <li>Driver cum Pump operator</li> <li>Fireman</li> <li>Other</li> </ul>
2	Surat	16	
3	Vadodara	08	
4	Rajkot	08	
5	Jamnagar	03	
6	Gandhinagar	01	
7	Bhavnagar	01	
8	Junagadh	01	
<b>Total</b>		<b>54</b>	



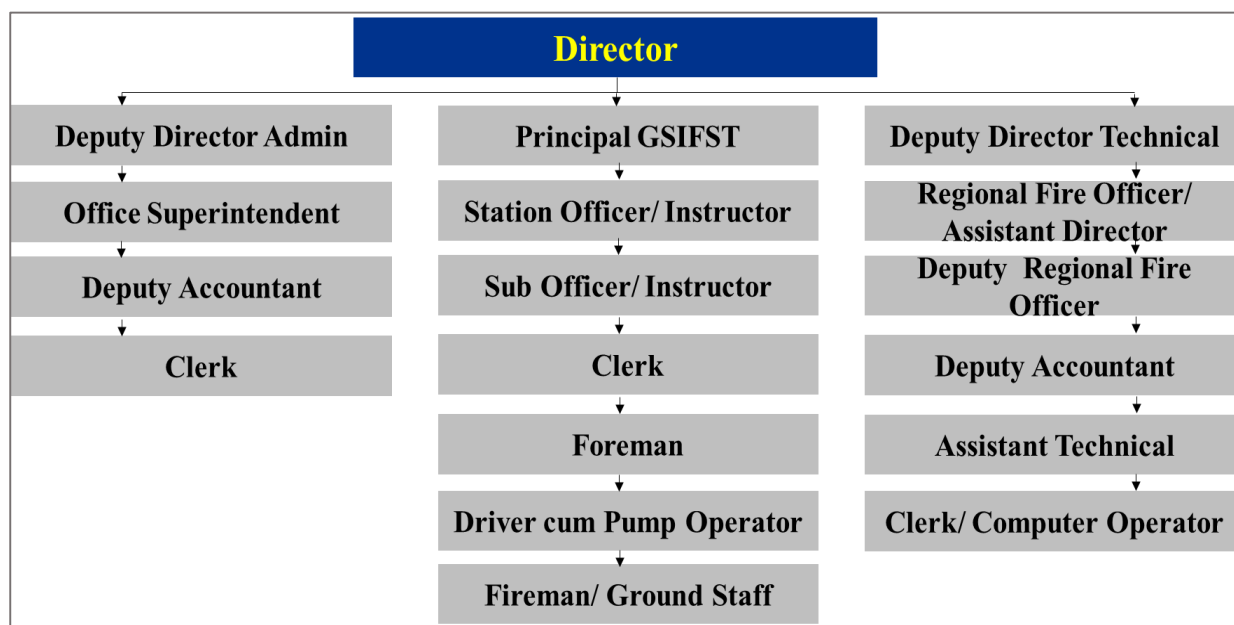
### 2.3.7. Details of Emergency Response Centers (ERC)

SR. NO.	NAME OF THE ECR	OPERATED BY AUTHORITY
1	Gandhinagar	Ahmedabad municipal corporation
2	Vadodara	Vadodara municipal corporation
3	Surat	Surat municipal corporation
4	Rajkot	Rajkot municipal corporation
5	Gandhidham	Collectorate, Bhuj

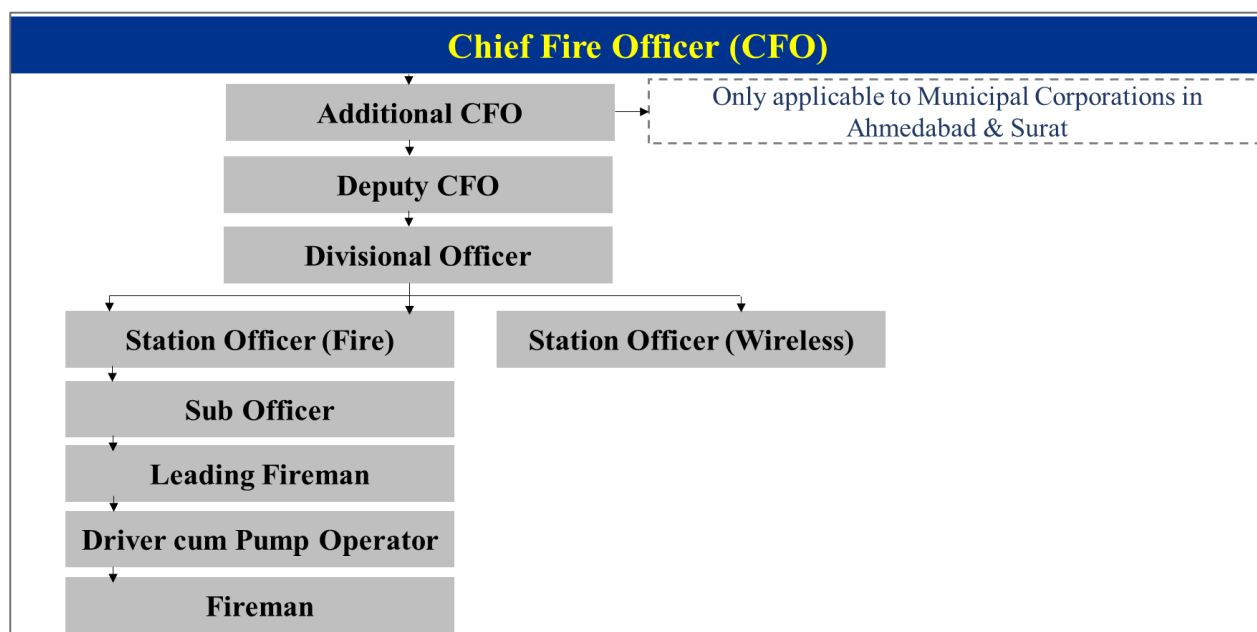
## 2.4. Understanding fire service hierarchy and ranks in other states and Gujarat

### 2.4.1. Understanding Fire Service hierarchy and ranks in other states and Gujarat

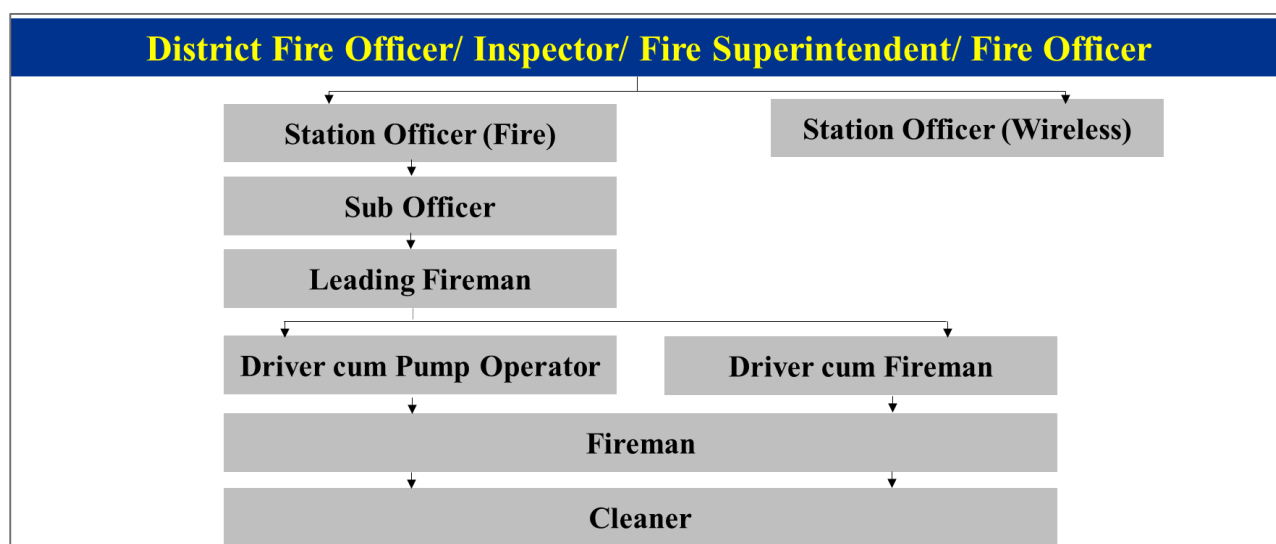
#### 1) Organogram of Gujarat state fire prevention services



#### 2) Organogram of Fire services at municipal corporations



### 3) Organogram of Fire services at nagarpalika



## 2.4.2. Powers and responsibilities of Fire service

### State fire prevention services

#### 1) Responsibilities of the Fire Director

The Director shall:

- (1) Function as the Head of Department in the office of the Director;
- (2) Subject to the rules made in this behalf, the Director may appoint subordinate staff only on the recommendations of the Gujarat State Subordinate Services Selection Board on such terms and conditions of salaries and allowances as may be fixed by the State Government;



- (3) Keep liaison with the Central Government and the State Government offices for development of fire services;
- (4) Frame policies in relation to development of fire services in the state and, on approval by the State Government, take steps to implement the same;
- (5) Exercise superintendence and control over all authorities in the matters relating to fire prevention and fire safety measures; and subject to the approval of the State Government, issue such directions to any authority in respect of fire services maintained or required to be maintained by them;
- (6) Represent the State Government on National and International forums with a view to updating the standard of fire services in the State;
- (7) Prepare and submit plans and proposals to the State Government with regard to the periodical review of fire equipment, fire property and fire manpower for effective implementation of fire services by the authorities;
- (8) Take or cause to be taken such effective steps and measures in cases of major fires, house collapse and other emergency services;
- (9) Investigate or cause to be investigated the cause of fire and advise the authorities for implementing fire precautionary measures;
- (10) Advise the State Government to set up additional Fire Training Centre or Centres for imparting training to the officers and staff of local authorities so as also to cater to the need of the various factories, commercial and mercantile establishments in the private sector and to impart training to officers and the staff or to provide them the trained and qualified fire service personnel;
- (11) Requisite fire-fighting equipment of any authority or any institution or individual, which in his opinion is required for the purpose of extinguishing fire in any area, and to determine the amount of compensation payable in respect of such equipment of in the area of which authority, such fire operation is required to be carried out;
- (12) Exercise such other powers and perform such other duties and functions as may be conferred, imposed or allotted to him by or under the provisions of this Act.

## **2) Responsibilities of the Assistant Director / Regional Fire Officer (RFO)**



- Implementation of various requirements and duties as per Gujarat Fire prevention and life safety measure act 2013
- Approving and issuing the Fire safety plan approval certificates and Fire safety certificate according to State Fire Prevention act/rule/regulations at online platform.
- Work related to RTI and proactive disclosures
- Maintaining the Departmental website
- Various duties related to quarries and record maintenance to be produced in the Gujarat state legislatures assembly.
- Day-to-day works related to departmental meetings
- Legal duties related to court matters
- Preparing and maintaining record and reports related to Fire and other emergencies.
- Organizing various seminars and associate duties
- Preparing weekly, bi-weekly, monthly and annually reports
- Preparing of Fire prevention plan and effectively implementing them in the state.
- Conduction fire audits, inspection and monitoring on FSO fire safety certificate renewal works

### **3) Responsibilities of the District Fire Officer (DFO)**

1. He will be reporting to Regional Fire officer of the respective region of The State.
2. To be in charge of a District and overall in charge of various fire stations of municipalities pertaining to respective districts.
3. Supervision of Fire Department works and Stations under their jurisdiction;
4. Maintenance of discipline and training on operational standards in the division;
5. Good understanding of both common and special fire hazards which may be encountered within the district;
6. Familiarity with all properties and installations in which fires may have to be fought with particular attention to target hazards in the district;
7. An adequate knowledge of the constructional features of the buildings, warehouses as an aid in fire-fighting operations to permit recognitions of dangerous situations and for co-operations with the local building authorities;
8. A good understanding of firefighting tactics and strategy to permit complete disposition of all fire units operating at a fire in his district;

### **Municipal corporation fire department**





## **1) Responsibilities of the Chief Fire Officer**

- (1) To see that the plans of operations are carefully prepared and strictly carried out;
- (2) To see that the human materials in the organization are suitable to the objectives of the department;
- (3) To see that there is a competent and vigorous management of the department;
- (4) To coordinate operations within the department and with other departments;
- (5) To make careful selection of staff and define duties clearly;
- (6) To see that Discipline is maintained at all levels;
- (7) To make decisions which are clean, distinct, reasonable, far sighted, precise and unambiguous;
- (8) To impose penalties for mistakes, blunders and violations of discipline;
- (9) To see that the individual interest do not interfere with the interest of the department or public;
- (10) To pay special attention to unity of command at various levels;
- (11) To see that everything is subjected to proper control and the entire administration is running smoothly and on a systematic basis absolutely in accordance with the Services Rules.

## **2) Responsibilities of the Deputy Chief Fire Officer**

- (1) To Assist the Chief Fire Officer in all administrative matters;
- (2) He is the Appointing Authority for certain cadres up to Assistant Divisional officer;
- (3) He Functions as a Leader in his own sphere and is answerable to the CFO in the proper functioning of the service;
- (4) Some monetary powers are also delegated to him to sanction certain expenditure such as repairs and replacement, POL etc.;
- (5) He is punishing authority up to the level of Assistant Divisional Fire Officers whom he can dismiss from service if any moral turpitude is involved or any grave nature of offence is committing, Re-examine the Disciplinary cases dealt with by the Divisional Fire Officers;
- (6) He is next in command to the CFO of Fire Service;



- (7) To pay special attention to unity of command at various levels;
- (8) To see that everything is subjected to proper control and the entire administration is running smoothly and on a Systematic basis absolutely in accordance with the Services Rules.

### **3) Responsibilities of the Divisional Officer**

- (1) To be in charge of a Division, comprising of 2 to 8 Fire Stations on the amount of risk covered in the division;
- (2) Supervision of Fire Department works and Stations under their jurisdiction;
- (3) Maintenance of discipline and training on operational standards in the division;
- (4) Good understanding of both common and special fire hazards which may be encountered within the division;
- (5) Familiarity with all properties and installations in which fires may have to be fought with particular attention to target hazards in the division;
- (6) An adequate knowledge of the constructional features of the buildings, warehouses as an aid in fire-fighting operations to permit recognitions of dangerous situations and for co-operations with the local building authorities;
- (7) A good understanding of firefighting tactics and strategy to permit complete disposition of all fire units operating at a fire in his division;
- (8) To assist the Dy. CFO in matters of administration and to be in overall in-charge of 2 to 3 Fire stations;
- (9) To supervise the working of fire stations under his jurisdiction. Assumes the charge of Dy. CFO in his absence due to leave, sickness or otherwise.

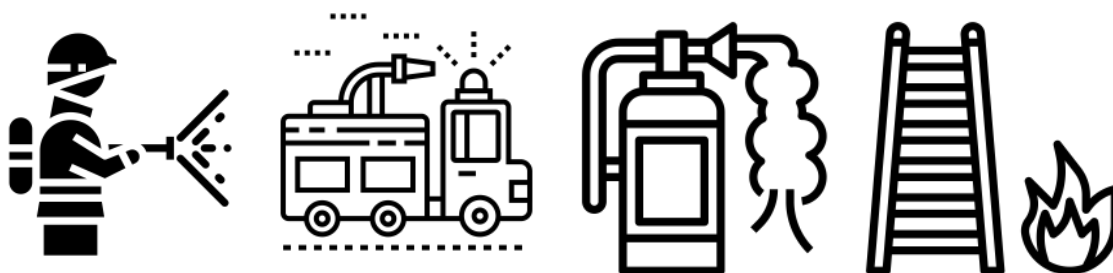
### **4) Responsibilities of Station Officer**

- (1) To be in-charge of at least one fire station and perform all Execution and administrative duties;
- (2) To manage a fire station establishment, supervising housekeeping, maintenance of appliances, apparatus, personnel and stores;
- (3) To be familiar with the Topography of station which he is in-charge and carry out inspections for every fire hazard;

- (4) To look after the drills, parades, station routine works and office work and keep them up to date at all time;
- (5) To maintain discipline and high standards of firefighting morale amongst the staff in his charge at the station;
- (6) To look after the distributions of staff duties and operational duties amongst the rank and file of the stations of which he is Incharge;
- (7) To lead the turn-outs and to scheme and conduct the operations at the fire ground;
- (8) Must have the mental alertness and capability of making proper size up and appraisal of a fire or other emergency and to determine whether help is needed or he will be able to go ahead with the works all on his own and to appropriately judge such time as he would feel the need of the presence of superior officer at the scene of occurrence;
- (9) In general, he is absolutely responsible for everything in connection with his station.

## 2.5. Different types of firefighting vehicles and equipment used by fire services

### 2.5.1. Different types of firefighting vehicles (tender) and equipment used by Fire Services<sup>6</sup>



The Role of a firefighter in fire and emergency services is to extinguish fire, rescue trapped persons, provide medical first aid and also respond to various fire accidents and disasters caused by various natural and manmade hazards. A firefighter fights fires to prevent loss

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<sup>6</sup> Source of icons – The Noun Project



of life, and/or destruction of property. In fact, it is a risky profession, that requires firefighting, rescue vehicles and specialized equipment to work effectively and safely to mitigate consequences of a fire & emergency incidence in an area.

Firefighting and rescue vehicles and specialized equipment used in fire services across the country are fabricated largely as per Bureau of Indian Standards (BIS). BIS formulate the specification for these firefighting vehicles and equipment as per the recommendation by a committee of fire chiefs, manufacturers and users of various departments. However, it has been observed that, there are new types of equipment used by various state fire services, which are not included under BIS specifications. The fire services can evaluate the performance of these new type of equipment depending upon the need of such an equipment in an area for a specific operation.

It is difficult to prepare a standard list of all the firefighting vehicles and equipment that can be provided for every fire station in the country, because of:

- (i) Size of firefighting and rescue vehicles will depend on several factors such as local road condition, topographic condition, etc.
- (ii) Need of accessories will also depend on specific requirements of a state/UT Fire & Emergency Service/ Fire Service. Accordingly, requirement of equipment mounted on firefighting and rescue vehicles may also be modified.

Therefore, the State Fire Services may modify the specification of firefighting and rescue vehicles and equipment based on specific prerequisite.

Some common firefighting/ rescue vehicles currently being used in fire services are enlisted below:

Water tender	Rescue van	Foam tender
Water cum Foam tender	Dry Chemical Powder (DCP) tender	Multipurpose Tender (Water/ Foam/ DCP)
Mini Fire tender	Quick Response Vehicle	Hydraulic elevated Platform vehicle



Turn table ladder vehicle, etc.	Water mist vehicle	Advance water Tender (Water/foam/rescue equipment)
PPV Fan vehicle	Fire Robot	

Imagery of equipment/ vehicle used:

### PPV Fan Vehicle



### Water tender



### Hydraulic Elevated Platform













Some of the common firefighting and rescue equipment carried by Fire Services on vehicles include:

1	Delivery hoses (1.5", 2.5", 3", 4")	11	Thermal Imaging Cameras
2	Suction Hoses (2.5", 3", 4")	12	Drones for surveillances
3	Nozzles & Handline branches	13	Flood lights
4	Ropes and Liners	14	Torches
5	Fire hook, Fireman Axe, Crowbars	15	Gas Cutters
6	Rescue equipment such as Cutters, Spreaders	16	Nets for Rescue
7	Breathing Apparatus Sets	17	Jumping Chutes
8	Medical First Aid equipment	18	Portable Ground Monitors
9	Portable light mast	19	Ladders
10	Portable PPV fans	20	PPE Kits

Below is an imagery of commonly used firefighting and rescue equipment

<p><b>Delivery hose</b></p> 	<p><b>Suction hose</b></p> 
<p><b>Fire hook</b></p> 	<p><b>Medical First Aid</b></p> 
<p><b>Flood light</b></p> 	<p><b>Thermal imaging camera</b></p> 
<p><b>Portable ground monitor</b></p> 	<p><b>Gas cutter</b></p> 



## 2.6. Emergency notification procedure

### 2.6.1. Emergency notification procedure, receiving and response mechanism for fire calls and deployment procedure by Fire Services



Fire authorities usually have a continuously staffed mobilizing and communications center, equipped with computer based Command & Control systems to deal with receipt of emergency calls and alerting & dispatching of fire service resources within its mobilizing area. Although these are considered to be the 'core' activities of the Control Room, many additional 'non-core' duties are performed by control personnel as stipulated by the Chief Fire Officer/HoD.

All emergency communications for the Fire Service are channeled through the Control Room which acts as a general communications and information resource for the fire brigade. It is usually housed in either a Control Suite at Brigade Headquarters or in a purpose built building with the manpower. The Control center is staffed (in shifts to provide 24 hour cover) by uniformed professionals.





Control personnel performing duties away from the Control Centre may need to be recalled if there is a sudden spate of calls or personnel become busy for other reasons. Easy access from anywhere within the area will enable personnel to respond quickly.

### 1) Basic call handling procedures



with efficiently.

The first contact an emergency caller has with the Fire Service is with the Fire Control Operator. The way the operator handles the call is vital and to this end, the operator must be immediately available to take control of the call. This will enable effective collation of call details to mobilize and indicate to the caller that they are being dealt

The primary function of the Control Room is to provide an essential communication link which enables the provision of emergency firefighting, rescue and humanitarian services to the public when they call for assistance. The detailed procedure for handling an emergency call differ in each brigade according to its size and the type of communications and mobilizing systems used.

Fire Control Room Operators are trained to elicit information from those calling for assistance. This activity requires identification of the incident address and confirmation of the type of emergency for which assistance is required plus number of peoples trapped, if any.

Difficulties in obtaining this information may result if the caller is unduly anxious or excited. A Fire Control Room Operator will still need to bear in mind that the primary purpose is to obtain information and will need to use effective call handling skills to overcome these difficulties, possibly by calming and reassuring the caller. It may be necessary to give advice for dealing with the emergency whilst waiting for fire service attendance.

Traditionally, Fire Control Room Operators are taught appropriate inter-personal skills by a combination of initial training including simulation exercises and 'on the job' training by experienced personnel.

## 2.7. Incident site procedures related to rescue and fire-fighting for building scenarios

Once the first fire tender (vehicle) reaches site, the officer in-charge will do a quick survey of the fire situation to determine if additional vehicles are required and if so, what type/s. He will accordingly inform his control room to dispatch additional vehicles and crew. As a general rule, if occupants are trapped, the first priority is to rescue those people. Firefighters may begin firefighting to keep the fire under control and improve survivability of occupants till additional help/ specialized vehicles reach to carry out rescue operations.

In some situations, firefighters will actually enter a building which is on fire to control or extinguish the fire, because it may not be practically possible to fight the fire externally. This could be because in very tall buildings, fire is on the upper floors and beyond the reach of fire service water jets or the layout and/or configuration of the building prevents external firefighting (internal firefighting is quite common in many developed countries).

During interior firefighting, firefighters will approach the floor on fire either through a fire tower (if available) or through exit stairs. In this situation, the fire resistance of shafts (including doors) becomes very important; their failure will render all efforts ineffective and hence their integrity is an important factor in interior firefighting.

### 2.7.1. Fire brigade features provided inside buildings – Fire brigade inlets, fire lifts, fire tower, internal communication systems, wet risers/down comers, etc.

Different systems/ features provided in the building at the design stage itself are meant to help in fire and rescue efforts by Fire Service in event of an emergency. These features/ systems include:

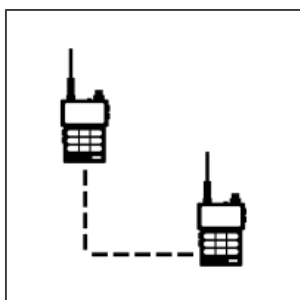
#### 1) Notification



While fire alarm systems are primarily for early warning to building occupants about a fire incident, at the same time, if this information (i.e., the fire alarm) is also conveyed to the Fire service, it allows them to reach the incident site earlier and tackle the fire which has still not grown to a size difficult to control.

## 2) Internal communication<sup>7</sup>

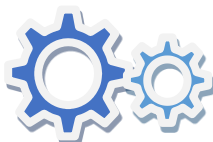
It should also be possible for the Incident Commander to communicate with firefighters at various locations inside the building, hence there is a need to



provide a reliable communication system which can be used by them during emergencies. This is normally done by providing a Telephone jack system with handsets, which firefighters can use during their operations. Firefighters have their own Radio sets (walkie talkie) which can be used for communication, but it has been experienced that in tall building

fire incidents in the past, radio communication has failed due to various reasons. Hence an alternative and robust system is recommended in terms of the Fireman jack system.

## 3) Fire protection systems



In the event of fires on floors much higher than ground level, it is practically very difficult to lay hoses from fire tenders to these floors.

In such instances, it is necessary to connect hoses to and use the building riser (standpipe) system for firefighting. Important requirements for risers with respect to firefighter use, besides the provision of adequate number of landing valves at proper locations, include regulation of pressure at the landing valves (pressure will vary due to the head difference between floors) so that constant pressure is available at all levels and sufficient water is available to carry out firefighting operations for the duration required.

In the event of failure of the building fire pumps, it is possible to pump in water to feed the building riser system, using the fire tender pumps. For this, there should be sufficient supply of water (municipal or external hydrants) and the fire brigade inlets should be properly located so that they can be easily connected to, without having to lay out too many hoses (there is a minimum distance requirement between the fire tender access road and the fire brigade inlet location in many codes).

## 4) Fire tower, fire lifts, access stairs<sup>8</sup>

When a fire incident is underway in a building, firefighters are entering an environment where conditions are becoming more and more dangerous by the second (as the fire is pumping in more and more heat and effluents into the building space). While they will

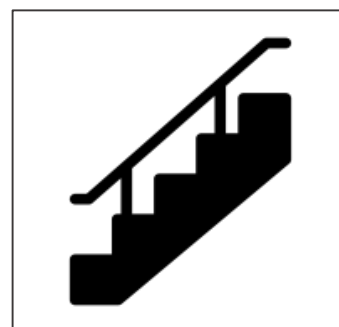
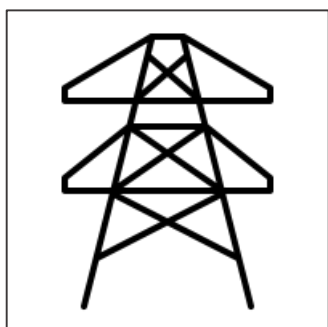
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<sup>7</sup> Source of walkie talkie icon – The Noun Project

<sup>8</sup> Source of icons – The Noun Project

normally wear protective gear to protect themselves against the effects of fire, the building layout should provide them with a safe environment to the extent possible. This can be achieved by providing stairs which are separated from the building space by fire resisting construction.

The concept of a 'fire tower' (in NBC Part 4) is an extension of this principle where the lift shaft, stair and the adjacent space is protected from the effects of a fire using rated construction and smoke control systems, thus keeping this space free from the effects of fire.

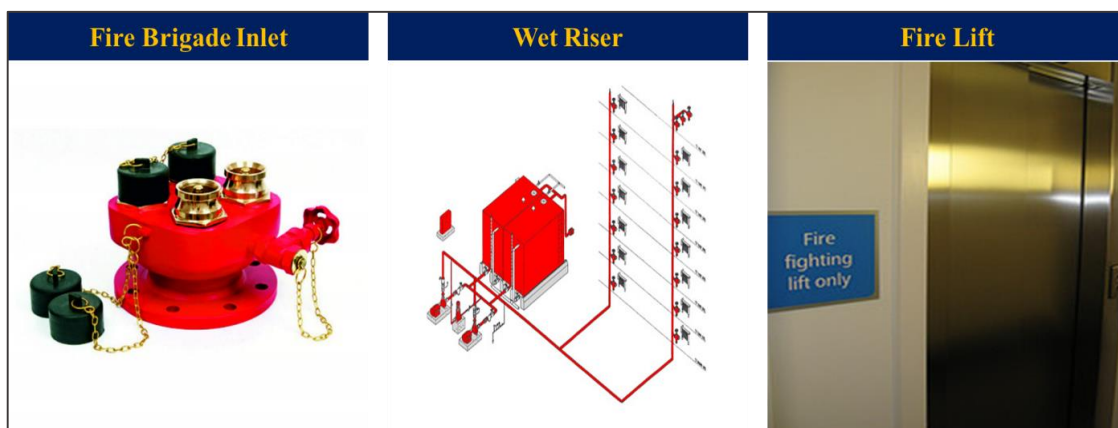


## 5) Fire command center



A Fire command center (FCC) should be provided in buildings as specified by codes. This should be easily and directly accessible to firefighters without a requirement to negotiate building spaces, hence these should be ideally located close to the main entrance of the building.

Being required to be operational in an emergency, it should be separate from the rest of the building by fire rated construction and should have an emergency power and ventilation.



## 2.8. Fire staff requirements with premises

### 2.8.1. Fire staff requirement in various type of occupancies as per National Building code, IS 13039, GFR



For certain occupancies due to the higher level of fire hazards present, immediate response by trained personnel to control the situation is essential especially in hazardous industries and premises. A firefighter is a person extensively trained in firefighting, primarily to extinguish hazardous fires that threaten life, property and environment as well as to rescue people and in some cases or jurisdictions also animals from dangerous

situations.

Fire service, also known in some countries as the fire brigade or fire department. They also take steps to prevent fires and investigate the causes of fires. A firefighter is almost always the first official "on the scene" of fires, car accidents, building collapse, industrial mishaps or other emergencies, which is why they are also sometimes called "**first responders**." Some firefighters are career professionals while others volunteer for duty within their communities.

### 2.8.2. Legal aspects for firefighting team

#### (1). As per IS 13039: Clause 11 - FIRE FIGHTING PERSONNEL: Clause 11.1



A squad consisting of watch and ward personnel, fire pump men and departmental supervisors and/or operatives trained in operation of fire service shall be maintained on premises round the clock. The number of personnel constituting the squad shall necessarily depend upon the size of the risk, but in no case shall less than eight trained persons be available at any time during day or night. Minimum number of trained persons required may further be reduced to six in case of automatic pressurized hydrant systems.

#### (1.2). IS 13039 – Clause 11.2



Squad leaders shall be trained by government recognized institution and their usefulness would be considerably enhanced, if they reside on the premises.

#### (1.3). IS 13039 – Clause 11.4





A muster roll showing the duties allocated to each member of the brigade shall be prepared and copies supplied to each squad leader as well as pasted in convenient places throughout the premises, so as to be quickly available for reference in case of emergency.

## **(2). Gujarat Factory Rule - SCHEDULE XIX – Rule 102 – chemical works - Part 3 – (8)**

Firefighting systems is also same as per above mentioned IS 13039 – clause 11, 11.1, 11.2 & 11.4. – Every factory employing 500 or more persons and carrying out processes listed in the First schedule of the act, shall provide – Fire personnel as per above.

A-276	GUJARAT FACTORIES RULES, 1963	Sch. XIX Pt. IV
8.	Fire-fighting systems.—	
(1)	Every factory employing 500 or more persons and carrying out processes listed in the First Schedule of the Act, shall provide -	
(a)	Trained and responsible fire-fighting squad so as to effectively handle the fire-fighting and life-saving equipment in the event of fire or other emergency. Number of persons in this squad shall necessarily depend upon the size of risk involved, but in no case shall be less than 8 such trained persons to be available at any time. The squad shall consists of watch and ward personnel, fire pump man and departmental supervisors and operators trained in the operation of fire and emergency services.	
(b)	Squad leaders shall preferably be trained in a recognised Government institution and their usefulness enhanced by providing residence in the premises.	
(c)	Squad personnel shall be provided with clothing and equipment including helmets, boots and belts.	
(2)	A muster roll showing the duties allocated to each member of the squad shall be prepared and copies supplied to each such leader as well as displayed in prominent places so as to be easily available for reference in case of emergency.	
(3)	The pump man shall be thoroughly conversant with the location of all appliances. He shall be responsible for maintaining all fire fighting equipment in proper working order. Any defect coming to his notice shall be immediately be brought to the notice of squad leader.	
(4)	As far as is practicable, the fire pump room and the main gate(s) of the factory be connected to all manufacturing or storing areas through telephone interlinked and placed in a convenient location near such areas.	

### (3). National Building Code-2016, Part 4: Clause: 4.10 Fire Officer<sup>9</sup>



Clause: 4.10.1- A qualified Fire Officer with experience of not less than 3 years shall be appointed who will be available on the premises, for large educational complexes, business buildings with height 30 m and above, residential building with height 60 m and above, institutional buildings of 15 m and above, starred hotels and D-6 occupancy.

#### (3.1). Clause 4.10.2: The Fire Officer shall

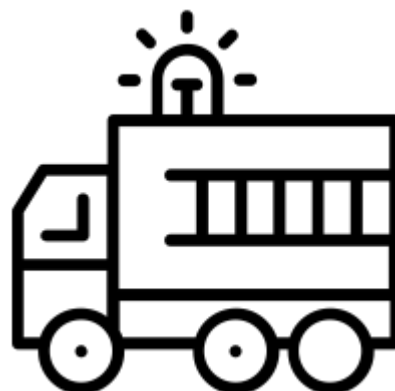
- a) Maintain the firefighting equipment in good working condition at all times.
- b) Prepare fire orders and fire operational plans and get them promulgated.
- c) Impart regular training to the occupants of the buildings in the use of firefighting equipment provided on the premises and keep them informed about the fire emergency evacuation plan.
- d) Keep proper liaison with the city fire brigade.
- e) ensure that all fire precautionary measures are observed at the times.

Note: Competent authority having jurisdiction may insist on compliance of the above rules in case of buildings having very large areas even if the height is less than 30 m.

## 2.9. Requirements related to fire vehicle access

### 2.9.1. Requirements related to fire vehicle access, firefighter access inside building and fire command center for buildings

A building should have sufficient access roads around it depending on the size (in terms of total floor area or volume) of the building. These access roads should meet requirements of level, load bearing capacity (of the expected response vehicles), clear width and height to allow unhindered movement and a design to allow proper turning or reversing of vehicles. To carry out firefighting and rescue operations at an incident site, it



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<sup>9</sup> Source of icon – The Noun Project



is important for the Fire Brigade to park their vehicles at a location which is safe, and which allows them to carry out their operations effectively.

Requirement related to firefighting vehicle's access depends on space available around the building and approach to the building.

Requirements related to fire vehicle access in Gujarat, are specified in the GFP&LSM Regulations and notifications issued.





Occupancy Category	Occupancy/ Main Category Type	NBC Part 4		Margins to be followed for Different Building Categories						
		SN	Building Categories as per Table 7, NBC Part 4	Margin between adjacent blocks of Building (in Mtrs)	Road side Margin (Mtrs)	Rear side margin (Mtrs)	Other Side margin (Mtrs)	Width of Approach road (in Mtrs)	Width of clear motorable open space in the front	Width of clear motorable open space in one of the sides
1	Residential	1	15 m and above but not exceeding 35 m in height	Min. 6 mtr	Min 4.5 mtr	Min 4.0 mtr	Min 4.0 mtr	Min 12.0 mtr	Min 4.0 mtr	Min 4.0 mtr
		2	Less than 15 m in height Floor area exceeding 500 m <sup>2</sup> but not more than 1000 m <sup>2</sup> on any of the floor	Min 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
		3	More than 9 m (but less than 15 m) in height (Ground + 1 or more storeys)	Min 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
3	Institutional	4	Less than 15 m in height but with plot area upto 1000 m <sup>2</sup> - (ii) upto ground plus one storey with beds	Min 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
4	Assembly	5	Less than 15 m in height but with plot area upto 1000 m <sup>2</sup> - (i) Ground plus two or more storeys, with beds	Min. 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
		6	Less than 10 m in height (upto 300 persons)	Min 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
		7	Less than 10 m in height (more than 300 persons)	Min 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
5	Business	8	Less than 10 m in height (i) upto 300 persons	Min 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
		9	Above 10 m but not exceeding 15 m in height	Min 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
		10	Above 15 m but not exceeding 24 m in height	Min. 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
6	Mercantile	11	Less than 15 m in height and (i) Ground storey + one, having total floor area > 500 m <sup>2</sup>	Min 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr
7	Industrial	12	covered area more than 500 m <sup>2</sup> (for building height more than 15 m)	Min. 6.0 mtr	Min. 6.0 mtr	Min 4.5 mtr	Min 4.5 mtr	Min. 12.0 mtr	Min 4.5 Mtrs	Min 4.5 Mtrs
10	Mixed Use (Residential/ Commercial/ Employee)	13	covered area more than 500 m <sup>2</sup> upto 1000 m <sup>2</sup> (for building height above 15 m)	Min. 6.0 mtr	Min. 6.0 mtr	Min 4.5 mtr	Min 4.5 mtr	Min. 12.0 mtr	Min 4.5 Mtrs	Min 4.5 Mtrs
		14	Buildings above 9 m in height (or Ground plus three floors)	Min. 6.0 mtr	Min 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr	Min. 12.0 mtr	Min 6.0 mtr	Min 6.0 mtr

# **Chapter 3:**

## **Fire Prevention & Life Safety in Buildings**





## 3. Fire Protection Equipment & Systems

### 3.1. Introduction

With technological advances on all fronts, not only the factor of susceptibility, but the complexity of fires, explosions and hazards to which buildings are exposed to, have also increased manifold. These hazards have been instrumental in causing heavy losses in lives and property throwing up fresh challenges to planners, architects and fire protection officers in evolving better and improved methods of design and fire protection in order to mitigate such losses.

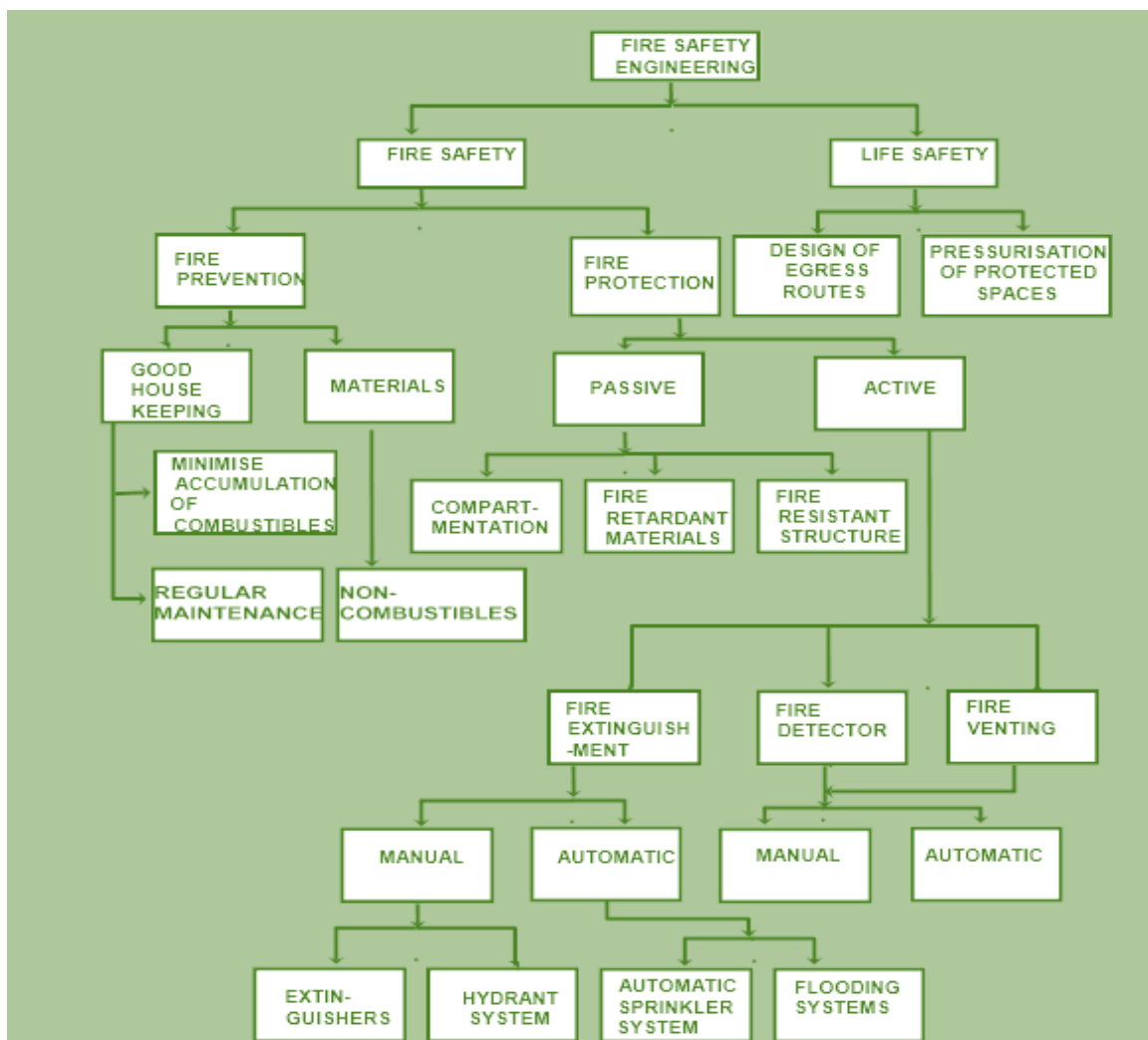
Fire prevention is an important step towards meeting fire and life safety objectives in buildings. Fire prevention encompasses control of fuel and ignition sources and to prevent their interaction in buildings. While this sounds simple, it is actually a complex task, considering the large number and variety of fuels and ignition sources that are present within the building itself, as well as the different building services and systems. Many building systems such as electricity are themselves energy sources and are therefore subject to strict requirements related to their design, installation and use. Similarly, different building services pose hazards with respect to fire and have control measures in place for reducing the associated risks.

An emergency situation inside a building will require its occupants to egress/ exit safely and quickly enough before the incident can affect them adversely. Fire is one such emergency and a fire inside a building will change the internal environment and make it untenable/ weak in a short period of time. Egress design of the building should ensure that all occupants can leave the building in a suitable time frame, beyond which the effects of the fire would jeopardize their escape ability. Building fire & life safety codes attempt to use past data and currently available knowledge to define various requirements related to life safety. It must be appreciated that while egress design is the primary factor governing life safety of occupants, a number of associated requirements such as the type of construction, exit lighting, exit signage, type of furnishings used as well as active and passive fire protection systems are other important factors which contribute in achieving the overall life safety objective.

For ensuring proper and adequate implementation of the provisions of the Building Codes and Regulations, it will be necessary to associate qualified and trained Fire Protection

Engineers/ Consultants with the building industry right from the planning and design stage of the buildings.

**Basic requirements of fire safety engineering as mentioned in the figure below:**



## 3.2. Building Occupancies & Sub-Groups

Modern building fire codes divide buildings into groups called occupancies. This is because a building having specific function/purpose has fire hazards, which are unlike another building having a different use. Therefore, it is more practical to specify code requirements based on the function or use of the building. This means that buildings need to be segregated based on its main function/use for the purpose of specifying code requirements.

### 3.2.1. Important Factors Influencing Occupancy Classification

The important factors which influence occupancy classification from a fire and life safety point of view are -



*Fire hazards:* This relates to the type and quantity of combustibles (fuel/fire load) and ignition sources within the building. Fire hazards differ from occupancy to occupancy and influences the type, size and development of a fire in event of ignition (and consequent effects on building occupants, property and structure).

*Building Layout & Configuration:* Depending on primary function and use, the basic building layout, configuration and systems will vary from building to building. Building configuration influences fire growth and movement of smoke. Building layout also affects occupant's awareness of his/her location with respect to the building layout and exit points.

*Occupant Type & Characteristics:* Along with the building hazards and building configuration, the type of occupants in a building greatly influence code requirements. With respect to occupants, the important factors considered are the number of persons normally occupying the building, the time they are in the building, whether they are familiar with the layout and exits of the building, whether they are physically and mentally able or not, and whether they spend time sleeping in the building.

### **3.2.2. Occupancies & Sub-Groups as Per NBC Part 4**

Different countries follow different methods for classifying occupancies; even within countries, different regions and jurisdictions may follow slightly differing classification method for building occupancies. However, many countries around the world follow similar occupancy classification. As per NBC Part 4, the following are the important occupancies and their sub-groups;

#### **Group A – Residential**

*Subdivision A-1* Lodging and rooming houses

*Subdivision A-2* One or two family private dwellings

*Subdivision A-3* Dormitories

*Subdivision A-4* Apartment houses

*Subdivision A-5* Hotels

*Subdivision A-6* Starred Hotels

#### **Group B – Educational**

*Subdivision B-1* Schools up to senior secondary level

*Subdivision B-2* All others/training institutions



### **Group C – Institutional**

*Subdivision C-1* Hospitals and sanatoria

*Subdivision C-2* Custodial institutions

*Subdivision C-3* Penal and Mental institutions

### **Group D – Assembly**

*Subdivision D-1* Buildings having a theatrical or motion picture or any other stage and fixed seats for over 1000 persons

*Subdivision D-2* Buildings having a theatrical or motion picture or any other stage and fixed seats up to 1000 persons

*Subdivision D-3* Buildings without permanent stage having accommodation for 300 or more persons but no permanent seating arrangement

*Subdivision D-4* Same as D-3 but with accommodation for less than 300 persons with no permanent seating arrangements.

*Subdivision D-5.* This subdivision shall include any building or structure, permanent or temporary meant for assembly of people not covered by Subdivisions D-1 to D-4

*Subdivision D-6* Buildings having mixed occupancies of assembly and mercantile (Malls)

*Subdivision D-7* Underground and elevated mass rapid transit system

### **Group E – Business**

*Subdivision E-1.* Offices, banks, professional establishments, like offices of architects, engineers, doctors, lawyers, post offices and police stations

*Subdivision E-2* Laboratories, outpatient clinics, research establishments, libraries, test houses

*Subdivision E-3* Electronic data processing centres, computer installations, information technology parks and call centres

*Subdivision E-4* Telephone exchanges

*Subdivision E-5* Broadcasting stations, T.V. stations and Air traffic control towers.

### **Group F – Mercantile**

*Subdivision F-1* Shops, stores, departmental stores, markets (with covered area up to 500 m<sup>2</sup>)

*Subdivision F-2* Shops, stores, departmental stores, markets (with covered area > 500 m<sup>2</sup>)



*Subdivision F-3 Underground shopping centres*

### **Group G – Industrial**

*Subdivision G-1 Buildings used for low hazard industries*

*Subdivision G-2 Buildings used for moderate hazard industries*

*Subdivision G-3 Buildings used for high hazard industries*

### **Group H – Storage**

These shall include any building or part of a building used primarily for the storage or sheltering (including servicing, processing or repairs incidental to storage) of goods, ware or merchandise (for example, warehouses, cold storages, freight depots, transit sheds, storehouses, truck and marine terminals, garages, hangars, grain elevators, barns and stables)

### **Group J – Hazardous**

These shall include any building or part thereof which is used for the storage, handling, manufacture or processing of highly combustible or explosive materials or products which are liable to burn with extreme rapidity and/or which may produce poisonous fumes or explosions, or storage, handling, manufacturing or processing which involve highly corrosive, toxic or noxious alkalis, acids or other liquids or chemicals producing flame, fumes and explosive, poisonous, irritant or corrosive gases; and for the storage, handling or processing of any material producing explosive mixtures of dust which result in the division of matter into fine particles subject to spontaneous ignition.

## **3.3. Internal planning and layout of building services and systems**

Most modern buildings are designed to include what are known as building services, i.e., those systems which make the building space livable and comfortable. Such building services include electricity, HVAC, water supply & plumbing, elevators, laundry/ garbage chutes, telecommunication, etc. Often very large buildings or building complexes are ‘intelligent’, i.e., all services are centered to a control room, which is usually manned (note: much of the equipment in the building will be self-monitoring).

Although not a part of the main building structure, building services influence its design as the system equipment and components need to be installed appropriately within the building. Factors such as equipment size, weight, location of service risers, routing of ducts



(where applicable) need to be considered at an early stage of design. While these services provide comfort and utility for the occupants, they can be a problem in the event of a fire, as these services form a link between different floors and even between different areas on a floor.



Examples of different building services (Elevator & Electric shaft)

A problem is that these services are common to the different floors and sometimes even to different areas on a floor. Hence, they provide a connection between various parts of the building and as has been observed in many building fires, these services & linkages provide means for the fire and smoke to spread. In the worst case, the services themselves (e.g. electricity) can be the source of fire, as there are combustible materials and energy sources involved with these different services as well. It is, thus, imperative to address these services from fire prevention of view. Building codes will, therefore, specify various requirements with respect to such services to ensure that they do not give rise to fires or do not aid in the growth and/ or spread of fire.

### 3.3.1. Compartmentation & segregation of hazardous areas

Compartmentation is the process of segregating a large fire compartment to smaller, more manageable compartments. The intent is to keep the fire limited to a smaller area so that its effect is limited, and it can be controlled quickly. It should be borne in mind that fire fighters will struggle to control and extinguish a fire involving multiple flats/ office blocks in a building as opposed to a single compartment fire, which can be more easily controlled and extinguished. The other reason is that a fire limited to a compartment will generate less smoke and heat as compared to a larger fire (involving multiple compartments), which improves survivability of occupants and reduces the damage to property and structure. Towards this, building codes will normally specify the maximum size of a compartment based on the occupancy.





It is common for smoke and heat from a fire to travel vertically due to buoyancy. This occurs through vertical shafts such as stairwells, lift shafts, service shafts (electrical, plumbing, garbage) and it is important that these openings be protected suitably to prevent travel of heat and smoke. The requirement of having fire rated enclosures for stairwells, lift shafts and service shafts arises from this requirement.

One more important reason for compartmentation is to separate a room/ area which has a higher fire hazard than the general hazard in the occupancy; e.g., linen storerooms, garbage rooms or workshops in hotels or kitchen/ cooking areas in restaurants or hazardous material storage in an industry. Compartmentation is also used to protect rooms having higher value or critical equipment such as Server rooms in Banks, record rooms, control rooms, etc.

### 3.4. Fire prevention measures for different building systems

#### 3.4.1. Electricity



As electrical energy is a basic requirement, electricity is present at almost all locations in buildings and in many cases, in close vicinity to fuels. Electrical systems typically consist of a transformer, which steps down the voltage from the much higher supply value to a lower (standard) value, which can then be used to meet lighting and power requirements of the building. The supply to the building or building units will be routed through cables to devices and accessories inside the building. A metering system and circuit breakers are used for the purpose of recording the consumption of power and protecting/ isolating the circuits

Use of electrical energy can lead to a possibility of sufficient heat being generated due to faults in equipment or wiring, which can ignite fuels located in vicinity of cables/ equipment. It should be noted that global fire data corroborates the fact that electricity is the most common ignition source in building fires. As such, building transformers and electrical (switchgear) rooms are required to follow strict norms related to design, installation, separation and fire protection arrangements. For supply and distribution, common protective measures include using cables rated for the voltage and current capacity of circuits, and in line with electrical codes of the country. Circuits shall have protective devices to prevent overcurrent/ short circuit/ earth leakage conditions. See further details/

information related to electrical safety in next section. As electricity is a major cause for indoor fires, additional information related to its safe use and installation is given below –

## 1. Cause of electrical hazards

Proper operation of electrical installations require that machinery, equipment & electrical circuits & lines be protected from hazards caused by both internal (arising within the installation) and external factors.



### **Internal Causes**

- Over Voltage
- Short Circuit
- Over Current
- Corrosion, leading to electrical current leakage to ground
- Heating of conducting and insulating material that may result in emission of toxic gases, component fires & inflammable atmosphere explosion
- Leaks to insulating fluids such as oil
- Generation of Hydrogen or other which may lead to the formation of explosive mixture

### **External Causes**

- Mechanical factors like fall, bumps, vibration
- Physical & Chemical factors, natural or artificial radiations, extreme temperature, oils corrosive liquids, humidity
- Wind, snow falls, lightening
- Animals in both urban & rural settings may damage the power lines insulation & so cause short circuit or false contact
- And least but not the last, adults & children who are careless, reckless or ignorant to risk & operating procedure

## 2. Protective devices

Different protective devices used in electrical systems include -

### 1) **Circuit Breakers**

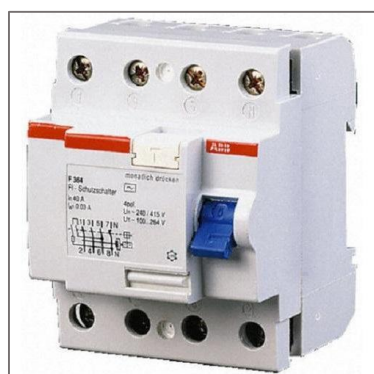
**(i) Miniature Circuit Breakers (MCB)** - A miniature circuit breaker (MCB)



automatically switches off the electrical circuit during an abnormal condition of the network means in overload condition as well as faulty condition. Nowadays we use an MCB in a low voltage electrical network instead of a fuse. The fuse may not sense it, but the miniature circuit breaker does it in a more reliable way. MCB is much more sensitive to over current than a fuse. Handling an MCB is also

electrically safer than a fuse. Quick restoration of supply is possible in case of a fuse as because fuses must be rewirable or replaced for restoring the supply. Restoration is easily possible by just switching it ON.

**(ii) Earth Leakage Circuit Breakers (ELCB):** Early earth leakage circuit breakers are



voltage detecting devices, which are now switched by current sensing devices (RCD/ RCCB). Generally, the current sensing devices are termed RCCB and voltage detecting devices named Earth Leakage Circuit Breaker (ELCB). Forty years ago, the first current ECLBs were introduced and about sixty years ago the first voltage ECLB was introduced. For several years, both the voltage and

current operated ELCBs were referred to as ELCBs. But the applications of these two devices led to significant mix-up in the electrical industry.

An ECLB is safety device used for installing an electrical device with high earth impedance to avoid shock. These devices identify small stray voltages of the electrical device on the metal enclosures and intrude the circuit if a dangerous voltage is identified. The main purpose of the Earth leakage circuit breaker (ECLB) is to stop damage to humans & animals due to electric shock. Prominent manufactures of ECLB include Fuji Electric, Major Tech, Siemens, ABB, Avera T&D, Tele-mecanique, Camsco, Crabtree, Orion Italia, Terasaki, MEM, and V guard.

**2) Fuses & relays**

A fuse is an autonomous protection device that interrupts the circuit when the current is too high. It is a one-time device primarily for protection and safety. It has two terminals that are normally connected in a near short but when activated the device becomes non-continuous with a near perfect open circuit.



A relay is a device that interrupts the circuit too. But it is controlled by external signal requiring at least two more terminals. The normal state can be an electrical connection, but it can also be an interruption (open circuit). It can be operated a nearly unlimited number of times, limited by

mechanical wear-out.

In conclusion, a fuse is a one-time protection device that interrupts a circuit whereas a relay is a device controlled by another part of the circuit and operated to connect or interrupt the circuit many times.

### 3) **Earthing**

(i) **Functional Earthing** - Grounding of metal conductors of 3 phase system, midpoint of transformers secondary

(ii) **Protective Earthing**: - Grounding all metallic portions

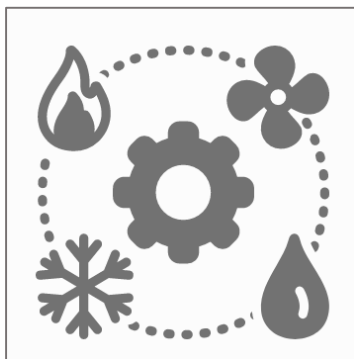
The process of transferring immediate discharge of electrical energy directly to earth by the help of low resistance wire is known as the electrical earthing. The electrical earthing is done by connecting the non-current carrying part of the equipment or neutral of supply system to the ground.

Mostly, galvanized iron is used for earthing. Earthing provides a simple path to the leakage current. The short circuit current of the equipment passes to the earth which has zero potential, thus protecting the system and equipment from damage.

The electrical equipment mainly consists of two non-current carrying parts. These parts are neutral of the system or frame of the electrical equipment. From the earthing of these two non-current carrying parts of the electrical system, earthing can be classified into the following two types:

- Neutral Earthing
- Equipment Earthing.

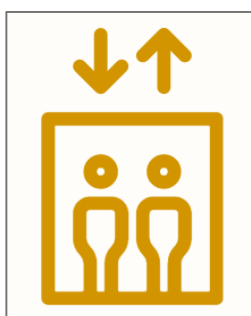
### 3.4.2. HVAC systems



HVAC systems are not so much a concern from fire ignition point of view, though they do have electrical components which can be ignition sources and use of combustible materials can provide fuel for a fire. The main concern, however, is that HVAC systems connect different parts and floors of a building, which can provide a path for heat and smoke to spread beyond the compartment of origin. Therefore, HVAC components (especially air filters) should be made of non-combustible materials.

It is logical to ensure isolation of HVAC ducts at each floor/ fire compartment by means of automatic fire dampers. Fire dampers shall also require an inlet of fresh air and return duct to each compartment. Openings around ducts penetrating fire walls shall be sealed with fire resistant materials. Other requirements include smoke detection inside return air and supply ducts and interlocking of AHUs (Air Handling Units) with the fire alarm system to automatically shut down the same on fire detection.

### 3.4.3. Elevators (Lifts)



As energy is required for elevator operation (mostly electrical, though hydraulic systems are used in some cases), ignition sources are present in form of electrical cables, motors and equipment. Lift cars are made of non-combustible construction and accumulation of waste in lift wells and in machine rooms are the main reasons why fires take place. The main concern is that lift shafts connect different floors of a building and will thus easily allow movement of heat and smoke from one floor to other floors of the buildings. Therefore, it is necessary to have lift shafts with required fire resistance, including lift landing doors.

It is also required to have pressurization of lift shafts (for buildings exceeding a specific height) in the event of a fire to prevent smoke from entering the shaft; this should be interlocked with the fire alarm system. Lift lobbies should have proper fire detection and

protection systems. Electric supply for lifts shall have a separate service with cables laid in route safe from fire and shall also be connected to a standby power supply.

#### 3.4.4. Other services



Other building services commonly found include water and plumbing, garbage chutes, laundry chutes and fuel (gas) supply systems. While water supply & plumbing systems are not a concern from fire prevention point of view, the shafts through which these services are routed, connect different floors of a building and hence provide a passage for smoke travel. Location and construction of these shafts is therefore important; they are not to be routed within stairwells or along with other service (HVAC) shafts. Refuse

chutes and collection systems handle substantial fuel loads and are hence considered as having a higher fire hazard than the rest of the occupancy; refuse shafts and walls, floors and roof of refuse chambers are therefore required to have suitable fire resistance as specified in codes. Openable panels in refuse shafts (for discarding refuse) should have equivalent fire resistance matching the shaft rating.



On the other hand, cooking gas supply systems are highly hazardous due to the inherent properties of the fuel handled. In the event of malfunction or physical damage, leakages can result in severe fires or even explosions. Therefore, there are strict requirements related to the material used for supply piping and fittings, and their physical and chemical properties. The routing of gas piping also becomes very critical as there should be no chance of leaked gas accumulating. In fact, the pipeline routing should be such as to allow natural dilution of gas and preventing accumulation in an event of leakage. Once the gas piping enters living spaces, it should be ensured that the piping is as short as possible and directly enters the cooking area (i.e., routing through other living spaces is not allowed). Additionally, protective measures include emergency shut-off in case of leakage (through suitable detection system).

### 3.5. Different Factors Affecting Safe Egress



Many case studies involving fatalities in building fires, suggest that visibility and toxicity effects of smoke are primary factors affecting occupants' ability to escape. Other effects such as heat from the fire and hot smoke become significant if a fire continues to grow. Building codes addressing life safety, therefore, focus on mitigating these effects and ensuring safe egress by providing a minimum criteria for the design of egress facilities so as to allow prompt escape of occupants from buildings to the outside or, into safe areas (refuge areas) within buildings. Therefore, the objective of building fire codes is to protect occupants who are not directly exposed to fire, but who will be at risk if the fire continues to grow.

The basic concept behind safe egress is that there is sufficient exit capacity for all occupants to leave the affected area or floor in a reasonably short period of time, before conditions become dangerous (Note: most codes consider this time to be within 2-3 minutes, though this can vary considerably depending on type and quantity of fuel, ventilation, configuration, etc.)

Building fire codes address this issue using the concepts given below -

1. **Egress facilities** - They establish minimum criteria for design of egress facilities so as to allow prompt escape of occupants from buildings or, where desirable, into safe areas within buildings.
2. **Other life safety related considerations** - They also address other considerations that are essential to life safety in recognition of the fact that life safety is more than a matter of egress. These include proper exit signage, illumination, voice evacuation systems and other factors.
3. **Minimizing danger to life from fire** - This covers other features/ systems necessary to minimize danger to life from the effects of fire, including smoke, heat and toxic gases created during a fire. Such arrangements include fire detection systems, fire protection systems for early detection and quick control and extinguishment of fire, as well as systems for removal of smoke and toxic gases.

### 3.5.1. Understanding egress design

The fundamental requirement for a safe egress design is to ensure that there is sufficient exit capacity as per the number of occupants present in the area or floor of fire origin to leave the affected area/ compartment quickly. The reason behind this is that conditions





quickly turn dangerous (untenable) in the fire compartment and/ or floor, and occupants should be able to egress before safe condition limits are breached. Different occupancies have different characteristics, primary among them being the type of occupants, the level of fire hazard and the building configuration and layout. The number of occupants on a floor/ compartment in a given occupancy (termed its Occupant load) is defined by building fire codes using the concept of Occupant Load Factors (OLF). The egress capacity in turn is defined based on the exit width available for a given area/ floor and is calculated using the clear exit width (of all exits) divided by the exit capacity factor for a given type of exit i.e., door/ stair/ corridor, ramp, etc. (Note: the exit capacity factor is different for level components such as doors/ corridors and non-level components such as stairs/ ramps).

With few exceptions, the minimum number of exits required for a floor (or a compartment with OL exceeding a certain value) is **two**. However, for high occupant loads, it may be difficult for higher occupant loads to egress the area in the stipulated time using only two exits (considering queuing and crowding at the exits), hence more than two exits are required in such cases. To serve higher occupant loads, it is possible to increase the number of exits and meet the egress capacity required to accommodate the given occupant load.

#### **Determining occupant load and egress capacity for a given occupancy & building**

**Floor or Compartment Area/ Applicable OLF = Occupant Load (for that compartment or Floor)**

**Total Exit Width/ Applicable Exit Width Capacity Factor = Egress Capacity Available (for the given compartment or Floor)**

**For a compliant (safe) design, Egress Capacity Available > Occupant Load**

**Below figure shows the NBC Part 4 Occupant load factors**





**Table 3 Occupant Load**  
(Clauses 4.3 and 4.4.2.1)

Sl No.	Group of Occupancy	Occupant Load Factor (m <sup>2</sup> /person) (see Note 1)
(1)	(2)	(3)
i)	Group A: Residential	12.50
ii)	Group B: Educational	4.00
iii)	Group C: Institutional (see Note 2):	
	a) Indoor patients area	15.00
	b) Outdoor patients area	10.0
iv)	Group D: Assembly:	
	a) Concentrated use without fixed seating	0.65
	b) Less concentrated use without fixed seating (see Note 3)	1.40
	c) Fixed seating	see Note 4
	d) Dining areas and restaurants with seating and table	1.80
v)	Group F: Mercantile:	
	a) Street floor and sales basement	3.00
	b) Upper sales floor	6.00
	c) Storage/warehouse, receiving and the like	20.00
vi)	Group E: Business	10.00
vii)	Group G: Industrial	10.00
viii)	Group H: Storage (see Note 5)	30.00
ix)	Group J: Hazardous	10.00

Below figure shows the NBC Part 4 Exit capacity factors

**Table 4 Capacity Factors**  
[Clauses 4.4.2.1, 4.4.2.3(c) and 4.4.2.4.2(a)]

Sl No.	Occupancy Group	Width per Person mm	
		Stairways	Level Components and Ramps
(1)	(2)	(3)	(4)
i)	Residential (Group A)	10	6.5
ii)	Educational (Group B)		
iii)	Institutional (Group C)		
iv)	Assembly (Group D)	15	13
v)	Business (Group E)		
vi)	Mercantile (Group F)		
vii)	Industrial (Group G)	10	6.5
viii)	Storage (Group H)		
ix)	Hazardous (Group J)		
		18	10

The next important factor is the distance to be traversed from a location within the compartment (or floor) to the nearest exit (generally defined as the ‘travel distance’ in codes). Basically, this distance determines the time required for occupants to traverse the distance from their location to an exit. It is logical to have shorter travel distances where fire hazard levels are high and longer travel distances where fire hazard level is lower.

Figure on the right shows the travel distance measurement

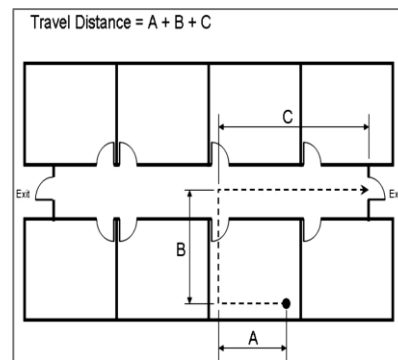


Figure on the right shows NBC Part 4 – Travel distances

Table 5 Travel Distance (Based on Occupancy and Construction Type) (Clauses 4.4.2.1 and 4.4.2.2)			
Sl No.	Occupancy Group	Maximum Travel Distance m	
		Types 1 and 2	Types 3 and 4
(1)	(2)	(3)	(4)
i)	Residential (Group A)	30.00	22.50
ii)	Educational (Group B)	30.00	22.50
iii)	Institutional (Group C)	30.00	22.50
iv)	Assembly (Group D)	30.00	30.00
v)	Business (Group E)	30.00	30.00
vi)	Mercantile (Group F)	30.00	30.00
vii)	Industrial (Group G)		
	G-1, G-2	45.00	See Note 3
	G-3	22.50	
viii)	Storage (Group H)	30.00	
ix)	Hazardous (Group J)	22.50	

NOTES

1 For fully sprinklered building, the travel distance may be increased by 50 percent of the values specified.

2 Ramp shall not be counted as an exit in case of basements below the first basement in car parking.

3 Construction of Type 3 or Type 4 is not permitted.

### 3.5.2. Other important/ associated systems for life safety



An important fact to be considered, where present, is that fire protection systems such as sprinklers will activate early in the fire growth stage and thus prevent full growth of the fire. This has an effect of reducing the generation of smoke and toxic gases and improving survivability. Taking this into consideration, codes will allow buildings having sprinklers installed to have

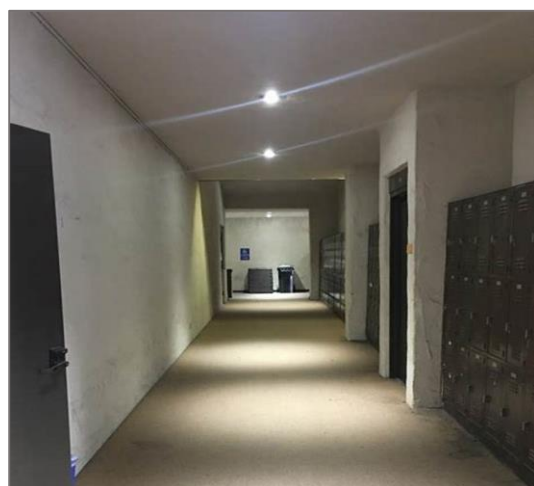
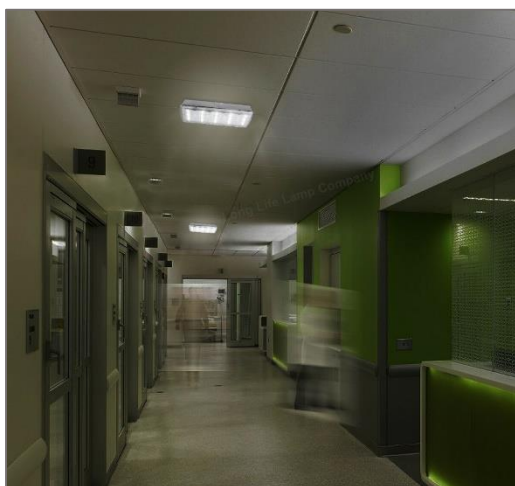
longer travel distances (by approximately 50%) as compared to buildings without them.

As there are openings such as doors in exit stairs, the chances of smoke entering the stair

from a fire floor cannot be entirely ruled out. To keep occupants safe from smoke, there is a requirement to have natural or artificial venting arrangements in exit stairs, so that occupants are protected from the effects of smoke. Exit stairs, therefore, need to have a minimum size of ventilation openings to allow smoke (which has entered in the stairs) to be vented out. Alternatively, stairs need to be positively pressurized to prevent ingress of smoke. A good egress design should ensure that occupants are able to leave the building without entering or passing through other areas of the building (as these could be involved in fire). This is also the reason why at least half the exits should discharge directly outside a building.

Illumination of Egress routes is another intervention.

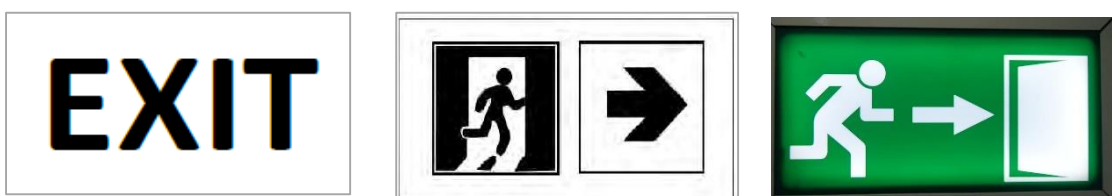
Egress routes should be adequately illuminated so that occupants can clearly see the path to be taken, and changes in direction and elevation can be safely negotiated. This



requirement applies to both normal as well as emergency conditions. In most buildings, natural light is not available in the interior of the building hence providing artificial lighting is necessary on the egress route. In emergency conditions, as main power is switched off, it becomes necessary to illuminate the egress path using emergency power. Different emergency sources of power can be used for this, most common being luminaires connected to standby generators, or battery operated units (with charging facility). These systems need to meet requirements related to switchover time (i.e. time between loss of main power and takeover of emergency power) and duration of operation (time for which the emergency lighting will function satisfactorily with acceptable deterioration)

Exit Signage

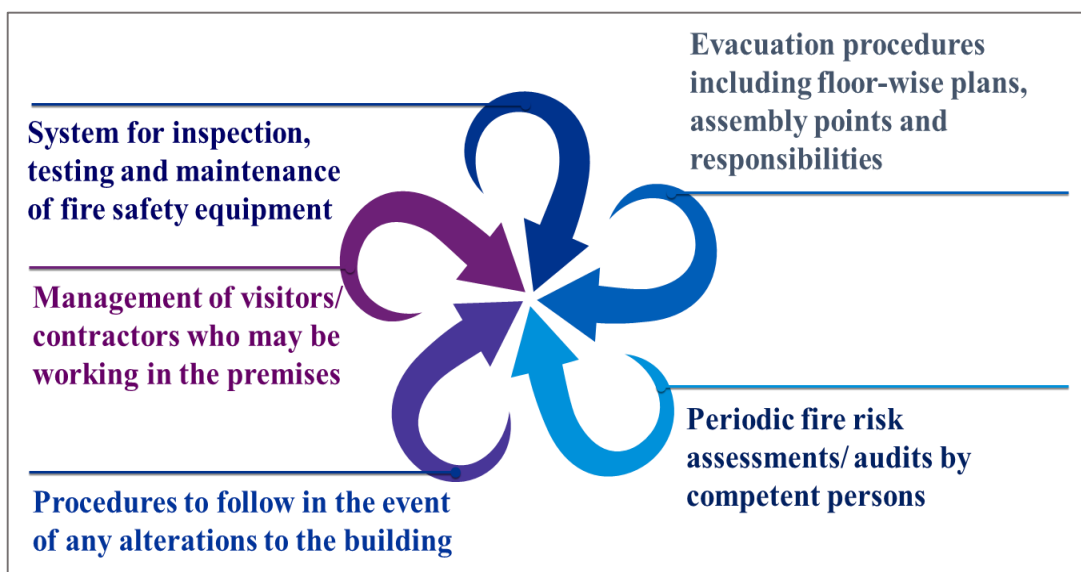
It is important to provide suitable directions and marking for exit routes in a building. This is all the more relevant for buildings which have complex internal geometry and configuration (such as shopping malls, airports, amusement parks, etc.). It is necessary to mark the exits (using exit signs) as well as the direction to the exits (using 'directional' exit signs) to avoid confusion in the event of an emergency. Doors not leading to exits, but which could be mistaken so, need to be marked appropriately to prevent their use in emergency. These exit and directional signs need to be visible during normal as well as emergency conditions (when normal power is switched off and presence of smoke due to fires cannot be ruled out). Different codes may have slightly differing requirement for visibility of such signs, but most commonly accepted maximum viewing distance for such signs is 30 meters. Below is an illustration of exit signages:



### 3.6. Importance of fire safety management

Fire safety management deals with proper upkeep of all fire prevention, life safety and fire protection systems and features in buildings, as well as the response to an event of fire in the building. Proper fire safety management is a key element in the overall fire safety of a building and in ensuring safety of its occupants in an emergency. Building occupants and people tasked with fire safety management need to plan effectively to mitigate the effects of a fire in their building and bring normalcy within the shortest time possible.

Building codes and related legislations will also require that proper maintenance/ upkeep of fire and life safety related measures is ensured during the lifetime of the building and proper emergency procedures are in place to respond effectively. This is applicable to occupied buildings of all types and uses. Some of the important factors that need to be considered include:



### 3.6.1. Fire emergency plan

There should be an emergency plan in place for dealing with a fire incident. The emergency plan is to ensure that the people on premise are aware of what to do in case of fire and that evacuation from that premise can be done safely. Clear and relevant information as well as appropriate instructions to occupants or staff as well as the employers of other people working in the premises including contractors should be provided regarding prevention of fires and what to do in case of a fire. Other people involved, using any part of the premise, should also be coordinated and co-operated with. These are essential for effective implementation of an emergency plan.

The basis of the emergency plan should be on the outcome of the fire risk assessment and be available to the employees, their representatives, as well as the enforcing authority. The emergency plan in very small premises may be no more than a fire action notice. However, in more complex and larger premises, the emergency plan should be more detailed and compiled after consultation with rest of the occupants as well as other responsible individuals such as owners that have control over the building or premises.

An emergency plan needs to be appropriate to the type of occupancy and size of the premises and should include:



1) Arrangements for fighting fire	2) Identifying key escape routes, how people can access them and escape from them to a place of complete safety	3) The assembly points once people leave the premises as well as procedures for checking if the premises have been evacuated
4) Arrangements for the safe evacuation of people considered particularly at risk, such as young persons, lone workers, and people with disabilities	5) Any processes/ appliances/ machines/ power supplies to be isolates/stopped in case of fire	6) The identity and duties of staff that have specific responsibilities in case of fire
7) How evacuation of the premises should be handled	8) What staff need to do in case of fire	9) The specific arrangements for high fire-risk areas
10) How people are to be warned in case of fire	11) Plans for dealing with people after they leave the premises	12) Phased evacuation plans
13) The training required for employees and arrangements for ensuring that it is given	14) Procedures for meeting the fire and rescue personnel upon arrival and notifying them of any special risks such as the location of highly flammable substances	
15) How the fire and rescue and other critical services will be	16) Contingency plans for when the life safety systems such as fire-detection,	



contacted and who will be responsible for this

evacuation lifts, and warning systems, smoke control systems, or sprinklers are out of order

### 3.7. Important information from Annexure D of NBC Part 4

The following clauses and Annexure from NBC Part 4 relate to Fire Drills & Evacuation Procedures and should be followed in buildings to ensure effective fire safety management during emergencies. The National Building code, 2016-Part 4 states:

**Clause 4.11: Fire Drills and Fire Orders:** Fire notices/orders shall be prepared to fulfil the requirements of firefighting and evacuation from the buildings in the event of fire and another emergency. The occupants shall be made thoroughly conversant with their action in the event of emergency, by displaying fire notices at vantage points and also through regular training. Such notices should be displayed prominently in bold lettering.

#### 3.7.1. Annexure D (Clause 4.11)

##### **Guidelines for fire drill and evacuation procedures for high rise buildings**

##### **D-1: Introduction**

In case of fire in a high rise building, safe evacuation of its occupants may present serious problems unless a plan for orderly and systematic evacuation is prepared in advance and all occupants are well drilled in the operation of such plan. These guidelines are intended to assist them in this task.

##### **D-2: ALARMS:**

Any person discovering fire, heat or smoke shall immediately report such condition to the fire brigade, unless he has personal knowledge that such a report has been made. No person shall make, issue, post or maintain any regulation or order, written or verbal, that would require any person to take any unnecessary delaying action prior to reporting such condition to the fire brigade.

##### **D-3: Drills:**



D-3.1	Fire drills shall be conducted, in accordance with the Fire Safety Plan, at least once every three months for buildings during the first two years. Thereafter, fire drills shall be conducted at least once every six months.
D-3.2	All occupants of the building shall participate in the fire drill. However, occupants of the building, other than building service employees, are not required to leave the floor or use the exits during the drill.
D-3.3	A written record of such drills shall be kept on the premises for a three years period and shall be readily available for fire brigade inspection

## D-4 Signs and plans

### D-4.1: Signs at lift landings



A sign shall be posted and maintained in a conspicuous place on every floor at or near the lift landing in accordance with the requirements; indicating that in case of fire, occupants shall use the stairs unless instructed otherwise. The sign shall contain a diagram showing the location of the stairways except that such diagram may be omitted, provided signs containing such diagram are posted in conspicuous places on the

respective floor.

A sign shall read “IN CASE OF FIRE, USE STAIRS UNLESS INSTRUCTED OTHERWISE”. The lettering shall be at least 12.5 mm block letters in red and white background. Such lettering shall be properly spaced to provide good legibility. The sign shall be at least 250mm × 300 mm, where the diagram is also incorporated in it and 62.5 mm × 250 mm where the diagram is omitted. In the latter case, the diagram sign shall be at least 200 mm × 300 mm. The sign shall be located directly above the call-button and squarely attached to the wall or partition. The top of the sign shall not be above 2 m from the floor level.



**D-4.2: Floor numbering signs**

A sign shall be posted and maintained within each stair enclosure on every floor, indicating the number of the floor, in accordance with the requirements given below. The numerals shall be of bold type and at least 75 mm high. The numerals and background shall be in contrasting colors. The sign shall be securely attached to the stair side of the door.

**D-4.3: Stair and lifts identification signs**

Each stairway and each lift bank shall be identified by alphabetical letter. A sign indicating the letter of identification shall be posted and maintained at each lift landing and on the side of the stairway door from which egress is to be made, in accordance with the requirements given in 4.4.2.4.3.2(h)(9).



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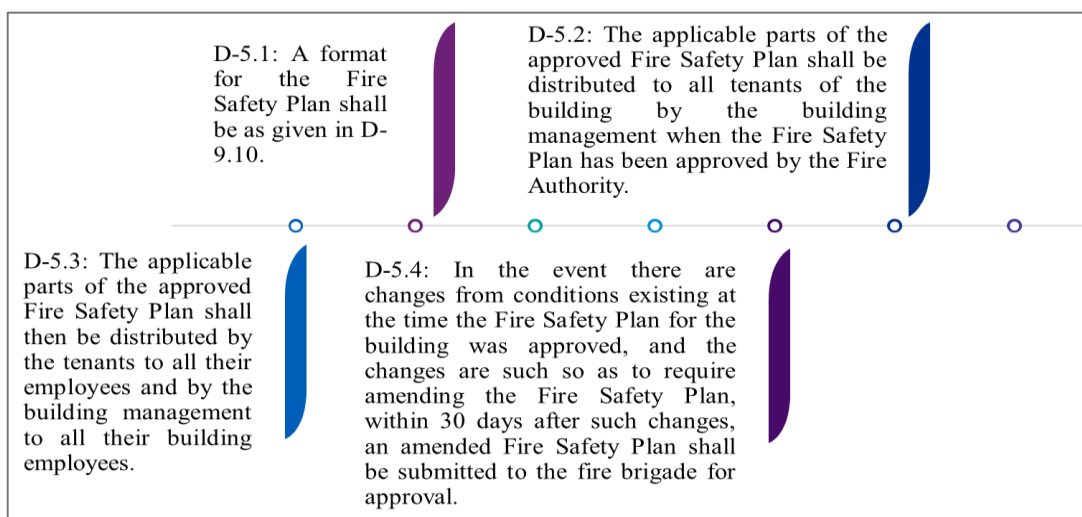
#### D-4.4: Stair Re-entry signs<sup>10</sup>

A sign shall be posted and maintained on each floor within each stairway and on the occupancy side of the stairway where required, indicating whether re-entry is provided into the building and the floor where such re-entry is provided, in accordance with the requirements given below.



The lettering and numerals of the signs shall be at least 12.5 mm high of bold type. The lettering and background shall be of contrasting colors and the signs shall be securely attached approximately 1.5 m above the floor level.

#### D-5 FIRE SAFETY PLAN



#### D-6 FIRE COMMAND CENTRE

A Fire Command Centre shall be established in the building (see 3.4.12).

#### D-7 COMMUNICATIONS AND FIRE ALARM

A means of communication and fire alarm for use during fire emergencies shall be provided and maintained by the owner or person in charge of the building.

<sup>10</sup> Source of image - [https://www.visibleinnovation.com/stair\\_id\\_signs.htm](https://www.visibleinnovation.com/stair_id_signs.htm)

# **Chapter 4:**

## **Fire Protection Equipment & Systems**



## 4. Fire Protection Equipment & Systems

### 4.1. Introduction

It is important to understand the functionality of fire protection systems. Systems work in different ways, but all have a common goal to detect fire and protect the building, its occupants, and valuables. A common fire protection system is a smoke detector and a



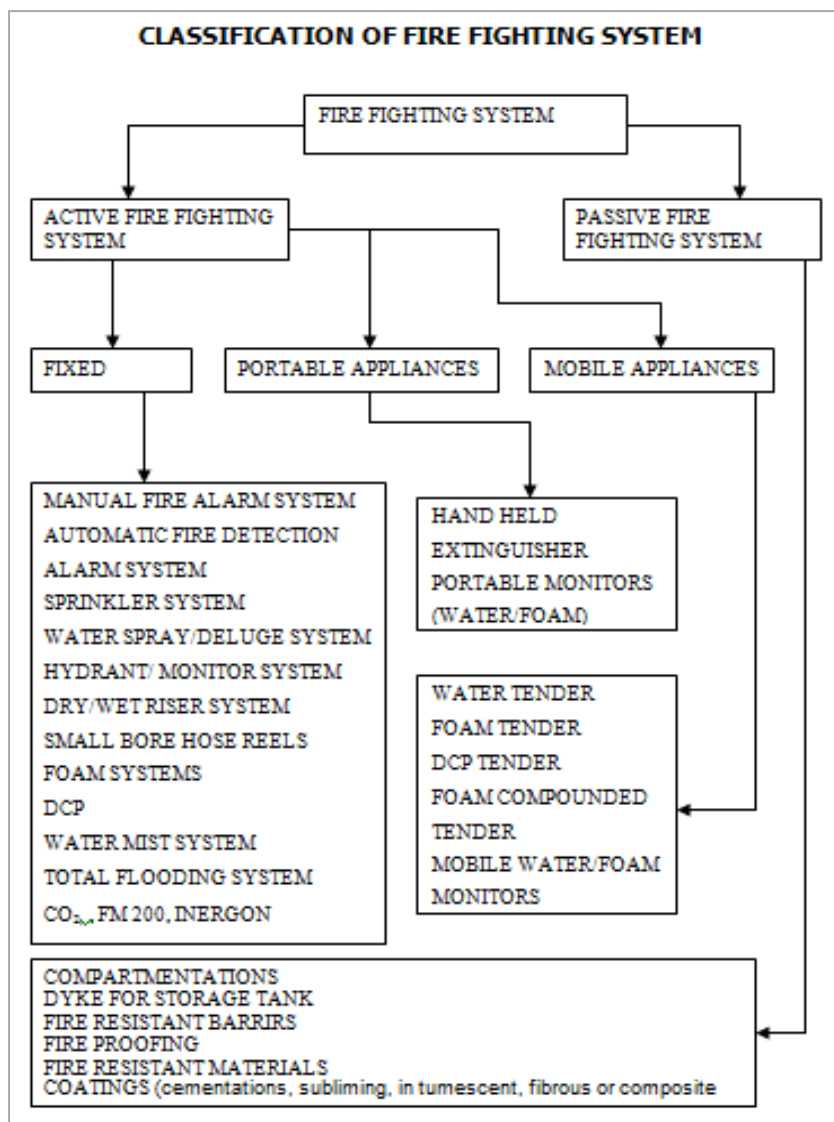
sprinkler. If a fire sparks, smoke sets off the detector causing the sprinkler system to activate. The water protects against the spread of fire. While this is an effective method, when dealing with certain critical equipment or special hazards, automatic fire suppression systems using clean agents are a better choice. These systems detect and suppress fire while leaving no residue.

One of the main benefits of a fire protection system is that in the long run, it saves life and money. If a fire impacts operation for a significant period of time, it could cost the company precious

lives and millions of rupees. A prime example is a machine shop that manufactures parts. If the shop were to experience a fire and shut down for multiple days or weeks, the business would suffer immensely.

Another benefit of some types of fire protection systems is the automatic dispatching of emergency services. These systems will work to immediately suppress the fire, while also notifying the authorities to send emergency professionals to the location.

Below imagery shows the classification of firefighting system.



## 4.2. Portable Fire Extinguishers

### 4.2.1. Introduction<sup>11</sup>

Portable fire extinguishers can control or extinguish small incipient or early growth stage fires quickly by trained personnel



Trained personnel should be familiar with their characteristics and be able to select and use them properly and must also be able to educate the public.

<sup>11</sup> Source of icon – The Noun Project



Trained personnel should have the skills required for inspecting, caring for, maintaining extinguishers.

All fires start small, and if immediately tackled with proper type and amount of extinguishing medium, can be easily extinguished.

In earlier days, in the absence of any other present-day equipment, portable buckets filled with water and sand were used for tackling incipient fires - water buckets for tackling ordinary fires and sand buckets for oil fires. Even now, in rural areas, as well as Railway and other remotely located public premises, water and sand buckets could be seen distributed for tackling small fires.

Portable fire extinguishers are specially designed for the purpose of tackling fires in their incipient stage and they are now commonly used. In fact, they are now considered as the first line of defense in firefighting operations and have assumed the front position among fire protection measures for all types of occupancies as well as fire risks.

The term portable, when applied to fire extinguishers, implies that they can be carried manually to any desired fire scene and operated by one person. In some of the foreign standards, including European standards, the maximum weight of portable extinguishers has been specified as 23 kg.



Apart from portable extinguishers, which are of comparatively smaller in size, there are bigger sized extinguishers which are trolley-mounted and could be pulled to the desired spot.

These bigger sized extinguishers also come under the broad term of first aid firefighting equipment.

#### 4.2.2. Types of extinguishers

Portable fire extinguishers can be divided into 6 categories according to the extinguishing agent they contain. They are as follows:

1) Water type extinguishers	2) Foam extinguishers	3) Dry powder extinguishers
4) CO2 extinguishers	5) Halon/ Halon alternative (Clean Agent) extinguishers	6) Wet Chemical extinguishers



They can also be grouped into categories according to their method of operation.

Extinguishers can be operated by the use of air or gas pressure in the upper part of the container, which forces the extinguishing medium out through a nozzle. They can also be operated using a cartridge containing an inert gas (normally CO<sub>2</sub>) under pressure. When the cartridge is pierced, the gas which comes out of the cartridge drives out the extinguishing medium. In other types, the pressurizing agent (air or inert gas) is stored inside the upper portion of the extinguisher itself, and therefore, the body of the extinguisher remains permanently pressurized. The first one is known by the name, gas cartridge type of extinguisher, and the second one is known by the name stored pressure type of extinguisher.

### 1) **Water (gas cartridge) type extinguisher**

- In this pressure is released from a cartridge which is stored inside the body of the extinguisher. The cartridge is pressurized with CO<sub>2</sub> gas (to a pressure of approx. 35 bars). On puncturing the cartridge, by striking the knob on the top, the gas is released, and on coming out of the cartridge, it expels the water from the body of the extinguisher. The expelled water comes out through the nozzle of the extinguisher in the form of a small jet, which can be projected on to the fire.
- The liquid capacity of the extinguisher, when filled to the specified level, is 9 liters.
- The gas cartridge is screwed on to a holder which is fitted on to the cap of the extinguisher. The maximum size of the gas cartridge is 60 g for a 9-litre extinguisher.
- On operation, the water jet should give an effective throw of not less than 6m for a minimum period of 60 second and at least 95% of water in the extinguisher should be discharged.

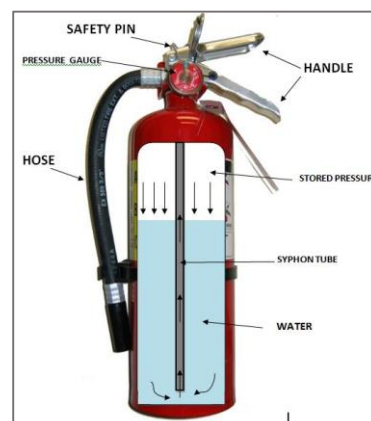


### 2) **Water (stored pressure) extinguisher**

- The extinguisher is filled with water and dry air pressurized up to 10 bars. The air can be supplied by compressed air cylinders or by certain type of pump.



- Operation is performed by withdrawing the safety pin, depressing the valve lever and directing the water jet by means of the hose.
- As this type of extinguisher is permanently pressurized, it can only be opened for inspection after discharged.
- The normal capacity of this extinguisher is also 9 liters.



### 3) Mechanical foam extinguisher (9 L)

- The extinguisher is filled with pre-mixed foam solution, i.e., a mixture of water and a foam concentrate (usually AFFF)
- Foam extinguisher can either be of the stored pressure type or gas cartridge type.
- The operation of these types is similar to what has been stated under the water type extinguishers.
- The figures of the two types are shown below:



### 4) Dry chemical powder extinguisher

- Various types of dry powder extinguishers are available in the market. Some of them are filled with dry powders suitable for class B & C fires and some suitable for class A B C fires.
- Dry chemical powders have excellent fire knocking down properties. However, for permanent extinguishment, more often, their use will have to be followed with discharge of extinguishing media like foam or water.



- The construction of this type of extinguisher is similar to that of water (stored pressure type). The pressure maintained inside the extinguisher is about 10 bars. It is normally fitted with a pressure gauge and a fan-shaped nozzle.

The throw of jet, and duration of discharge for extinguishers of different capacities are given below:

Capacity of fire extinguisher kg	Minimum Period Which Throw of jet Maintained S	Maximum period Discharge at Last 85% of Contents S	Range or throw of jet M
0.5	5	8	Not less Than 1.5
1 and 2	6	12	Not less Than 4
5 and 10	15	25	Not less Than 4

1) From nozzle to center of Pattern of discharge.



#### 5) **Dry chemical powder extinguisher (gas cartridge) type**

4 sizes of extinguishers of this type are available in the market - 1kg, 2kg, 5kg & 10 kg capacities. The sizes of the gas cartridges also vary according to the extinguisher size. This type of extinguisher is quite common as a requirement for various type of occupancies. However, note that cartridge type extinguishers are slowly being phased out in favor of the pressurized type.



## 6) CO<sub>2</sub> extinguisher

The main features of this extinguisher are:

- It consists of a high-pressure cylinder.
- CO<sub>2</sub> is retained mostly in a liquid condition at about 51 bars pressure (at a temperature of 15°C)
- Different capacities are available, viz., 2kg, 3kg and 4.5 kg (portable types). Trolley mounted types are of capacities 6.5kg, 9kg and 22.5kg.
- The discharge time of various types is given below:



Nominal size of extinguisher, Kg	Discharge time, sec.	
	Min	Max
2	8	18
3	10	20
4.5	10	24
6.5	10	30
9	12	36
22.5	20	60

### Hazards of CO<sub>2</sub> extinguishers:

- Although not itself toxic, CO<sub>2</sub> will not support life when used in large quantities to extinguish a fire.
- If used in an unventilated area, it dilutes the oxygen supply and makes human survival difficult.
- A thick cloud of CO<sub>2</sub> gas may cause disorientation

## 7) Clean agent extinguishers

- In India Halon 1211 extinguishers are still available although they are- getting phased out.



- Other clean agents (HFC236Fa, FE 36) are being used in portable extinguishers currently.
- The standard capacities of these extinguishers are 1.25 kg, 2.5 kg, 4 kg, 5 kg & 6.5 kg.
- They are quite effective on fires in electrical / electronic equipment
- They are getting replaced gradually by other extinguishers containing Halon alternatives.

## 8) **Wet chemical extinguishers**

Changes in frying oils from animal fats to vegetable oils have reduced the ability of Multipurpose ABC fire extinguishers to extinguish many kitchen fires. As we know, vegetable oils have a much higher auto ignition temperature than animal fats, because of this, the heat breaks down the weaker foam layer created, and re-ignition takes place.

Class F extinguishers work on the principle of saponification. Saponification takes place when alkaline mixture such as wet chemical (mixture of potassium acetate, potassium citrate or potassium carbonate) is applied to burning oil or fat, the wet chemical combined with the fatty acid creates a soapy foam layer on the surface which holds in the vapor and steam and extinguishes the fire. Class F fire extinguishers have the ability to maintain the foamy layer enough to allow complete cooling. In addition, these wet chemical agents pose minimal damage threat to hot appliances.



- The standard capacities of these extinguishers are 12,3,6 & 9 liters
- The discharge nozzle should be specially designed to ensure gentle application on the burning surface of the oil
- Class F extinguishers are also given a rating as like Class A & B extinguishers

## 9) **Soda acid & chemical foam extinguishers**

These have already been phased out and their IS withdrawn.

### 4.2.3. **Selection and installation of extinguishers**

1. The most important consideration while selecting extinguishers is the nature of the area to be protected and the nature of the hazard involved.



2. Another factor to be considered is the human element involved. An individual's reaction to a fire will be largely influenced by his familiarity with the extinguishers, his training and experience in its operation and his self-confidence. Training, therefore, is very important.
3. Detailed instructions regarding selection, installation and maintenance of first-aid fire extinguishers are contained in IS:2190. It is essential that all users (at least organizations) should be familiar with these instructions, so that maximum advantage can be gained for promotion of fire safety standards for their own benefit.

#### 4.2.4. Inspection and maintenance of fire extinguishers

- An inspection is a quick check that visually determines that the fire extinguisher is properly placed and will operate.
- Maintenance, as distinguished from inspection, means a complete and thorough examination of each extinguisher. A maintenance check involves opening the extinguisher, examining all its parts, cleaning, replacing defective parts, reassembling, recharging and repressuring the extinguisher, where necessary.
- Detailed instructions regarding periodical maintenance, hydrostatic pressure testing and refilling of extinguishers are given in IS:2190-1992 which should be scrupulously followed.

#### 4.2.5. Classification and usage of fire extinguishers

As described earlier, fire has been categorized into 4 classes based on the burning material involved. To extinguish the fire, one has to use the most suitable and compatible fire extinguisher. Suitability of different fire extinguishers for different classes of fires is as below:

Sr. No.	Type of Extinguisher	Type of Fires				
(1)	(2)	(3)				
		A	B	C	D	F



Sr. No.	Type of Extinguisher	Type of Fires				
		A	B	C	D	K
i)	Fire extinguisher, water type (gas cartridge), IS 940 and IS 13385	S	NS	NS	NS	NS
ii)	Fire extinguisher, water type (stored pressure), IS 6234	S	NS	NS	NS	NS
iii)	Fire extinguisher, mechanical foam type (gas cartridge), IS 10204 and IS 13386	S	S	NS	NS	NS
iv)	Fire extinguisher, mechanical foam type (stored pressure), IS 14951 and IS 15397	S	S	NS	NS	NS
v)	Fire extinguisher, dry powder type (stored pressure), IS 13849	S	S	S	NS	NS
vi)	Fire extinguisher, dry powder type (gas cartridge), IS 2171 and IS 10658	S	S	S	NS	NS
vii)	Fire extinguisher, dry powder type for metal fires, IS 11833	NS	NS	NS	S	NS
viii)	Fire extinguisher, carbon dioxide type, IS 2878 and IS 8149	NS	S	S	NS	NS
ix)	Fire extinguisher, clean agent gas type, IS 15683	S	S	S	NS	NS
x)	Fire extinguisher, halon 1211 type, IS 4862 (Part I) and IS 11108	S	S	S	NS	NS
xi)	Fire extinguisher, Wet chemical type, IS 15683	S	NS	NS	NS	S
Note:	S : Suitable, NS : Not Suitable					

#### 4.2.6. Number and size of fire extinguishers

Fire extinguishers should be provided both for protecting a building structure as well as occupancy hazard contained therein.



The number and size of fire extinguishers required for any particular premises shall be determined with the premise to minimize hazards by the appropriate authority; taking into consideration the severity of incipient fire anticipated behavior characteristics of different materials and structure elements of buildings, rapidity with which a fire may spread; intensity of heat that may be developed, accessibility to fire; type of extinguisher; the smoke contributed by the burning material; special features of building construction and nature of occupancy (single or mixed) and electrical fitting, equipment, etc., installed therein.

The required number of fire extinguishers may be determined by considering any single extinguisher of a suitable type or a combination of two or more types.

Fire extinguishers designed and installed in premises is as per IS 15683 and IS 2190.

#### **4.2.7. Fire extinguisher ratings explained**

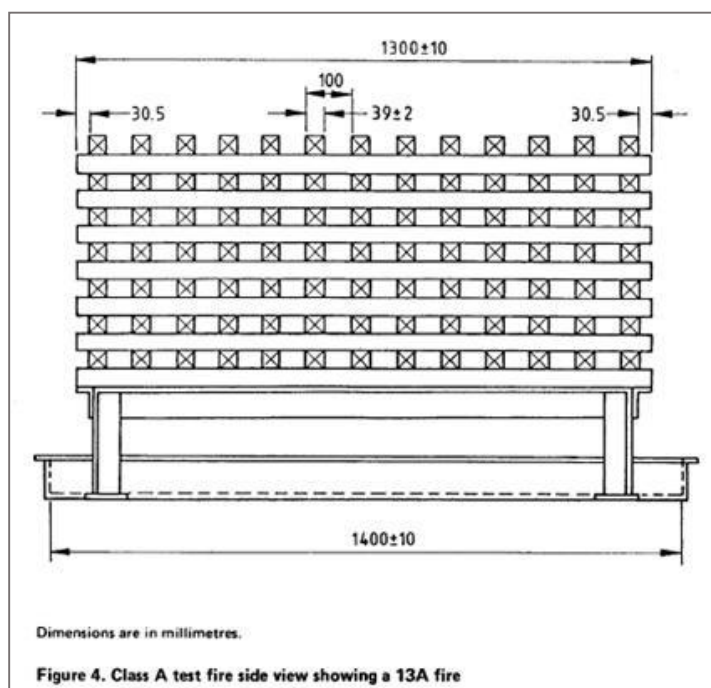
These mystical codes that are printed on all quality-approved fire extinguishers are there to indicate, not just the type of fire that particular extinguisher can combat, but also the size of the fire the contents can effectively put out.

Different tests apply to each Class of fire (from A, B, C & D), but the rule is, the larger the number before the Code letter the bigger the fire (of that Class) that can be extinguished.

Most fire extinguishers have a fire rating printed on the canister. This code, for example 13A/55B, defines the Class (or type) of fire and the size of fire this type of fire extinguisher is capable of extinguishing.

Thus, in 13A/55B example, this extinguisher will combat a Class A fire (typically freely burning materials like wood, cloth and coal) of Size 13 or a Class B fire (flammable liquid) of size 55. For Class A fires the Size test is conducted using a fire comprising an open latticework of wooden sticks approx. 40mm square x 500mm long piled 14 high. The number 13 comes from the number of sticks in each row as the example below. Fire extinguishers that can put out a fire up to this size are rated 13A. A 34A would extinguish a stack with 34 sticks and so on, so the higher the number the bigger the fire it can extinguish.





#### Examples of available 13A rated extinguishers:

Water with Additive 3 liter	Foam (AFFF) 3 liter	ABC Dry Powder 2kg (CO <sub>2</sub> is unsuitable for this type of fire)
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#### In the example 13A/55B, 55B means the following:

Class B fires involve burning liquids like petrol, oils (not cooking oils) heptane, etc. Only AFFF foam, CO<sub>2</sub> fire extinguishers and dry powder extinguishers are suitable for this application. (See Extinguisher Chart)

The prefix 55 again defines size of the fire and in this case is easier to visualize as the test uses 55 liters of burning fuel. A 175B rating uses 175 liters and so on.

Also, there is no such thing as a Class E rating in the UK – often thought to cover Electrical fires. Many fires are caused by electrical faults which in consequence ignite other flammables. If an extinguisher is described as “safe to use” on fires involving live electricity it means the suppressant is not inherently electrically conductive, so you don’t risk electrocution when combating the fire. In any event, a sensible approach is to cut off the power supply to any area where a fire occurs.

**4.2.8. Hydro test of fire extinguishers as per is 2190**

<b>ANNEX E</b> <b>[Clauses 12.2.1 and 12.2.2 (g)]</b> <b>SCHEDULE FOR HYDRAULIC PRESSURE TESTING OF FIRE EXTINGUISHERS</b>				
<b>E-1</b> Every extinguisher installed in premises shall be hydraulically pressure tested as per the schedule given below. There shall not be any leakage or visible distortion. Extinguisher which fails in this requirement shall be replaced.		<b>E-2</b> The carbon dioxide type and clean agent type fire extinguishers shall be pressure tested every time when the cylinders are sent for recharging ( after periodic discharge test or otherwise ) to the pressure specified in the relevant Indian Standard specifications.		
<i>Sl No.</i>	<i>Type of Extinguisher</i>	<i>Test Interval Year</i>	<i>Test Pressure kg/cm<sup>2</sup></i>	<i>Pressure Maintained for min</i>
i)	Water type (gas cartridge) (IS 940)	3	35	2.5
ii)	Water type (stored pressure) (IS 6234)	3	35	2.5
iii)	Water type (gas cartridge) (IS 13385)	3	35	2.5
iv)	Mechanical foam type (gas cartridge) (IS 10204)	3	35	2.5
v)	Mechanical foam type (stored pressure) (IS 15397)	3	35	2.5
vi)	Mechanical foam type (gas cartridge) (IS 13386)	3	35	2.5
vii)	Mechanical foam type (gas cartridge) 135 litre (IS 14951)	3	35	2.5
viii)	Dry powder ( stored pressure ) ( IS 13849)	3	35	2.5
ix)	Carbon dioxide IS 2878	5	250	2.5
x)	Clean agent (IS 15683)	3	35	2.5
xi)	Dry powder (gas cartridge) ( IS 2171, IS 10658 and IS 11833)	3	35	2.5
NOTE — Extinguisher's should be hydraulically tested with cap.				

**4.2.9. Life of fire extinguishers as per is code 2190**

<b>ANNEX F</b> <b>(Clauses 12.2.1)</b> <b>LIFE OF FIRE EXTINGUISHERS</b>		
<i>Sl No.</i>	<i>Type of Extinguisher</i>	<i>Life Time, Year</i>
i)	Water type	10
ii)	Foam type	10
iii)	Powder type	10
iv)	Carbon dioxide	15
v)	Clean agent	10
<b>NOTES</b> <b>1</b> Life of extinguishers shall be considered from date of manufacture of extinguishers. <b>2</b> In case of failure in hydraulic pressure testing, extinguisher shall be rejected immediately before the life time given above.		

**4.2.10. Refiling schedule of extinguishers as per is 2190**

<b>ANNEX D</b> <b>(Clauses 11.4.1 and 12.3)</b> <b>REFILLING SCHEDULE FOR FIRE EXTINGUISHERS AND SCHEDULE FOR</b> <b>OPERATIONAL TEST ON FIRE EXTINGUISHERS</b>	
<b>D-1 EXTINGUISHERS TO BE REFILLED/ OPERATED FOR PERFORMANCE TEST IN ANNUALLY CYCLIC MANNER</b>  <b>D-1.1 Once in Two Years</b> <ul style="list-style-type: none"> <li>a) Portable fire extinguisher, water type stored pressure.</li> <li>b) Portable fire extinguisher, mechanical foam type stored pressure.</li> <li>c) 135 litre fire engine, foam type.</li> </ul> <b>D-1.2 Once in Three Years</b> BC and ABC powder extinguisher confirming to IS 4308 and IS 14609 respectively.	<ul style="list-style-type: none"> <li>c) Portable fire extinguisher, water type 50 litre (gas cartridge).</li> <li>d) Portable fire extinguisher, mechanical foam type 50 litre (cartridge type).</li> <li>e) Fire extinguisher, carbon dioxide type (portable and trolley mounted).</li> <li>f) Higher capacity dry powder fire extinguisher (trolley mounted).</li> <li>g) Dry powder fire extinguisher for metal fires.</li> <li>h) Clean agent fire extinguishers.</li> </ul>
<b>D-1.3 Once in Five Years</b> <ul style="list-style-type: none"> <li>a) Portable fire extinguisher, water type 9 litre (gas cartridge).</li> <li>b) Portable fire extinguisher, mechanical foam type 9 litre (cartridge type).</li> </ul>	<b>NOTES</b>  <b>1</b> In corrosive environments, it is desirable to have the discharge test carried out at half the frequency mentioned.  <b>2</b> As per the restriction on release of halon in atmosphere, it need not be necessary to refill/operate Halon 1211 type portable fire extinguisher with in any stipulated period. However, as regards the pressure of injections gas, that is dry N <sub>2</sub> should be checked up for the adequate pressure on the pressure gauge/ indicating gauge and the contents by weighing the fire extinguisher.

**4.2.11. Extinguisher's color code as per is 15683**

<b>10 MARKING AND COLOUR</b>	
<b>10.1 Colour</b>	
The recommended colour for extinguisher bodies is red conforming to shade No. 536 or 538 of IS 5. A small band of distinguishing colour of approx 5 percent/ prominent of surface area shall be painted for different type of extinguishers as given below:	
<i>Extinguishers</i>	<i>Band Colour</i>
Water based extinguishers	Red
Foam based extinguishers	Yellow
Powder based extinguisher	Blue
Carbon dioxide based extinguishers	Black
Clean agent extinguishers	Green
Water mist extinguishers	Red



## 1) Example of layout marking for an extinguisher as per IS 15683:






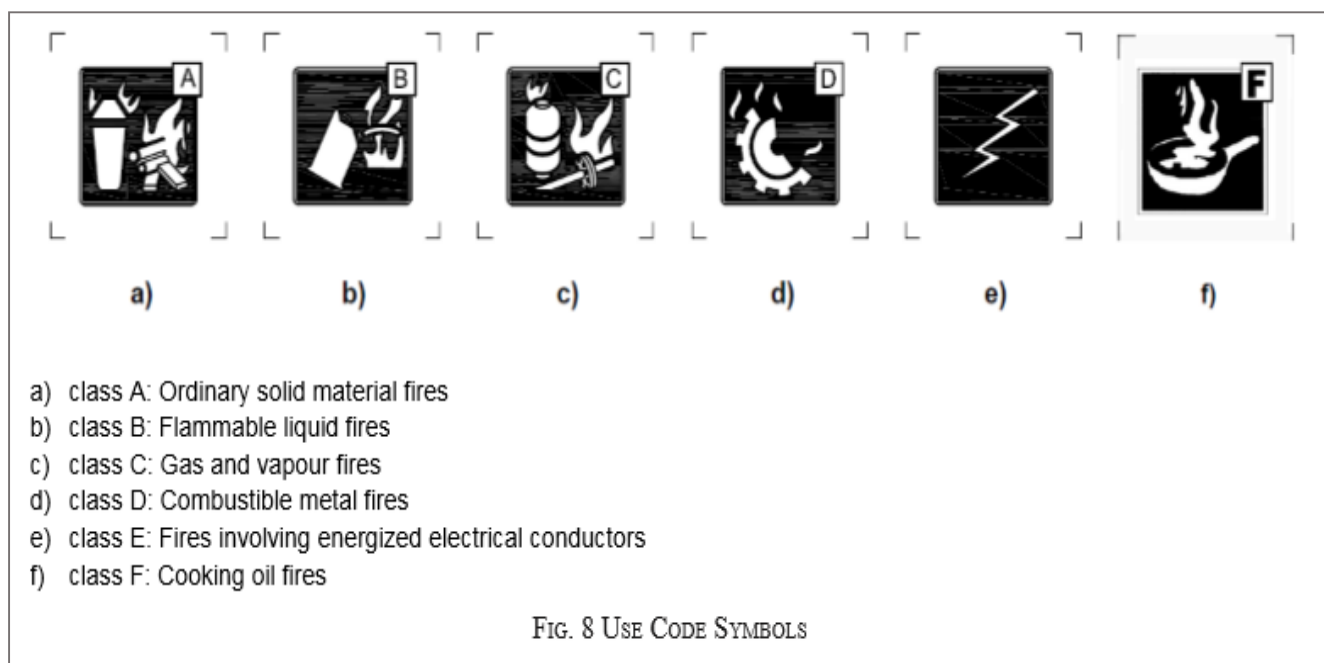
<p><b>2 KG CARBON-DIOXIDE FIRE EXTINGUISHER</b></p> <p><b>INSPECTION :</b> INSPECT MONTHLY CHECK THAT EXTINGUISHER IS CHARGED, UNDAMAGED AND SEAL IS INTACT. MAKE SURE HORN IS UNOBSTRUCTED.</p> <p><b>MAINTENANCE :</b> EXAMINE CAREFULLY EVERY 12 MONTHS TO ENSURE EXTINGUISHER IS OPERABLE. RECHARGE IF MASS LOSS EXCEEDS 0.2KG. REPLACE ANY DAMAGED PARTS. CHECK HORN FOR OBSTRUCTIONS. HYDROSTATIC RETEST TO DOT/TC REQUIREMENTS EVERY 5 YEARS.</p> <p><b>USE :</b> AFTER ANY USE RECHARGE IMMEDIATELY.</p> <p><b>RECHARGE :</b> CO<sub>2</sub> CHARGES IS 2 KG. FULL MASS STAMPED ON VALVE BODY INCLUDES HORN ASSEMBLY.</p> <p><b>RECORD :</b> RECORD MAINTENANCE AND RECHARGE DATES ON ATTACHED TAG.</p> <p>FOR INDUSTRIAL USE.</p>	<p style="text-align: center;"><b>INSTRUCTIONS</b></p> <div style="display: flex; justify-content: space-around;"><div style="text-align: center;"><p>①</p><p>HOLD UPRIGHT PULL RING PIN</p></div><div style="text-align: center;"><p>②</p><p>START BACK 3 m AIM AT BASE OF FIRE</p></div><div style="text-align: center;"><p>③</p><p>SQUEEZE LEVER SWEEP SIDE TO SIDE</p></div></div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"></div>	<div style="border: 1px solid black; padding: 5px; text-align: center; margin-bottom: 10px;"><b>APPROVAL MARK</b></div> <p>CARBON-DIOXIDE FIRE EXTINGUISHER</p> <p>CLASSIFICATION 21B</p> <p>SERIAL NO. XX-XXXXX</p> <p>2 KG CARBON DIOXIDE FIRE EXTINGUISHER</p> <p>SUITABLE FOR USE AT TEMPERATURES FROM -30°C TO 60°C PRESSURE TESTED TO 20 MPa</p> <div style="display: flex; justify-content: space-between; margin-top: 10px;"><div style="border: 1px solid black; padding: 5px; width: 40%;">MODEL</div><div style="border: 1px solid black; padding: 5px; width: 40%;">2018</div></div> <p style="text-align: center;">MFG. NAME</p> <p style="text-align: center;">MFG. ADDRESS</p>
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FIG. 7 EXAMPLE OF LAYOUT MARKING FOR AN EXTINGUISHER

## 2) Use code symbol for fire extinguishers as per is 15683



## 4.3. Water as an extinguishing media

### 4.3.1. Extinguishing properties of water

Despite the many new techniques which have come to the assistance of firemen, water is



still the most efficient, cheapest and most readily available medium for extinguishing fires of a general nature. The method of applying water to a fire varies according to the size of the fire.

For major fires, greater quantities of water are necessary, and the built-in pumps driven by the vehicles. engines are often capable of pumping 4,500 liters (1000 gallons) per minute (or more) giving the necessary

energy to water to provide adequate striking power. A variation in the application of water can be made by means of nozzles that produce jets or sprays ranging from large sized droplets down to atomized fog effects. Judicious use of this type of application can not only cut down the amount of water used, minimizing water damage, while also ensuring its use to greater effect.

Some of the special properties which makes water the most efficient and generally accepted extinguishing agent are:

Water has a high specific heat capacity are 4.2 kJ / kg / per °C	Water has a high latent heat of evaporation per unit mass, at least 4 times higher than that of any other non-flammable liquid
It is non-toxic	Its B.P. (100°C) is well below the 250°C to 450°C range of pyrolysis temperatures for most solid combustibles

Water extinguishes a fire by a combination of mechanisms: cooling the combustible substance, cooling the flame itself, generating steam that prevents oxygen access and as fog blocking the radiative transfer of heat.

Note: In a practical firefighting, water has to be applied at 10 to 100 times the rates prescribed in laboratory tests because of the difficulty in ensuring that the bulk of it reaches the burning surfaces.

### 4.4. Specific heat



When heat is applied to a body, its temperature rises. The heat energy required to raise the temperature of unit mass of a substance through  $1^{\circ}\text{C}$  is referred to as specific heat capacity of the substance ( $\text{J/kg per }^{\circ}\text{C}$ ).

Specific heat capacities of some substances are given below:

Substance	Specific Heat Capacity( $\text{J/kg per }^{\circ}\text{C}$ )
Steel	460
Aluminum	900
Copper	400
Ice	2100
Methylated Spirit	2400
Water	4200 ( $4.2 \text{ kJ/kg/}^{\circ}\text{C}$ )

Materials with a low specific heat capacity will heat up more rapidly in a fire situation than those of high specific heat capacity. Petrol, alcohol, etc. have low specific heat capacity and also vaporize readily. Low specific heat capacities are of considerable importance in promoting fire risks.

Specific heat capacity of water is unusually high, viz.,  $4200 \text{ J/kg}$  ( $4.2 \text{ kJ/kg}$ ) per  $^{\circ}\text{C}$ . This is one of the reasons why water is effective as an extinguishing agent.

#### 4.5. Latent heat

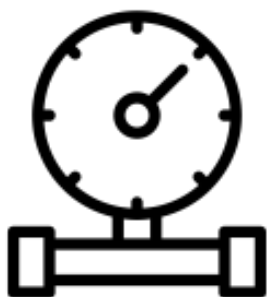


A substance absorbs heat when it is converted from a solid to a liquid, or from a liquid to a gas/ vapor. This thermal energy is called latent heat. It is measured in Joules per unit mass ( $\text{J/kg}$ ).

When a container with water is heated, the temperature of water goes on rising until it reaches  $100^{\circ}\text{C}$ , the BP of water. At this temperature, the water boils. However, the temperature remains constant at  $100^{\circ}\text{C}$ , although heat continues to be applied to the container. This heat which is absorbed by water for conversion to steam (vapor stage) is what is known as latent heat of vaporization of water. The latent heat of vaporization of water is extremely high, approx.  $2260 \text{ kJ/kg}$ . This is the main reason why water is chosen as an extinguishing agent. The heat absorbed by water while evaporating from the surface

of a burning solid reduces its temperature as well as the rate of pyrolysis and ultimately extinguishes the fire.

#### 4.6. Principal characteristics of pressure



The S.I. unit of pressure is the newton per square meter ( $\text{N/m}^2$ ) another name for which is the Pascal. However, it has been decided that because this is a very small unit, the fire service unit of pressure will be the 'bar'. The relationship between these units is:

**1 bar = 100000  $\text{N/m}^2$  or 10<sup>5</sup>  $\text{N/m}^2$**

**Normal atmospheric pressure = 1.013 bar**

There are a number of basic rules governing the principal characteristics of pressure in liquids. These are:

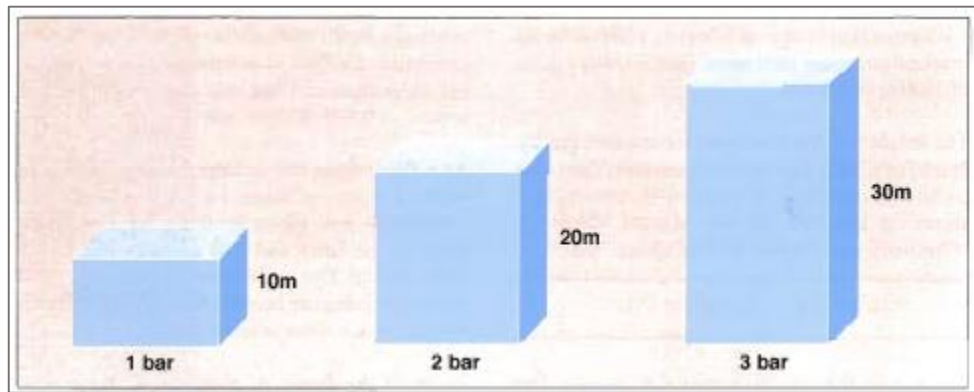
- 1) **The pressure exerted by a fluid at rest is always at right angles to the surface of the vessel which contains it.**
- 2) **The pressure at any point in a fluid at rest is the same in all directions:**

A gauge connected onto a line of piping or hose, or to the bottom of a storage tank, containing a fluid at rest will give the same reading no matter what its orientation is because the pressure exerted by the fluid is the same in all directions. This is equally true regardless of whether the pressure is due to the height of the column of fluid itself or is externally applied e.g., by a pump.

- 3) **Downward pressure of a fluid in an open vessel is proportional to its depth:**

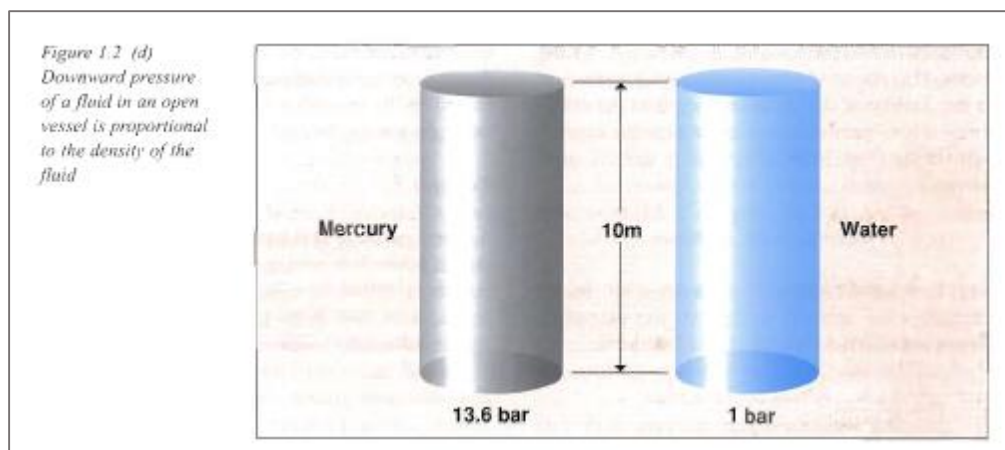
Figure below shows three vertical containers, the depth of water in them is 10m, 20m and 30m. If pressure gauges were to be placed at the bottom of each container, they would show readings of approximately 1 bar, 2 bar and 3 bar respectively, i.e., the pressure indications would be in the same ratio as the depths.





- 4) **The downward pressure of a fluid in an open vessel is proportional to the density of the fluid:**

In the figure below, are shown two containers, one holding mercury and the other water. The depth of liquid is same in both the containers. If pressure gauges were to be placed at the bottom of each container, the pressure at the bottom of the mercury container would be 13.6 times the pressure at the bottom of the water container because mercury is 13.6 times as dense as water.



- 5) **The downward pressure of a fluid on the bottom of a vessel is independent of the shape of that vessel:**

This last principle is illustrated in figure which shows a number of containers of varying shapes. The pressure at the bottom of each is exactly the same provided the depth of liquid (or head) is the same in each case. One practical consequence of this principle is that the static (i.e., no flow) pressure at the delivery end of a pipeline leading from an elevated storage tank or reservoir is decided solely by the vertical distance between the water surface and the point where the pressure is measured, because the head of water is the same no matter how convoluted the route which the pipeline takes. Also, if water is being pumped up to such a container, or to an elevated branch for firefighting purposes, the amount of



pump pressure required to overcome the head will be independent of the precise route which the pipe or hose takes. However, once flow is taking place, friction between the moving water and the inside surface of the pipe or hose becomes a complicating factor which will be considered later in this chapter.

#### 4.7. Hydrant systems/ installations

Water being the main extinguishing medium, major fires can be controlled and extinguished by the use of water from firefighting hoses operated by the regular fire services. This firefighting water is usually obtained from hydrants installed on public mains or other premises.

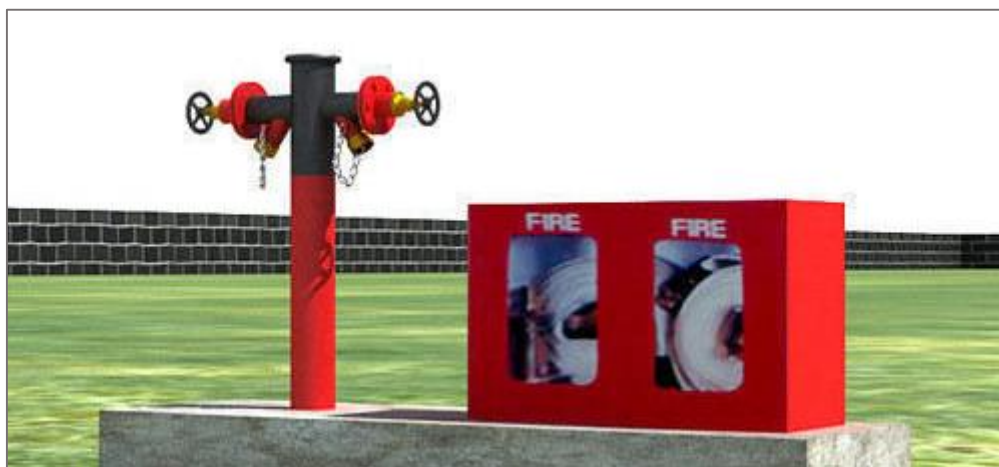
**Hydrant systems can be of two types:**

<u>External Hydrant System</u>	<u>Internal Hydrant System</u>
where the hydrants are installed in the open, like the city or town water mains, or hydrant systems installed in the open areas in industrial or such other occupancies	installed in buildings or structures to be protected

**The basic requirements of any hydrant systems are:**

Water reservoir or source of water supply (for supply of water for firefighting purposes).
Pump(s) for imparting energy to the water (for conveying water through pipelines, and to make water available at the required pressures for firefighting purposes);
Pipelines, which may be laid underground or above ground, for conveying water under pressure to the required places.
Hydrants (which are the outlets installed on the pipelines at strategic locations on the water mains for drawing water, using delivery hoses, for firefighting purposes.

### 4.7.1. External hydrant systems



- 1) These systems are essential and important requirements for fighting fires in cities, towns and individual occupancies or premises. The guidelines for provision, installation, inspection and maintenance of these systems are given in IS:13039-1991, Code of Practice for Provision, and Maintenance of External Hydrant System.

Population of less than	Capacity of fire fighting reservoirs in m <sup>3</sup> or kilo litres
5000	50
10,000	100
20,000	200
30,000	300
40,000	350
50,000	400

- 2) The guidelines regarding water reservoirs and such other details for water supply are given in IS:9668-1991, Code of Practice for Provision and Maintenance of Water Supplies for Fire Fighting.
- 3) The capacity of pumps required for these systems have to be worked out based on the requirements of output and pressure for the systems. Provision has to be made for standby pumps fed from a different source of power at the rate of 50% of total number of pumps, subject to a minimum of one. The static firefighting pumps should conform to the requirements given in IS:12469-1988, Pumps for Fire Fighting Applications.
- 4) The pressure for systems is normally designed based on practical considerations and specific needs. A minimum residual pressure 1.5kg/cm<sup>2</sup> (20psi) should usually be maintained at hydrants delivering the required fire flow.



5) Pressure and flow in mains

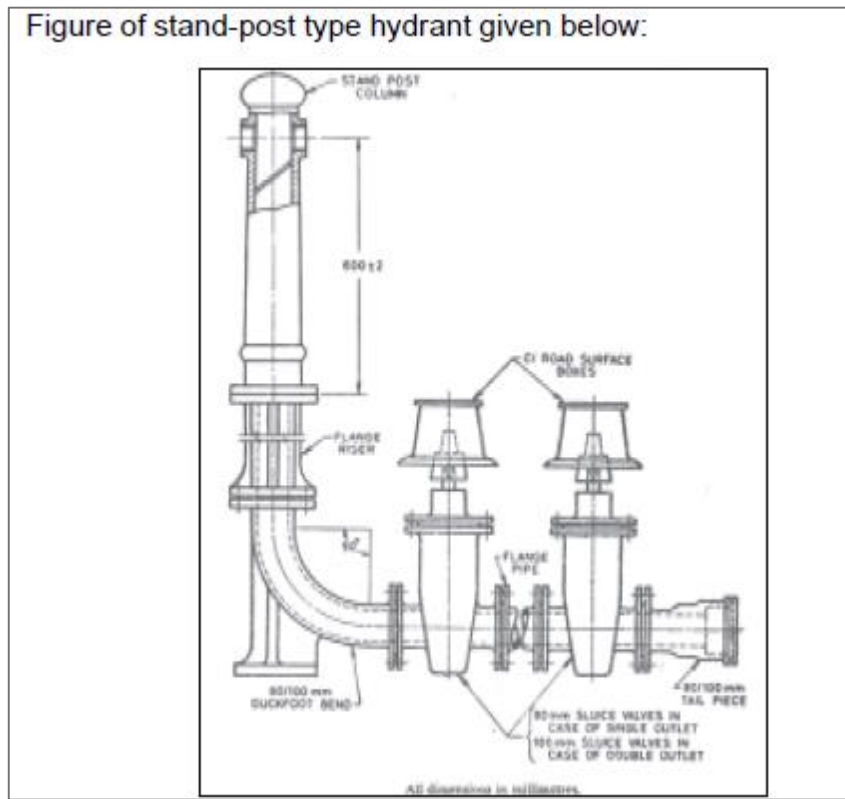
- i. The pressure of water flowing in the water mains can be expressed either in kg/cm<sup>2</sup> or bars (1atmosphere = 14.7psi or 101.325 kN/m<sup>2</sup> or 1.013 bar) (1 bar = 100kN/m<sup>2</sup>), or as meters head (1meter head = 0.0981 bar)
- ii. The amount of water a hose or pipe will transmit or convey in a given time depends on its size (cross-sectional area) and its velocity of flow. While flowing through the hose or pipe some loss of pressure is experienced due to friction loss.
- iii. The five principal laws governing the loss of pressure due to friction in hoses or pipes are:
  - Friction loss varies directly with the length of the pipe (for double the length of hose, the friction loss will also be doubled);
  - For the same velocity, friction loss decreases directly with the increase in diameter(If the diameter of the hose is doubled, the friction loss will be reduced to one-half, but the quantity of water is increased to four times);
  - Friction loss increases directly as the square of the velocity (if the velocity of the water is halved, friction loss is reduced to one-quarter);
  - Friction loss increases with the roughness of the interior of the pipe/hose.
  - Friction loss, for all practical purposes, is independent of pressure.

6) Fire Hydrants

- i. Fire hydrants provide the means of drawing water from the water mains for firefighting. The water main is provided with a branch or T-piece to which the hydrant is attached either directly or with a short length of pipe.
- ii. There are two types of hydrants - stand-post type, or underground type(sluiice-valve type)
- iii. Stand-post type hydrant - General requirements:
  - Shall have one or two sluiice-valves
  - Road surface boxes
  - Duck foot bend
  - Flange riser
  - Stand post column fitted with one (single headed) or two (double headed) 63mm male couplings (male couplings with blank caps are normally provided for city

or street hydrants, and female couplings with blank caps are normally provided for internal private hydrants)

Figure of stand-post type hydrant given below:



Note: Generally, in the case of private systems, beside each stand-post type hydrant, a hose box or cabinet will also be provided which usually contains the following items:

- Two lengths of 63 mm firefighting hose conforming to Type A of IS:636-1988 with couplings
- One universal branch pipe conforming to IS:2871-1983 (jet and spray branch)
- Spare rubber washers for the couplings

Since the water mains are charged, fire hoses can be directly connected to the hydrants and firefighting operations can be carried out without delay.

The capacities of pumps for hydrant systems can vary according to the risks to be covered.

	Litres/sec.	Litres/min.	M <sup>3</sup> /Hr.
INTERNAL HYDRANTS	27	1620	96
	38	2280	137
	47	2820/2850	171
EXTERNAL HYDRANTS (INDUSTRIES)	76	4560	273
	114	6840	410

#### 4.7.2. Internal hydrant systems<sup>12</sup>



- 1) These systems are generally installed for fire protection of buildings or special structures. An internal hydrant installation comprises of the following elements:
  - i. Static or terrace tank for storing water for firefighting purposes.
  - ii. Rising mains, down comer mains or external mains to feed water from the source to the required point under pressure.
  - iii. Firefighting pump(s) with all fitments and components; and
  - iv. Other necessary components like internal hydrants (also called as landing valves, external hydrants (also called as yard hydrants), hose reels, hoses and branch pipes, in cabinets.
- 2) The main features and requirements for the internal hydrant systems are listed below:
  - i. The capacities of the underground static water tanks/ terrace tanks vary according to the fire risks involved in the occupancy.
  - ii. Internal hydrants form part of any of the following systems:

<sup>12</sup> Source of image - <https://fireextinguishersindia.wordpress.com/2018/03/10/all-about-internal-fire-hydrant-system/>



- Dry riser system,
  - Wet riser system,
  - Wet riser cum down comer system, and
  - Down-comer-system
- iii. Dry riser system is not normally charged with water but could be charged either through the fire service inlet provided at the bottom, or through an installed pump when required, or directly from a fire appliance.
- iv. A wet riser system remains charged throughout so that by connecting delivery hoses, firefighting operations could be carried out immediately. Generally, hose reels are also connected to this system alongside landing valves. The landing valves provided in the system are required to be sited so as to ensure that no part of the building protected is more than 30m from the landing valve. This system is normally charged by the operation of the static firefighting pump installed in the building. However, a fire service inlet is also provided for charging it from fire service appliances.
- v. The fire service inlet for 100mm internal dia rising main should have a collecting head with 2 nos. of 63mm inlets, and for 150mm rising main should have a collecting head with 4 nos. of 63mm inlets.
- vi. The down comer system is connected to a terrace tank through a terrace pump.
- vii. In addition to wet riser systems, first aid hose reels are required to be installed on all floors of high-rise buildings or special type of buildings. The hose reel is generally taken directly from the rising main by means of a 37mm socket and pipe to which the hose reel (generally of 19mm dia) is attached.
- viii. The internal hydrant system should conform to IS:3844 - 1989, .Code of Practice for Installation and Maintenance of Internal Fire Hydrants and Hose Reels on Premises. The hose reel should conform to Type-A of IS:884-1985, .First-aid hose-reel for firefighting.;
- ix. For a wet-riser system, two automatic pumps should be installed to independently feed the wet-riser main, one of which should act as stand-by, each pump being supplied by an independent source of power. However, an interlocking arrangement will ensure that only one of the pumps operate at a time.
- x. For bigger systems, it is desirable to install a small pump of approx. 180-300 lpm capacity, with pressure switches for automatic start and stop, which is known as jockey pump.





- xi. The system should be tested before use for a minimum pressure of 7kg/cm<sup>2</sup> for at least 30 min., after which a flow test should also be carried out.
- Details of periodical tests and maintenance etc. are given in IS:3844 1989.

## 4.8. Types of fire pumps

Various types of fire pumps are used in fire protection systems. Types of fire pumps include horizontal split case, vertical split case, vertical in-line, end suction and vertical turbine. These fire pumps may be powered by an electric motor or diesel engine and on rare occasion powered by a steam turbine.

### 4.8.1. Horizontal split case

These are the most commonly used type of pump. This is due to their ease of access to all working parts, availability of various sizes, ability to efficiently move large amounts of water and their long-term dependability. This type of pump requires a water source that provides a positive suction pressure.



### 4.8.2. Vertical split case

The functionality of a vertical split case pump is similar to that of a horizontal split case pump with the exception of the vertical orientation of the pump and motor. The vertical motor placement offers the advantages of less required floor space and the protection of the motor against potential flooding conditions. This type of pump also requires a water source that provides a positive suction pressure.

### 4.8.3. Vertical in-line

These pumps also have a vertical motor orientation. Generally, these are smaller, compact pumps requiring less space than other pumps. They are suited for applications with limited space for a pump room. Another benefit includes in-line mounting that generally does away with the need for special pads or foundations.



A drawback to the in-line pump is that the entire driver unit must be removed to perform maintenance or repairs. A positive suction pressure is required for this type of pump.

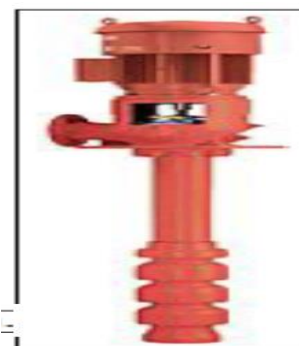
#### 4.8.4. End suction

This pump is considered a horizontal pump. NFPA 20 - Standard for the Installation of Stationary Pumps for Fire Protection defines end suction pumps as follows: A single suction pump having its suction nozzle on the opposite side of the casing from the stuffing box and having the face of the suction nozzle perpendicular to the longitudinal axis of the shaft. Similar to the Vertical turbine pump, the water flowing through an End suction pump makes a 90° radial turn from suction to discharge.



#### 4.8.5. Vertical turbine pump

Unlike the previously discussed fire pumps, the vertical turbine pump does not require a water source that provides a positive suction pressure. As such, this type of pump is able to operate without priming. The typical supplies for these pumps are underground tanks or wells. When operating, these pumps force water up through the column pipe to the pump discharge.

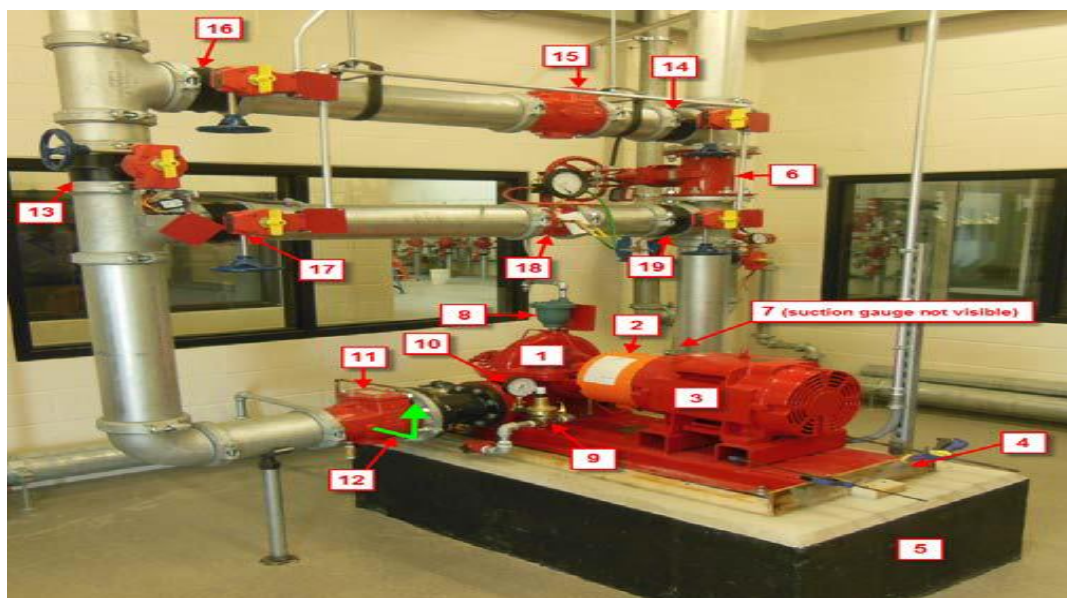


#### 4.8.6. Common components of an electric fire pump installation

Electric fire pump (Photo source: Rich Gallagher, Zurich)

1. Fire pump	2. Coupling guard	3. Electric motor
4. Grouted base (wood forms still in place to retain curing grout)	5. Plinth or housekeeping pad	6. Fire pump suction valve (gate type valve)
7. Fire pump suction gauge (not visible)	8. Automatic air release	9. Circulation relief valve
10. Fire pump discharge gauge	11. Discharge check valve	12. Fire pump pressure sensing line (location show with green line)

13. Fire pump discharge valve (butterfly type)	14. Bypass supply valve (butterfly type)	15. Bypass check valve
16. Bypass system valve (butterfly type)	17. Flowmeter isolation valve (butterfly type)	18. Flowmeter
19. Flowmeter throttling valve (butterfly type)		



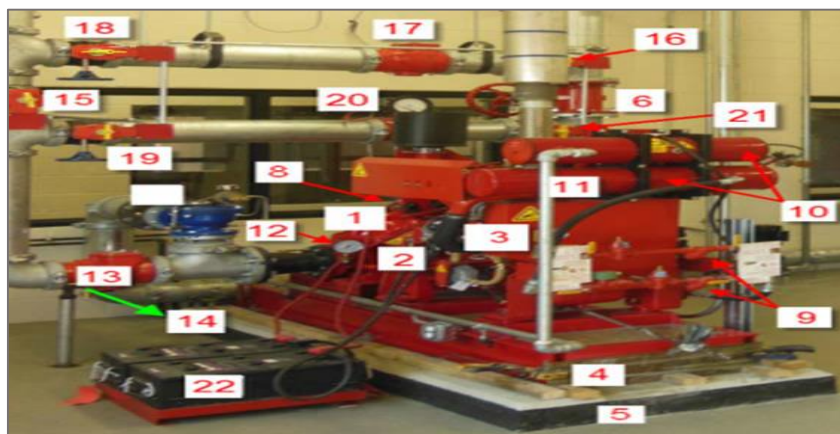
#### 4.8.7. Common components of a diesel fire pump installation

Diesel fire pump (Photo source: Rich Gallagher, Zurich)

1. Fire pump	2. Coupling guard	3. Electric motor
4. Grouted base (wood forms still in place to retain curing grout)	5. Plinth or housekeeping pad	6. Fire pump suction valve (OS&Y type)
7. Fire pump suction gauge (not visible)	8. Automatic air release	9. Engine cooling water line with bypass
10. Engine heat exchanger	11. Engine heat exchanger discharge line	12. Fire pump discharge gauge



13. Discharge check valve	14. Fire pump pressure sensing line (location show with green line)	15. Fire pump discharge valve (butterfly type)
16. Bypass supply valve (butterfly type)	17. Bypass check valve	18. Bypass system valve (butterfly type)
19. Flowmeter isolation valve (butterfly type)	20. Flowmeter	21. Flowmeter throttling valve (butterfly type)
22. Batteries		



#### 4.8.8. Common components of a diesel fire pump fuel tank installation

Example of a diesel fuel tank (Photo source: Rich Gallagher, Zurich) is mentioned below:



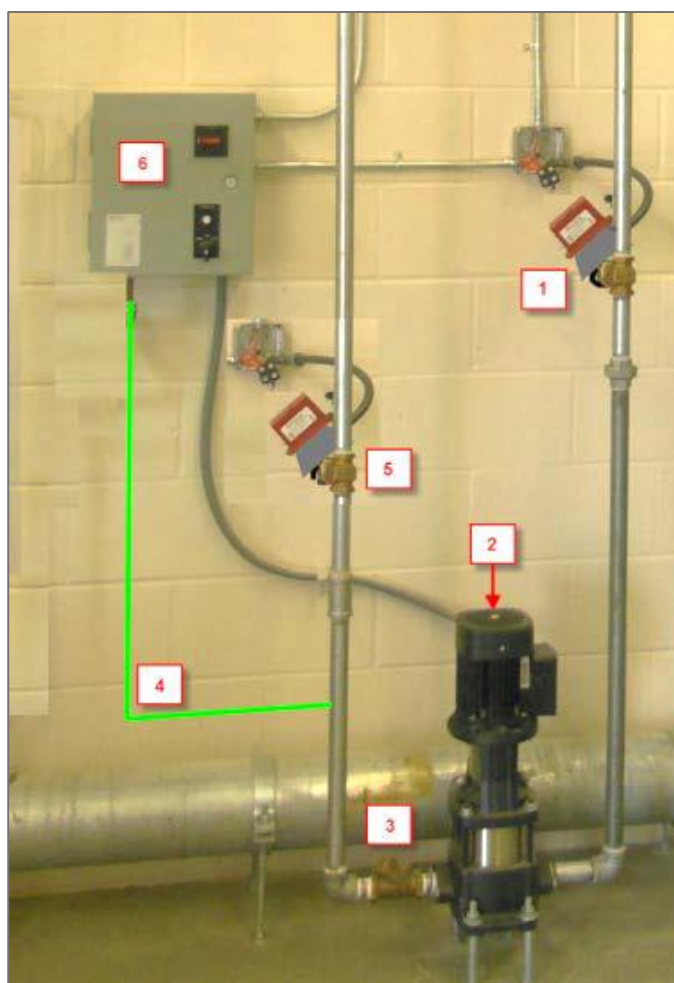


1. Tank fill	3. Tank secondary containment space vent (where provided)	5. Tank level float switch (where provided)	7. Fuel return line
2. Tank vent	4. Tank level indicator	6. Fuel supply line and manual shutoff valve	

#### 4.8.9. Common components of a jockey pump installation

Jockey pump installation (Photo source: Rich Gallagher, Zurich)

1. Jockey pump suction valve	2. Jockey pump	3. Jockey pump discharge check valve
4. Jockey pump pressure sensing line (location show with green line)	5. Jockey pump discharge valve	6. Jockey pump controller





#### 4.8.10. Common components of an electric fire pump controller

Electric fire pump controller (Photo source: Rich Gallagher, Zurich)



1. Operating handle (single handle for both the manual isolation switch and circuit breaker disconnecting means)
2. Start pushbutton
3. Stop pushbutton
4. Emergency stop
5. Test push button
6. Emergency run handle

#### 4.8.11. Common components of an electric fire pump controller

Electric fire pump controller (Photo source: Rich Gallagher, Zurich)



1. NA
2. NA
3. Operating handle for manual isolation switch
4. Start pushbutton (break glass)
5. Stop push button

#### 4.8.12. Common components of a UL-listed diesel fire pump controller

Diesel fire pump controller (Photo source: Rich Gallagher, Zurich)

1. Crank engine using battery set 1
2. Crank engine using battery set 2
3. Stop engine
4. Break glass access to selector switch (manual – off – auto) and engine test





#### 4.8.13. Common components of a diesel fire pump controller

Diesel fire pump controller (Photo source: Rich Gallagher, Zurich)

1. Switch to select cranking engine using battery set A

2. Switch to select cranking engine using battery set B

Note: Switch at 1 & 2 also isolated DC power

3. Stop engine

4. Switch (AC power isolator)

5. Indicator lamps (trouble conditions)



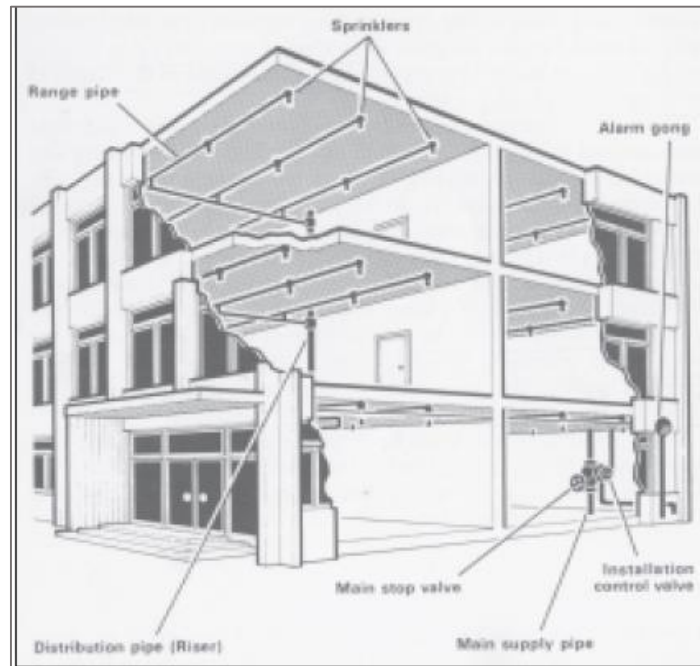
### 4.9. Water based fire extinguishing system

#### 4.9.1. Automatic Sprinkler Systems

##### General

Automatic sprinklers are devices for automatically distributing water upon a fire in sufficient quantity to extinguish it completely or to prevent its spread, by keeping the fire under control, by the water discharged from the sprinklers. The water for firefighting is fed to the sprinklers through a system of piping, normally suspended from the ceiling, with the sprinklers installed at intervals along the pipes.

The orifice of the sprinkler head, incorporating the fusible link or fusible bulb of the automatic sprinkler, is normally kept closed, which is thrown open on the actuation of the temperature-sensitive fusible link or fusible bulb. The figure depicting the layout of a typical sprinkler installation is given below:



Automatic sprinkler systems are quite effective for ensuring life safety, since they give early warning of the existence of fire and simultaneously start application of water on to the fire which will help control and extinguishment of the fire. The downward force of the water spray from the sprinklers also help minimize the smoke accumulation in the room of fire besides cooling the environment and promoting survival of the occupants.

NBC Part-4, Fire and Life Safety also recognizes the importance of sprinklers for achieving fire and life safety. The provision of the sprinkler system in buildings helps to offset deficiencies in fire protection requirements in existing buildings and the Code provides trade-offs. in the matter of various fire protection requirements when automatic sprinkler systems are provided. For e.g., longer travel distances to exits, higher fire load density, etc. are allowed with the provision of sprinklers.

However, it has to be mentioned that partial coverage of the buildings by sprinkler protection is neither advisable from fire protection point of view nor from cost effectiveness. In case a fire originates from an unprotected area and after growing into a well-developed fire spreads to the protected area, it would have generally developed sufficient intensity to overpower the sprinklers.

### **Types of sprinkler systems**

There are four main types of sprinkler systems



<b>Wet</b> - The pipes are permanently charged with water and used for all locations except where freezing temperatures are likely to occur, or special conditions exist.	<b>Dry</b> - The pipes are normally charged with air under pressure.
<b>Alternate</b> - Can be arranged to be either wet or dry depending upon ambient temperature conditions.	<b>Pre-action</b> - The pipes are normally charged with air and get filled with water when a fire actuates a separate detection system.

### Classes of system as per fire hazard

There are three classes of systems based on the fire load of the occupancy to be protected. The design densities of discharge and the assumed maximum area of operation for the three classes are given below:

Type of System	Design density of discharge	Assumed maximum area of of operation
Low Hazard System(LH)	2.25 lpm/m <sup>2</sup>	84m <sup>2</sup>
Moderate Hazard System (MH)	5.0 lpm/m <sup>2</sup>	360m <sup>2</sup>
High Hazard System(HH)		
(a) Process risks	7.5/12.5 lpm/m <sup>2</sup>	260m <sup>2</sup>
(b) High piled storage risks	7.5/30 lpm/m <sup>2</sup>	260/300 m <sup>2</sup>

### Water supplies

It is essential that sprinkler systems are provided with a suitable and acceptable water supply. The Rules accept the following sources subject to certain specific conditions:

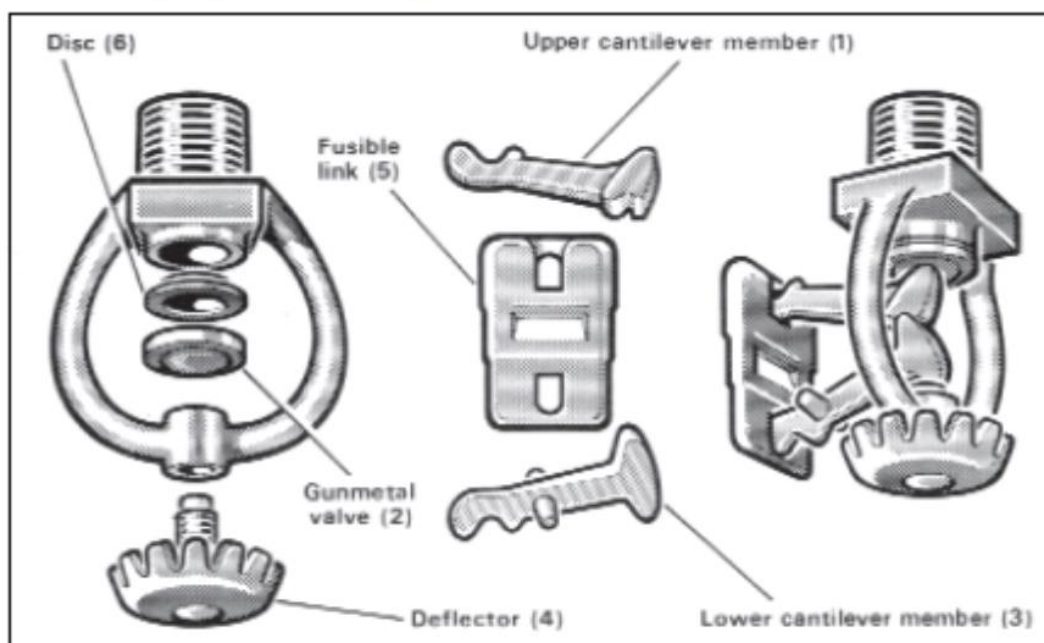
- town mains
- elevated private reservoirs
- gravity tanks
- automatic pump supply
- pressure tanks

## Sprinkler heads

Their operation can be divided into two main types:

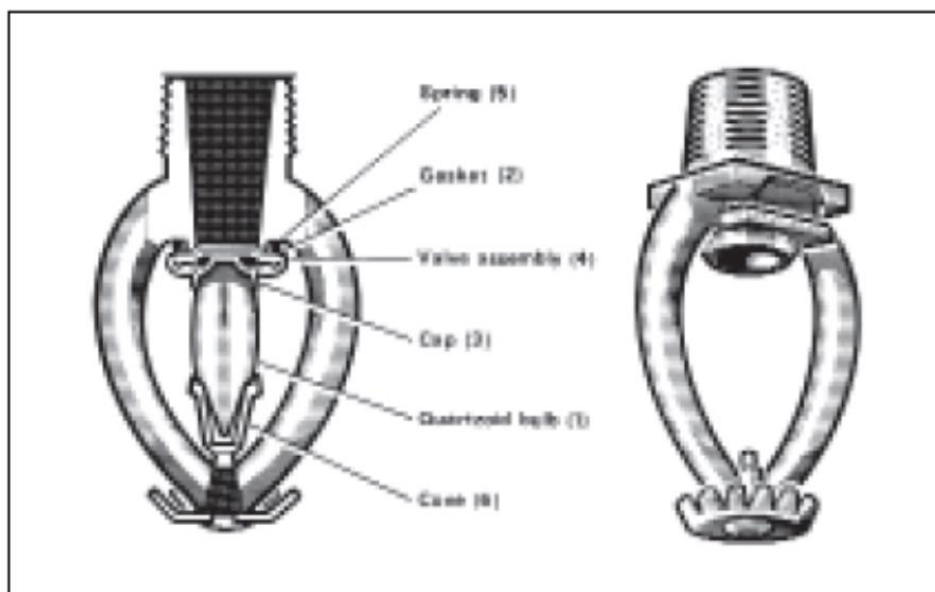
- (i) Those in which the **operating medium is fusible solder**
- (ii) Those in which the **operating medium is a glass bulb (quartzoid bulb)**.

**Fusible solder type:** In this type, the body of the sprinkler is held in place by two yokes and a flexible metal diaphragm into which a valve is fitted. Three parts, viz., the strut, the hook and the key are held together by a special fusible solder. In a fire condition the fusible solder (or link) melts and the component members are thrown clear of the head, allowing the water to flow out in the form of spray after hitting the deflector. The solders used with automatic sprinklers are made of alloys of metals like tin, lead, cadmium etc.



*A typical fusible solder type sprinkler head  
showing component parts*

**Fusible bulb type:** The second type of operating element of the sprinkler head utilizes a frangible bulb. In this, a small bulb of special glass contains a liquid leaving a small air bubble entrapped in it. When exposed to heat from fire, the liquid expands, and the bubble disappears. Due to increase of pressure the bulb shatters, releasing the water in the form of spray. The operating temperature is regulated by adjusting the amount of liquid, the nature of the liquid itself, as well as the size of the bubble.



*A typical fusible bulb type sprinkler head showing component parts*

### Temperature ratings of automatic sprinklers

Automatic Sprinklers have various temperature ratings that are based on standardized tests in which a sprinkler is immersed in a liquid and the temperature of the liquid raised slowly until the sprinkler operates. All heads are marked with their operating temperature ratings and are color coded for easy identification. Temperatures and colors are as follows:

Sprinkler Temperature Rating	Bulb Type (Colour of Bulb)	Fusible Link Type
57°C	Orange	-
68°C	Red	Uncoloured
79°C	Yellow	-
93°C	Green	White
141°C	Blue	Blue
182°C	Mauve	Yellow
204 to 260°C	Black	Red (227°C)

### Orifice Size



The sprinkler orifice sizes are 10 mm, 15 mm, and 20 mm, which are generally used respectively for Light Hazard, Moderate Hazard and High Hazard, but this may vary according to the spray pattern and type of head used.

### **Types of sprinklers**

The following are the types of sprinklers which are accepted for general use:

**1) Conventional sprinkler**

These produce a spherical type of discharge with a portion of the water directed upwards to the ceiling. They may be of upright or pendent type.

**2) Spray pattern**

This operates with a hemispherical discharge pattern below the deflector with no water being directed upwards.

**3) Ceiling flush pattern**

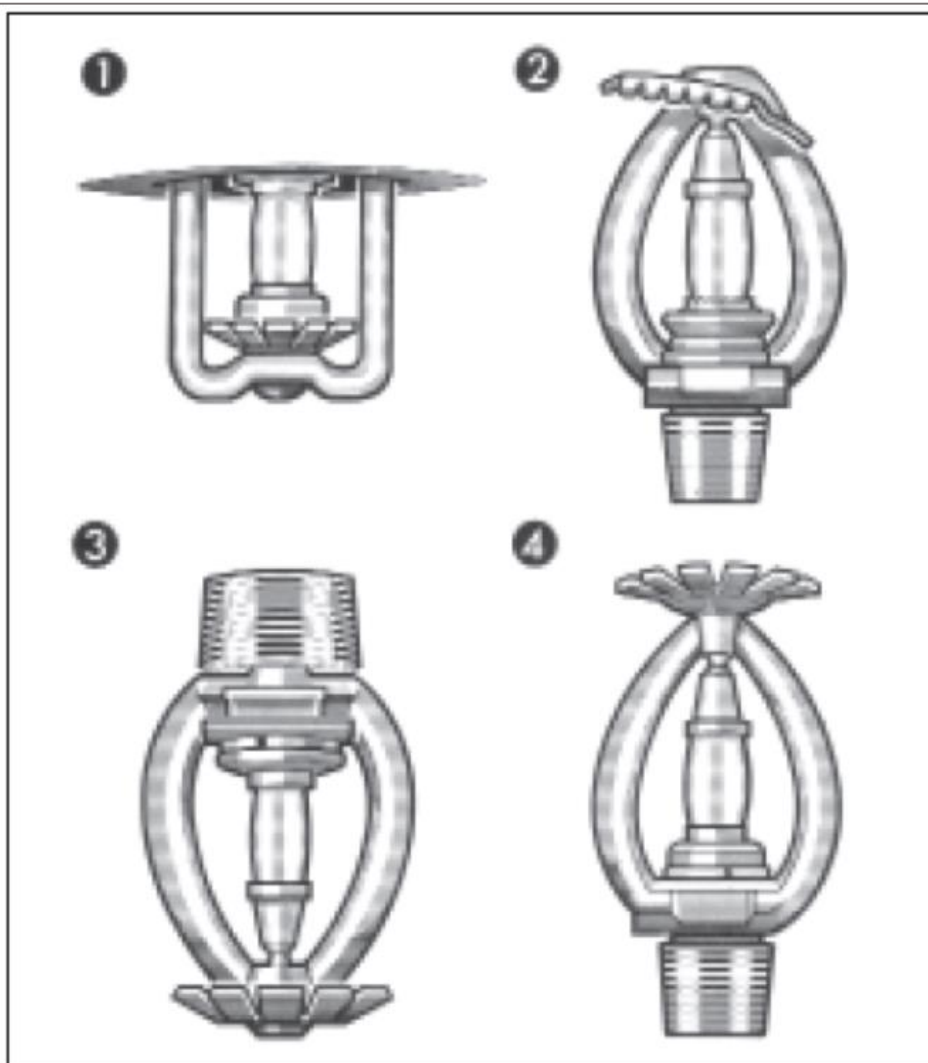
The heads are installed with the base flush to the ceiling, and heat sensitive elements facing downwards. The pipe work remains concealed above the ceiling.

**4) Side wall pattern**

These are installed along the walls of a room close to the ceiling and produces a horizontal pattern of spray. These are commonly used for guest room fire protection in hotels.

**5) Dry upright pattern**

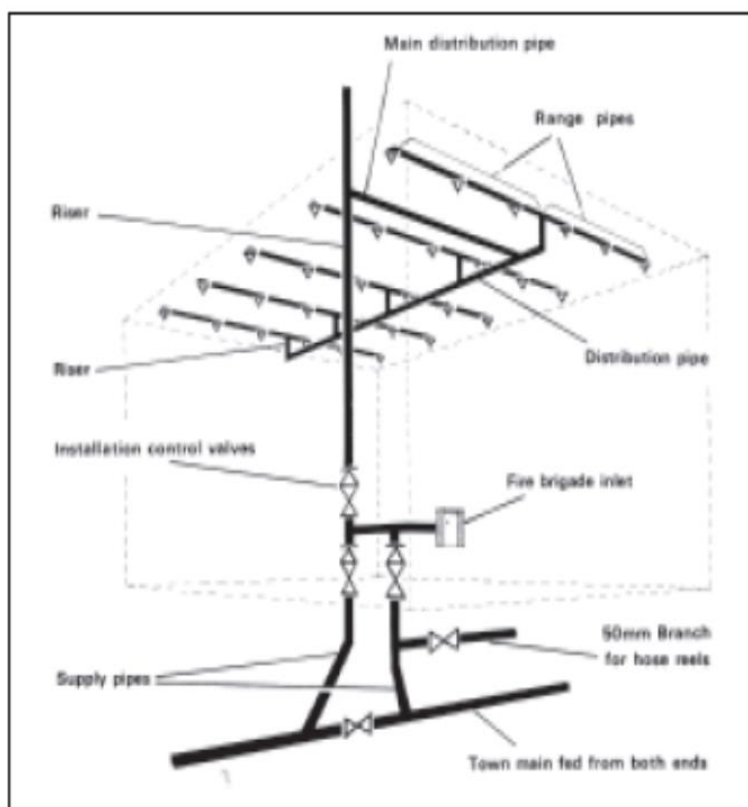
These are the same as pendent type sprinklers.



*Types of sprinklers (bulb type)*

- (1) Ceiling flush pattern    (2) Sidewall pattern  
(3) Pendent type    (4) Dry upright type





*Diagrammatic lay out of pipework of a sprinkler installation.*

### Area covered by sprinklers

The maximum area covered by a sprinkler in different hazard classes of occupancies are shown below:

Hazard class	General	Special risk areas or storage racks
Extra light hazard	21 m <sup>2</sup>	9 m <sup>2</sup>
Ordinary hazard	12 m <sup>2</sup>	9m <sup>2</sup>
Extra high hazard	9m <sup>2</sup>	7.5 to 10 m <sup>2</sup>

### Early Suppression Fast Response Sprinklers (ESFR)

ESFR type of sprinklers was developed in the late 1980s to meet the challenges of high-tech and complex fires. It differs from standard sprinklers, in that, it is designed to suppress or extinguish a fire in its early stages rather than control it. Fire suppression is achieved by quickly discharging a large volume of water directly onto the fire to suppress it. The better performance of this type of sprinkler is achieved by increasing the diameter of the sprinkler orifice to 18mm allowing significantly more water to flow from one head. The flow from



one ESFR sprinkler is roughly around 375 - 400 lpm, nearly 2 to 3 times as much as a standard head.

Testing in the US and in the UK has shown that, if installed correctly, ESFR sprinklers offer probably the best form of automatic fire protection available for high hazard occupancies.

Like the ESFR, another type of sprinkler, known by the term, .Quick Response Extended Coverage Sprinkler has also come into world market which responds quickly to fires with larger coverage areas up to 36m<sup>2</sup>.

If properly designed, installed and maintained, sprinkler systems remain the best option for providing cost-effective life safety and property protection.

In India also, TAC and insurance companies encourage the installation of sprinkler systems in buildings by giving substantial reduction in insurance premiums (even up to 50%) for buildings so equipped.

International experience: An analysis conducted in UK of a large number of fires in sprinkler-protected premises, provided the following statistics:

- 55% of fires were extinguished by the operation of two or less sprinkler heads.
- 80% of fires were extinguished by the operation of eight or less sprinkler heads.
- 90% of fires were extinguished by the operation of eighteen or less sprinkler heads.
- Sprinkler coverage for fire protection of occupancies has full legislative as well as insurance support.

A statistical report released by NFPA for a 10-year period reveals:

- 55% of fires were controlled and extinguished by the operation of three sprinklers.
- 80% of fires were controlled and extinguished by the operation of eight sprinklers.
- 94% of fires were controlled and extinguished by the operation of twenty-one to twenty-five sprinklers.

**Automatic Sprinklers shall be installed in (as stipulated in Part-4, NBC):**

- a) basements used as car parks or storage occupancy, if the area exceeds 200 m<sup>2</sup>;



- b) multi-level basements covered upper floors used as car parks, and for housing essential services ancillary to a particular occupancy or for storage occupancy, excluding any area to be used for sub-station, A.C. plant and DG set.
- c) any room or other compartment of a building exceeding 1 125m<sup>2</sup> in area except as in (g) (see Note), if so, advised by local authority.
- d) departmental stores or shops if the aggregate covered area exceeds 750 m<sup>2</sup>.
- e) all non-domestic floors of mixed occupancy which constitute a hazard and are not provided with staircases independent of the remainder of the buildings.
- f) Godowns and warehouses, as considered necessary.
- g) On all floors of the buildings other than residential buildings, if the height of the building exceeds 30 m (45 m in case of group housing and apartments)
- h) dressing room, scenery docks, stages and stage basements of theatres.
- i) in hotels, hospitals, industries low and moderate hazard, mercantile buildings of height 15 m or above.
- j) in hotels below 15 m, if covered area at each floor is more than 1000 m<sup>2</sup>.
- k) false ceiling voids which are used for storage or as return air plenums exceeding 800 mm in height in sprinklered buildings (see Note 2); and
- l) canteen provided in upper floors of D-1 and D-2 occupancies shall be sprinklered.

Notes:

1. It is desirable that all high-rise buildings should be fully sprinklered irrespective of their height and occupancy. If selective sprinklering is adopted, there is a real danger of a fire starting on one of the lower unsprinklered floors gathering momentum, spreading upwards from floor to floor through the unsprinklered floor and reaching the first sprinklered floor as a fully developed fire. In such an event, the sprinklers can be rendered useless or ineffective.
2. Use of false ceiling voids for storage or as return air plenums should be discouraged.

#### **4.9.2. Water spray systems**

##### **General**

- 1) Water Spray System is a special fixed pipe system connected to a reliable source of pressurized water supply and equipped with water spray nozzles for application on area /



equipment to be protected. The system can be operated automatically by connection to an automatic detection and alarm system or manually, or both.

- 2) These systems can be used for any one or more of the undermentioned purposes:
  - Extinguishment of fire.
  - Control of fire.
  - Exposure protection(cooling); and
  - Prevention of fire (cooling).
- 3) The suppression or extinguishment of fire is achieved by cooling, dilution of oxygen supplies (smothering), dilution (or removal) of the liquid fuel (starvation or emulsification).
- 4) Water spray systems are generally used for fire protection of flammable liquid and gas storage tanks, piping, pumping equipment, electrical equipment such as transformers, oil switches, rotating electrical machinery etc. and for protection of openings in fire walls and floors.
- 5) The type of water spray required will depend on the nature of the hazard and protection required.
- 6) Size of the system: Since most systems perform as deluge systems, large quantities of water are required. Normally, a design discharge rate of about 13600 lpm (3000 gpm) is the limit for one system.
- 7) Strainers are required to be installed in the supply lines of fixed piping spray systems to prevent clogging of the nozzles. Water spray nozzles having very small water passages may have their own internal strainers.

### **Types of water spray systems**

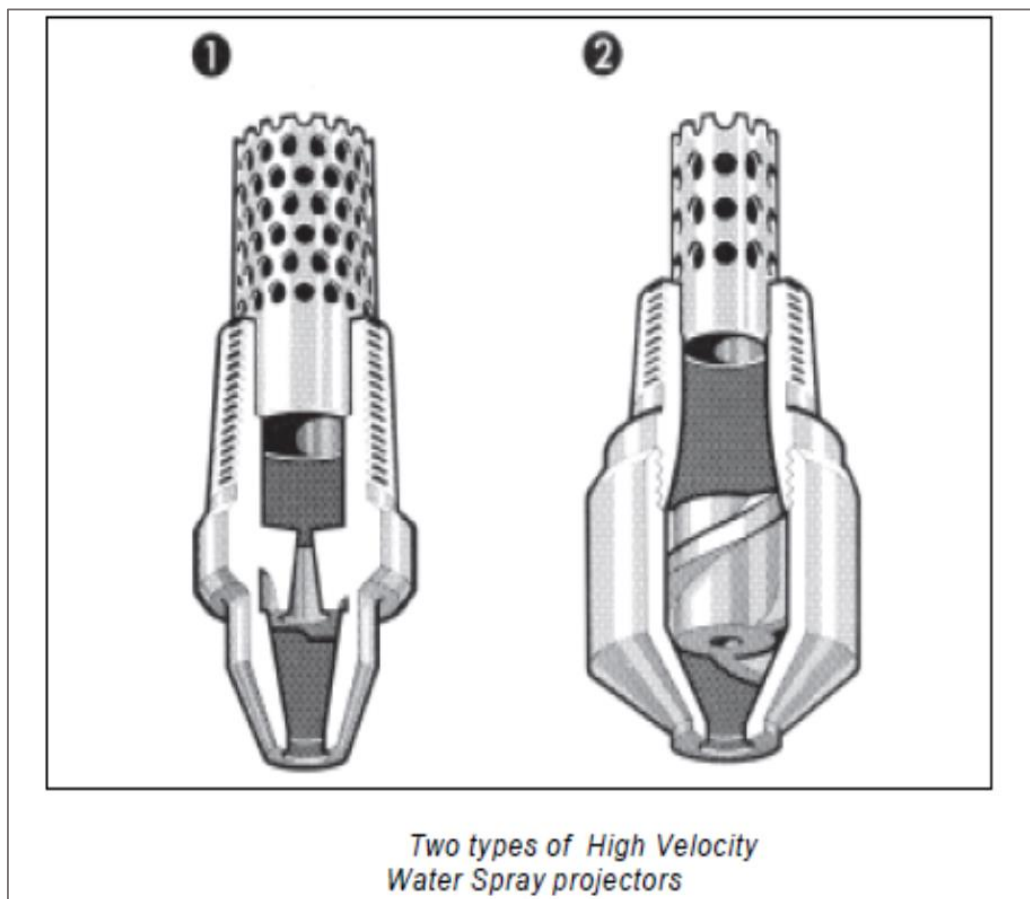
There are two basic types of water spray systems installed as fixed systems. One of these is used to extinguish oil fires and usually referred to as Water Spray Projector System.; the other is mainly used to provide protection to plant, processes, equipment and to prevent explosions, and is generally known as a Water Spray Protector System.

#### **1) High velocity system**

This is generally used for extinction of fires in flammable medium and heavy oils or similar flammable liquids having a flashpoint above 65°C. (e.g.: Transformer fires)

The system projects water in the form of a conical spray, with the droplets of water travelling at high velocity. Extinguishment is achieved by the three principles of emulsification, cooling and smothering. Some of the water droplets while passing through

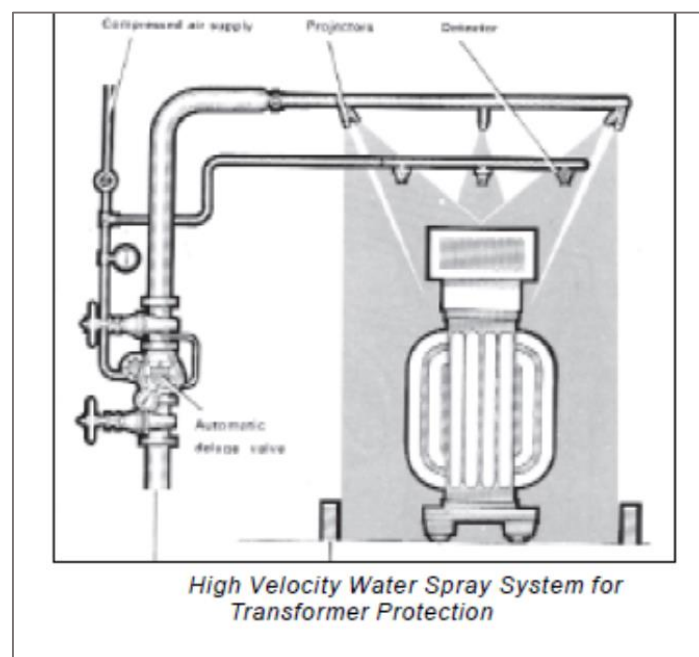
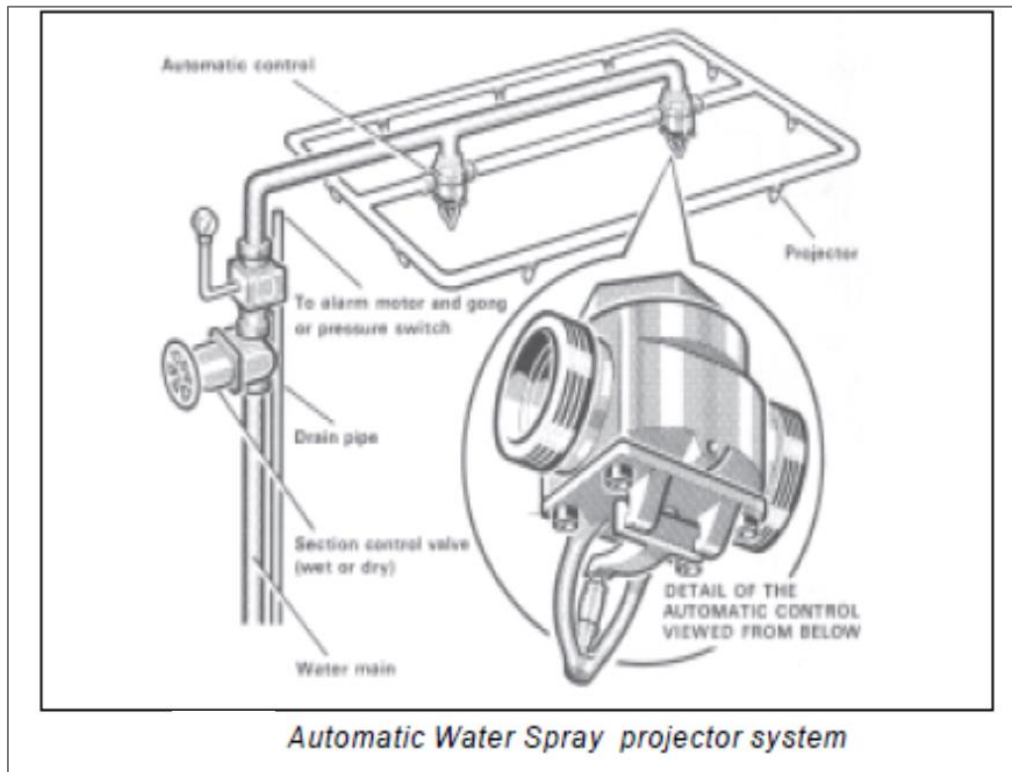
the flames get converted into steam, thereby achieving the smothering effect. The high velocity sprays of water are discharged through specially designed projectors. These systems can be operated either manually or automatically.



The high velocity spray system for transformers should be well designed to have adequate coverage of the entire transformer unit including the conservation tanks, the bushings and the bottom area.

The positioning of nozzles should be such as to protect all surfaces of the transformer and to give a discharge rate of not less than 10 lpm / m<sup>2</sup> of the area to be protected. The system should be of pre-action type.

The water spray systems should have isolation facilities so as to enable periodic testing, maintenance etc. Normally, all cut-off valves should be locked open.



The high velocity water spray system for transformer protection operates on the same principle as a deluge system. The detectors mounted on a separate pipeline on detecting the fire releases the compressed air within the pipe, thereby operating the deluge valve. This allows the water to flow out through the projectors in the form of high velocity water spray and extinguishes the fire. Generally, a water motor operated gong(as in the case of sprinkler



systems) sounds the fire alarm. Sometimes, additionally an electrical alarm may also be provided.

## **2) Medium velocity water spray systems**

- (i) This system applies water in finely divided droplets at medium velocity. This is mainly used for fire protection of areas with fire risks from low FP flammable liquids (FP below 65°C) and also for fire extinguishment of water miscible liquids (polar solvents, alcohols etc.). It gives protection to tanks, structures, equipment, etc. by cooling, by controlled burning of flammable liquids and also by dilution of explosive gases.
- (ii) These systems are similar in operation and lay out to the high velocity systems.
- (iii) Operation can be done automatically as well as manually.
- (iv) Application rates for water spray systems are as follows:
  - For extinguishment -- 8.1 lpm to 20.4 lpm/m<sup>2</sup> of protected surface.
  - For fire control -- not less than 20.4 lpm / m<sup>2</sup> (for protection of pumps, glands other critical areas)
  - For exposure protection (for cooling) -- not less than 10.2 lpm/m<sup>2</sup>

### **4.9.3. Automatic deluge installations**

These are installations fitted with open spray nozzles, controlled by a single deluge valve and operated on the actuation of automatic fire detectors, or sprinkler heads, so that the entire area to be protected is sprayed with water. The installation can be controlled manually also.

These systems are provided where there is a concentration of highly flammable liquids like aircraft hangars, tank farms filling gantries etc. and for cooling purposes.

The deluge system primarily caters for special hazards where intensive fires with a very fast rate of fire propagation are expected, and it is desirable to apply water simultaneously over complete area.

### **4.9.4. Automatic drencher systems**

While sprinkler system provides protection for buildings from internal fires, drencher systems (placed on roofs, windows and external openings) protect buildings from damage by exposure to fire in adjacent premises.



The system comprises of drencher heads, generally similar to those of sprinklers, which may be sealed or open (in the latter case water is turned on manually).

Drenchers are of three main types:

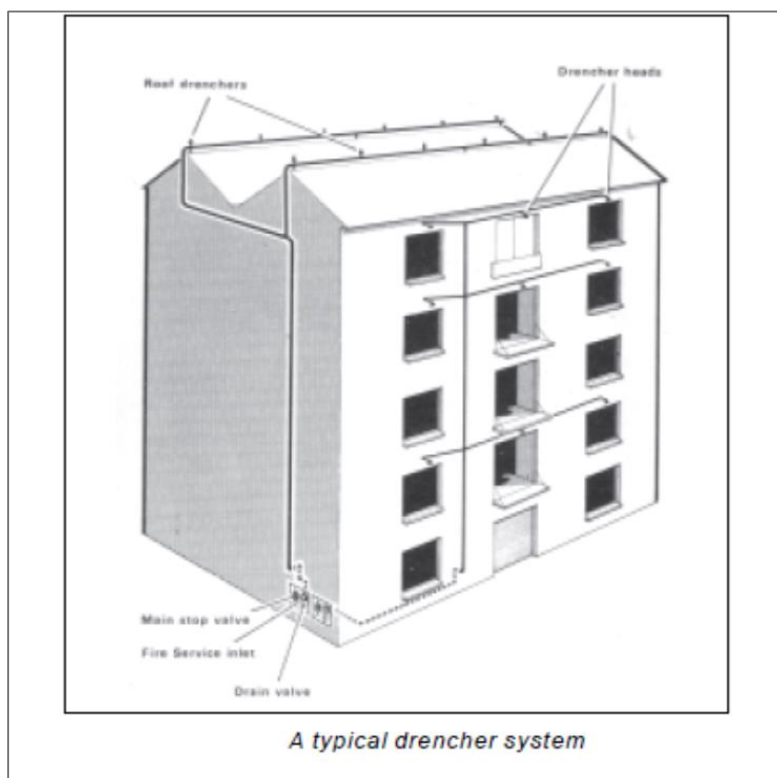
**(a) Roof drenchers** - From the roof edge they throw a curtain of water upwards which then runs down the roof

**(b) Wall or curtain drenchers** -- These operate in the form of a flat curtain over the wall openings or portions of a building most likely to be exposed to fire. The usual practice is to put a line of drenchers just below the eaves of the building, so that they provide a water curtain over the wall

**(c) Window drenchers** - These are used to protect window openings and placed on the top level of the windows so as to provide a water curtain over the windows.

The installation should normally be connected to the same supplies which cater to hydrant systems. Besides, a fire brigade inlet should also be provided at the bottom. The maximum horizontal spacing of 2.5m is normally kept between the drencher heads

Not more than 12 drenchers may be fixed on any horizontal line of pipe and not more than 6 on the vertical feed pipe.





## 4.10. Foam based fire extinguishing systems

### 4.10.1. Foam and foam-making compounds

Foam as used by fire brigades is usually generated by the mechanical agitation of a diluted foam compound solution in the presence of air.

The desirable characteristics of foam are resistance to radiant heat, to fuel vapors and to loss of water content by drainage. It should flow readily and recover a surface if disturbed, without being too sloppy.



The most satisfactory measure of the efficiency of the foam as a firefighting agent is the minimum rate of application at which a fire is controlled by the agent. As per conventional standards, it was usual to allow 50 liters per square meter (1 gallon of foam per square foot) of surface area per minute as the ideal rate, although in most cases it would be less than this.

#### Classification

Foam concentrates can be classified in two ways:-

#### 1) Classification by expansion ratio

- Low expansion up to 20:1 (Usually between 5:1 and 15:1)
- Medium Expansion: Between 21:1 and 200:1 (Usually between 30:1 and 100:1)
- High Expansion: Between 201:1 and 2000:1 (Usually between 300:1 and 1200:1)

#### 2) Classification by constituents

- Protein foam concentrate
  - Generally used at 4% concentration for low expansion foam production.
  - Expansion
    - Ratio about 8:1.
    - Effective on most hydrocarbon fuels but not on water miscible liquids.
    - Makes a stiff foam with good resistance to burn back.
- Fluro protein foam concentrate
  - Generally used at 4% concentration for low expansion foam production having an expansion ratio of about 9:1.
  - More fluid than protein foam giving quicker control and extinction of fires.



- Good resistance to burn back and resistant to fuel contamination, making it the most suitable type for sub-surface injection for oil tanks.
- Aqueous Film Forming (AFFF) foam concentrate
  - Generally used at 3% to 6% concentration for low expansion foam production having an expansion ratio of about 10:1.
  - Effective on hydrocarbon fuels and some water miscible liquids.
  - Very fluid foam, gives rapid control and extinction of fire, but burn back resistance not as good as the protein and fluoro protein types.
  - The name AFFF is because it provides a film over the liquid surface which prevents vapor formation.
- Synthetic foam concentrate
  - Generally used at 2% to 3% concentration for low and medium expansion foams, and 1.5% to 2% for high expansion foam, (Expansion Ratios 11:1, 75 to 150:1, and 750 to 1000:1 respectively).
  - Particularly effective on low boiling point hydrocarbon fuels.
  - Gentle surface application will give quick control and extinction, but burn back resistance is not good, and it is susceptible to fuel/foam mixing and breakdown by radiant heat and hot fuel.
  - Undiluted concentrate may strip paint and care should be taken not to allow contact with the skin.
- Alcohol resistant foam concentrate
  - Usually, protein or foams with additives used at 4% to 6% concentration for low expansion foam.
  - Has the ability to resist water miscible liquids and is the only practical choice for fires in many polar solvents, like acetone.

#### 4.10.2. Foam extinguishing systems/ installations

##### General

- 1) The general characteristics of foam as an extinguishing agent have already been dealt with.
- 2) A foam system consists of an adequate water supply that can be pressurized, a supply of foam liquid concentrate, a proportioning device, pipework or hose for transportation and foam applicators/ pourers for distribution of foam over the risks.
- 3) There are certain criteria in general, to be adhered to, for foam to be effective:
  - The burning liquid must be below its boiling point at NTP.



- Care must be taken in application of foam to liquids with a temperature higher than 100°C. At these temperatures, foam forms an emulsion of steam, air and fuel. This may produce an increase in volume which may lead to slop over or boil over.
  - The liquid must not be unduly destructive to the foam.
  - The liquid must not be water reactive.
  - The fire must be a horizontal surface fire. Three dimensional fires (of falling fuel) cannot be extinguished by foam unless the liquid has a high flash point.
- 4) It is widely accepted that foam is the only permanent extinguishing agent used for extinguishing fires in flammable/ combustible liquids. A foam blanket over a liquid surface is capable of preventing vapor formation. Fuel spills are quickly rendered safe by foam blanketing. Foam may also be applied as a protection against accumulation of toxic and flammable gases in hidden enclosures or cavities. It is an essential extinguishing agent for aircraft as well as flammable liquid storage and handling areas.

### **Foam generation methods**

The foam production process assumes three separate operations:

Foam concentration proportioning process	Foam generation process	Foam distribution methods
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### **Foam concentrate proportioning**

- a) By pre-mixing, the concentrate in water - The shelf life of foam concentrate has a direct bearing on this method. Generally, only AFFF type of foam concentrate is used for premixing purposes.
- b) By induction of the concentrate into the water stream. The following methods are adopted for this:
- Self-Induction (by using an inductor or pick-up tube). This method can be used for fixed or portable branch pipes and monitors.
  - Inline induction: Inline inductors are placed in the hose lines, usually at a distance of 25m to 50m from the branch. The pressure drop across the inductor is usually about one third of the inlet pressure. There is a modified version of inline variable inductor also for water flows of 225 lpm, 450 lpm and 900 lpm, with an additional knob for control of foam compound of induction ratio from 1% to 6%.



### 4.10.3. Types of foam systems

There are three basic types of systems and each may be used inside or outside buildings:

Installed, fixed or semi-fixed	Portable	Mobile
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#### 1) Fixed

This type has permanent steel pipework connected from the water supply via the fire water pump (if fitted) and foam liquid. Foam can be projected under favorable circumstances, over proportioning device to the foam maker(s) which protect the hazard.

#### 2) Semi-fixed

Has steel pipework from outside the bund wall (or similar location) up to the foam makers/pourers. The pipework has provisions for water supply hoses to be connected (and sometimes foam proportioning device also). The water supply is taken from hydrant system and the foam concentrate / solution is provided through mobile fire appliances.

#### 3) Portable systems

Includes portable foam producing equipment that can be carried manually and connected via fire hose to pressurized water/ pre-mixed solution supply to produce foam jets/ sprays.

#### 4) Mobile system

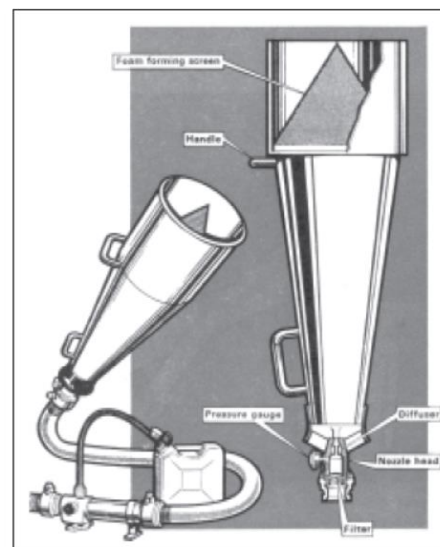
Includes foam producing units mounted on wheels (self-propelled fire tenders) or towed, connected to the water supply (foam compound carrying units mounted on wheels have also to be included).

### 4.10.4. Medium and high expansion foam system

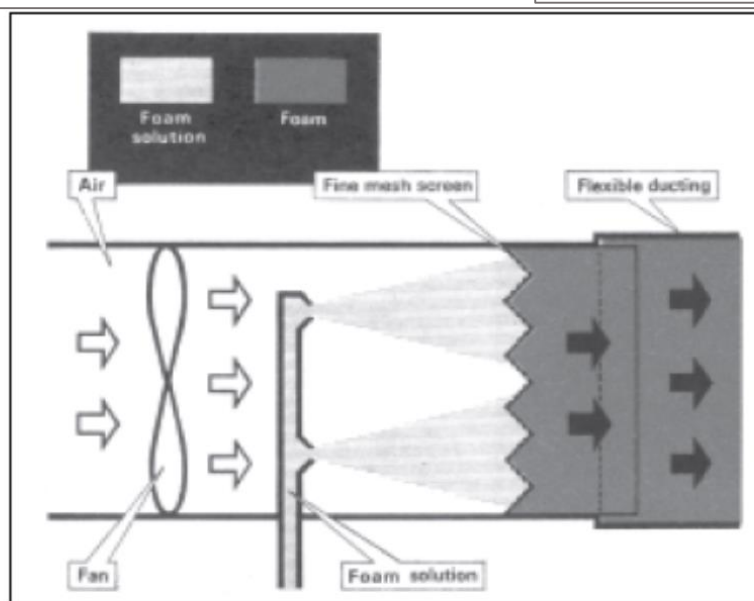
#### a) System design and use:

- i. This type of foam is an aggregation of bubbles resulting from mechanical expansion of a foam solution by air or by other gases, with expansion ratios in the range of 50:1 to 1000:1
- ii. There are 3 type of systems:
  - 1 total flooding
  - 1 local application portable

- iii. Medium expansion foam generators are of the aspirator type and are mostly used for local and portable type applications.
- iv. The blower type generator is normally designed for production of high expansion foam. In this the foam solution is discharged onto a screen through which air is blown by a fan or a blower. As the air passes through the screen which is wetted with foam solution, large masses of bubbles or foam are formed. The blower may be powered by a hydraulic or water motor, compressed air or gas, an electric motor, or an internal combustion engine.



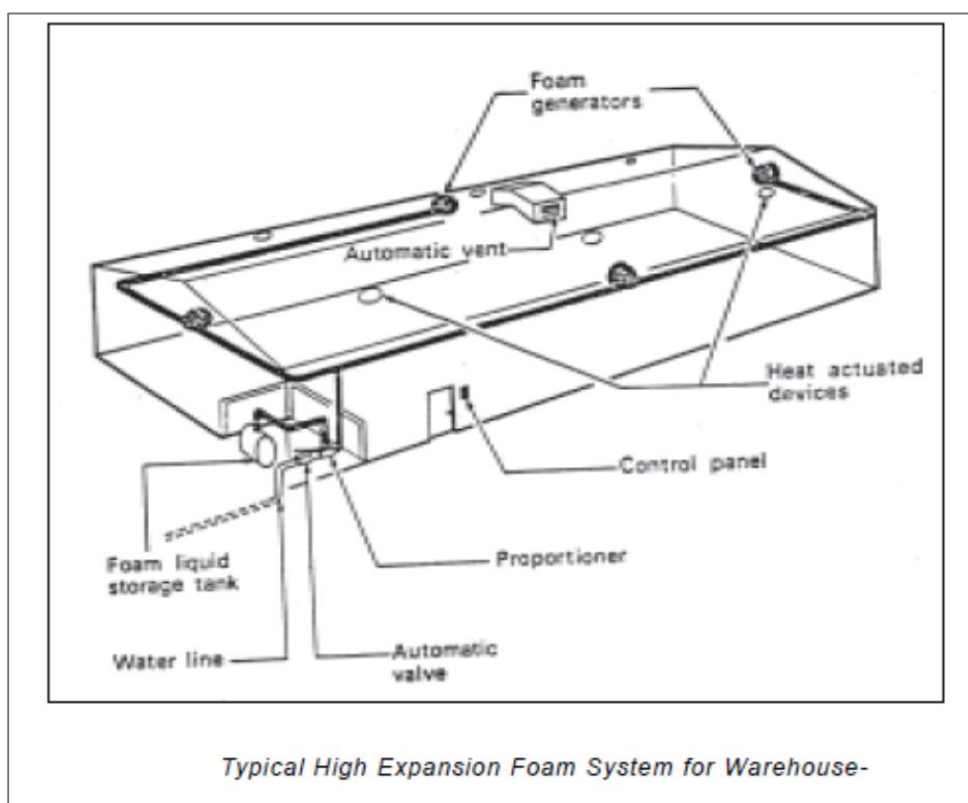
*A typical medium expansion foam generator*



*Principles of operation of a high expansion foam generator*

- v. Basically, medium and high expansion foam systems are used to control or extinguish surface fires in flammable and combustible liquids and solids and deep-seated fires involving solid smoldering materials.
- vi. High expansion foam may be used in controlling LNG fires and unignited spills by forming an ice layer on the liquid and by helping to disperse the vapor cloud.

- vii. Total flooding system may be used in enclosures surrounding the hazard to be protected like walls, basements, ship's holds, mines, cable tunnels, high-rack storages etc.
- viii. It is important that leakage of the foam from the enclosures protected is avoided. Windows and doors in such premises should be designed to close automatically with provisions for high level venting of the air in the enclosure which is displaced by the foam.
- ix. Generally, the minimum depth above the hazard should be about 0.6m (2 feet). For high expansion foam system, the minimum 50% drainage time should be approximately 8 min. (1 liter of foam concentrate can produce approx. 50m<sup>3</sup> of high expansion foam)
- x. The submergence time should be approx. 2 to 3 min. Polyethylene tubes which are used for conveyance of discharge of foam should be correctly designed for efficient projection of the foam.
- xi. After extinguishment, entering the foam filled space should be avoided unless adequate precautions are taken, since loss of vision and disorientation may be experienced by the persons involved. A coarse water spray may be used for clearing the foam. Personnel entering the space should wear BA sets and carry a lifeline with them.







## 4.11. Special extinguishing systems

### 4.11.1. Water mist systems

Interest in the use of very fine water sprays (water mist) in fire suppression systems has been intense for the last 15 years. The economic force behind this interest has been driven by two major fire protection needs. First, in the early 1990s the international maritime regulatory organizations mandated the installation of sprinkler systems on passenger ships. This mandate inspired a search for a system that could be considered equivalent to sprinklers but that would discharge less water, use smaller-diameter piping, have lower overall weight than a standard sprinkler system, and hopefully cost less. The second driving force was the need to find a replacement for ozone - depleting substances such as the halons, which had been used for decades to protect machinery spaces, flammable liquids rooms, computer rooms, and rooms for materials sensitive to water damage. The halon alternative search included the possibility of using water in applications where water was not previously considered practical. Thus, a technology that could minimize droplet size and application rate, enhance evaporation and help reduce oxygen levels to extinguish hidden fires began to have marketable value.

#### Applications of water mist systems

Machinery spaces	Turbine enclosures	Marine accommodation	Public spaces, and service areas	Aircraft passenger compartments
Hotels, heritage buildings, and galleries	Electrical equipment rooms	Computer rooms	Tunnels	

#### Summary of water mist system features



1	Protect lives and property in a compartment from external fire threat.
2	Control fire temperatures in a compartment to prevent flashover and fire spread to adjacent compartments.
3	Extinguish Class A and Class B fires.
4	Use water to provide protection where there was no previous protection (aircraft passenger compartments).
5	Use water where halon or CO2 was previously used (Class B fires in machinery rooms).
6	Provide freedom from sprinkler system design constraints (e.g., allow use of smaller pipe sizes) with equivalent level of safety.

### Extinguishing mechanisms

The extinguishing action of sprays of finely divided water applied to commonly encountered fires appears to be predominantly due to dilution of the air (oxygen) supply in the zone of burning with vapor (steam) resulting from evaporation of water droplets in the heated area surrounding the fire. The cooling effects of the water may also be important factors in extinguishment in many cases. In order to obtain extinguishment, the water droplets comprising the spray must be relatively small and the amount of water applied must be adequate in relation to the specific fire.

#### 4.11.2. Dry chemical powders extinguishing systems

On most fires involving burning metals, the result of applying water can be explosively disastrous and so new methods of extinction have been evolved.

The base chemical of most dry chemical powders is sodium bicarbonate. This, with the addition of a metallic stearate as a waterproofing agent, is widely used as an extinguishant, not only in portable extinguishers, but also for general application in large quantities. Apart from stearates, other additives like silicones are also used to decrease the bulk density and to reduce packing in the cylinder.



Dry chemical is expelled from containers by gas pressure and by means of specially designed nozzles and is directed at the fire in a concentrated cloud. This cloud also screens the operator from the flames and enables a relatively close attack to be made.

Dry chemical powder can also be supplied in polythene bags for metal fires, as it is more effective to bury the fire under a pile of bags which melt and allow the contents to smother the fire.

Special powders have been developed for some metal fires, especially for the radioactive metals such as uranium and plutonium. These are known as the ternary eutectic chloride group, (Chlorides of Sodium) (Na), Potassium(K) and Barium(Ba) (in the proportions of 20%, 29% and 51% respectively for the three chlorides) . These powders contain an ingredient which melts, then flows a little and forms a crust over the burning metal, effectively sealing it from the surrounding atmosphere and isolating the fire.

Dry chemical powders are also tested for their compatibility with foam, as it was discovered that the early powders tended to break down foam, and the two should complement each other on fires where foam is the standard extinguishant.

These powders which are 10 to 75 microns in size are projected on the fire by an inert gas (usually CO<sub>2</sub> or N).

The commonly used dry chemical agents are listed below:

Chemical Name	Formula	Other Name(s)
Sodium bicarbonate	NaHCO <sub>3</sub>	Baking soda
Sodium chloride	NaCl	Common salt
Potassium bicarbonate .	KHCO <sub>3</sub>	Purple K.
Potassium chloride.	KCl	Super K.
Potassium sulphide	K <sub>2</sub> SO <sub>4</sub>	-
Monoammonium (NH <sub>4</sub> ). phosphate Powder	H <sub>2</sub> PO <sub>4</sub>	ABC. or Multipurpose
Urea + potassium.	NH <sub>2</sub> CONH <sub>2</sub>	Monnex.
bicarbonate +	KHCO <sub>3</sub>	(Pot. Carbamate)



Only one among the above is effective against deep-seated fires because of a glassy phosphoric acid coating that forms over the combustible surface on application and that is mono ammonium phosphate (MAP).

Any dry chemical powder can cause some degree of corrosion or other damage, but MAP, being acidic, corrodes more readily than other dry chemicals which are neutral or slightly alkaline. These dry chemicals, especially MAP, can damage delicate electrical / electronic equipment.

The powders act on a flame by some chemical mechanism, like breaking of chain reaction presumably forming volatile species that react with H atoms or hydroxyl radicals. They also absorb heat by blocking radiative heat transfer, and in the case of MAP, by forming a surface coating.

Potassium bi-carbonate based agent, often known by the name Purple K is approximately twice as effective, on unit weight basis, as conventional soda bi-carb based dry chemical Monnex dry chemical is approximately 3 times as effective as the conventional soda bi-carb based dry chemical.

### **Dry chemical extinguishing systems/ installations**

#### **1) General**

- a) The characteristics etc. of dry chemical powder as an extinguishing agent have already been covered. Dry chemical is a highly effective extinguishing agent possessing the unique property of quick knocking down of fires. In addition, it has negligible toxic effects. However, on discharge of dry chemical powder system, there will be visibility problems as well as the need for lot of cleaning up after use.
- b) When applied on fire, the flame is immediately put out (knocking down effect). Smothering, cooling and radiation shielding contribute to the extinguishing efficiency of dry chemical. However, research has proved that its power of chain breaking reaction (inhibition of free radicals) in the flame is the principal cause of extinguishment.

#### **2) Uses and limitations of dry chemical system**

- a) Dry chemical is primarily used to extinguish flammable liquid fires.
- b) Being electrically non-conductive, it can also be used on flammable liquid fires involving live electrical equipment.
- c) Due to its quick extinguishing ability, it is useful for surface fires involving ordinary combustible materials.



- d) The systems are used primarily for flammable liquid fire hazards such as dip tanks, flammable liquid storage rooms and flammable liquid spill areas.
- e) They are not recommended for use on delicate electrical equipment such as telephone switch boards and electronic computers since such equipment are liable to damage by dry chemical deposit.
- f) Regular dry chemical will not extinguish fires that penetrate beneath the surfaces.
- g) They will not extinguish fires that supply their own oxygen by combustion.
- h) Although dry chemical can knock down fires quickly, the extinguishing effect is not permanent. Therefore, following the dry chemical application, another permanent extinguishing agent, like water or foam has to be applied on the fire for achieving permanent extinguishment.

### 3) **Methods of application**

The two basic types of dry chemical systems are fixed systems and hand hose line systems. Portable extinguishers constitute another method of application of dry chemical.

#### 4.11.3. Clean agent fire extinguishing systems

##### 1) **General**

- a) The phase-out of Halon production had dramatic impact on the fire and explosion protection industry. Since Halons occupied an important place in fire protection, their replacement for various applications posed several challenges and problems for fire protection communities all over the world. The process of developing and application of Halon alternatives has been making rapid progress during the past few years
- b) Clean fire suppression agents are fire extinguishants that vaporize readily and leave no residue.
- c) Clean agent Halon replacements fall into two broad categories:

- (i) **Halocarbon agents**

These are compounds containing carbon, hydrogen, bromine, chlorine, fluorine and iodine. They are grouped into five categories:

Categories of halocarbon agents	
Hydrobromofluorocarbons (HBFC)	Hydrofluorocarbons (HFC)
Hydrochlorofluorocarbons (HCFC)	Perfluorocarbons (FC or PFC)
Fluoriodocarbons (FIC)	



Their common characteristics are:

Electrical non-conductivity	Are clean agents which vaporize readily leaving no residue
Are liquefied gases.	Can be stored and discharged from typical Halon 1301 hardware(except HFC 23)
All use nitrogen super pressurization for discharge purposes(except HFC 23)	All are less efficient fire extinguishants than Halon 1301, in terms of storage volume and agent weight
All are total flooding gases after discharge	All produce more decomposition products (mainly HF) than Halon 1301
All are more expensive than 1301 on weight basis	

**(ii) Inert gases and mixtures**

These include the following:

- Inergen - IG - 541(mixture of N<sub>2</sub> 52%, Argon(A) 40% and CO<sub>2</sub> 8%)
- Argonite - IG - 55 (mixture of N<sub>2</sub> 50% and A 50%)
- Argon - IG 01 (A) 100%
- Nitrogen - 100%

These are clean agents stored as pressurized gases and, hence, require substantially greater storage volume. They are electrically nonconductive, form stable mixtures in air, and leave no residue.

**2) Extinguishing Properties**

- a) Halocarbon clean agents extinguish fires by a combination of chemical and physical mechanisms. HBFC and HFC compounds are similar to Halon 1301 in chemical suppression mechanisms, i.e., by inhibition of free radicals or breaking chain reaction. Other replacement agents primarily extinguish the fires by reducing the flame temperature by a combination of heat of vaporization, heat capacity and the



energy absorbed by the decomposition of the agent. Oxygen depletion also plays an important role in reducing flame temperature.

The lack of significant chain breaking reaction inhibition in the flame zone by HCFC, HFC and FC compounds results in higher extinguishing concentrations, relative to Halon 1301. On the other hand, the relative efficiency in breaking Halogen species bonds, results in higher levels of agent decomposition, relative to Halon 1301.

- b) Inert gas agents suppress flames by reducing the flame temperature below combustion reaction thresholds. This is achieved mainly by reducing the oxygen concentration. If oxygen concentration is reduced below 12 % (in air) most of the flaming fires will be extinguished

**Table-1 shows the new technology halon alternatives, as given in one HTOC document is reproduced**

**Table-2 shows the physical properties of halocarbon gaseous agents for fixed systems**

Table-1 New Technology Halon Alternatives	
Table-2 - Physical Properties	
Total Flooding Gaseous Alternatives	
Halocarbons	Composition
HCFC:	HCFC Blend A, HCFC 124
HFC:	HFC-23, HFC-125, HFC-227ea, HFC-236fa
PFC:	FC-3-1-10, FC-2-1-8
FIC:	FIC-1311
Inert Gases	
Nitrogen:	IG-10
Argon:	IG-01
Nitrogen/argon blend:	IG-55
Nitrogen/argon/CO2 blend:	IG-541
Water Mist Technologies	Manufacturer
Single Fluid, Low/Moderate Pressure (3 - < 50 bar)	Grinnell, Kidde, GW Sprinkler, and Total Walther
Single Fluid, High Pressure (> 50 bar)	Marioff, Reliable, Ultra Fog, Semco, and Unifog
Dual Fluid Systems	Securiplex, ADA Technologies, Kidde and Ginge Kerr (BP)
Flashing Liquid Systems	MicroMist Ltd.
Inert Gas Generators	Manufacturer
	ICI and Primex
Fine Particulate Aerosols	Manufacturer
	Kidde, Powsus, Spectrex, Russian Research Institute for Applied Chemistry, Soyz Association, Intertexnolog Assoc., and Dynamit-Nobel
Streaming Agents	Composition
HCFC:	HCFC Blend B, HCFC Blend E, HCFC-124
HFC:	HFC: HFC-227ea, HFC-236fa
PFC:	PFC: FC-5-1-14

- c) **Toxicity** tests are conducted based on (i) the duration and frequency of the exposure, and (ii) specific biological effects.

The two terms normally used while referring to toxicity are:





- No Observed Adverse Effect Level (NOAEL); and
- Lowest Observed Adverse Effect Level (LOAEL).

**d) Environmental factors**

Primary environmental factors to be considered for halon alternative clean agents are:

- Ozone Depletion Potential (ODP).
- Global Warming Potential (GWP); and
- Atmospheric Life Time (ALT)

It is important to select the fire protection choice with the lowest environmental impact that will adequately provide the necessary fire protection performance for the specific applications.

**Table-4 shows the Environmental factors for the halocarbon gaseous agents, and Table-5 shows the toxicity, storage and the environmental factors for inert gases**

**Table-4- Environmental Factors for Halocarbon Gaseous Agents**

Generic Name	Trade Name	Ozone Depletion Potential	Global Warming Potential* 100 yr.	Global Warming Potential* 500 yr.	Atmospheric Lifetime* years
Halon 1301	BTM	10	6,900	2,700	65
HCFC Blend A	NAF S-III	HCFC-22 = 0.05 HCFC-124 = 0.02 HCFC-123 = 0.02	HCFC-22 = 1,900 HCFC-124 = 620 HCFC-123 = 120	HCFC-22 = 590 HCFC-124 = 190 HCFC-123 = 36	HCFC-22 = 11.8 HCFC-124 = 6.1 HCFC-123 = 1.4
HCFC-124	FE-24	0.02	620	190	6.1
HFC-23	FE-13	0	14,800	11,900	243
HFC-125	FE-25	0	3,800	1,200	32.6
HFC-227ea	FM-200	0	3,800	1,300	36.5
HFC-236fa	FE-36	0	9,400	7,300	226
FC-2-1-8	CEA-318	0	8,600	12,400	2,600
FC-3-1-10	CEA-410	0	8,600	12,400	2,600
FIC-1311	Triiodide	0.0001	<1	<<1	0.005

\* Source of GWP and ALT values "Scientific Assessment of Ozone Depletion: 1998." World Meteorological Organization, Global Ozone Research and Monitoring Project - Report No. 44

- e) Inert gases are used in design concentrations of 35 - 50 % by volume, which reduces the ambient oxygen concentrations to between 14 % to 10% by volume respectively. It is known that for most typical fuels, oxygen concentrations below 12 - 14 % will not support flaming combustion. These inert gas agents are electrically non-



conductive and clean for fire suppression. They differ from halocarbon agents in the undermentioned ways:

They are not liquefied gases. They are stored as high-pressure gases and, therefore, require high pressure storage cylinders with weight impact.

These systems use pressure reducing devices at or near the discharge manifold. This reduces the pipe thickness requirements and alleviates concerns regarding high pressure discharges.

Discharge times are about 1 to 2 min. This may limit some applications involving very rapidly developing fires.

Inert gas agents are not subject to thermal decomposition and, hence, form no by-products.

Many countries have granted health and safety approval for use of inert gases in occupied areas in the workplace.

There is no concern regarding the ODP or GWP potential for inert gas systems.

#### 4.11.4. CO<sub>2</sub> extinguishing systems/ installations

- Carbon-di-oxide possesses a number of properties which make it a good fire extinguishing agent. It is non-combustible, does not react with most substances and provides its own pressure for discharge from the storage container. Being a gas, it can easily penetrate and spread to all parts (including hidden) of the fire area. It will not conduct electricity and can be used on energized electrical equipment. Also, it leaves no residue.
- At normal temperatures, carbon-di-oxide is a gas, 1.5 times as dense as air. It can be easily liquified and bottled, where it is contained under a pressure of approximately 51 bars (750 lbf/in) at about 15°C. As the fire extinguisher is discharged, the liquid boils off rapidly as a gas, extracting heat from the surrounding atmosphere. The gas, however, extinguishes by smothering, or reducing the oxygen content of the air.
- As regards to toxicity, a concentration of 9% in air is the maximum most persons can withstand without losing consciousness within a few minutes.
- The extinguishing concentration of CO<sub>2</sub> required for various types of fuels vary from approx. 30% to 62% depending upon the fuel.

**Minimum CO<sub>2</sub> concentration required for extinguishment of various materials**

<b>Materials</b>	<b>Minimum extinguishing concentration required</b>
Acetylene	55
Acetone	26*
Benzol, Benzene	31
Butadiene	34
Butane	28
Carbon Disulphide	55
Carbon Monoxide	53
Coal Gas or Natural gas	31*
Cyclopropane	31
Dowtherm	38*
Ethane	33
Ethyl Ether	38*
Ethyl Alcohol	36
Ethylene	41
Ethylene Dichloride	21
Ethylene Oxide	44
Gasoline	28
Hexane	29
Hydrogen	62
Isobutane	30*
Kerosene	28
Methane	25
Methyl Alcohol	26



Materials	Minimum extinguishing concentration required
Pentane	29
Propane	30
Propylene	30
Quench, Lubricating Oils	26

Note: Apart from the above, the safety factor concentration is also to be added

- On a volume basis, CO<sub>2</sub> is substantially more effective than N. However, on weight basis, both have nearly equal effectiveness as CO<sub>2</sub> is 1.57 times heavier than N.
- It is actually the depletion of the O<sub>2</sub> level in the air which is responsible for extinguishment in the case of inert gases. A reduction of the O<sub>2</sub>% in the air from 21% to 10% by volume would make fires and explosions impossible, except for a few special gases like H, C<sub>2</sub>H<sub>2</sub>, or CS<sub>2</sub> which would require greater dilution.

### **CO<sub>2</sub> extinguishing systems/ installations**

#### **1) General**

##### i. CO<sub>2</sub> is suitable for extinguishing the undermentioned types of fires:

- Fires involving smoldering carbonaceous solid materials (Class A fires);
- Fires involving flammable and combustible liquids (Class B fires);
- Fires involving combustible gases, except where explosive atmospheres are likely to develop (Class C fires); and
- Fires involving live electrical apparatus and installations.

##### ii. CO<sub>2</sub> is not suitable for fires involving the following:

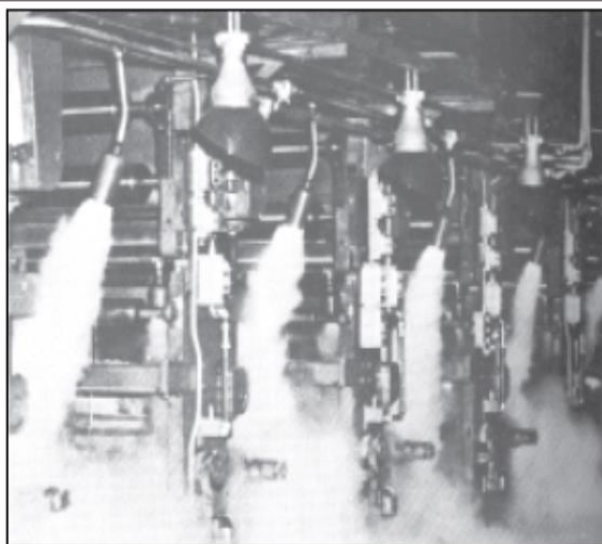
- Chemicals containing their own supply of oxygen such as cellulose nitrate, chlorates etc.
- Reactive metals such as sodium, potassium, magnesium, titanium and zirconium, and their halides.

#### **2) Methods of application**

There are two basic methods of applying CO<sub>2</sub> in the fire extinguishing systems:

i. Total flooding:

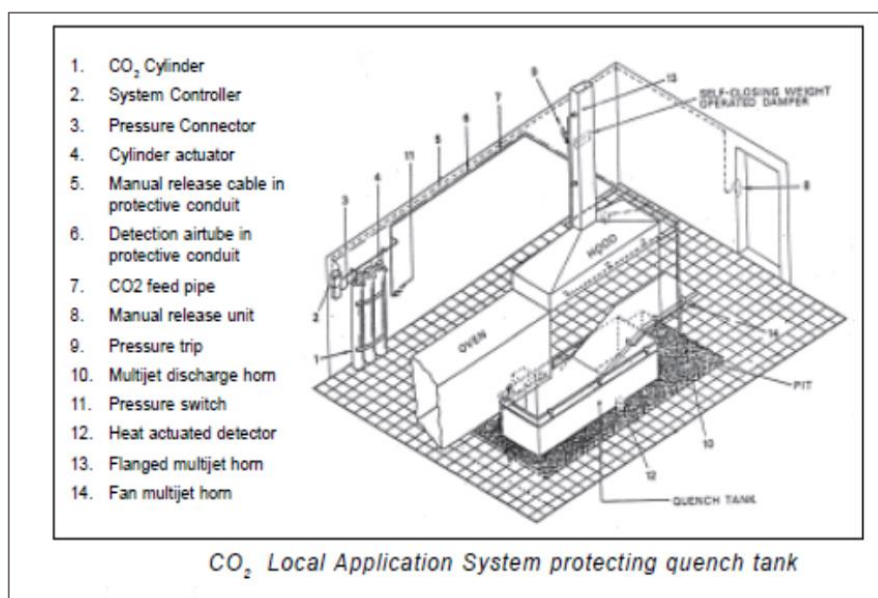
- In these systems, CO<sub>2</sub> is applied through nozzles to develop a uniform concentration of CO<sub>2</sub> in the protected enclosure. The minimum concentration used in the total flooding system is 34% CO<sub>2</sub> by volume for surface-burning materials. 50% concentration will be required for electrical machines; bulk paper requires 65%, and for storage vaults and dust collectors 75%.



*A CO<sub>2</sub> Extinguishing System that has been activated*

ii. Local application:

- In this system CO<sub>2</sub> is discharged directly on the fires through specially designed nozzles. The discharge should be continued for a minimum of 30 sec. or longer, if required



### iii. Extended discharge:

- This method is used when the risk enclosure is not tight to retain the extinguishing concentration.
- Extended discharge is particularly applicable to enclosed rotating electrical equipment like generators, where it is difficult to prevent leakage until rotation stops (In some cases, the time delay for stoppage of rotating machinery is up to 30 mins.)

## 4.12. Fire detection and alarm systems (automatic fire alarm systems)

### 4.12.1. General

Among the fire protection requirements of a building, fire detection and alarm system have an important role to fulfil. If properly designed, installed and maintained, automatic fire alarm systems can be a substantial help in minimizing losses of lives and property from fires in buildings of all types of occupancies.

One of the primary objectives of good fire protection in a building is to reduce, to the utmost possible extent, the time delays which follow a serious fire outbreak, viz., the alerting time, the reaction time, evacuation time, response time and extinguishment time. This objective can be achieved to any satisfactory level only if the building has been provided with a well-designed and reliable automatic fire alarm system.



Automatic fire alarm systems are used primarily for the protection of lives, and secondarily for the protection of property.

Building Codes may stipulate, sometimes, partial coverage by detection systems. It will be useful if the designers and builders are aware of the recent fire research and analytical studies such as, a study suggests that partial detection does not often, if ever, provide early warning of a fire condition.

Detectors are designed to detect one or more characteristics of fire (also known by the term fire signatures, as per NFPA), viz., heat, smoke, (aerosol particles) and flame (radiant energy-IR, visible, UV). No one type of detector can be considered as the most suitable for all applications and the choice will depend on the type of risk to be protected.

Different types of fires can have widely different fire characteristics (fire signatures). For e.g., some materials burn intensely giving out high levels of thermal energy, but with little or no smoke, whereas smoldering fires have no visible flame and usually have low heat output. Under the circumstances, proper selection and siting of fire detectors are essential for achieving the fire protection objectives.

#### 4.12.2. Heat detectors

There are two types of heat detectors:

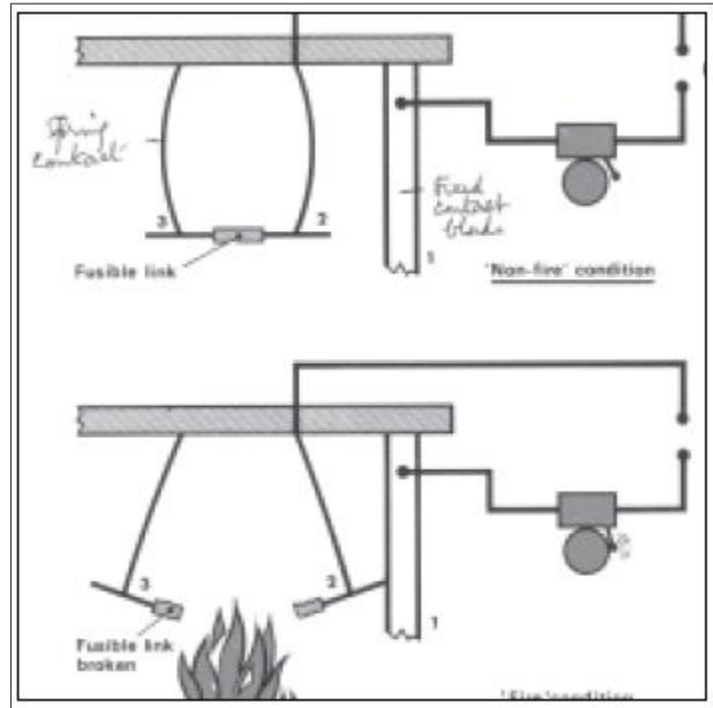
- a. **Fixed temperature detectors**, which are designed to operate when the detecting mechanism or element reaches a pre-determined temperature. These can again be subdivided into two types:
  - (i) Point detectors, which are small, each protecting a limited area, or
  - (ii) Line detectors, which have a linear sensing device usually protecting a larger area.
- b. **Rate-of-rise detectors**, designed to operate when the temperature rises abnormally quickly, or when a pre-determined temperature is reached.

Note: The temperature range normally adopted for heat sensitive (point) detectors is from 55°C to 180°C, inclusive if the rate of rise of the temperature is less than 1°C/min.

**The methods used to detect heat are given below:**

- i. **By fusible metals or metal alloys**, which melt when a pre-determined temperature is reached, which operates an electrical circuit and which in turn activates the fire alarm. A figure depicting this principle is given below:



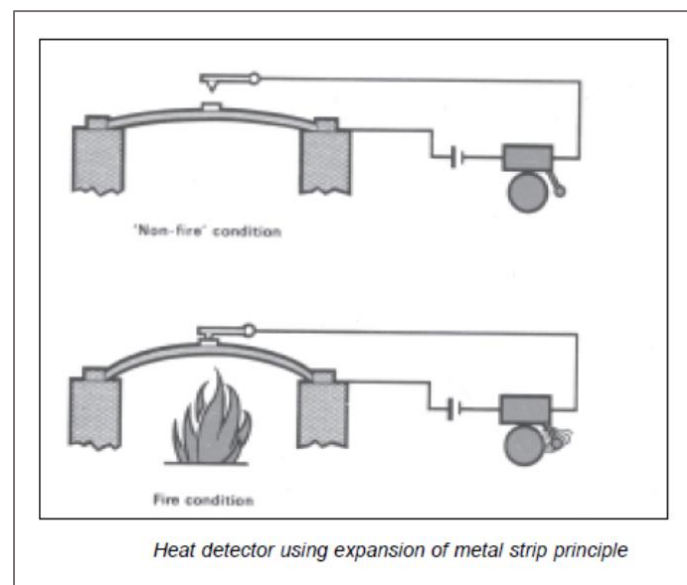


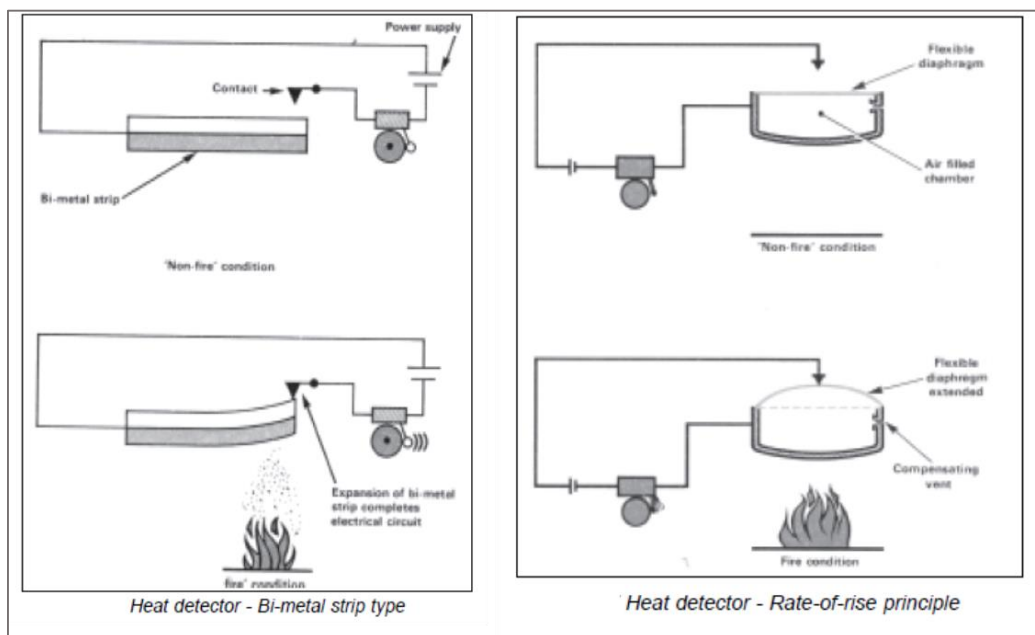
## ii. Heat sensitive covering in cable assembly (thermostatic cables)

In this, two conductors are insulated from each other by a heat sensitive covering. At the rated temperature, the covering melts and the two conductors come into contact initiating an alarm.

## iii. Expansion of metals

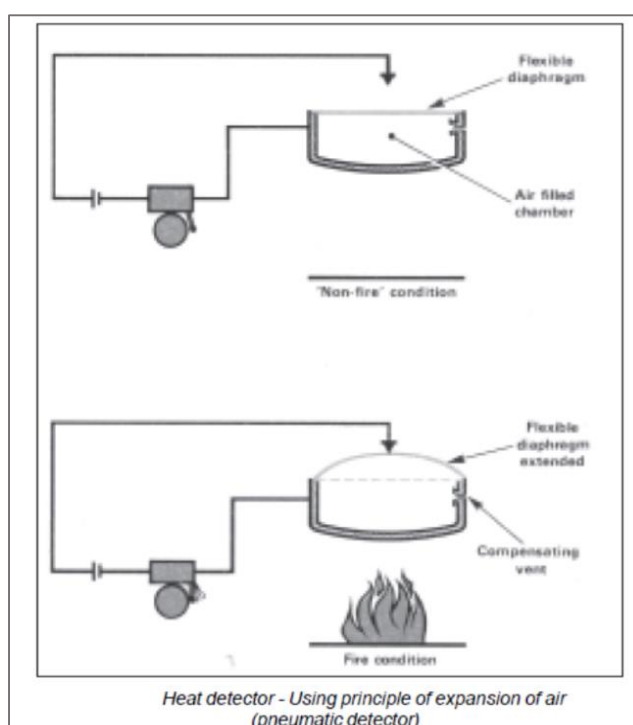
The movements created by expanding metals or bi-metal strips are used to make or break electrical circuits. Figures depicting these principles are given below:





#### iv. Expansion of gases (pneumatic detector)

This consists of an air chamber having a flexible diaphragm which can move an electrical contact. Heat causes the air pressure in the chamber to increase, making the diaphragm flexed to close the electrical contact. A figure of this follows:

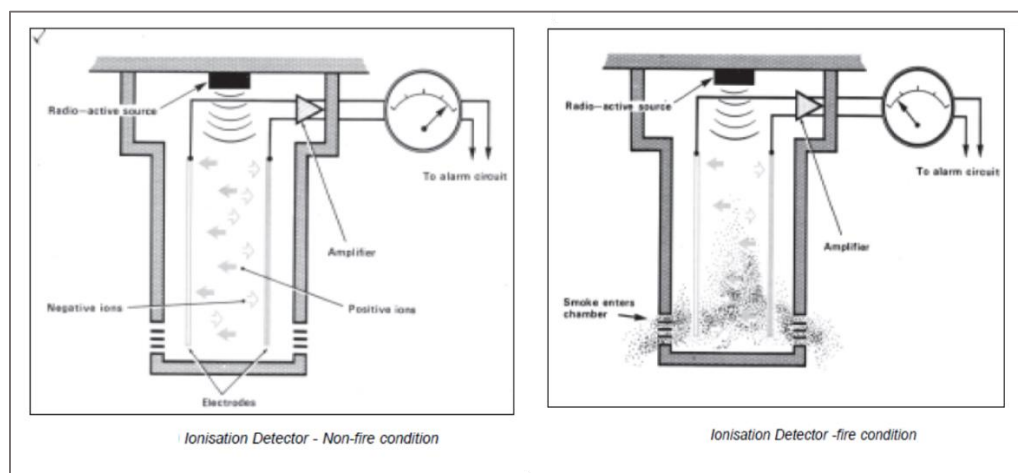


#### 4.12.3. Smoke detectors

There are two types:

##### Ionization detector

Figures depicting Ionization type of smoke detector under non-fire condition as well as fire condition are shown below:

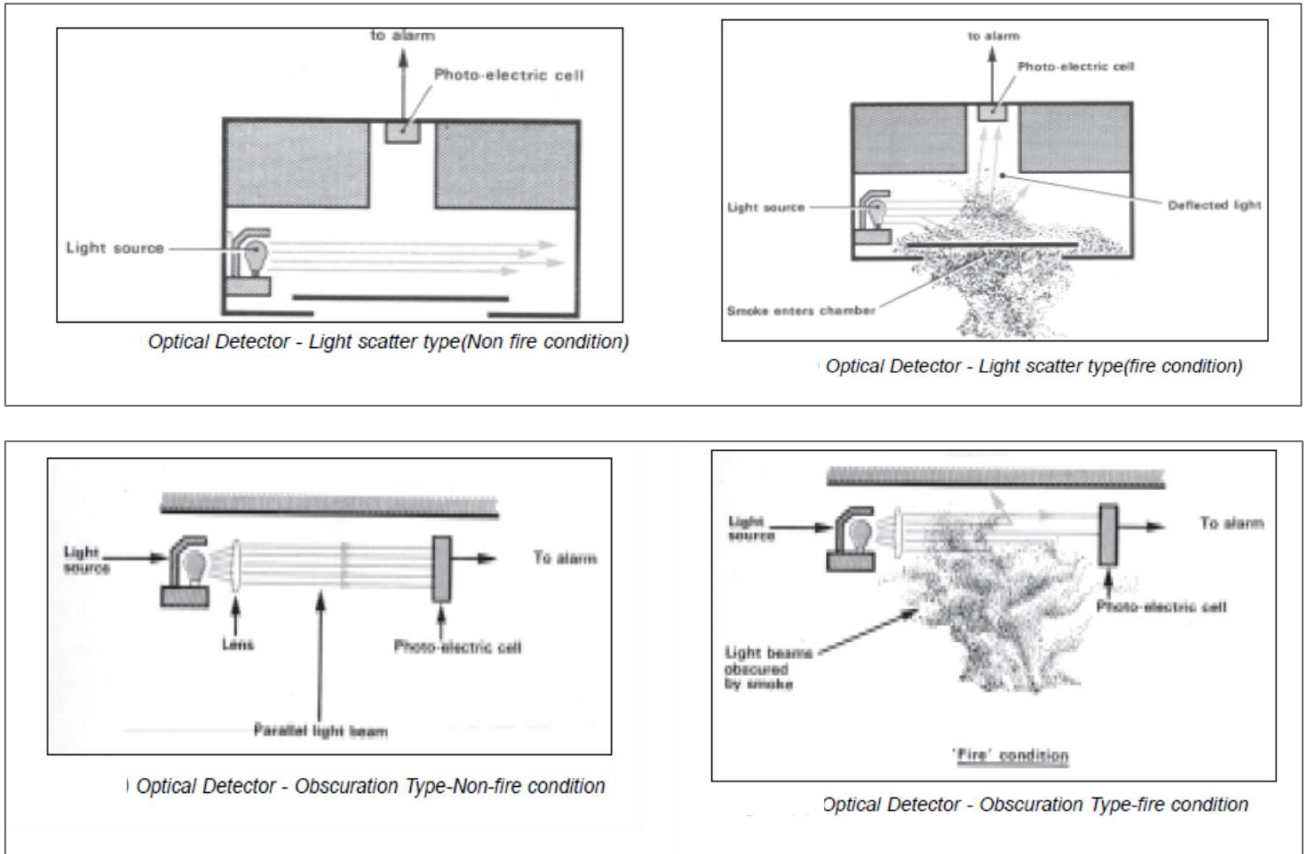


**The basic principle involved in Ionization detector are as follows:**

- The detector head consists of one (or two) Ionization chamber(s) connected to form a balanced electrical circuit. The Ionization chamber contains two electrodes, across which a potential difference is maintained, and a radioactive source (usually an alpha-particle source - usually Americium 236) ionizes the air producing positive and negative ions which get attracted to the electrodes of opposite polarity. This flow of ions creates a current flow across the electrodes. When smoke particles enter a chamber, the charged ions attach themselves to some of the particles thereby slowing the movement or flow to the electrodes. This results in a reduction in the current flow in the chamber which actuates an alarm.

### Optical detector

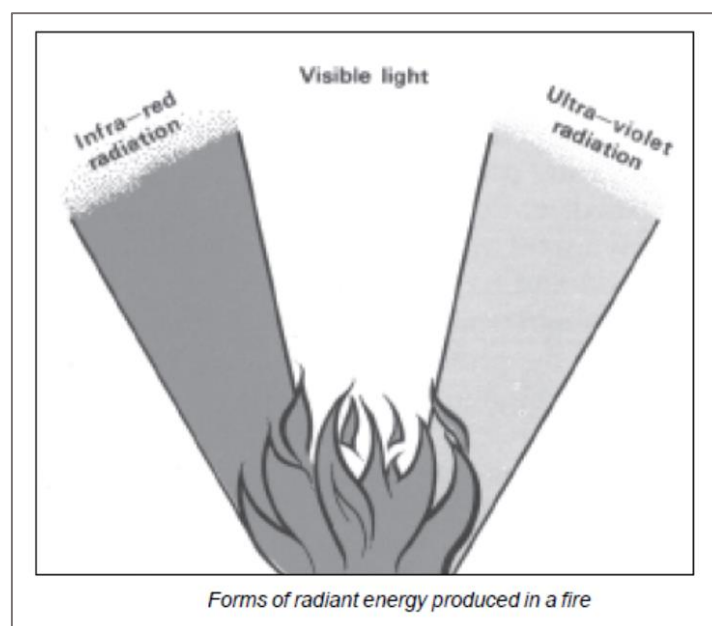
While the Ionization detector responds to the invisible products of combustion including, small particles of smoke, the optical detector, as its name implies, reacts to the visible products of combustion. An optical detector has two important components, a light source and a photo-electric cell. The critical factor in the operation of this type of detector is the amount of light falling on the photo-electric cell. Some optical detectors are designed so that, in a fire situation, more light is thrown onto the photo-electric cell. These are called the light scatter type. Others are designed so that less light is thrown onto the photo-electric cell in a fire situation. These are called the obscuration type. The figures of these two types are shown below:



#### 4.12.4. Flame detectors

Apart from producing hot gases, fire releases radiant energy in the form of :

Infra-red radiation	Visible light	Ultra-violet radiation
---------------------	---------------	------------------------

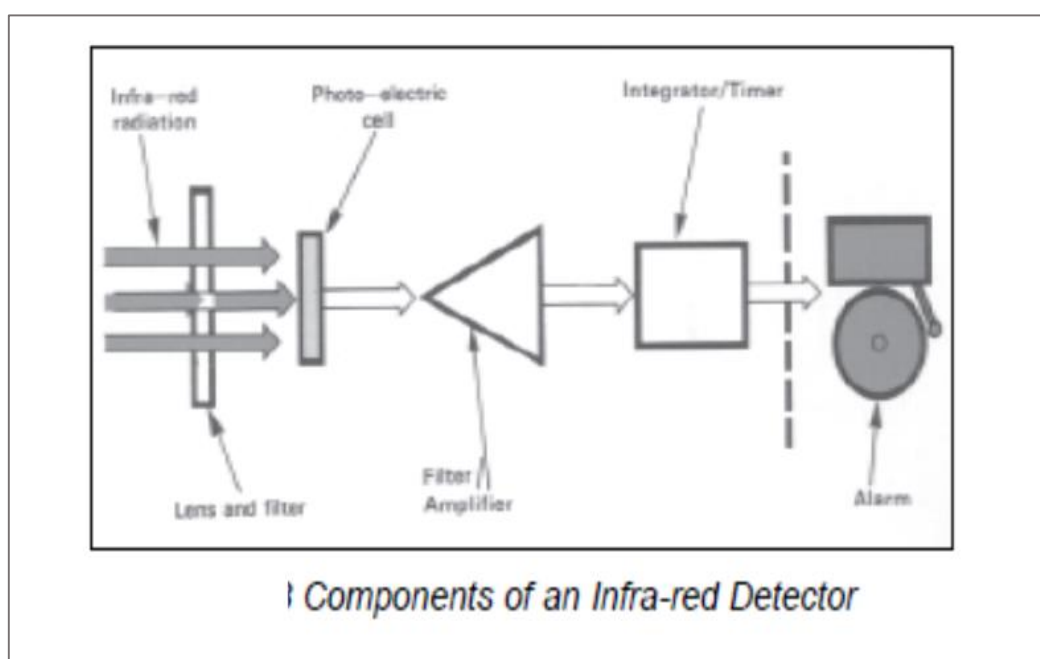


These forms of energy travel in waves radiating from the point of origin and radiation detectors (flame detectors) are designed to respond to this radiation. These detectors are designed to respond specifically to:

- (i) Infra-red radiation
- (ii) Ultra-violet radiation
- (iii) Combination of IR/UV radiation

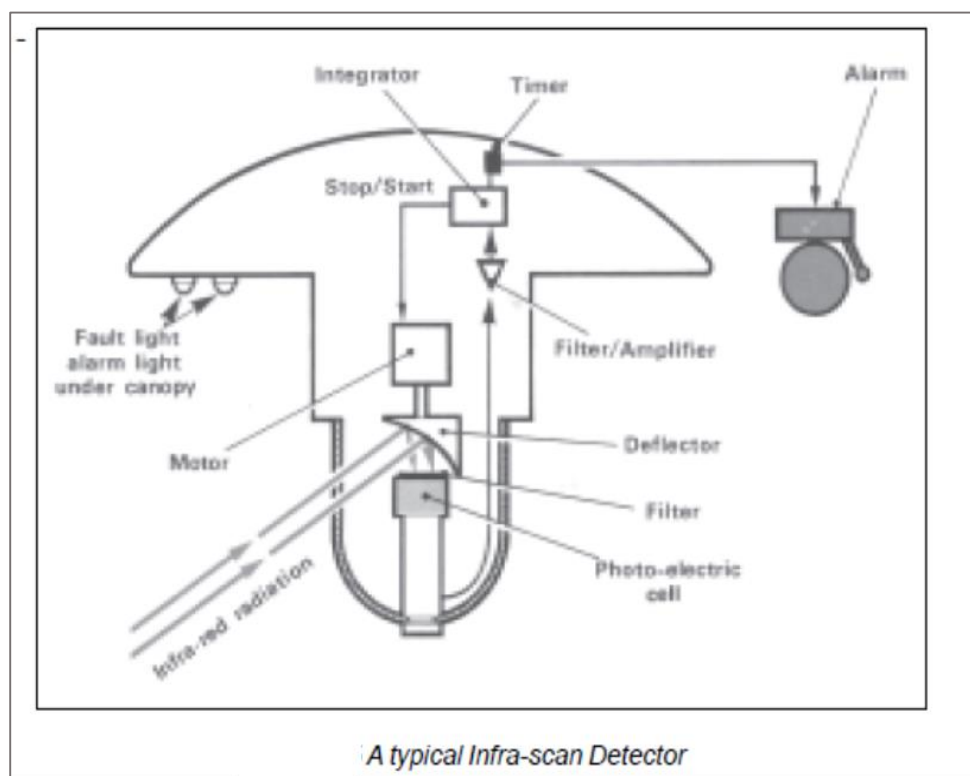
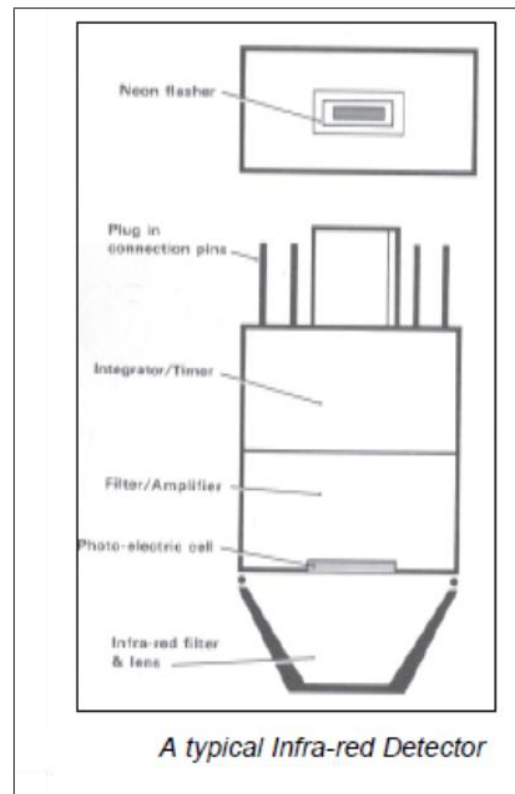
### Infra-red detector

- The figure below illustrates the basic components of this detector:



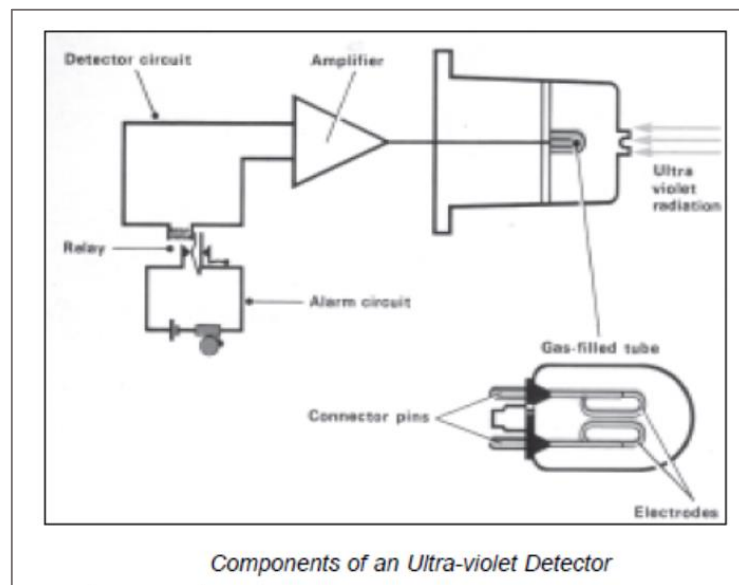
- The lens and filter will allow only infra-red radiation to fall on the photo electric cell. On getting the radiation, the cell will transmit a signal to the filter / amplifier. The flame has a distinctive flicker, normally in the frequency range of 5Hz - 50Hz. The filter / amplifier will amplify signals in this range as well as filter out signals which are not in this range. The signals in this range are then fed to the integrator/ timer which will activate the alarm circuit only if the signal persists for a pre-set period of normally 2-15 secs. Thus, false alarms are avoided or minimized. The detector has a neon flasher to indicate which head has been activated. The figure of a typical Infra-red radiation detector unit is given below.

- **Infra-scan radiation detector** - The conventional Infra-red detector is designed to protect small areas. For larger areas with a more open plan, infra-scan radiation detectors are provided. In this, the detector monitors 360 degrees in the horizontal plane and a wide angle on the vertical plane. The moment the photo-electric cell is struck by deflected infra-red radiation, the filter amplifier identifies it and the integrator stops the deflector so that the radiation falls continuously on the photo-electric cell. The timer checks whether the flame flicker persists for more than the 2-15 secs. period and then raises the alarm. This detector is able to provide protection for a large area even up to a radius of approx. 90m. The figure of a typical infra-scan detector is given below:



## Ultra-violet detector

- This detector responds only to ultra-violet radiation emitted from flames and normally operates in the range of wavelengths from 200 nm. to 270 nm. Solar radiation in this range is absorbed by the high-altitude ozone layer and hence UV detectors do not normally respond to sunlight. The components of an ultra-violet detector are shown in the figure below:



- The principle of operation of this detector is very similar to that of the Ionization detector. When ultra-violet radiation strikes the gas filled tube, it ionizes the gas in the tube. A small current is set up between the two electrodes and the alarm is raised when there is a change in the current flow. The integrator helps reduce false alarms caused by external sources of ultra-violet radiation like lightning or even sunlight.
- This type of detector is commonly used for specialized applications, as for aircraft engine nacelles, fuel storage tanks, oil rigs, warehouses, paint spray booths etc.
- In a smoky fire infra-red detectors are preferable to ultra-violet types because the former can penetrate smoke better.

## Multi-sensor fire detectors

These detectors are also under use and they are designed as point type resettable multisensory fire detectors installed in buildings, incorporating at least one smoke sensor and another sensor which responds to heat, and in which the signal(s) of the smoke sensor(s) is combined with the signal(s) of the heat sensor(s).

## Choice / Selection of Fire Detectors





## 1) General

Automatic fire detection system should have detectors suited to the risks and the environmental conditions so that they provide the earliest reliable warning. Each type of detector responds at a different rate to different kinds of fire.

Main characteristics of different types of fire detectors are enumerated below. This information will help with the choice of detectors for providing protection for various kinds of fire situations as indicated against them. In general, smoke detectors give faster responses than heat detectors, but may be more liable to give false alarms.

Ionization smoke detectors are unsuitable for smoldering/ PVC/ polyurethane foam/ clearly burning fires like hydrogen, certain grades of petroleum fires etc.

Optical smoke detectors are more sensitive to the larger, optically active, particles found in optically dense smoke, but are less sensitive to the smaller particles found in clean burning fires.

Both types of smoke detectors have sufficiently wide range of response for general use.

Smoke detectors cannot detect products from clean burning liquids such as alcohol, which do not produce smoke particles.

Optical beam smoke detectors incorporating thermal turbulence detectors are particularly suitable for clean burning fires. Ionization smoke detectors are suitable for detection of rapidly burning fires.

In a life safety situation, it is essential to pay primary attention to early detection of smoke and to protect escape routes, ensure operation of detectors on escape routes before optical density exceeds 0.05 dB / m (visibility falls below 20m.)

Heat detectors are not suitable for detection in life safety installations and in slow burning / air-conditioned premises.

Heat detectors are suitable in compartments / areas where heat producing equipment are used (e.g., kitchen, pantry etc.) and in other unsupervised spaces / areas with low value contents.



Heat detectors with rate-of-rise elements are more suitable where ambient temperature is low or vary only slowly, while fixed temperature detectors are more suitable where the ambient temperature is likely to fluctuate rapidly over short period.

Flame detectors are particularly suited for outside applications, and for general surveillance of large open areas in warehouses etc. or for critical areas where flaming fires may spread very rapidly, e.g., at pumps, valves or pipe work containing flammable liquids etc.

Detailed guidelines for selection, installation, system design and maintenance etc. (for fire detection and alarm systems for buildings, selection/choice of fire detectors etc.) are given in relevant national/international Standards like IS : 2189 : 1999; BS : 5839 : Part-1 : 1988; NFPA-72 : 2002 etc.

## **2) General requirements for automatic fire detection and alarm systems.**

- (i) The systems consist of fire detectors and manual call points connected by cables to sector / zonal panels which, in turn, are connected to Control and Indicating equipment(C&I)
- (ii) The protected area should be divided into zones, each zone covering only one storey of the building or any other prescribed area like stairwell, lift well, other vertical shafts etc.
- (iii) Individual zones/sectors are necessary if the number of detectors in any area exceeds 20.
- (iv) One of the chief objectives of zoning is to make it easier to determine the location of fire.
- (v) The sounders for the fire alarm should be electronic hooters / horns / electric bells having frequency range of 500 Hz. to 1000Hz.
- (vi) The distribution of fire alarm sounders should be such that they have a minimum sound level of either 65 dB (A) or 5 dB(A) above any other noise likely to persist for more than 30 secs., whichever is greater, and that the alarm is heard at all designated locations in the building.
- (vii) A multi-state addressable analogue detector system is designed to reduce the incidence of false alarms.
- (viii) In large and / or high-rise buildings and / or special buildings it may be necessary to have two-stage alarms for facilitating evacuation of the areas involving greater life hazard. In this case, while the alert signal will be sounding in all areas, the evacuation



signal will be restricted only to the floor area as well as other areas immediately affected by the fire.

- (ix) A Control Centre should be provided especially for high rise and special buildings, preferably in the ground floor, where the following facilities should be made available:
- The Control Centre should have an area of approx. 16m<sup>2</sup> - 20m<sup>2</sup>.
  - The C&I equipment, power supply units, and other fire protection ancillary panels should be installed in the Control Centre.
  - It should have emergency lighting system.
  - It should have intercom and direct telephone facilities. It will be desirable to have a direct hot line to local Fire Brigade Control Room.
  - It should have attached WC bath, drinking water facilities and other appropriate furniture etc.
  - It should have a mimic panel of the premises protected and all the fire protection systems.
  - Copy of the Fire Orders for the premises should be prominently displayed.
  - It should have preferably an independent A/c system.
  - All relevant records etc. should be maintained in the Centre.
  - The Centre should be manned 24 hours by trained competent fire and / or security staff.

# **Chapter 5:**

## **Structural Fire Safety & Passive Fire Protection**





## 5. Structural Fire Safety & Passive Fire Protection

### 5.1. Different terms used for fire resistance rated components

#### 5.1.1. Fire resistant wall

Fire resistant rated wall, having opening(s) with specified fire resistant rating, which restricts the spread of fire from one part of the building to another part of the same building.

##### 1) **Fire compartment**

A space within a building that is enclosed by fire barrier or fire resistant walls on all sides, including the top and bottom.

##### 2) **Firewalls (or fire separating wall)**

They not only have a rating, they are also designed to sub-divide buildings such that if collapse occurs on one side, this will not affect the other side. They can also be used to eliminate the need for sprinklers, as a trade-off.

##### 3) **Fire-resistant glass**

Using multi-layer intumescent technology or wire mesh embedded within the glass may be used in the fabrication of fire-resistance rated windows in walls or fire doors.

#### 5.1.2. Fire-resistance rated floors

##### 1) **Occupancy separations**

Barriers designated as occupancy separations are intended to segregate parts of buildings, where different uses are on each side; for instance, apartments on one side and stores on the other side of the occupancy separation).

##### 2) **Closures (fire dampers)**

Sometimes fire stops are treated in building codes identically to closures. The lowered rating is then referred to as a fire protection rating, both for fire stops, unless they contain plastic pipes and regular closures.

##### 3) **Fire Stop**

A fire resistant material or construction, having a fire resistance rating of not less than the fire separating elements, installed in concealed spaces or between structural elements of a building to prevent the spread/propagation of fire and smoke through walls, ceilings and the like as per the laid down criteria.

##### 4) **Fire stops in grease ducts**



These refer to the ducts that lead from commercial cooking equipment such as ranges, deep fryers and double-decker and conveyor-equipped pizza ovens to grease duct fans.

**5) Cable coating**

Application of fire retardants, which are either endothermic or intumescent, to reduce flame spread and smoke development of combustible cable-jacketing

**6) Spray fireproofing**

Application of intumescent or endothermic paints, or fibrous or cementitious plasters to keep substrates such as structural steel, electrical or mechanical services, valves, liquefied petroleum gas (LPG) vessels, vessel skirts, bulkheads or decks below either 140 °C for electrical items or 500 °C for structural steel elements to maintain operability of the item to be protected

**7) Fireproofing cladding**

Boards used for the same purpose and in the same applications as spray fireproofing. Materials for such cladding include perlite, vermiculite, calciumsilicate, gypsum, intumescent epoxy, Durasteel (cellulose-fiber reinforced concrete and punched sheet-metal bonded composite panels) etc.

**8) Enclosures**

Boxes or wraps made of fireproofing materials, including fire-resistive wraps and tapes to protect specialty valves and other items deemed to require protection against fire and heat—an analogy for this would be a safe or the provision of circuit integrity measures to keep electrical cables operational during an accidental fire.

## **5.2. Structural fire safety & passive fire protection**

### **5.2.1. Introduction**

The possibility of collapse of a building at an incident has been an ever-present problem for firefighters and an ability to assess a situation is important. Any large fire or explosion can make a building potentially dangerous as what remains will be under a great deal more stress than usual.

That is why Fire/ Safety Officers are detailed at an incident for the specific purpose of detecting dangerous conditions and warning the Incident Commander in time for him to make a decision on what action to take to safeguard personnel. But modern buildings may

include lightweight roofs, cladding (both heavy and light), curtain walling, large areas of glass or polycarbonates in relatively light framing, cantilevered support structures etc. Their behavior has only been fire-tested usually as individual elements of structure; the reaction of the whole building, together with its internal fire loading is not tested.

Building regulations usually attempt to redress this situation by requiring the building to be stable and remain stable under fire conditions. This is achieved by dividing the building into fire components and specifying a degree of fire resistance for the elements of structure forming that compartment appropriate to the size, height and use of that compartment.

It is necessary for firefighters/ Auditors to have some basic knowledge of the principal methods of building construction. Below is an image of a failure of building structure.



### **5.2.2. Understanding the concept of active and passive fire protection**

It has become more apparent over the years how important it is to have adequate fire protection in every building. For most people, what comes to mind when they think of fire protection are smoke detectors and fire extinguishers. However, these two elements only cover a small portion of the protection services one should have at all times. There are many parts of a building's fire protection that often go overlooked or are completely forgotten about.





There are in fact two types of fire protection: Active Fire Protection (AFP) and Passive Fire Protection (PFP). One type of protection must not be chosen over the other. On the contrary, both AFP and PFP must be used together for full fire protection. It is important to understand the difference between AFP and PFP.

### **Active fire protection**

Active fire protection consists of the components of fire protection that require some kind of action to work. This action may be manual, like using a fire extinguisher or automatic like the sprinkler system dousing flames. The action that results from active fire protection is triggered by some sort of alert or signal. The action itself will help contain, suppress or extinguish a fire that has already started. Although fire suppression systems are the most obvious examples of AFP, fire detection or fire alarm systems are equally as important and are also considered AFP. After picking up a signal, these systems will trigger a response such as alerting the fire department, activating sprinklers or closing fire doors. Working fire alarm system and fire suppression systems can greatly increase one's chances of suppressing a fire or even extinguishing it before it causes harm.

All AFP systems are required to be installed and maintained in accordance with strict guidelines in order to maintain compliance with the local building code and the fire code.

AFP works alongside modern architectural designs and construction materials and fire safety education to prevent, retard and suppress structural fires.

### **Passive fire protection**

Passive fire protection is frequently overlooked but is a fundamental component of your fire protection. Despite its name, it is always working. PFP are a set of components used to compartmentalize a building in order to keep a fire from spreading and require no action to work. Passive fire protection is usually structural and built into the building. It includes compartmentalization of the overall building through the use of fire-resistance rated walls and floors. Organization into smaller fire compartments, consisting of one or more rooms or floors, prevents or slows the spread of fire from the room of fire origin to other building spaces, limiting building damage and providing more time to the building occupants for emergency evacuation or to reach an area of refuge.

By using fire-resistant walls and floors, PFP gives people time to escape from a building that has a fire. Other examples of PFP include dampers which prevent the spread of fire and smoke through a building's ductwork, and fire doors which compartmentalize fires.



Passive fire protection successfully compartmentalizes fires and keeps damage to a minimum by eliminating possible fuel a fire could use to spread or ignite with in the first place. A small fire or a fire restricted to a small area gives one a greater chance of putting it out, avoiding costs, and avoiding injury.

### **Why one needs both?**

There is no argument over which type of protection is better. Active fire protection and passive fire protection perform fundamentally different tasks that are equally as important. Active fire protection takes action in order to put out a fire. Passive fire protection will help prevent a fire from spreading or resist the initial ignition. They work together by alerting people inside the building of a fire and safely containing the fire so that people may evacuate and/ or try to suppress the fire.

### **5.2.3. Concepts of construction**

This section deals with some of the constructional methods used and gives examples of both traditional and new types of buildings.

#### **Construction methods**

##### **1) Solid construction**

Solid construction, often referred to as "traditional" or masonry construction, consists of loadbearing external walls which support the floors and roof. The materials most commonly used were brick, concrete blocks and stone. This form of construction was almost done for all kinds of industrial and commercial buildings. The example like warehouses, factories, cotton and woolen mills and old office blocks are all similarly built.

##### **2) Structural steel frame construction**

This type of building has a great advantage from an architect's/ designer's point of view in that, in its construction, the load of the floors and cladding is carried at each level by beams which, in turn pass the load on to the columns.

Within a skeleton framework floor space, divided in a variety of ways, can be provided and a suitable non-loadbearing cladding material used as a weather and insulation wall. Beams and columns are designed to support the loads (static and rolling) on the floors, the cladding and the wind pressure. How the columns are arranged is usually determined by various circulation spaces in the building and to some extent, the window openings. The steel work would, normally, be required to be protected against fire by either "solid" or "hollow" protection.



**3) Reinforced concrete construction**

The reinforced concrete frame was, when first used, treated as an alternative to steel frames, i.e., the columns supported the main beams which, in turn, supported the floor slabs. This, however, gradually changed to a monolithic type of construction, where the columns, beams and floors were cast integrally.

**4) Precast reinforced concrete frame**

Here the reinforced concrete frame components are manufactured at the factory and then assembled on site in a similar manner to steel frames (like Metro rail)

**5) Composite construction**

In this case the technology of lightweight structural steel works is combined with the strength of precast concrete columns.

**6) Modular systems**

The differences between modular systems, composite construction and precast construction are blurred but the main advantage of most modular systems is that, within certain parameters, prefabricated components can be used in an almost unlimited variety of ways. This includes their positioning for varying floor heights, spans, vertical spacing etc. plus an ability to use the same cross-sectional component in different loading conditions. Most systems use specially designed connectors with which to assemble the building.

These can be molded into the precast columns or beams at whatever position suits the design of the building. The steelworks in these components is usually encased in concrete and the steel connectors are covered in concrete in situ giving a degree of protection against fire and corrosion.

**7) Lift-slab construction**

In this system the columns are constructed, the roof slab is formed, and hydraulic jacks lift it first to the top of the column. Other floor slabs are formed, and these too are lifted and "parked" on the columns. The sequence of lifting cycles is repeated until the structure is complete.

**8) Insulating sandwich panels**

Sandwich panels have been implicated in a number of fires in recent years in many countries and concerns have been expressed regarding the risks that they present both to occupants and firefighters. The most common use of insulating core panels, when used for internal structures, is to provide an enclosure in which a chilled or sub-zero environment

can be generated for the production, preservation, storage and distribution of perishable foodstuffs. However, this type of construction is also used in many other applications, particularly where the maintenance of a hygienic environment is essential.

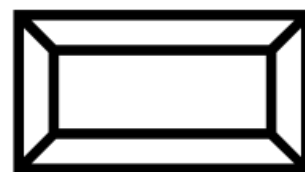
- However, panels with the following core materials are also in use: Expanded Polystyrene, Extruded Polystyrene, Foam Glass, Polyurethane, Polyisocyanurate, Mineral Fiber, Modified Phenolic.

In summary, performance of the building structure, including the insulating envelope, the superstructure, the substructure, etc., must be considered together in relation to their performance in the event of a fire.

## **The basic elements of structure**

### **1) Beams**

The beam is probably the oldest structural member. It is not hard to imagine primitive man dropping a tree across a stream to form the first bridge.



A beam transmits forces in a direction perpendicular to such forces to the reaction points (points of support). Consider a load placed on a floor beam. The beam receives the load, turns it laterally, divides it, and delivers to the reaction points. E.g. Simple beam, continuous beam, lintel, Reinforced concrete, Pre-stressed concrete etc.

### **2) Columns**

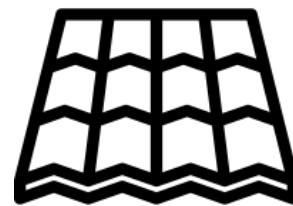


A column is a structural member, which transmits a compressive force along a straight path in the direction of the member. Columns are usually thought of as being vertical, but any structural member, which is comparatively loaded, is governed by the laws of columns, despite its attitude.

The function of a column is to carry part of the weight of the building where an internal wall would interfere with the designed use or where a large open space is needed. A column is often designed to withstand only vertical loads and any eccentric loading greatly increases the stress. Non-vertical columns are often called by other names, such as struts or rakers, which are diagonal columns, which brace foundation piling. A bent is a line of columns in any direction. E.g. Cast-iron, Structural steel, laminated timber, Brick, Stone, Reinforced concrete, Cast-iron, Structural steel etc.

### 3) Roofs

It has been stated that "a roof is a structure, which surmounts a building to keep out the weather and may be flat, pitched or curved". Since that statement was made there have been significant developments and advancement in design. Whether this statement could still be applied to some modern buildings with roofs made of fabric, glass, plastics, tubing, cables etc., and which are suspended, cantilevered, sometimes geodetic, frequently braced and, occasionally, inflated is problematical.



Some of the materials now used, such as polytetrafluoroethylene (PTFE) have a design life of many years (25 years or more) and the use of this technology appears to be finding increased applications. This is very much the case where there is a reluctance to destroy many fine buildings in city centres to provide a protected environment for shoppers. The installation of a lightweight fabric roofing structure may find increasing favor in the future.

- E.g. Flat roofs, pitched roofs, close-coupled roofs, mansard roofs, trussed roofs, portal or rigid frame roof, monitor roofs monitor roofs etc.

### 4) Stairs and stairways



An important aspect of means of escape in multi-story buildings is the availability of a sufficient number of adequately sized and protected escape stairs. The relevant building regulations address the number, width and protection of stairs necessary to ensure safe escape. In all cases stairways and ramps which form part of the structure of the building are required to provide a safe passage for users. In many cases

they may represent the only way out of the building in the event of a fire.

The requirements are basically that they should be made from materials of limited combustibility and are continuous leading, ultimately, to a place of safety. This applies whether the stairway is internal or external.

### 5) Walls

#### i. Walls (loadbearing)

As with steel, walls are usually referred to by the function they perform e.g. external, compartment, separating, and loadbearing. e.g. Solid brick, Cavity brick, Timber-framed, other walls such as:- numerous types of solid walls ranging from old stone walls a meter thick to stone-fronted brick walls. Other walls can consist of hollow blocks



faced with stone slabs or concrete blocks built up in brick formations and rendered with plaster.

### **Behavior of loadbearing walls in fire**

The stability of a brick or stone wall depends, amongst other things on:

- Its thickness in relation to its height;
- On proper bonding (in particular on the use of sufficient headers to tie the wall together); and
- To some extent on its age;
- On any horizontal pressure or levering effect which may be exerted on it.

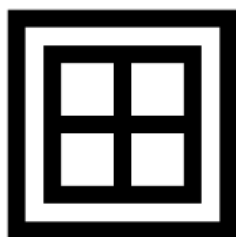
### **ii. Non-loadbearing partition walls**

The term "partition" or "partition wall" is used when referring to walls whose sole function is the division of a space within a building into separate rooms/ compartments. In this section the term "partition" is used in the "space division" sense. These partitions are designed and constructed to carry their own weight and any fixture and fittings included in them, i.e., doors or glazing. They should also be robust enough mechanically for normal conditions of use, for example, able to resist vibration set up by doors being opened and slammed.

Partition walls are made from a variety of materials. Plasterboard bonded on either side of a strong cellular core to form rigid panels is suitable as non-loadbearing partitions. Compressed strawboard panels provide another alternative method and partially prefabricated partitions such as plasterboard and strawboard can be erected on site.

Non-loadbearing partitions often have quite good sound insulation qualities and will provide a certain period of fire resistance. For example, the fire resistance of timber-framed non-loadbearing partitions will be determined as much as anything by their lining/ finishes. Plasterboard linings have an established resistance dependent upon the thickness applied. Plywood and chipboard linings of appropriate thickness also make a contribution to fire resistance.

## **6) Windows**



Windows allow natural light into buildings and also serve to ventilate rooms. Window frames can be made from a variety of materials such as timber, uPVC and metals like aluminum and steel.

Windows can also be designed to operate in various ways by arranging for the sashes (the opening portion of the window including glass and frame) to slide, pivot or swing, by being hung on to one of the frame members. Windows are generally referred to as being of two types according to the method of opening, these being "casement" or "sash".

## 7) Doors, door sets and shutters

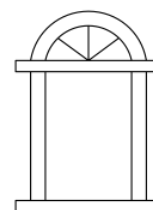
Doors and shutters are of seven principal types:

Hinged doors	Swing doors	Revolving doors	Sliding doors
Folding doors	Cantilever doors	Roller shutters	

In many gates and doors of industrial premises, a small door, often referred to as a 'wicket door', may be inset, e.g. a hinged door set in a sliding gate.

### A fire door may be defined as:

A door or shutter provided for the passage of persons, air or things which, together with its frame and furniture as installed in a building, is intended, when closed, to resist the passage of fire and/or gaseous products of combustion and is capable of meeting specified performance criteria to those ends.



### Fire doors have at least two functions:

- To protect escape routes from the effects of fire so that occupants can safely reach a final exit: and/or



- To protect the contents and/or the structure of a building by limiting the spread of fire.



Doors for compartmentation and segregation of special risks are doors which must be capable of achieving the period of fire resistance appropriate to the structure which is not less than 30 minutes and may be as much as 4 or even 6 hours in exceptional circumstances. The required fire resistance may need to be achieved by the provision of two fire doors in series, both having half the required fire resistance. If

such doors are required to protect an escape route, they will need also to have the smoke control capabilities.

All fire doors should be fitted with an automatic self-closing device except for fire doors to cupboards and to service ducts, which are normally kept locked shut.



Where a self-closing device would be considered a hindrance to the normal approved use of the building, self-closing devices may be held open by:

- A fusible link, but not if the door is fitted in an opening provided as a means of escape.
- An automatic release mechanism actuated by an automatic fire detection and alarm system;
- A door closure delay device; however,

### 5.3. Structural Fire Safety



More accurate classification of the fire is possible from fire risk point of view of hazard afforded by the materials under consideration. This has been done in IS 1641 “General principle of fire safety of building and fire grading” of which salient features are below:

**Clause 2. IS 1641 - Fire safety of building could be considered from three different angles:**

**Personal Hazard** - Possibility of loss or damage to human life.

**Internal Hazard** - Spreading of fire inside the campus or building or campus or building itself.

**Exposure Hazard** - Spreading of fire from adjoining building or campus.

The consideration of personal hazard is of paramount importance whereas the exposure hazard is of social nature. Internal hazard concerns destruction of building and influence directly related to fire load which in turn enables the building to be graded when duration of fire.

This grading of building is considered from two points of view, first, in terms of damage and exposure to hazard for which the protection is mainly provided by structural precautions and second, in terms of personal hazard for which protection is provided primarily by each means of escape.

The severity of fire depends largely upon the amount, nature and distribution of combustible material in a building. Thus, in determining the requisite degree of the fire protection, it is necessary to take into account the use and size of given building and by this means, to assess the probable amount and type of combustible material which would contribute to fire.

**Fire load in the building**

This assessment of the severity of a fire due to the combustible materials in a building is made by references to that is known as the fire load, which is the amount of heat expressed in K cal's which would be generated per m<sup>2</sup> of floor area of a compartment of building by complete combustion of its content and any combustible part of the building.

**Calculation of fire load**



It is determined by multiplying the weight of all the combustible material by their calorific values and dividing by the area of the floor, it is based on the assumption of at the materials are uniformity distributed over the whole areas of the floor.

The calorific value is the property of a material which indicates the amount of heat which will be generated by a particular quantity of that material and it governs the ultimate severity of fire. Thus, the maximum heat is evolved from materials having calorific values. The calorific values of some materials are given below:

Bitumen	3521.58 cal/kg
Cork	16731.27 cal/kg
Paper	16266.52 cal/kg
Petrol	46475.77 cal/kg
Rubber	39504.40 cal/kg
Wood	18590.60 cal/kg

### **Grading of occupancies based on fire load**

- The fire load is used as means of grading occupancies and the grading set out by the joint committee on Fire Grading of Building.

#### **Low fire load occupancy**

- Fire load not exceeding 275,000 K cal/m<sup>2</sup>
- Building types
  - Flats, offices, restaurants, hotels, hospitals, schools, museum, public libraries etc.
- Equivalent Severity of Fire:- 1hour

#### **Moderate fire load occupancy**

- Fire load between 275,000 K cal/m<sup>2</sup> to 550,000 K cal/m<sup>2</sup>
- Equivalent Severity of Fire - 2hours

#### **High fire load occupancy**

- Fire load between 5500,000 K cal/m<sup>2</sup> to 11,00,00 K cal/m<sup>2</sup>.
- Building Types - Warehouses used for bulk storage of materials of non-hazardous nature.



- Equivalent Severity of Fire: 4hours

No material is actually fireproof and will eventually fail in some way or the other, when exposed to a fire; the time of failure depending on the material properties and the duration and severity of the fire it is exposed to. This is the reason why buildings constructed of fire resistive materials also fail/collapse when exposed to fires. Besides its requirement of maintaining structural stability, another factor related to load bearing and non-load bearing vertical and horizontal barriers is the need to provide effective insulation between spaces and prevent spread of fire to adjoining compartments. Therefore, it is important to select the right materials of construction, which will be able to withstand the effects of a likely fire in the building.

The type of construction will be defined based on the fire resistance of structural elements. Different codes follow different systems and terminology for the type of construction, but most codes will have at least 4 distinct types of construction, from the most fire resistant to the least. Typically load bearing elements will have a 4 hours resistance for the most resistant type down to 1 hour resistance for the least resistant construction. Non-load bearing elements and barriers and components are not part of the structure and will normally have their fire resistance defined based on their function and the type of fire it is likely to be exposed to (this could change depending on type of construction or even be same though the type of construction changes).

**Figure below shows different fire resistance ratings for structural and non-structural elements:**



**Table 1 Fire Resistance Ratings of Structural and Non-Structural Elements (minutes)**  
(Clauses 3.3.1 and 3.3.2)

SI No.	Structural Element	Fire Resistance Ratings (min) for Type of Construction			
		Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	Exterior walls:				
	a) Fire separation less than 3.7 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	120	90	60	60
	b) Fire separation of 3.7 m or more but less than 9 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	90	60	60	60
	c) Fire separation of 9 m or more:				
	1) Bearing	240	120	120	60
	2) Non-bearing	60	60	60	60
ii)	Fire separation assemblies (like fire check doors)	120	120	120	120
iii)	Fire enclosures of exits	120	120	120	120
iv)	Shafts for services, lift hoistway and refuse chutes	120	120	120	120
v)	Vertical separation between adjacent tenant spaces	60	60	60	60
vi)	Dwelling unit separation:				
	a) Load bearing	120	120	60	60
	b) Non-load bearing	60	60	30	30
vii)	Interior bearing walls, bearing partitions, columns, beams, girders, trusses (other than roof trusses) and framing:				
	a) Supporting more than one floor	240	120	120	120
	b) Supporting one floor only	180	90	60	60
	c) Supporting a roof only	180	90	60	60
viii)	Walls supporting structural members	180	90	60	60
ix)	Floor construction	120	90	60	60
x)	Roof construction:				
	a) 5 m or less in height to lowest member	120	90	60	60
	b) More than 5 m but less than 6.7 m in height to lowest member	60	60	60	60
	c) 6.7 m or more in height to lowest member	0	0	0	0

## 5.4. Containment and compartmentation for fire safety

### 5.4.1. Compartmentation

It is the process of segregating large fire compartments to smaller and more manageable compartments. The intent is to keep the fire limited to a small area so that it can be mitigated quickly. Fire fighters may struggle to control and extinguish a fire involving multiple flats/office blocks in a building as opposed to a single compartment fire, in which fire can be easily extinguished. The other reason is that a fire limited to a compartment will generate less smoke and heat as compared to a larger fire (involving multiple compartments). Compartmentalization increases the probability of survival of occupants and reduces the damage to property and structure. Generally, building codes specify the maximum size of a compartment depending upon the occupancy.

It is common for smoke and heat from a fire to travel vertically due to buoyancy. This occurs through vertical shafts such as stairwells, lift shafts, service shafts (electrical,



plumbing, garbage) and it is important that these openings be protected suitably to prevent the travel of heat and smoke. The requirement of having fire rated enclosures for stairwells, lift shafts and service shafts arises from this requirement.

Vertical compartmentation consists of separating the floors of a building from each other and enclosing floor openings and shafts using fire rated construction. As convected heat and buoyant gases from a fire have a tendency to rise, vertical openings between floors allow the growth of fire in upward direction. It is common to observe fire spreading in the upper direction from the floor of fire origin in building fires. This is possible through vertical shafts such as stairwells, lift shafts, service shafts (electrical, plumbing, garbage) and it is important that these openings be protected suitably to prevent the travel of heat and smoke. Hence, requirement of having fire rated enclosures for stairwells, lift shafts and service shafts is imperative.

Therefore, compartmentation is essential because it:

- Prevents the spread of fire, smoke and toxic gases.
- Subdivides buildings into manageable areas of risk
- Provides adequate means of escape enabling time for the occupants to safely evacuate the premises.

The most common cause of death during a fire incident is consumption of gas or smoke or toxic fumes. Where an escape route needs to be separated from the rest of the premises by fire-resisting construction e.g. a dead-end corridor or protected stairway the following compartmentation should be ensured:

- Doors (including hatches to cupboards, ducts and vertical shafts linking floors), walls, floors and ceilings protecting escape routes should be capable of resisting the passage of smoke and fire for long enough to enable people to escape the building.
- Where suspended or false ceilings are provided, the fire resistance should extend up to the floor slab level above.
- Cavity barriers, fire stopping and dampers in ducts should be appropriately installed.

#### **5.4.2. Openings in separating walls and floors**

At the time of designing openings in separating walls and floors, particular attention shall be paid to all such factors as it will restrict spread of fire through these openings and maintain fire rating of the structural member.



For type 1 to 3 construction, a doorway or opening in a separating wall on any floor shall be limited to 5.6 m<sup>2</sup> in area with a maximum height/width of 2.75 m. Every wall opening shall be protected with fire-resisting doors having the fire rating of not less than 2 h in accordance with accepted standard. All openings in the floors shall be protected by vertical enclosures extending above and below such openings, the walls of such enclosures having a fire resistance of not less than 2 h and all openings therein being protected with a fire-resisting assembly.

For type 4 construction, openings in the separating walls or floors shall be fitted with 2 h fire-resisting assemblies.

Openings in walls or floors which are necessary to be provided to allow passages of all building services like cables, electrical wirings, telephone cables, plumbing pipes, etc., shall be protected by enclosure in the form of ducts/shafts having a fire resistance not less than 2 h. The inspection door for electrical shafts/ducts shall be not less than 2 h and for other services shafts/ducts, the same shall have fire resistance not less than 1 h. Medium and low voltage wiring running in shafts/ducts, shall either be armored type or run through metal conduits. Further, the space between the conduits pipes and the walls/ slabs shall be filled in by a filler material having fire resistance rating of not less than 1 h.

Note: In the case of buildings where it is necessary to lower or lift heavy machinery or goods from one floor to the other, it may be necessary to provide larger openings in the floor. Such openings shall be provided with removable covers which shall have the same strength and fire resistance as the floor.

#### **5.4.3. Vertical opening**

Every vertical opening between the floors of a building shall be suitably enclosed or protected, as necessary, to provide the following:

- Safety to the occupants while using the means of egress by preventing spread of fire, smoke, or fumes through vertical openings from floor to floor to allow occupants to complete their use of the means of egress. Further it shall be ensured to provide a clear height of 2100 mm in the passage/escape path of the occupants.
- Limitation of damage to the building and its contents.

#### **5.4.4. Fire stop or enclosure of openings**

Where openings are permitted, they shall not exceed three-fourths the area of the wall in the case of an external wall and they shall be protected with fire resisting assemblies or





enclosures having a fire resistance equal to that of the wall or floor in which these are situated. Such assemblies and enclosures shall also be capable of preventing the spread of smoke or fumes through the openings so as to facilitate the safe evacuation of building in case of a fire *{see also accepted standard [4 (8)]}*.

#### **5.4.5. Main characteristics of passive fire protection**

To accomplish PFP objectives, many different types of materials are employed in the design and construction of systems. For instance, common endothermic building materials include calcium silicate board, concrete and gypsum wallboard. During fire testing of concrete floor slabs, water can be seen to boil out of a slab. Gypsum wall board typically loses all its strength during a fire. The use of endothermic materials is established and proven to be sound engineering practice. The chemically bound water inside these materials sublimates. During this process, the unexposed side cannot exceed the boiling point of water. Once the hydrates are spent, the temperature on the unexposed side of an endothermic fire barrier tends to rise rapidly. However, excessive water can be a problem. Concrete slabs that are wet, will explode during a fire, which is why testing laboratories insist on measuring water content of concrete and mortar in fire test specimens, before running any fire tests. PFP measures can also include intumescent and ablative materials. The point is, however, that whatever the nature of the materials, they on their own bear no rating. They must be organized into systems, which bear a rating when installed in accordance with certification listings

Passive fire protection measures, such as fire stops, fire walls, and fire doors, are tested to determine the fire-resistance rating of the final assembly, usually expressed in terms of hours of fire resistance (e.g.,  $\frac{1}{3}$ ,  $\frac{3}{4}$ , 1,  $1\frac{1}{2}$ , 2, 3, 4 hour).

Contrary to active fire protection measures, passive fire protection means do not typically require electric or electronic activation or a degree of motion. Exceptions to that particular rule of thumb are fire dampers (fire-resistive closures within air ducts, excluding grease ducts) and fire door closers, which have an open and shut movement in order for them to work, as well as all intumescent products, which swell, thus move, in order to function.

PFP in a building can be described as a group of systems within systems. An installed fire stop, for instance, is a system that is based upon a product certification listing. It forms part of a fire-resistance rated wall or floor, and this wall or floor forms part of a fire compartment which forms an integral part of the overall fire safety plan of the building. The building itself, as a whole, can also be seen as a system.



The parameters for passive fire protection systems such as are typically demonstrated in fire testing set-ups. An important requirement is the ability to maintain the item or the side to be protected at or below either 140 °C (for walls, floors and electrical circuits required to have a fire-resistance rating) or 550 °C (in case of steel members), which is considered the critical temperature for structural steel, above which it is in jeopardy of losing its strength, leading to collapse. Smaller components, such as fire dampers, fire doors, etc., follow suit in the main intentions of the basic standard for walls and floors. Fire testing involves live fire exposures upwards of 1100 °C, depending on the fire-resistance rating and duration one is after. More items than just fire exposures are typically required to be tested to ensure the survivability of the system under realistic conditions.

#### **5.4.6. Inspection and regulation of passive fire protection measures**

The most important goal of PFP is life safety. This is accomplished by maintaining structural integrity for a time during the fire and limiting the spread of fire and the effects thereof (e.g., heat and smoke). Property protection and continuity of operations are usually secondary objectives in codes. Typically, during the construction of buildings, fire protective systems must conform to the requirements of building code that was in effect on the day that the building permit was applied for. Enforcement for compliance with building codes is typically the responsibility of municipal building departments. Once construction is complete, the building must maintain its design basis by remaining in compliance with the current fire code, which is enforced by the fire prevention officers of the municipal fire department. An up-to-date fire protection plan, containing a complete inventory and maintenance details of all fire protection components, including fire stops, fireproofing, etc. are typical requirements for demonstration of compliance with applicable laws and regulations.

Changes to fire protection systems or items affecting the structural or fire-integrity or use (occupancy) of a building is subject to regulatory scrutiny. Large and very common deficiencies in existing buildings include the disabling of fire door closers through propping the doors open and running rugs through them and perforating fire-resistance rated walls and floors without proper fire stopping.

### **5.5. Fire resistance – concepts & testing**



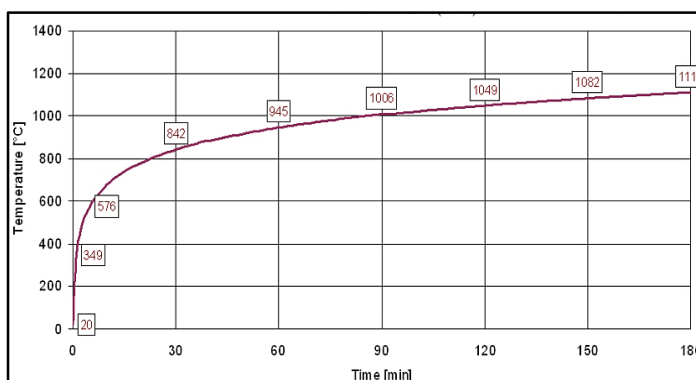
It is important to understand how Fire resistance requirements specified by a code are applied in actual practice. While building fires will mostly follow a similar pattern of growth, steady state burning and decay, these stages will vary in their intensity and duration based on various factors such as fuel load density, ventilation and compartment features. It is, therefore, necessary to have some reference for determining fire resistance, and this is achieved through standard fire tests. Also, as building elements have different functions, the fire resistance tests should represent those functions to the extent possible.

Fire resistance is the property of an assembly, not an individual element, because in real practice, it is the assembly which will be exposed to the effects of a fire and has to perform its desired function. Fire resistance for an assembly is normally obtained by carrying out standard tests in furnaces designed for this purpose.

It is normally measured in terms of time, temperature or strength. The fire resistance of an element of construction is a measure of its ability to withstand the effects of fire in one of the following ways:

- Resistance to collapse i.e. the ability to maintain loadbearing capacity
- Resistance to fire penetration, i.e. an ability to maintain the integrity of the elements
- Resistance to transfer of excessive heat i.e. ability to provide insulation from high temperature.

The standard fire curve is defined in terms of furnace temperature against time. Various such fire curves are in use, with the most common being ISO 834, ASTM E119, BS 476 and in India, IS:3809 (subsequently, ISO 834 has been accepted as the standard



in India as well under BIS collaboration with ISO). The time-temperature relation in these curves is more or less similar with small variations. The curve mentioned above are used for building elements and is known as a 'cellulosic curve' because it represents fuels normally found in buildings, which consist mostly of Class A materials or cellulose based material. Other fire curves can also be used for testing materials/assemblies which are expected to be exposed to other type of fires (such as a hydrocarbon fire in the Oil & Gas industry). Examples are the UL 1709 hydrocarbon curve (for exposure to hydrocarbon



fires), and the ISO 22899-1 curve (for simulating hydrocarbon jet fires as experienced on upstream Oil & Gas facilities).

## 5.6. Construction materials & their behavior in fire

### 5.6.1. Introduction

The construction industry uses a variety of building materials for different aspects of a home build. Architects consult with structural engineers on the load-bearing capabilities of the materials with which they design, and the most common materials are concrete, steel, wood, masonry, and stone. Each has different strength, weight, and durability, which makes it right for various uses. There are national standards and testing methods that govern the use of building materials in the construction industry, so that they can be relied on for providing structural integrity. Architects also choose materials based on cost and aesthetics.

Building materials are usually categorized into two sources: natural and manmade. Materials such as stone and wood are natural, and concrete, masonry, and steel are manmade. But both must be prepared and treated before they're used in building. Here is a list of building materials that are commonly used in construction.

#### Steel

Steel is a metal consisting of alloy of iron, carbon and other alloying material in its composition. Presence of these materials makes it stronger and more fracture-resistant than iron. Stainless steels resists corrosion and oxidation because of the presence of an additional chromium in their make-up. Since it is so strong compared to its weight and size, structural engineers use it for the structural framework of tall modern buildings and large industrial facilities. Some of its qualities are captured below:

- Steel has high strength-to-weight and strength-to-size ratios.
- It is high-cost relative to other metals. Structural engineers can consult on choosing the most cost-effective sizes to use in a house to support the actual load on the building.
- Less time is required for usage/ installation as compared to concrete.
- It can be installed in any environment.
- Steel can be susceptible to corrosion if improperly installed or maintained

Structural steel starts getting affected at temperatures  $> 200^{\circ}\text{C}$ . At this temperature, it begins to soften. It starts losing strength at about  $400^{\circ}\text{C}$  but these effects are reversible on cooling. However, once the temperature exceeds  $500^{\circ}\text{C}$ , permanent loss of strength occurs (at a temperature of about  $540^{\circ}\text{C}$ , the yield strength of steel will drop to approximately 50% of its original, and at  $650^{\circ}\text{C}$ , it will reduce to approximately 30%). These temperatures are common in building fires, and so it is important to protect steel members.



Different factors which determine the behavior of steel members in fire include its mass, temperature (which depends on the severity of the fire), loading on the member. Large size steel columns and girders would take longer to crack as compared to slender members with less mass (as compared to steel, cast iron columns found in old construction as they have good thermal properties).

The most common methods of protecting steel is through the use of an insulating material such as concrete (For example, a steel column encased in 3 inches of concrete would have an approximate fire resistance of 4 hours). However, as concrete increases the weight considerably, and due to aesthetic requirements, structural designers also use other insulating materials such as gypsum boards, sprayed-on cementitious coatings, intumescent coatings, special paints, etc.

## Concrete

Concrete is a composite material made of fine and coarse aggregate (think gravel, crushed stone, recycled concrete, and geosynthetic aggregates) bound together by a liquid binder such as cement that hardens or cures over time. Portland cement is the most common type of cement, and is a fine powder, produced by heating limestone and clay materials in a kiln and adding gypsum. After mixing with water and aggregates, the cement hardens or cures into the stone-like material we think of as concrete. Following points may be noted:

- Strength of concrete varies depending upon the mix. Suppliers to the concrete industry usually provide the materials used for their concrete and test the concrete mix for its strength.
- Concrete can be poured into a form to take virtually any shape and harden into a material similar to stone.



- It takes at least seven days to cure, so engineers and architects must factor in that hardening time when they devise building schedules for concrete construction.
- Its versatility, cost, and strength make it the ideal material for a house foundation. Since it can carry a heavy load and withstand the forces from the surrounding environment, a concrete home foundation is common.
- To increase the tensile strength of concrete, engineers often plan for it to be reinforced with steel rods or bars (rebar).



Concrete in the right mix ratio and properly cured is inherently resistant to the effects of fire, but begins to lose its strength at about 300°C, and has negligible residual strength as temperature exceeds 600°C. In some fires, spalling of concrete occurs -

fragments of concrete break loose from the rest of the concrete, sometimes violently. Spalling is a physical process associated with breakdown of surface layers of concrete when exposed to high temperatures. The concrete crumbles into small pebble-like pieces during spalling, which is believed to occur due to uneven expansion of materials that make up concrete (such as cement, sand, gravel).

Accumulation of water inside concrete to produce steam causes pressures to build (called 'pore' pressure), which also contributes to explosive spalling. Application of cold water to a heated concrete surface during firefighting can also be the cause spalling due to sudden changes in temperature. Spalling reduces the cross sectional area of structural members and hence directly affects its load bearing capacity. It has been observed that a proper cured concrete will spall less as compared to concrete poorly or incompletely cured.

Fire resistance for RCC members depends on factors such the cross-sectional area, and the amount of concrete cover over the reinforcing steel bars. Studies are ongoing with different concrete mixtures and addition of different materials to reduce spalling and



improve their fire resistance (some accepted practices include addition of polymer fibers to the concrete mix and using specific tie techniques for the steel bars).

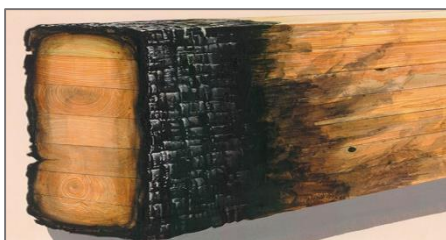
## Wood

Among the oldest, or perhaps the oldest, of building materials, wood has been used for thousands of years and has properties that make it an ideal building material—even in the days of engineered and synthetic materials.

Some tree species are better for some uses and for use in some climates than others. Structural engineers and architects can determine which type of wood is ideal for a construction project.

- It is readily available and an economical natural resource.
- Wood is relatively lightweight and easy to standardize in size.
- It provides good insulation, which is why many architects and engineers like using it for homes and residential buildings.
- Wood has high tensile strength—keeping its strength while bending—and is very strong when being compressed vertically.
- Because it is lightweight and needs to be pressure treated to come into contact with surrounding soil, wood is a less popular choice for foundations or basement walls. More often, wood-framed homes usually have a reinforced concrete or pier and beam foundations.

Wood is combustible and will burn when exposed to a certain temperature. It should be noted that large pieces of wood (generally referred to as ‘lumber’), such as those used for columns do not burn easily. This is because when wood burns it develops a layer of ‘char’ at the surface, which insulates the inner layers of wood from the heat and prevents further burning. Wood can be treated to improve its fire resisting properties; the methods used include pressure impregnation and coating



the surface of the wood with suitable chemicals (ammonium phosphate, ammonium sulfate, boric acid, zinc chloride, etc.). Due to aesthetic requirements, many new surface coatings in different





shades/ colors have been developed in the recent past and are available in the market.

## Stone

This long lasting building material has been there for thousands of years. In fact, the most ancient buildings still in existence in the world are made of stone. It has many advantages, though engineers and architects must make some special considerations when planning a building using stone:

- Dry stone walls made of dense rock have been used for thousands of years. Different forms of mortar were later used to hold them together.
- Stone can be difficult to work with because of its weight and the difficulty in moving it.
- Stone is not an efficient insulator, since it is difficult to heat it.
- Various stone types are best for different uses. For instance, slate is fire-resistant. Granite is one of the hardest stones and one of the most durable products available; the Incas used limestone or granite to build their incredibly strong buildings.



## Brick/ masonry

Masonry construction uses individual units (such as bricks) to build structures that are usually bound together by some kind of mortar. Historically, clay bricks were formed in a mold and kiln-fired. The strongest and most commonly used masonry unit now is a concrete block, which may be reinforced with steel. Glass, brick, and stone can all be used in a masonry structure.

- Masonry is durable and fire-resistant.
- This method of construction is able to resist compression loads, which makes it a good material for load-bearing walls.
- Reinforced with concrete, or in combination with reinforced concrete, masonry can support multi-story buildings, and can be an economical choice.
- While it is a strong method to use in many types of construction, lasting masonry installation can depend on the quality of mortar and workmanship.

While masonry is resistant to fire, sustained exposure to high temperatures from a fire results in a loss of compressive strength. As masonry walls are normally covered by a layer



of concrete plaster, these are subject to spalling in event of a fire. Unequal thermal expansion of the two faces of a wall can cause cracking and separating of the layers of masonry. All types of masonry give much better performance if plaster is applied, which improves insulation and reduces thermal shock. Therefore, fire resistance is directly proportional to thickness of layer provided on the masonry wall, hence increasing thickness is an accepted practice for increasing fire resistance.

### **Glazing**

Glazing though not used for structural purpose, has been in use in buildings for at least the past two centuries in buildings, especially where the transmission of light was desirable, or for aesthetic purposes, and its use continues in modern construction. In fact, its use is now increasing with applications such as exterior curtain walls for buildings. Glass is a brittle material and shatters when it is struck. This property is useful for firefighting as it is easy to ventilate by breaking glass members.

While glass is non-combustible, it is not fire resistive. When heated due to a fire, internal thermal stresses develop because of increasing temperature and cause the glass to shatter. This allows the passage of heat and smoke from the area of fire origin to other areas. Openings created by shattering of glass allow hot combustion gases to travel outside and burn there, and these flames can ignite materials on floors above the fire floor (known as a leapfrogging effect). To prevent shattering of glass, two types of glass are used for improving its fire resistance – wired glass (made by rolling a mesh of wires into the glass) and fire rated glass (made from a combination of glass and plastic). It has been observed that in many cases, the framing fails before the glass, causing the glass to fall out and shatter due to impact).

## **5.7. Protecting steel members**

As unprotected steel members perform poorly when exposed to fire, it is important to protect them using suitable methods:

### **Concrete**

The member is encased with concrete using normal cement or modified fire-resistant cements; both dense & lightweight concretes are used. These are capable of withstanding direct flame impingement up to 2000°F (1100°C). The disadvantage is, of course, the



substantial increase in weight of the structure. Another problem, especially in chemical, corrosive and marine environments, is the separation of the concrete cover due to corrosion

### **Board encasement**

Another common method of protecting steel members. Materials used for board encasement include gypsum board, mineral fiber, vermiculite-sodium silicate board, and reinforced calcium silicate board. They are fixed to steel work using screws, straps and/or galvanized angles; remember that the attachment of the boards around a member is critical for the performance of the assembly and has to be done as per specified procedures.

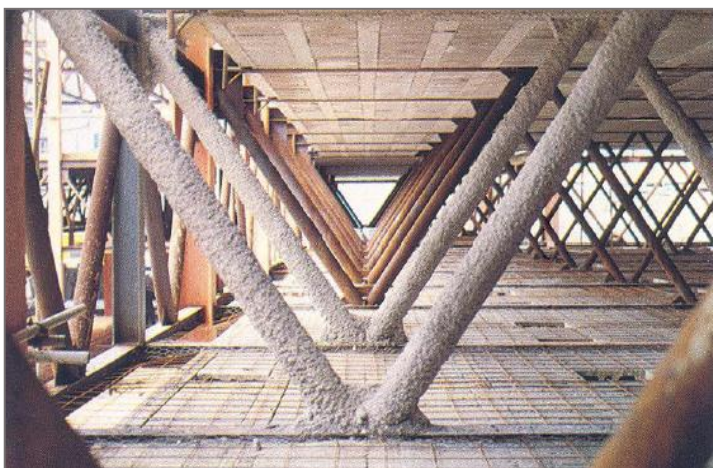
### **Spray-applied materials**

Lightweight materials, mainly 2 classes i.e. those based upon vermiculite plus binder, and others based on mineral fibers. The protective layer is directly applied to the steel surface and follows its profile; can be sprayed on or troweled. They are particularly suitable for members which are generally concealed by suspended ceiling or facades; However, surface preparation is important, and they have not been found very effective in high moisture/humid environments.

### **Intumescent coatings**

These have become very popular in the past 2 decades and can be water, solvent, or epoxy based. 'These coatings intumesce, or swell, when heated, thus forming an insulation around the steel and protecting it. However, it should be noted that prolonged exposure to flame can destroy this char coating'. Thin film coatings are typically used in building structural steel, while thick-film coatings tend to find use in industrial and harsh applications. Protective coatings may be applied over intumescent coating for harsh environments or for aesthetics (however these need to be checked with manufacturer and certification bodies). It is a relatively fast to apply, and ideal for indoor applications but control is required for film thickness so skilled manpower is required.

Different types of steel protective methods shown below -



## **Chapter 6:**

# **Gujarat Fire Safety Legislation & Enforcement**





## 6. Gujarat Fire Safety Legislation & Enforcement

### 6.1. The Gujarat Fire Prevention and Life Safety Measures Act, 2013

State Government enacted the Gujarat Fire Prevention and Life Safety Measures Act in 2013. The Act provides to make effective provisions for fire prevention, safety and protection of life and property, in various types of buildings and temporary structures or *shamiyana* or tents or mandap likely to cause a risk of fire in different areas in the State of Gujarat.

Salient features of the Act are mentioned below:

#### 6.1.1. Organization, Superintendence, Control and Maintenance of Fire Service

##### **One fire service for whole of State.**

1. There shall be one State fire service for the whole of the State and all officers and subordinate ranks of the fire service shall be liable for the posting to any office of the fire service:

Provided that, the State Government may, by notification in the *Official Gazette*, declare any Fire Brigade or any other Local Fire Service of any local authority of the State, by whatever name called, that the same shall form or shall not form the part of State Fire Service at any time:

Provided further that, this provision shall not apply to the private fire services maintained for providing fire protection coverage to specific building or industry by the owner or occupier thereof.

2. Notwithstanding anything contained in this Act or any other law for the time being in force relating to the local authorities, the State Government may, by notification in the *Official Gazette*, declare the services relating to any fire brigade or fire prevention a part of State Fire Service with effect from such date as may be specified in the notification.
3. Upon such declaration under sub-section (2),-
  - i. the officers and employees responsible for providing the fire services in the areas of such local authority, shall be deemed to have been absorbed in the State Fire Service, subject to such terms and conditions as may be notified;
  - ii. terms and conditions applicable to the employees after such absorption shall be such as may be decided by the State Government,





- iii. all proceeding pending before any fire officer, immediately before the declaration, be deemed to be proceeding pending before him in his capacity as the holder of the office to which he is deemed to be appointed under sub-clause (2), One fire service for whole of State.
- iv. all assets, rights and liabilities relating to the fire services of such local authorities shall stand transferred to the State Fire Service, subject to such terms and conditions as the State Government may deem fit,
- v. the State Government may take such necessary actions as it deems fit.

#### **4. Superintendence of Fire Service to vest in State.**

The superintendence of, and control over, the Fire Service throughout the State shall vest in the State Government and the Fire Service shall be administered by the State Government in accordance with the provisions of this Act and of any rules made thereunder through such fire officers as the State Government may, from time to time, appoint in this behalf.

#### **5. Constitution and classification of Fire Service.**

- (1) Subject to the provisions of this Act, the State fire service shall consist of such number of staff in several ranks and have such organization and have such powers, functions and duties as the State Government may, by general or special order, determine.
- (2) The State Government may prescribe by rules, -
  - (a) the different posts of the State Fire Service;
  - (b) the mode of recruitment of staff, grade of post, the qualification, pay, allowances and other conditions of service of the officers and other staff engaged therein, and matters connected therewith;
- (3) The State Government may, by notification in the *Official Gazette*, review the existing pattern of the existing different fire services in the State and if deem fit may modify:

Provided that, for local fire services the rules framed under this subsection may not include mode of recruitment of staff, pay, allowances and matters connected therewith.
- (4) Save as otherwise provided by or under this Act, every person holding office either as a Chief Fire Officer or Fire Officer or staff or an employee (by whatever designation called) on an existing Fire Brigade or Fire Service of any authority on





the date immediately before the commencement of this Act shall continue to hold office on the same terms and conditions as were applicable to him immediately before such date and shall exercise such powers and perform such duties as before and in addition to those as are conferred on them by or under this Act.

## **6. Appointment of Director.**

- (1) The State Government shall appoint a person to be the Director and such other officers and staff as may be necessary from time to time to assist the Director while exercising the powers or discharging the duties or functions conferred under this Act or the rules made thereunder.
- (2) The jurisdiction of the Director so appointed shall extend to the entire State in matters relating to fire services.
- (3) Subject to the control, directions and superintendence of the State Government, the Director shall exercise such powers and perform such duties as are conferred and imposed upon him by this Act or the rules made thereunder.

## **7. Powers, duties and functions of Director.**

- (1) Without prejudice to the provisions of sub-section (3) of section 6, the Director shall,
  - 
  - (i) function as the Head of Department in the office of the Director;
  - (ii) subject to the rules made in this behalf, the Director may appoint subordinate staff only on the recommendations of the Gujarat State Subordinate Services Selection Board on such terms and conditions of salaries and allowances as may be fixed by the State Government;
  - (iii) keep liaison with the Central Government and the State Government offices for the development of fire services;
  - (iv) frame the policies in relation to the development of fire services in the State and, on approval by the State Government, take steps to implement the same;
  - (v) exercise superintendence and control over all authorities in the matters relating to fire prevention and fire safety measures; and subject to the approval of the State Government, issue such directions to any authority in respect of fire services maintained or required to be maintained by them;
  - (vi) represent the State Government on National and International forums with a view to updating the standard of fire services in the State;



- (vii) prepare and submit plans and proposals to the State Government with regard to the periodical review of fire equipment, fire property and fire manpower for effective implementation of fire services by the authorities;
  - (viii) take or cause to be taken such effective steps and measures in cases of major fires, house collapse and other emergency services;
  - (ix) investigate or cause to be investigated the cause of fire and advise the authorities for implementing fire precautionary measures;
  - (x) advise the State Government to set up additional Fire Training Centre or Centres for imparting training to the officers and staff of local authorities so as also to cater to the need of the various factories, commercial and mercantile establishments in the private sector and to impart training to officers and the staff or to provide them the trained and qualified fire service personnel;
  - (xi) requisite fire-fighting equipment of any authority or any institution or individual, which in his opinion is required for the purpose of extinguishing fire in any area ; and to determine the amount of compensation payable in respect of such equipment of in the area of which authority, such fire operation is required to be carried out;
  - (xii) exercise such other powers and perform such other duties and functions as may be conferred, imposed or allotted to him by or under the provisions of this Act.
- (2) The Director, with the approval of the State Government, direct and regulate all matters of firefighting equipment, machinery and appliances, training, observation of persons and events mutual relations, distribution of duties, study of laws, orders and modes of proceedings and all matters of executive detail or the fulfillment of duties and maintenance of discipline of fire officers and members of the Fire Service under him.
- (3) The Director shall appoint such number of officers and employees as may be necessary to assist any Fire Officer of the State Fire Services, while exercising his powers or discharging his duties or functions under this Act or the rules made there under.
- (4) When the Director is informed, on a complaint made or otherwise that default has been made in the performance of any duty imposed on an authority by or under this Act or by or under any enactment in relation to firefighting measures or operations for the time being in force, the Director, if satisfied after due inquiry, that the alleged



default has been made, may, by order, fix a period for the performance of that duty and communicate such order to the authority.

- (5) If the duty is not performed within the period so fixed, the Director may appoint such other person to perform it, and may direct that the expenses of performing it, with a reasonable remuneration to the person appointed to perform it, shall be forthwith paid by the person or the authority, as the case may be.
- (6) If the expense and remuneration are not so paid, the Director may make an order directing the bank in which any moneys of the person or the authority are deposited or the person in-charge of the local Government Treasury or of any other place of security in which the moneys of the authority are deposited, to pay such expenses and remuneration from such moneys as may be standing to the credit of the authority in such bank or may be in the hands of such person or as may, from time to time, be received from or on behalf of the authority by way of deposit by such bank or person, and such bank or person shall be bound to obey such order. Every payment made pursuant to such order shall be a sufficient discharge to such bank or person from all liability to the authority in respect of any sum or sums so paid by it or him out of the moneys of the authority so deposited with such bank or person.
- (7) The Director or any Fire Officer, authorized by general or special order in this behalf, may, for the purpose of discharging his duties under this Act, require the owner or occupier of any building or other property as may be specified to supply information with respect to the character of such building or other property as may be specified, the available water supplies and means of access thereto, any other material particulars, and such owner or occupier shall furnish all the information in his possession.
- (8) The Director may, with the previous sanction of the State Government, enter into an agreement with any fire service or the authority which maintains the said fire service, beyond the limits of any area in which this Act is in force for providing personnel of equipment or both, for firefighting purpose on such terms and conditions as may be provided by or under the agreement on reciprocal basis in public interest.
- (9) The Director may, with the previous sanction of the State Government, enter into arrangements with any person or organization who employs and maintains personnel or equipment or both, for firefighting purposes, to secure, on such terms as to payment or otherwise as may be provided by or under the arrangements, the provision



by that person or organization for assistance for the purpose of dealing with fire occurring in any area in which this Act is in force.

## **8. Constitution of fire region.**

- (1) For the purpose of providing adequate number of officers and staff for meeting the needs of fire services, having regard to the population, potential fire hazards in certain industries and large commercial and mercantile establishments and buildings and the number of fire stations required to be provided for and maintained, the State Government may, for the purpose of securing fire prevention and life safety measures within the State, by notification in the *Official Gazette*, constitute as many fire regions as it deems fit.
- (2) Every notification issued under sub-section (1) shall define the limits of the region to which it relates.
- (3) The State Government shall, for each fire region, appoint a person to be the Regional Fire Officer.
- (4) Subject to the control, direction and superintendence of the Director, the Regional Fire Officer, shall exercise such powers and perform such duties as are conferred and imposed upon him by this Act or the rules made thereunder, or orders issued in this behalf.
- (5) Without prejudice to the provisions of sub-section (4), the Regional Fire Officer shall,  
-
  - (i) function as the Head of the Fire region;
  - (ii) prepare the fire management plan for the region.
- (6) The qualifications for appointment and other conditions of service of the Officer, appointed under sub-section (3) shall be such as may be prescribed.

## **9. Division of fire region into fire divisions.**

The State Government may, by notification in the *Official Gazette*, divide each fire region into such fire divisions as may be specified in the notification. The fire divisions may comprise of the area of one or more local authority. The fire division may also be further divided into fire stations and define their boundaries as may be necessary for administrative and operational efficiency.

## **10. Appointment of Fire Officers.**

- (1) For the purposes of this Act, the State Government may appoint, for each,-
  - (a) fire division, a person as the Divisional Fire Officer,



- (b) fire station, a person as the Station Fire Officer.
- (2) The qualifications for appointment and other conditions of service of the Officers, appointed under sub-section (1) shall be such as may be prescribed.
- (3) For the purposes of this Act, the State Government may for each Local Fire Services,-
  - (a) classify the category of Chief Fire Officer taking into consideration the population and class of local authority or authority or such other factors as may be prescribed;
  - (b) prescribe the norms and qualifications of each category of Chief Fire Officer;
- (4) Subject to sub-section (3), the State Government may by an order direct the local authority or the authority, as the case may be, to appoint a person to be the Chief Fire Officer.

## **11. Powers, duties and functions of Fire Officers.**

- (1) Subject to the control, directions and superintendence of the Director, the Regional Fire Officer or the Chief Fire Officer appointed under sub-section (3) of section 8 and under section 10 respectively, shall exercise such powers and perform such duties as are conferred and imposed upon him by this Act or rules or orders made thereunder.
- (2) Without prejudice to the provisions of sub-section (1), in case of fire prevention and disaster, the Regional Fire Officer or the Chief Fire Officer, as the case may be, for their jurisdiction shall in case of any fire or emergency act as commanding officer for that event and all other fire services engaged shall work under him.
- (3) Without prejudice to the provisions of sub-sections (1) and (2), the Regional Fire Officer or the Chief fire officer, as the case may be, shall for their jurisdiction, be the head of the office.

## **12. Appointment of Fire Safety Officer.**

- (1) To ensure the effective operation of fire prevention and life safety measures in good repair and efficient condition in the buildings or premises as may be prescribed, the owner and occupier or occupiers individually or jointly, as the case may be, at least two months prior to expiry of fire safety certificate issued under section 21, shall appoint a fire safety officer, for renewal of such fire safety certificate, having qualification and experience and duties to be performed as may be prescribed;
- (2) The owner and occupier or occupiers, individually or jointly, as the case may be shall appoint fire safety officer from the list of fire safety officers enrolled by the Director.



- (3) In case of a vacancy of the fire safety officer appointed under sub-section (1), either on resignation or otherwise, the owner and occupier or occupiers individually or jointly, as the case maybe, shall be required to immediately appoint the fire safety officer.
- (4) In case of non-appointment of the fire safety officer, as envisaged under sub-section (1), the Regional Fire Officer or the Chief Fire Officer, as the case may be, may take such steps as he deems necessary.

### **6.1.2. Requisition, Compensation for Fire Equipment**

#### **13. Requisition of firefighting property.**

- (1) Where, the Director or the Regional Fire Officer or the Chief Fire Officer or any other Fire Officer of any authority, who is in-charge of a fire fighting operation requires firefighting equipment or property of any other authority or any institution or individual, he may order requisition of such equipment or property for the purpose of extinguishing fire in any area and take possession thereof from the authority or any institution or individual, as the case may be.
- (2) As soon as may be, after the firefighting operations are over, such officer shall release the equipment or property, taken possession of by requisition under sub-section (1) and restore the same to the authority, institution or individual from whose possession such property was taken.
- (3) Where any firefighting equipment or property is requisitioned under sub-section (1), there shall be paid to the owner of such property, compensation the amount of which shall be determined in accordance with the principles hereinafter set out, that is to say,-
  - a) where the amount of compensation can be fixed by agreement between the Director or, as the case may be, the Chief Fire Officer and the owner of the firefighting property, it shall be paid in accordance with such agreement;
  - b) where no such agreement can be reached, the Director or, as the case may be, the Chief Fire Officer shall refer the matter to the District Magistrate having jurisdiction over the area in which the firefighting equipment or property was kept, used or procured and the Magistrate shall, after hearing the parties and such other persons as he deems necessary, fix the amount of compensation taking into consideration the rent which the firefighting equipment or property would normally fetch if rented out for a similar purpose. The orders of the District Magistrate fixing the amount of compensation shall be final.



#### **14. Functions in case of fire.**

- (1) In case of any fire in any area, the Director or the Regional Fire Officer or the Chief Fire Officer or any other Fire Officer who is in-charge of firefighting operations on the spot may,-
- a) remove, or order any other fire officer or fire personnel to remove, any person who by his presence, interferes with or impedes the operations for extinguishing the fire or for saving life or property;
  - b) close any street or passage in or near which fire has taken place;
  - c) break into or through, or pull down, any premises, for the passage of hose or appliances or cause them to be broken into or through, or pulled down, doing as little damage as possible for the purpose of extinguishing fire:  
Provided that, the owner or occupier, as the case may be, of any such premises shall be paid reasonable compensation to the extent of the damage so caused in such manner as may be prescribed;
  - d) require the authority in-charge of water supply in the area to regulate the water mains so as to provide water at a specified pressure at the place where the fire has broken out and utilize the water of any stream, cistern, well or tank or of any available source of water, public or private, for the purpose of extinguishing or limiting the spread of such fire;
  - e) exercise, in the absence of aid from the police, the same powers for dispersing an assembly of persons likely to obstruct the firefighting operations as if he were an officer-in-charge of a police station;
  - f) generally, take such measures as may appear to be necessary for extinguishing the fire or for the protection of life or property.
- (2) Any damage cause to any premises or property, due to fire, by members of the fire service in the discharge of their duties shall be deemed to be damage by fire within the meaning of any policy of insurance against fire.

#### **15. Power to arrange supply of water.**

It shall be lawful for the officer-in-charge of the firefighting operations to draw water from any source in the area which he considers necessary for such operations and on such occasions as may be required and the authority or owner or occupier having control over such water source shall supply water for that purpose at such rates as may be prescribed.

#### **16. Power to enter into agreement.**





Notwithstanding anything contained in section 14, the Regional Fire Officer or the Chief Fire Officer of any authority or any other officer authorized in this behalf, may enter into agreement with any person who employs and maintains personnel or equipment or both for fire-fighting purposes, to secure, on such terms as may be prescribed, for the purpose of dealing with fires occurring in any area.

### **6.1.3. Training to Fire Personnel and Fire Safety Officers**

#### **17. Training.**

- (1) The State Government may establish and maintain training centres in the State for providing courses of instruction in the prevention and extinguishment of fire for the personnel of any Fire Service and private services of industries, hotels, multi-storied buildings and such other Government and non-Government establishments as which the State Government may specify.
- (2) The State Government may extend the training facilities at such centres to be established under sub-section (1) to the fire service under the control of local bodies and industrial undertakings on payment of fees as may be prescribed.
- (3) The State Government may prescribe such fee and such procedure as it may deem fit for providing a course of instruction in the prevention and extinguishment of fire.

#### **17 A. Fire Safety officers to undergo training.**

- (1) The Fire Safety Officers shall undergo training as may be prescribed.
- (2) The State Government may prescribe such fees and such procedure as it may deem fit for providing training mentioned in sub-section (1).”.

### **6.1.4. Provisions Relating to Fire Prevention and Life Safety Measures**

#### **18. Requirement for fire prevention and life safety measures.**

- (1) Without prejudice to the provisions of any other law or the rules, GDCR or building bye-laws made thereunder or the National Building Code of India, relating to fire prevention and life safety measures as in operation in the State for the time being in force, housing society or the owner or where the owner is not traceable, the occupier, who are either individually or jointly responsible, of a building as classified by regulations or part thereof, shall provide fire prevention and life safety measures therein:

Provided that the owner or the occupier, as the case may be, shall, -

- (i) provide minimum firefighting and life safety installations as provided in the regulations;



(ii) maintain the fire prevention and life safety measures in operational condition at all times, in the manner and specifications specified in regulations.

(2) The regulations so made shall be notified in the *Official Gazette*.

## **19. Manner of compliance for prevention and life safety measures.**

(1) Notwithstanding anything contained in any other law for the time being in force, -  
a) no authority empowered to issue the Building Use certificate, shall issue the same, unless it is satisfied that the owner or the occupier, either individually or jointly, has complied with the provisions of section 18 and has obtained a fire safety certificate;

b) in case of building or part thereof, on the date of commencement of this Act, where development permission is issued and construction is not commenced or the construction is commenced but not completed or the construction is completed but occupancy certificate is not issued, and where the housing society or the owner or the occupier, individually or jointly liable, as the case may be, is required to comply the provisions of section 18, the Regional Fire Officer or the Chief Fire Officer, as the case may be, shall either suo moto or otherwise serve on the owner or occupier, as the case may be, a notice in the manner as may be prescribed and direct him to undertake and carryout fire prevention and life safety measures, as deemed necessary, within two months from the commencement of this Act, or within such period or periods as may be extended by the State Government by order in writing:

Provided that any owner or the occupier, as the case may be, who has been served with the notice under clause (b) or not, may undertake and carryout fire prevention and life safety measures, as required to be complied under the provisions of section 18 or as mentioned in the notice issued by the Regional Fire Officer or the Chief Fire Officer or the nominated officer, as the case may be, for getting fire safety certificate.

(2) The owner or the occupier, individually or jointly, as the case may be, shall inform to the Regional Fire Officer or the Chief Fire Officer or the nominated officer, about the compliance with respect to sub-section (1).

(3) The owners or occupiers, as the case may be, who are liable individually or jointly, for the building or part thereof, shall furnish to the Regional Fire Officer or the Chief Fire Officer or the nominated officer, a certificate regarding the compliance of the



fire prevention and life safety measures as required under the provisions of section 18 issued by a Licensed Agency.

**20. Consequences for non-compliance of section 19.**

The owners or occupiers, as the case may be, individually or jointly, who are liable to provide fire protection and life safety measures in building or part of building or premises, who, at any time, fail to comply with regard to sub-section (1) of section 19, shall be deemed to be in default. In case, where a fire safety certificate is issued earlier shall remain suspended for a period from the date of the notice for non-compliance issued by the Regional Fire Officer or the Chief Fire Officer or nominated officer and till the date compliance is made to the satisfaction of the Regional Fire Officer or the Chief Fire officer or nominated officer, as the case may be, and the same shall be duly recorded on the fire safety certificate.

**21. Issuance and cancellation of fire safety certificate.**

- (1) The Regional Fire Officer or the Chief Fire Officer or the nominated officer, as the case may be, may scrutinize the compliances, with regard to the requirement of section 18, made by the owners or the occupiers, as the case may be, either independently or jointly, may after making necessary inquiry, if any, issue fire safety certificate.
- (2) If the owner or occupier, as the case may be, fails to comply with the directions issued by the Regional Fire Officer or the Chief Fire Officer or the nominated officer, the fire safety certificate, issued under sub-section (1) shall be cancelled after giving owner or occupier an opportunity of hearing to show- cause.
- (3) The owner or occupier of the building or premises whose fire safety certificate has been cancelled due to default on his part, shall not be entitled to occupy the building or premises on the ground of non-compliance of fire prevention and life safety measures under section 18.
- (4) No person shall tamper with, alter, remove or cause any injury or damage to any fire prevention and life safety equipment installed in any such building or part thereof or instigate any other person to do so.
- (5) The fire safety officer, with regard to the requirement of section 18, shall check the maintenance and operational condition of fire prevention and life safety measures as specified in the regulations and on satisfaction that these are in good repair and efficient operational condition, may issue the fire safety certificate renewal

**22. Safety Measures for fire hazardous materials.**



- (1) The State Government may, by notification in the Official Gazette, frame the regulations in respect of categorization of fire hazardous materials, trade and premises used for such purposes.
- (2) Upon issuances of notification under sub-section (1) it shall be lawful for the Director or the Regional Fire Officer or the Chief Fire Officer or the nominated officer or any fire officer authorized either by the Director or the Regional Fire Officer or the Chief Fire Officer to direct the removal of objects or goods likely to cause the risk of fire, to a place of safety and on failure by the owner or occupier to do so, the Director or the Regional Fire Officer or the Chief Fire Officer or fire officer may, after giving the owner or occupier a reasonable opportunity of making the representation, seize, detain or remove such objects or goods. The opportunity of representation as aforesaid may be dispensed with to avoid an imminent or alarming foreseeable risk of fire.

**23. Assistance of police in fire prevention and firefighting operation.**

In firefighting operations or any other duties relating to seizure, detention or removal of any goods involving risk of fire, it shall be the duty of a police officer or members of the police force to assist and aid to the Director or such fire officer in performance of such duties under this Act.

**24. Power to entry and inspect.**

- (1) The Director or the Regional Fire Officer or the Chief Fire Officer or the Nominated Officer may, after giving three hours' notice to the housing society or occupier or if there is no occupier, to the owner of any place or building or part thereof, as the case may be, enter and inspect such place or building or part thereof at any time between sunrise and sunset where such inspection appears necessary for ascertaining the adequacy or contravention of fire prevention and life safety measures:  
Provided that, the Director or the Regional Fire Officer or the Chief Fire Officer or the Nominated Officer may enter into and inspect any such place or building or part thereof at any time if an industry is working or an entertainment or function is going on at such place, building or part thereof, or if it appears to him to be expedient and necessary to do so in order to ensure safety of life and property.
- (2) The Director or the Regional Fire Officer or the Chief Fire Officer or the Nominated Officer shall be provided with all possible assistance by the owner or occupier, as the case may be, of such place or building or part thereof for carrying out the inspection under sub-section (1).



- (3) The owner or occupier or any other person shall not obstruct or cause any obstruction to the entry of a person empowered or authorized under this section into or upon any land or building or shall not molest such person after such entry for inspection.
- (4) When any such place or building or part thereof used as a human dwelling is entered under sub-section (1), due regard shall be paid to the social and religious sentiments of the occupiers; and before any flat, apartment or a part of such building in the actual occupancy of any woman, who, according to the custom does not appear in public, is entered under sub-section (1), notice shall be given to her that she is at liberty to withdraw, and every reasonable facility shall be afforded to her for withdrawing.
- (5) Where the inspection is carried out by the Nominated Officer under the preceding provisions of this section, he shall give a report of such inspection to the Director or the Regional Fire Officer or the Chief Fire Officer of the authority concerned.

## **25. Steps to be taken for non-compliance of notice.**

- (1) Without prejudice to the prosecution for an offence of non-compliance of the notice issued under clause (b) of sub-section (1) of section 19, the Director or the Regional Fire Officer or the Chief Fire Officer may, in the event of non-compliance of any such notice, take such steps including exercising the power to have the place, building or any part thereof sealed and / or disconnected facilities of water, power and drainage under section 26, as may be necessary for the compliance of such notice.
- (2) All expenses incurred by the Director or the Regional Fire Officer or the Chief Fire Officer in relation to any steps taken by him under sub-section (1) shall be payable on demand, by the owner or occupier on whom such notice is served, and shall, if not paid within fifteen days after such demand be recoverable, as if it were the arrears of tax on property and the provisions under the relevant law or any other law for the time being in force and is in operation within the area of jurisdiction of the local authority concerned for recovery of arrears of tax on property, shall apply mutatis mutandis for such recovery as they apply to the recovery of arrears of tax on property or where any such law is not in operation then, as an arrears of land revenue.

## **26. Evacuation and power to seal.**

- (1) If the Director or the Regional Fire Officer or the Chief Fire Officer is satisfied that due to inadequacy of fire prevention and life safety measures the condition of any place or building or part thereof is in imminent danger to person or property, then notwithstanding anything contained in this Act, or any other law for the time being in force, he shall, by order in writing, require the persons in possession or in



- occupation of such place or building or part thereof to remove themselves forthwith from such place or building or part thereof.
- (2) If an order made by the Director or the Regional Fire Officer or the Chief Fire Officer under sub-section (1) is not complied with, he may direct, -
    - a) the authority responsible for supply of electricity or supply of water, to disconnect the supply of electricity or water, as the case may be;
    - b) any police officer having jurisdiction in the area, to remove such persons from such place or building or part thereof and such authority or police officer shall comply with such directions.
  - (3) After the removal of the persons under sub-section (1) or sub-section (2), as the case may be, the Director or the Regional Fire Officer or the Chief Fire Officer shall cause such place or building or part thereof, to be sealed by such police officer forthwith.
  - (4) No person shall remove such seal except under a written order made by the Director or the Regional Fire Officer or the Chief Fire Officer suo motu or on an application of the owner or occupier.

#### **6.1.5. Provisions for Temporary Structures**

#### **27. Provisions for temporary structures.**

- (1) The State Government may by notification in the Official Gazette, declare any class of temporary occupancy such as a mandap, shamiyana or tents or such other temporary structures for hosting any event, which, in its opinion, is likely to cause a risk of fire.
- (2) The measures for fire prevention and life safety to be taken by the promoter, organizer, owner or occupier of such premises where such temporary structures are likely to take place or the erectors of temporary structures or shamiyana or tents or mandap, as the case may be, shall be such as may be prescribed.
- (3) The Regional Fire Officer or the Chief Fire Officer or the Nominated Officer may grant permission for the use of the temporary structures or shamiyana or tents or mandap, as the case may be, ensuring an undertaking in the prescribed form is given by the promoter, organizer, owner or occupier.
- (4) The Director or the Regional Fire Officer or the Chief Fire Officer or the Nominated Officer may enter and inspect any temporary structure about the correctness of the declaration and may point out the inadequacy, if any, with a direction to comply within a specified time.



- (5) If the directions of the inspecting officer are not complied with within the time so given, the inspecting officer may seal the temporary structure or shamiyana or tents or mandap or dismantle such structure and the costs incurred therefore shall be recovered from such defaulter.
- (6) The Regional Fire Officer or the Chief Fire Officer or any officer authorized by him in this behalf shall direct the removal of encroachments or objects or goods likely to cause a risk of fire or any obstruction to firefighting, to a place of safety, and on failure of the owner, occupier or erector, as the case may be, to do so, he may, after giving the owner or occupier or erector, as the case may be, a reasonable opportunity of making representation, report the matter to the Sub-Divisional Magistrate, in whose jurisdiction the premises or temporary structure or shamiyana or tents or mandap is situated, requesting to adjudicate the matter:  
Provided that where the Regional Fire Officer or the Chief Fire Officer considers such encroachments or objects or goods to be an imminent cause of risk of fire or obstruction to firefighting, he may direct the owner or the occupier or erector of such premises or building to remove the encroachments or objects or goods forthwith and report the matter to the Sub-Divisional Magistrate accordingly.
- (7) On receipt of a report under sub-section (6), the Sub-Divisional Magistrate may make an order to seize, detain or remove such encroachment; or objects or goods likely to cause a risk of fire or obstruction to firefighting.
- (8) The person charged with the execution of the order made under subsection (7), shall forthwith make an inventory of the objects and goods which he seizes under such order, and shall, at the same time, give a written notice as may be prescribed in this behalf, to the person in possession thereof at the time of seizure, that the said objects or goods shall be sold as mentioned in the order as if the same are not claimed within the stipulated time specified in the notice.
- (9) On the failure of the person in whose possession the objects or goods were at the time of seizure to claim the seized goods pursuant to notice given under sub-section (8), the Sub-Divisional Magistrate shall sell them by public auction.
- (10) Any person aggrieved by a notice or order of the Sub-Divisional Magistrate under sub-section (8) may, within thirty days from the date of such order, prefer an appeal to the Director:





Provided that the Director may entertain an appeal after the expiry of the said period of thirty days if he is satisfied that there was sufficient cause for not filing the appeal within prescribed period.

- (11) An appeal to the Director shall be made in such form and shall be accompanied with a copy of the notice or the order appealed against and with such fees as may be prescribed and the order passed by him shall be final.

#### **6.1.6. Licensed Agency**

### **28. Licensed Agency.**

- (1) The Director may grant a license to a person or association of persons as he thinks fit, to act as a Licensed Agency for the purposes of this Act.
- (2) Any person intending to have or renew such license shall apply to the Director in the prescribed form and in the prescribed manner along with such fee as may be prescribed.
- (3) On receipt of an application made under sub-section (2), the Director may, after holding such inquiry as he deems fit, either grant the license in the prescribed form for a period of two years or renew the same for a like period or, for reasons to be recorded in writing, by order refuse to grant or renew the license.
- (4) Where the Director has reason to believe that any person to whom a license has been granted has contravened any of the provisions of this Act or of the rules or has failed to comply with the conditions of the license or is unfit by reason of incompetency, misconduct or any other grave reasons, the Director may, after giving to the person a reasonable opportunity to show cause, for reasons to be recorded in writing, by order suspend or cancel the license.

### **29. Work to be carried out by the Licensed Agency.**

- (1) No person other than a Licensed Agency shall carry out the work of providing fire prevention and life safety measures or performing such other related activities required to be carried out in any place or building or part thereof:

Provided that, if the Regional Fire Officer or the Chief Fire Officer is satisfied that, for any reason, to be recorded in writing, the owner or occupier is not able to carry out the fire prevention and fire safety measures in any such place or building or part thereof through a Licensed Agency, the Regional Fire Officer or the Chief Fire Officer may, with the approval of the Director, authorize any other licensed agency



to carry out such work. The cost for the work carried out shall be recovered from the owner or the occupier, as the case may be.

- (2) The Licensed Agency shall give a certificate under sub-section (3) of section 19 as to the compliance of the fire prevention and life safety measures or maintenance thereof unless without there being actual compliance or maintenance as specified in the regulations.

#### **6.1.7. Levy of Fire Fee and Other Charges**

##### **30. Levy of fire fees.**

- (1) For the purpose of providing for the cost of fire prevention and life safety services in the State, the State Government may levy and collect a fire fees on lands and buildings which are situated in any area in which this Act is in force notwithstanding any declaration made under proviso to sub-section (1) of section 3.
- (2) The fire fees shall be levied at such rate in terms of percentage of such property tax as the State Government may, by notification in the Official Gazette, determine from time to time:

Provided that, the State Government may determine different rate of percentage for different areas or different local authority or authorities.

##### **31. Mode of assessment, collection, etc. of fire fees.**

- (1) The authorities empowered to assess, collect and enforce payment of property tax under the relevant law authorizing the local authority of the area to levy such tax shall, on behalf of the State Government and subject to any rules made under this Act, assess, collect and enforce payment of the fire fee in the same manner as the property tax is assessed, paid and collected and for this purpose, and may exercise all or any of the powers conferred on them under the relevant law and the provisions of such law including provisions relating to return, appeals, reviews, reference and penalties shall apply accordingly.
- (2) Such portion of the total proceeds of the fire fees as the Government may determine shall be deducted to meet the cost of collection of the fire fee.

##### **32. Constitution of fund.**

- (1) There shall be constituted a fund to be known as "Fire Prevention and Life Safety Fund".
- (2) The proceeds of fire fees and penalties (other than fines) recovered under this Act, shall first be credited to the Consolidated Fund of the State and after deduction of the expenses of collection and recovery therefrom, under appropriation duly made by



law in this behalf, be entered in, and transferred to, fund constituted under sub-section (1).

- (3) Any amount transferred to the fund under sub-section (2) shall be charged on the Consolidated Fund of the State.
- (4) The amount in the fund shall be expended in such manner and under such conditions as may be prescribed, for the purposes of this Act.
- (5) The fund shall be reflected into the budget estimate of the respective authority and the accounts in respect thereof shall be maintained and audited in accordance with the procedure prescribed for the purpose of maintenance of accounts in the relevant law or the rules and orders made thereunder as are applicable to the respective authority.

#### **6.1.8. Appeal**

### **33. Appeal.**

Any person aggrieved by -

- (i) the notice issued under clause (b) of sub-section (1) of section 19, or
- (ii) the refusal of the Regional Officer or the Chief Fire Officer to pass an order under sub-section (4) of section 26, may prefer an appeal to the Director. Such appeal shall be made in such manner and accompanied with such fees, as may be prescribed. The Director after giving a reasonable opportunity to the appellant of being heard, pass an order, and every such order passed under this section shall be final:

Provided that in case of local fire service of any local authority, in so far as the area comprising of Municipal Corporation is concerned, the Commissioner shall be the appellate authority.

### **34. Limitations for filing Appeal.**

No appeal under section 33 shall be entertained unless, such appeal is preferred within fifteen days from the date of service of notice or the date on which the refusal is communicated to the Director or the Commissioner, as the case may be:

Provided that, the Director or the Commissioner, as the case may be, may admit the appeal preferred after the expiration of the fifteen days if he is satisfied that the appellant had sufficient cause for not preferring the appeal within said period.

#### **6.1.9. Offences and Penalties**

### **35. Jurisdiction of Court.**



No court inferior to that of a Metropolitan Magistrate or Judicial Magistrate First Class shall try an offence punishable under this Act or the rules made thereunder.

**36. Bar of Court.**

No court shall entertain any suit, application or other proceedings in respect of any notice given under section 19 or any action taken under subsection (2) of section 26 or an order of refusal to permit removal of seal passed under sub-section (4) of section 26 and sub-section (10) of section 27 of this Act or any action or any order shall be called in question otherwise than by preferring an appeal as provided by this Act.

**37. Cognizance of offence.**

Save in the case of cognizable offences, no court shall take cognizance of an offence punishable under this Act or the rules made thereunder except on the complaint made by the Regional Fire Officer or the Chief Fire Officer or any other officer authorized by him in this behalf.

**38. Compounding of offence or withdrawal of proceedings.**

- (1) The Director or the Regional Fire Officer or the Chief Fire Officer, or any officer authorized in this behalf by the Director may by general or special order, either before or after the institution of the proceedings, compound any offence made punishable by or under this Act or the rules made thereunder or withdraw from such proceedings at any stage.
- (2) When an offence has been compounded under sub-section (1), the offender, if in custody, shall be discharged, and no further proceedings shall be taken against him in respect of the offence compounded.

**39. Offences and penalties.**

- (1) Whoever contravenes any of the following provisions,-
  - a) under sub-section (1) of section 18, fails to provide and maintain the fire prevention and life safety equipment in good repair and efficient condition;
  - b) under sub-section (1) of section 19, fails to comply with the notice directing to undertake and carry out fire prevention and life safety measures;
  - c) under sub-section (4) of section 21, tampers with, alters, removes or causes any injury or damage to any fire prevention and life safety equipment installed in a building or instigating any other person to do so;
    - (ca) Under sub-section (5) of section 21 giving a fire safety certificate renewal without there being actual compliance or maintenance of fire prevention and life safety measures and equipment



- d) under sub-section (2) of section 22, after non-compliance of the direction of removal of objects or goods likely to cause the risk of fire to a place of safety, causes obstruction in authorized seizure, detention, and removal of such objects or goods;
- e) under sub-section (3) of section 24, obstructs the entry by an authorized or empowered person or molests such person after such entry for inspection; under sub-section (4) of section 26, removes the seal of the building without written order made by the Regional Fire Officer or the Chief Fire Officer;
- f) under sub-section (4) of section 27, fails to comply with the directions issued by the Director or the Regional Fire Officer or the Chief Fire Officer;
- g) under sub-section (1) of section 29, carries out the work of providing fire prevention and life safety measures, or performing such other related activities by a person other than the Licensed Agency; or
- h) under sub-section (2) of section 29, giving a certificate under subsection (3) of section 19 without there being actual compliance or maintenance of fire prevention and life safety measures and equipment;  
without prejudice to any other action taken or which may be taken under any of the provisions of this Act, be punished with imprisonment for a term which shall not be less than one month which may extend up to two years or fine which shall not be less than rupees 10,000 which may extend to rupees 1,00,000, or both and where the offence is continuing one with a further fine which may extend to rupees 3000 for every day during which such offence continues after the conviction for the first such offence.

Provided that enrolment of fire safety officer may also be kept in abeyance, suspended or revoked by the Director, in case of dereliction of any duty by the fire safety officer

(2) Whoever -

- a) willingly attempts, in any manner whatsoever, to evade any fee or interest leviable under this Act, or
- b) contravenes any of the provisions of this Act or the rules for which no specific penalty has been provided for by this Act, or
- c) fails to comply with the requirement of any order or any notice or any direction, issued under any of the provisions of this Act or the rules, by the Director or any authority or the Regional Fire Officer or the Chief Fire Officer of such Authority



or any other officer authorized by any of them, for which no specific penalty has been provided by this Act, shall, on conviction, be punished, -

- i. in case where the amount, of fees and/or interest exceeds rupees 50,000 during the period of a year, with imprisonment for a term which shall not be less than three months, but which may extend to two years or with fine or with both;
- ii. in case where such amount is less than rupees 50,000 during a year, with imprisonment for a term which shall not be less than one month, but which may extend to one year or with fine or with both;
- iii. in case of contravention of any provision of this Act or the rules made thereunder or failure to comply with the requirement of any order or notice as aforesaid, with imprisonment for a term which shall not be less than three months but which may extend to two years or with fine or with both.

- (3) Whoever aids or abets any person in commission of any offence specified in sub-section (1) or (2) shall, if the act is committed in consequence of the abetment, and no express provision is made by this Act for the punishment of such abetment, be punished with the punishment provided for the offence.

**Explanation.** - An act or offence is said to be committed in consequence of abetment, when it is committed in consequence of the instigation, or in pursuance of the conspiracy, or with the aid which constitutes the abetment.

**40. Offences and penalties for removing seal.**

Offences under sub-section (4) of section 21 and of removal of seal without an order under sub-section (4) of section 26 shall be cognizable and non-bailable.

**41. Assistance to Fire Officers.**

Every police officer, Government and private agency or person shall be bound to assist the members of the Fire Service reasonably demanding his or its aid in the performance of their duties under this Act.

**42. Failure to give information.**

Any person who without adequate justification fails to communicate information in his possession regarding an outbreak of fire shall be deemed to have committed an offence punishable under section 176 of the Indian Penal Code, 1860 (45 of 1860).

**43. Penalty for willfully obstructing firefighting rescue operations.**

Any person who willfully obstructs or interferes with any member of the Fire Service who is engaged in firefighting operations, shall be punished with imprisonment for a term which



may extend to three months, or with fine which may extend, to five thousand rupees, or with both.

**44. False report.**

Any person who knowingly gives or causes to be given a false report of the outbreak of a fire to any person authorized to receive such report by means of a statement, message or otherwise shall be punished with imprisonment which may extend to three months or with fine which may extend to one thousand rupees, or with both.

**45. Offence by a company.**

(1) Where an offence punishable under this Act has been committed by a company, every person who, at the time the offence was committed, was in charge of, and was responsible to, the company for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the offence and shall be liable to be proceeded against and punished accordingly:

Provided that, nothing contained in this sub-section shall render any such person liable to any punishment if he proves that the offence was committed without his knowledge or that he had exercised all due diligence to prevent the commission of such offence.

(2) Notwithstanding anything contained in sub-section (1), where any offence punishable under this Act has been committed by a company and it is proved that the offence has been committed with the consent or connivance of, or is attributable to any neglect on the part of any director, manager, secretary or other officer of the company, such director, manager, secretary or other officer shall also be deemed to be guilty of that offence and shall be liable to be proceeded against and punished accordingly.

**Explanation.** - For the purposes of this section,-

- (a) "company" means a body corporate and includes a firm or other association of individuals ; and
- (b) "director", in relation to a firm, means a partner in the firm, and in relation to any association of persons or body of individuals, means any member controlling the affairs thereof.

**6.1.10. Miscellaneous**

**46. Officers and employees to be public servant.**





- (1) Every officer or employee shall, when acting or purporting to act in pursuance of the provisions of this Act or of any rule or regulation made thereunder, shall be deemed to be a public servant within the meaning of section 21 of the Indian Penal Code, 1860.
- (2) Fire safety officer shall not be considered as public servant under this Act.”

**47. Death of member of Fire Service.**

In the event of a member of the Fire Service (other than a Gazetted Officer), dies while on active duty, the State Government shall pay, to the next of kin as funeral expenses, such amount as the State Government may by an order determine.

**48. Employment on other duties.**

It shall be lawful for the Government or any officer authorized by it in this behalf, to employ the Fire Service in any rescue, salvage or other works for which it is suitable by reason of its training, appliances and equipment.

**49. Effect of inconsistency with other Act.**

- (1) The provisions of this Act and the rules made thereunder shall have effect notwithstanding anything inconsistent therewith contained in any other law for the time being in force or in any instrument having effect by virtue of any other law.
- (2) Subject to the provisions of sub-section (1), the provisions of this Act shall be in addition to, and not, save as expressly provided hereinabove, be in derogation of the provisions of any relevant law for the time being in force in any area in which this Act is in force.

**50. Act to have overriding effect and effect of other laws.**

- (1) The provisions of this Act shall have overriding effect notwithstanding anything contained in any other law for the time being in force, in so far as the provisions relating to fire prevention and life safety are concerned.
- (2) Notwithstanding anything contained in any other law for the time being in force, when anything in relation to the fire prevention and life safety measures is required to be done or approved under this Act, any such thing shall not be deemed to have been unlawfully done or approved by reason only of the fact that permission, approval or sanction required under such other law therefor has not been obtained.

**51. Transfer of assets, rights, etc. by State Government to State Fire Services.**

In order that the effective fire prevention and life safety measures are provided by the State Fire Service, the State Government may by an order, transfer all or any assets, rights and



liabilities of anybody owned or controlled by the State Government to the State Fire Service.

**52. Delegation of power.**

- (1) The State Government may, by notification in the Official Gazette, delegate any of its powers, except the power of making rules, exercisable by it under this Act or the rules made thereunder, to the Director in such matters and subject to such terms and conditions, if any, as may be specified in such notification.
- (2) The Director may, with the prior approval of the State Government, by an order in writing, delegate any of its powers exercisable by him under this Act or the rules made thereunder to the Regional Fire Officer or the Chief Fire Officer subject to such terms and conditions, if any, as may be specified in such order.

**53. Power to issue directions.**

The Director may, for the purpose of performing functions under this Act and for reasons to be recorded in writing, issue such directions to a person to do or abstain from doing a specified thing within the affected areas in which the emergency relief measures are being undertaken and any person on receipt of such directions shall comply with the same.

**54. Reporting by Regional Fire Officer or Chief Fire Officer.**

Every Regional Fire Officer or the Chief Fire Officer shall furnish to the Director such reports, returns and other information as the Director may, from time to time, require.

**55. Power of State Government to give directions.**

The State Government may issue, from time to time, directions to the Director as it may deem fit for giving effect to the provisions of this Act and it shall be the duty of the Director to comply with such directions.

**56. Decision of State Government to be final.**

If any dispute arises with respect to the exercise of powers and discharge of functions by the Director or the Regional Fire Officer or the Chief Fire Officer under this Act, the same shall be referred to the State Government and the decision of the State Government thereon shall be final.

**57. Power to make rules.**

- (1) The State Government may, by notification in the Official Gazette, and subject to the condition of previous publication, make rules, not inconsistent with this Act, for carrying out the purposes of this Act:



Provided that if the State Government is satisfied that circumstances exist which render it necessary to take immediate action, it may dispense with the previous publication of any rule to be made under this Act.

- (2) In particular and without prejudice to the generality of the foregoing provisions, such rules may provide for all or any of the following matters, namely:-
- a) prescribing number of fire sub-divisions of fire divisions and fire divisions of fire region under clause (j) and clause (1) respectively, of sub-section (1) of section (2);
  - b) prescribing qualifications for appointment of nominated officer under clause (u) of sub-section (1) of section 2;
  - c) prescribing rules governing the mode of recruitment of staff, grade of post, the qualifications, pay, allowances and other conditions of service of the officers and employees under sub-section (2) of section 5;
  - d) prescribing the qualifications for appointment and other conditions of service of the Regional Fire Officer under sub- section (6) of section 8;
  - e) prescribing the qualifications for appointment and other conditions of service of the Divisional Fire Officer and the Station Fire Officer under sub-section (2) of section 10;
  - f) prescribe other factors for the classifications of the category of Chief Fire Officer for each Local Fire Service under clause (a) of sub-section (3) of section 10;
  - g) prescribing the norms and qualifications of each category of Chief Fire Officer under clause (b) of sub-section (3) of section 10;
  - h) prescribing the norms, qualification, experience and duties of each category of Fire Safety Officer under sub-section (1) of section 12;
  - i) prescribing the form of enrolment certificate under sub-section (2) of section 12;
  - j) prescribing the manner in which and the extent to which compensation shall be paid for damage caused under clause (c ) of sub-section (1) of section 14;
  - k) prescribing rates of water supply, for drawing the water during firefighting operations under section 15;
  - l) prescribing the terms of agreement with any person to maintain equipment for fire-fighting under section 16;
  - m) the fees payable for the training of personnel of any Fire Service and private services of industries, hotels, multi-storied buildings under sub-section (2) of section 17;



- n) prescribing the fee and the procedure for providing a course of instruction under sub-section (3) of section 17;
  - o) (na) prescribing the fee and the procedure for providing training under section 17A
  - p) prescribing the manner of service of notice under clause (b) of subsection (1) of section 19;
  - q) prescribing the measure for fire prevention and life safety under of sub-section (2) of section 27;
  - r) prescribing the form of undertaking under sub-section (3) of section 27;
  - s) prescribing the manner of service of notice under sub-section (8) of section 27;
  - t) prescribing the form of appeal and fees under sub-section (11) of section 27;
  - u) prescribing the fee to be paid, the form of application and form of license and the manner under sub-section (2) of section 28;
  - v) prescribing the fee to be paid for renewal of License, the form and the manner under sub-section (2) of section 28;
  - w) prescribing the manner and conditions for the expenses made from the fund under sub-section (4) of section 32;
  - x) prescribing the manner and fees for filing an appeal under clause (ii) of section 33.
- (3) All rules made under this section shall be laid for not less than thirty days before the State Legislature as soon as may be they are made and shall be subject to rescission by the State Legislature or to such modification as the State Legislature may make, during the session in which they are so laid or the session immediately following.
- (4) Any rescission or modification so made by the State Legislature shall be published in the *Official Gazette* and shall thereupon take effect.

**58. Power to make regulations.**

- (1) The Director may, with the previous approval of the State Government, by notification in the Official Gazette, make regulations not inconsistent with the Act and the rules made there under, for enabling it to perform its functions under this Act.
- (2) In particular and without prejudice to the generality of the foregoing power, such regulations may be made to provide for all or any of the matters expressly required or allowed by this Act to be specified by regulations.

**59. Power to remove difficulty.**



- (1) If any difficulty arises in giving effect to the provisions of this Act, the State Government may, as occasion requires, by order do anything not inconsistent with the objects and purposes of this Act, which appears to it to be necessary or expedient for the purpose of removing the difficulty.

Provided that, no order shall be made under this section after the expiry of three years from the date of coming into force of this Act.

- (2) Every order made under sub-section (1) shall be laid, as soon as may be, after it is made, before the State Legislature.

**60. Removal of doubt.**

For the removal of doubt, it is hereby declared that fire prevention and life safety measures specified under this Act shall be without prejudice to any civil or the criminal liability to which a person may be subject to under any law for the time being in force.

**61. Protection of action taken in good faith.**

No suit, prosecution or other legal proceedings shall lie against any person for anything which is in good faith done or intended to be done under this Act or the rules.

**62. Recovery of dues.**

Any amount payable under this Act shall be recovered as an arrears of land revenue.

**63. Savings.**

Every member of the fire service shall perform functions imposed by or under this Act in addition to and not in derogation of functions performed by the State Government or any of its officers in pursuance of the provisions of any law for the time being in force or in exercise of the executive powers of the State for the prevention of fire and life safety in the State or in relation thereto.

**64. Fire Services to be consider as Emergency Services.**

In order to assist any disaster, other than resulting due to fire, all Fire Services shall be considered as emergency services:

Provided that, in case where the emergency services are not related only to fire, the decisions and directions of the authority in charge of the emergency service shall prevail.

**6.2. The Gujarat Fire Prevention and Life Safety Measures Rules, 2014**

For information visit: <https://gujfiresafetycop.in/Grid.aspx?Id=11>



### **6.3. The Gujarat Fire Prevention and Life Safety Measures Regulations, 2016**

For information visit: <https://gujfiresafetycop.in/Content/regulations-117>

### **6.4. Gujarat fire safety compliance portal (GUJFIRESAFETYCOP)**

#### **6.4.1. Introduction**

Besides comfort and hygiene, it needs to be ensured that buildings are safe and protected from expected hazards, fire being one of them. Fire & Life Safety in buildings is ensured by following the building laws prevalent in the region, typically in form of General Development Control Regulations (GDCR) or Building Bye-Laws.

The normal process of regulating fire & life safety requirements during building life cycle comprises of three stage process. It begin with the Design stage where Developer/ Owner needs Fire Safety Plan Approval to allows them to proceed with construction, followed by issuance of Fire Safety Certificate (FSC) at the End of Construction stage (and before occupancy), after check and verifications of the fire prevention, life safety and fire protection features provided in the building. And during the Lifetime of the Building, it is important to ensure that systems provided for the control of fire risks remain in effective working condition as originally planned. Periodic inspection/ testing, will be required to check this, and if found satisfactory, Fire Safety Certificate (FSC) is renewed for a specific validity period.

Considering the same, State Government took a conscious decision to develop a simple, efficient and transparent system to provide End to End (E2E) solution for approval and renewal of Fire Safety Certificate in the State of Gujarat. Accordingly, Gujarat Institute of Disaster Management (GIDM) has been given the responsibility to propose the comprehensive and implementable system.

The Guj Fire Safety COP will provide a complete solution starting from facilitation and empanelment of FSOs to approve & renew the FSC along with provision of online payment. The portal will also help state government in monitoring the compliance level of FSC approval and renewal in the state. This system will complement and supplement the current procedures, and limited compliance of fire prevention, life safety and fire



protection measures in the buildings/ premises as per the GFP&LSM Regulations 2016 and as revised from time to time. The portal is available on: <https://gujfiresafetycop.in/>



# **Chapter 7:**

## **Industrial Fire Prevention & Fire Protection**





## 7. Industrial Fire Prevention & Fire Protection

### 7.1. Introduction

Industrial occupancies cover those buildings or parts of a building/ structure, in which products or materials of all kinds and properties are processed, manufactured fabricated and/ or assembled. By itself, this covers a wide variety of industries and industrial activities, right from small and simple units such as laundries or garages to large oil processing refineries and steel plants. Thus, the level of hazard also varies considerably based on the type of material handled, activity carried out and other related factors such as overall fuel load (which will include other fuels besides the main material), interior finish, release of smoke and/ or toxic gases, explosion risk, etc.

As the activities and processes under this occupancy vary considerably; diverse industries and industrial activities can be found in this occupancy which includes industrial workshops, laboratories, small and medium scale factories, power plants, plants handling agricultural produce, dairies, oil & gas exploration and production, gas plants, large fertilizer, chemical and petrochemical complexes, etc.

A wide variety of fuels is used in the industrial occupancy, which include solid, liquid and gaseous materials which can be combustible, flammable or explosive. Note that while the quantity of fuel in a given area is an indication of the total energy which could be released during a fire, the growth and intensity of the fire will depend on various other factors such as the form of the combustible material, configuration of fuel as well as ventilation conditions.

Hence, industrial occupancies are sub-divided into 3 categories (low, medium & high) based on the level of fire hazard inherent in that industry or industrial activity. This is also aligned with the NBC Part 4 which is subsequently highlighted.

#### 1) **Low (Light) hazard**

Factory-Industrial uses that involve the fabrication or manufacturing of noncombustible materials, which during finishing, packing or processing, do not involve a significant fire hazard.

#### 2) **Moderate (Medium) hazard**

These industries are those where contents or industrial processes can give rise to fires which will burn with moderate rapidity, and/or generate considerable smoke. However, highly hazardous products of combustion or explosions are not expected.

### 3) High hazard

These industries are those where extremely fast growing fires, explosions, generation of toxic gases/fumes are possible in event of accidents.

Classification of industries based on Fire Hazard as given in Annex B of NBC Part 4 is shown below:

<b>ANNEX B</b> (Clause 3.1.8) <b>BROAD CLASSIFICATION OF INDUSTRIAL OCCUPANCIES INTO DIFFERENT DEGREE OF HAZARD</b>		
Light Hazard	Moderate Hazard	High Hazard
Abrasive Manufacturing Premises Aerated Water Factories Agarbatti Manufacturing Areca Nut Slicing and/or Betel nut Factories Analytical and/or Quality Control Laboratories	Aluminium Factories Atta and Cereal Grinding Bakeries and Biscuit Factories Beedi Factories Bobbin Factories Bookbinders, Envelopes and Paper Bag Manufacturing	<b>SUB-CATEGORY (A)</b> Aircraft Hangers Aluminium/Magnesium Powder Plants Bituminised Paper and/or Hessian Cloth/Tar Felt Manufacturing Cotton Waste Factories

These occupancies normally do not have high number of external visitors, and occupants in industries are employees, who are expected to be physically able, aware of the layout of their workplace/s, the hazards within their industry and the actions required to be taken during an emergency. Normally, the fire hazards in industrial occupancies are well identified and required control measures put in place accordingly; the risk goes up when these control measures fail or are compromised due to various reasons.

## 7.2. Engineering approach to industrial fire protection

In industrial scenarios, fire prevention and fire protection has three main goals:

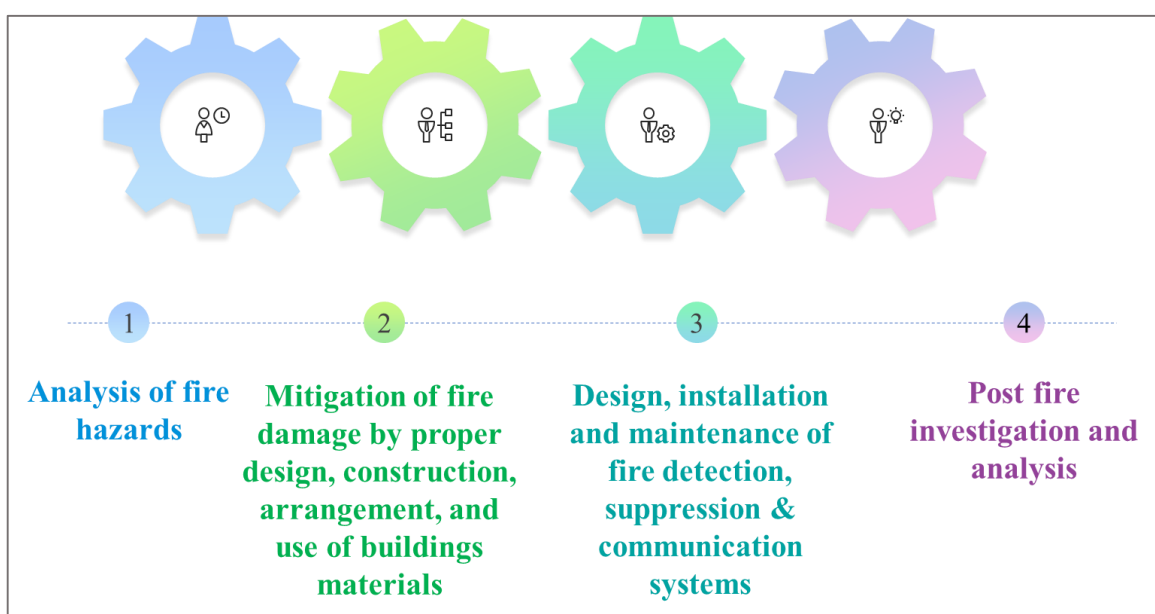


While life safety is the primary objective, property protection and business continuity are also critical due to heavy investment, especially in large industries. Note that for large industries, losses resulting from downtime can be enormous.

Risks in modern industry include fires and/ or explosions involving flammable liquids, gases or dusts and the resulting contamination of production and storage areas, by smoke or other substances released by fire or equipment damage. Reducing fire risks and keeping them under control means controlling the factors that are responsible for a fire to begin. Effectively it means controlling the fuel, oxygen and the heat that take part in the combustion reaction. Hence all efforts are directed towards ensuring that under no circumstances is there sufficient heat, fuel and air to allow ignition and combustion.

Briefly, this means that the focus of fire prevention activity is mainly on control of fuel and on ignition sources. Control of oxidants (mostly atmospheric oxygen) is not possible, though chemical oxidants are required to be controlled. Various methods/ concepts adopted by the industry for fire prevention and protection, discussed subsequently, are based on these simple facts.

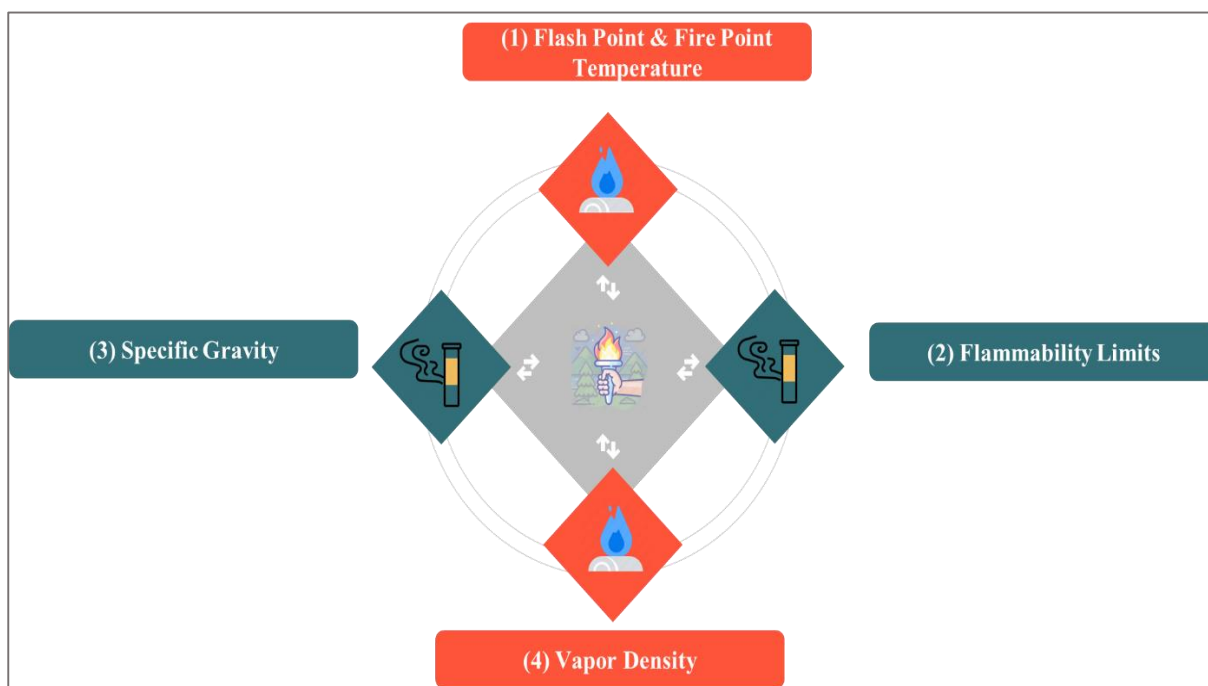
While code requirements can be prescribed for small industrial sheds and buildings, this is not possible for large industries, especially those handling combustible/ flammable materials or other hazardous process. The industry, therefore, follows an engineering approach for industrial fire protection. This involves different methods and techniques; some of the commonly employed methods, for fire risk reduction and control are given below:



Identification of fire hazards of the materials/ processes present in the industry is a primary activity in the risk reduction process. This requires good knowledge of important properties of the fuels handled and possible ignition sources. Amongst the important properties studied for hazard identification are the flash point and autoignition temperatures, flammability range, ignition temperatures, and physical properties such as the vapor density, etc. Certain classifications methods such as the Dow's chemical hazard index or the NFPA hazard rating system can be used as guidelines. This helps to classify the hazard into suitable categories.

### 7.3. Important properties of combustible and flammable fuel influencing the fire hazard

The following four important properties must be understood well from fire safety point of view:



#### 1) Flash point & fire point temperature

The observed temperature when the flame momentarily ignites the vapor/ air mixture is the Flash Point.

The ignitions repeat as the liquid temperature continues to rise. The observed temperature when the burning becomes continuous is the Fire Point. Liquid is heated, but without an ignition source. Fire Point is also sometimes called as Ignition Temperature



## 2) **Flammability limits**

The term ‘Lower Flammable Limit’ (LFL) describes the minimum concentration of vapor to air, below which propagation of a flame will not occur even in the presence of an ignition source. The ‘Upper Flammable Limit’ (UFL) is the maximum vapor-to-air concentration above which propagation of a flame will not occur. If a vapor-to-air mixture is below the lower flammable limit it is described as being “too lean” to burn, and if it is above the upper flammable limit is “too rich” to burn.

## 3) **Vapor density**

The weight of a vapor or gas compared to the weight of an equal volume of air; an expression of the density of the vapor or gas. Materials lighter than air have vapor densities less than 1.0 (example: acetylene, methane, hydrogen). Materials heavier than air (examples: propane, hydrogen sulfide, ethane, butane, chlorine, sulfur dioxide) have vapor densities greater than 1.0.

## 4) **Specific gravity**

Relative density, or specific gravity, is the ratio of the density (mass of a unit volume) of a substance to the density of a given reference material. Specific gravity for liquids is nearly always measured with respect to water at its densest (at 4 °C)

If a substance's relative density is less than 1, then it is less dense than the reference; if greater than 1, then it is denser than the reference.

If the relative density is exactly 1 then the densities are equal; that is, equal volumes of the two substances have the same mass.

If the reference material is water, then a substance with a relative density (or specific gravity) less than 1 will float in water. For example, an ice cube, with a relative density of about 0.91, will float.

A substance with a relative density greater than 1 will sink.



## 7.4. Plant siting and layout fire protection siting considerations

### 7.4.1. General principles for plant siting and layout

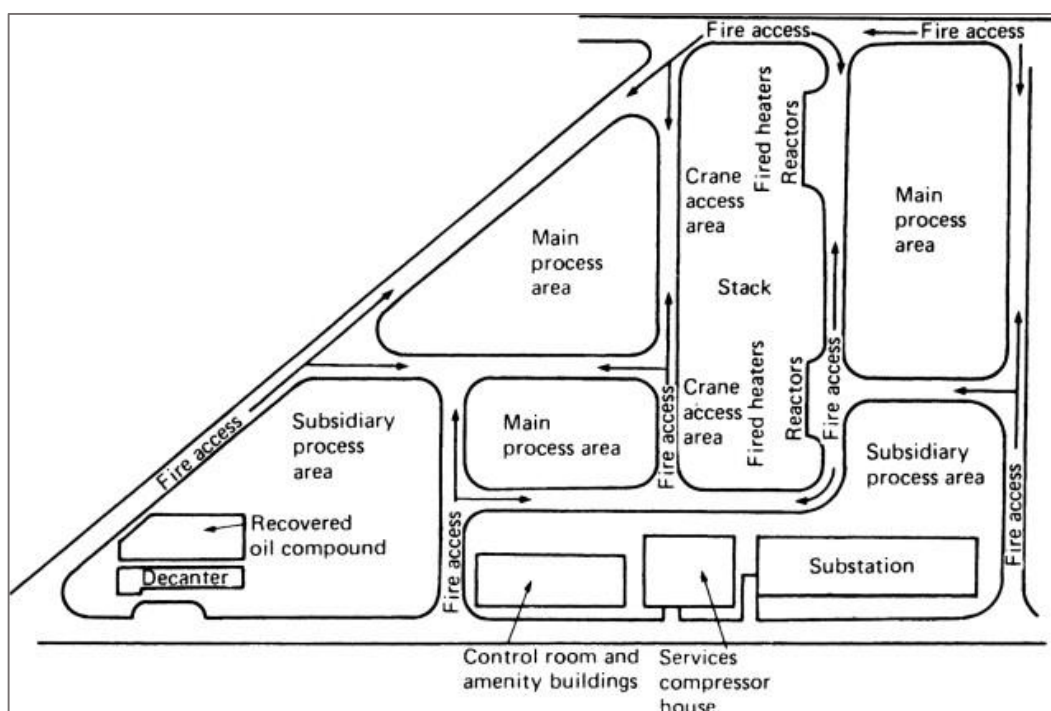
Plant layout is often a compromise between a number of factors such as:

<b>1</b>	The need to keep distances for transfer of materials between plant/storage units to a minimum to reduce costs and risks.	<b>6</b>	Need to locate hazardous materials facilities as far as possible from site boundaries and people living in the local neighborhood.
<b>2</b>	The geographical limitations of the site.	<b>7</b>	The need to prevent confinement where release of flammable substances may occur.
<b>3</b>	Interaction with existing or planned facilities on site such as existing roadways, drainage and utilities routings.	<b>8</b>	The need to provide access for emergency services.
<b>4</b>	Interaction with other plants on site.	<b>9</b>	The need to provide emergency escape routes for on-site personnel.
<b>5</b>	The need for plant operability and maintainability.	<b>10</b>	The need to provide acceptable working conditions for operators.

The most important factors of plant layout as far as safety aspects are concerned are those to:







### 7.4.2. Plant layout philosophy

Following philosophy should be adopted in layout of an installation;

- Block layout should be adopted as far as possible. Plant layout arrangement should follow the general route of raw material to process unit(s) with tankages interposed as required followed by storage & dispatch facilities. The entire area should be subdivided into blocks.
- All process units and dyked enclosures of storage tanks shall be planned in separate blocks with roads all around for access and safety.
- Primary traffic roads in the installation should be outside hazardous areas. Roads separating the blocks shall act as firebreaks.
- Pedestrian pathways should be provided / marked alongside the primary traffic roads.
- Alternative access shall be provided for each facility so that it can be approached for firefighting in the event of blockage on one route.
- Road widths, gradient and turning radii at road junctions shall be designed to facilitate movement of the largest fire-fighting vehicle in the event of emergency.
- Rail spur (if available) shall be located close to the periphery of the plant to minimize road/pipe crossings and blockage of roads during shunting.



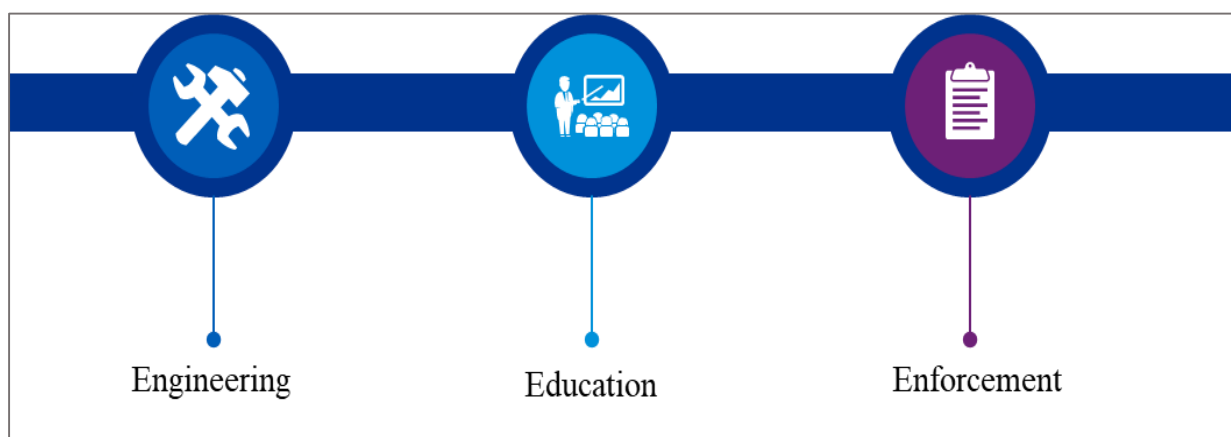
- h) Layout of the facilities shall be made to minimize truck traffic ingress in the plant.
- i) Two road approaches from the highway / major road should be provided, one for employees and other for product / material movement. Both these approaches should be available for receipt of assistance in emergency.
- j) Presence of ignition source shall always be contemplated beyond the boundary wall of the installation.
- k) Orientation of flares, furnaces & heaters, dusty operations (e.g. sulphur handling etc.) and cooling towers should be decided based on prevailing wind direction to avoid travel of hydrocarbon vapor over sources of ignition.
- l) Erection methods shall be studied for all types of equipment / structures. Towers, reactors, fired equipment etc. should be located in such an area so to facilitate erection.
- m) Maintenance requirements for each type of equipment shall be identified and considered.
- n) For construction activities, area should be earmarked.
- o) Future expansion should be assessed, and space provision be made accordingly.

Below are examples of an Industrial factory layout:



### 7.4.3. Fire prevention principles

Fire prevention activities can be categorized into the following three functions:



A brief description of each of these areas follows:

### 1) **Engineering**

Engineering refers to the planning of fire safe buildings and processes. It also includes the interpretation of fire codes and the control of process hazards through design and installation of fire protection and detection systems.

- Engineering plays an extremely important role in any fire prevention program. Without a foundation of engineering principles, the best educational and enforcement programs will not prevent fires. Engineering principles related to fire prevention and fire protection include such subjects as building design and construction, building equipment, installed fire protection systems, and water supply.
- Adequate fire protection and detection systems must be determined and installed for protection of the plant buildings and occupants. The type and amount of suitable fire protection equipment will depend upon the process and storage hazards found in the plant. Water supplies and distribution systems for firefighting are also considered. The fire prevention authority must be responsible to see that all firefighting systems and equipment are designed and installed to meet the fire protection needs of the plant.
- Another facet of engineering for fire prevention is the interpretation of fire codes. Plant fire prevention personnel should be aware of all fire codes and regulations that apply to their particular industrial plant. These may include:



They should also be knowledgeable of the specific requirements of more commonly applied codes and regulations.

- Modern plant operations include fire safety as a part of the total safety effort. However, if fire safety is not addressed as such, a local "fire safety committee" should be formed.
  - The fire safety committee can function as an important aid in the work of the fire protection specialists.
  - The committee's specific jobs may vary from plant to plant depending on conditions, but may include identification of hazards, inspections of specific processes, planning prevention activities, serving in a public relations capacity, interacting with peer groups and serving as a sounding board for the fire protection specialists.

## 2) Education

Education includes those activities that promote fire safety consciousness among employees. This is accomplished by informing employees how to recognize and eliminate fire hazards around the workplace. It also includes special and seasonal fire prevention programs.

## 3) Enforcement

Enforcement is another important part of the fire prevention. Enforcement deals with inspection practices to assure compliance with fire codes and regulations. Attention must also be given to the thoroughness and scheduling of fire inspections.



Enforcement deals with the activities of inspecting plant facilities to ensure compliance with federal, state, and local codes, along with insurance and corporate requirements. Inspection practices are usually considered to be the most important non-firefighting activity performed by plant personnel. A carefully planned inspection program carried out by conscientious, well trained personnel can prevent many serious fires. Through inspection, many hazardous conditions are discovered, and effective control measures taken before fires occur.

#### **7.4.4. Hazardous area classifications (As per IS 5572:2009)**

The objective of area classification is the notional division of a plant into zones within which the likelihood of the existence of an explosive gas/air mixture is judged to be high. Medium, low or so low as to be regarded as negligible. An area classification established in this way provides a basis for the selection of electrical apparatus that is protected to a degree appropriate to the risk involved. The type of protection of the apparatus selected will be such that the likelihood of it being a source of ignition, at the same time as the surrounding atmosphere is explosive, is accepted as being small.

##### **1) Hazardous area**

An area in which an explosive gas atmosphere is present, or likely to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

##### **2) Non-hazardous area**

An area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

##### **3) Zones**

Hazardous areas are classified in zones based upon the frequency of the appearance and the duration of an explosive gas atmosphere as follows. Area classification is a method of analyzing and classifying the environment where explosive gas atmospheres may occur to allow the proper selection of electrical apparatus to be installed in that environment.

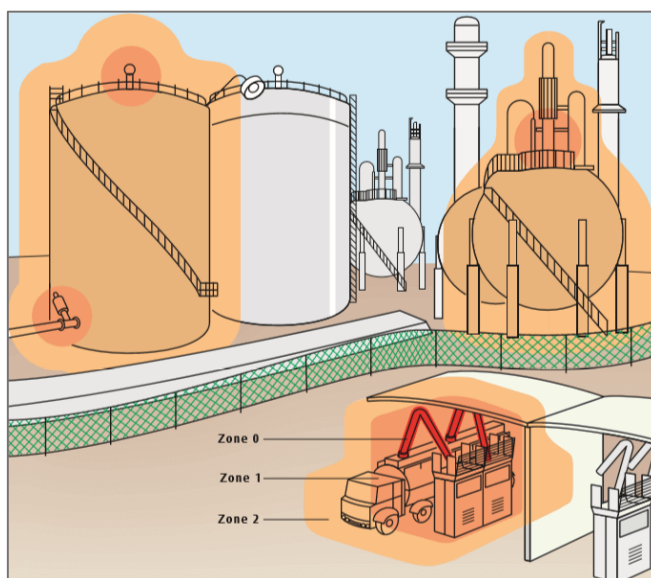
**Zone 0:-** An area place in which an explosive atmosphere is present continuously or for long periods or frequently.

**Zone I :-** An area in which an explosive atmosphere is likely to occur in normal operation occasionally.

**Zone 2 :-** An area in which an explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

The objective of the classification procedure is to enable electrical apparatus to be selected, installed, operated and maintained safely in these environments. Where it is necessary to use electrical apparatus in an environment in which there may be an explosive gas atmosphere, the following steps should be taken:

- a) Eliminate the likelihood of an explosive gas atmosphere occurring around the source of ignition: or
- b) Eliminate the source of ignition.



Where this is not possible; protective measures, process equipment, systems and procedures should be selected and prepared so that the likelihood of coincidence of (a) and (b) is so small so as to be acceptable.

In most practical situations where flammable materials are used, it is difficult to ensure that an explosive gas atmosphere will never occur. It may also be difficult to ensure that electrical apparatus will never give rise to a source of ignition. Therefore, in situations where an explosive gas atmosphere has a high likelihood of occurring, reliance is placed on using electrical apparatus which has an extremely low likelihood of creating a source of ignition. Conversely, where the likelihood of an explosive gas atmosphere occurring is reduced, electrical apparatus which has an increased likelihood of becoming a source of ignition may be used. To apply this approach, the first step is to assess the likelihood of an explosive gas atmosphere occurring in accordance with the definitions of Zone 0, Zone I and Zone 2.

### 7.4.5. Fire & explosion resistant construction<sup>13</sup>



Heat from a fire will travel due to conduction, convection and radiation; and it is necessary to ensure that this travel is prevented, or at least, minimized to the maximum extent possible. Other means of fire propagation include the spread of flammable material through drains, ducts and ventilation systems. This spread of fire from its origin to other parts of the premises can be prevented by vertical/horizontal compartmentation using fire-resisting walls and floors. Failure of structural elements and holding vessels can release combustible/flammable material, further escalating the fire.

Hence, the need arose to make construction elements more fire resistant to bring down huge economic losses resulting from collapse of fire affected structures. The most common method of developing fire resistance design involves combining the use of structural mechanics and the effect of elevated temperatures on the mechanical properties of construction elements. Thus, fire resistance principles consists mainly of characterization of the expected fire severity, determination of the extent of heat transmission to the structural elements and evaluating their behavior in these conditions.

One method of improving fire resistance of a structure is to identify combustible construction elements used and substitute them with those which have better heat resisting properties (for e.g., provision of heat resistant fire doors made of specific grades of steel instead of wood or similar material). Other examples of improving fire resistance of combustible materials include coating of such surfaces with materials which retard fire spread. Steel is non-combustible; however, it is not immune to collapse. In fact, due to its high thermal conductivity it absorbs a lot of heat quickly. For smaller steel members, the temperatures will rise very rapidly in most fires, and at temperatures above 550 °C, their load bearing capacity will fall to below 60% (which is considered the critical point). For the commonly used steel members, failure can occur from as early as 10 to 20 minutes. Hence, to raise the fire resistance of steel members, at least to an hour or more, a steel member must be protected by an insulating skin which will keep its temperature below this critical temperature. Commonly employed techniques include encasing in concrete, brick,

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<sup>13</sup> Source of icon – The Noun Project



plaster, etc. Of late, other materials such as cementitious coatings, heat resisting paints and special epoxy coatings are also used. Use of such coatings is, however, dependent to a large extent, on cost.

Since concrete is normally made of inorganic materials having low thermal conductivity and heat capacity, it does not require much protection. However, it also loses its compressive strength under increasing temperatures, and hence is designed with additional cushioning to ensure sufficient reserve strength under fire conditions. Typically fire resistance ratings of 1, 2, 3 and 4 hours are assigned to materials which are used in construction, depending upon the type of application and occupancy.



Explosion effects are different from those of fire, as in this case the main threat is from the blast effects. The other secondary effects include fragments and a heat wave (in case of explosions involving combustion reactions), however the focus is on protection from the expected blast wave.<sup>14</sup> As the blast wave travels away from the explosion source, it can cause immediate collapse of structures, leading to secondary accidents

and fires. Thus, unlike fires, it can affect areas far away from the explosion source. The important design aspect in this case, therefore, is to ensure that the blast wave is directed so as to cause minimum damage. The other aspect involves maintaining suitable distances between units where explosion risks exist and other units, so that the blast effects are not likely to cause any damage. Some of the commonly employed construction features for explosion protection include:

Keeping proper distances between units to ensure that no damage to adjacent units occur in the event of explosions.

Provision of suitably strong barriers, such as blast walls to resist the effect of blast waves and protect equipment /personnel from the same.

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<sup>14</sup> Source of icon – The Noun Project

Giving additional protection to equipment/ vessels to protect against damage e.g. providing thicker walls for vessels.

Redirecting the blast wave using blast walls and such structures, towards relatively 'safe' areas such as open areas, boundaries, etc. to ensure that it does not affect other adjacent plants, buildings, etc.

## 7.5. Storage of combustible & flammable liquids<sup>15</sup>



Since the advent of the industrial revolution, the use of non-water-based chemicals has increased dramatically. Hence, the exposure to the hazards associated with these chemicals has also increased.

One potential hazard is flammability. To prevent fires, hazardous liquids require special precautions, viz, storage, handling and use. The National Fire Protection Association (NFPA), Oil industries Safety directorate

(OISD) and Petroleum and explosive safety organization (PESO) have developed guidelines for safe storage and use of flammables.

Liquid Storage tanks are important components of lifeline and industrial facilities.

- **Modern Oil and Liquid fuel storage tanks** included in lifeline system vary from 12 to 76 m in diameter with height that are nearly always less than the diameter.
- **Ground supported, circular cylindrical tanks** are more frequent than any other types because they are simply in design, efficient in resisting primary hydrostatic pressure and can be easily constructed.

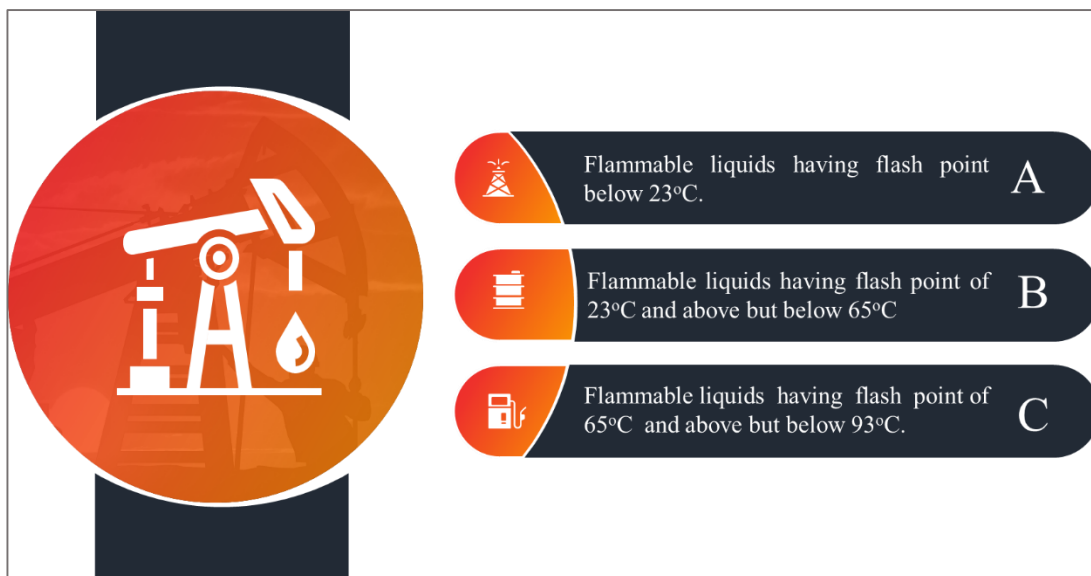
### 7.5.1. Classification of petroleum

Petroleum products are divided into three classes based on their flash points as follows:

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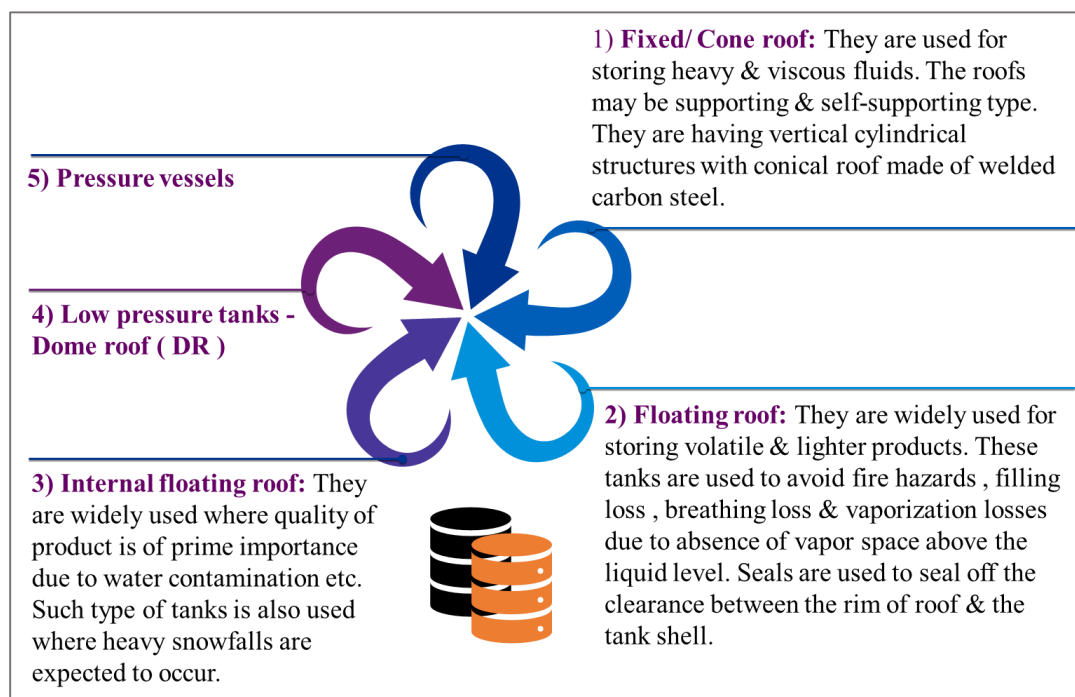
<sup>15</sup> Source of icon – The Noun Project

(Note: Liquids having flash point of 93°C and above are excluded)



### 7.5.2. Types of storage tanks and their suitability

Generally following, type of storage tanks being used for storage of petroleum products are listed below along with their suitability & use:



## 7.6. Industrial fire detection & protection systems<sup>16</sup>



Fire and explosion prevention and protection systems in industries are designed around managing the risk. Risk management, as defined here, is about controlling the probability of occurrence and the magnitude or the severity of a fire or deflagration event. Thus, active prevention systems are used to reduce the probability of occurrence of a fire or deflagration.

As fires can spread very quickly, it is very important in industries to ensure that any outbreak of fire is detected at the earliest, emergency personnel such as the fire brigade alerted and information passed on to other concerned personnel for evacuation and shutting down of equipment/ machinery. Undoubtedly, properly designed, installed and maintained fire alarm and detection systems can play a major role in reducing fire losses. Most fire detection systems will consist of different type of fire detectors (depending upon the type of fire risk), means of manual activation (popularly called manual call points or manual pill boxes) and the provision for audio - visual alarms. The various components in the system are connected to a main control panel, or in some cases, to more than one panel.



Fire prevention is based on various hazard monitoring systems that include but not limited to:

Spark Detection and Extinguishing Systems, including spark, ember, black body, smoke and flame detection	Bearing temperature, belt alignment, plug-up detection systems	Linear heat detection
Rate of rise heat detection	Smoke Detection	CO Detection

<sup>16</sup> Source of icon – The Noun Project



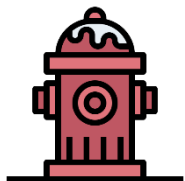
Combustion Gas detection	Emissions monitoring	Video smoke and flame detection
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Various other complimentary detection systems are designed to detect and prevent fires in the incipient stage. Various types of detectors can be mounted on conveyors, transitions, ductwork, in the production area and on production equipment itself to monitor hazards and alert operators, as well as interlocking various types of alarms, suppression and deluge systems, machinery shutdown, etc. Various levels of alarms can be interlocked depending on the threat level. Fire prevention is also based on active monitoring systems designed to detect the first signs of combustion and react to prevent the incipient fire from developing.

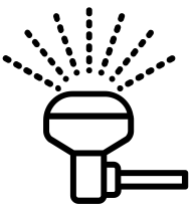





## Fire protection

While all precautions are taken to prevent any outbreak of fire, accidents still do occur. However, if proper pre-planning is done and suitable arrangements provided for tackling such accidents, they can be quickly controlled, and the damage be kept to a minimum. Therefore, it is necessary at the design stage itself, to make provisions for all the essential fire protection systems. These systems fulfil two main functions; one, to ensure that information about the fire is quickly passed on to all concerned personnel and second, that all firefighting equipment/ systems required for tackling the fire are available in proper condition at the affected site. Unlike fire prevention systems, fire protection equipment and systems are reactive, and thus designed to manage the risk of the event once it occurs.

Any industrial site should have firefighting arrangements to handle the largest fire emergency likely to occur on site. These systems include fire water storage and distribution networks, fixed fire protection systems, fire alarm and detection systems and manual firefighting appliances. Depending upon the risks, various types of fire protection systems are considered for installation during the design stage. However, certain systems, discussed below, are common to most industries, regardless of the risks. Fire Protection Equipment and Systems include but are not limited to:



Fire water (Hydrant) systems

	Water sprinkler and deluge systems
	Water mist systems
	Foam system
	Suppression system
	Inerting gas
	Dry chemical system

While these systems require detailed study and calculations, they are explained in brief below:

### 1) Fire water systems

The total fire water quantity depends on the highest demand of any installed hydraulically calculated water-based protection system, the use of hydrants and monitors and possible additional exposure cooling requirements. The fire water storage can be a dedicated storage or can be a part of the process water storage, provided a minimum storage of water is always available (in case of high hazard industries, however, a separate storage is insisted upon). The water supply to the storage should be from a reliable source, such as municipal water supply, natural lakes or rivers.



The pumping arrangements should be sufficient to provide the required amount of water at requisite pressure, to the fire site which has the greatest demand. As far as possible, these pumps should be solely dedicated for firefighting. It is advisable to have multiple pumps instead of a single large pump, so that reliability is ensured in the event of failure of a pump.

Prime movers for the pumps can be electric motor driven or diesel engine driven. It is a normal practice to have both type of drives for the pumps with at least 50% being diesel engine driven so that they are not dependent upon the electric supply.



## 2) **Fixed fire protection systems**

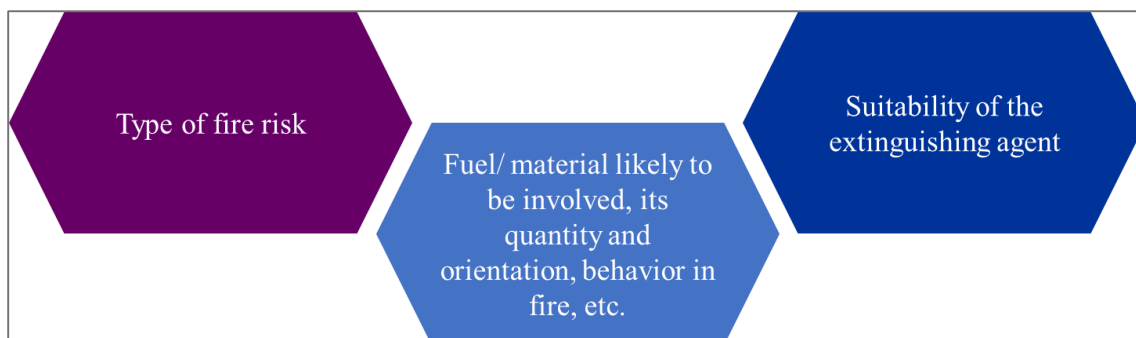
Today fixed fire protection systems form a very crucial part of the emergency response plan of any industry. The need for such systems was brought about by two main factors – first, the fact that in modern industry, the trends are towards more and more automation, with less



dependence upon manpower. Fixed fire protection systems, are therefore, conceived with minimum involvement of manpower. The other important advantage in this is, that it reduces the risk to human life. Second, as compared to fire risks outside, the risks in the industry are to a large extent, defined. Therefore, it is possible to design extinguishing systems which can effectively extinguish such fires.



Fixed fire protection systems normally provided in the industry should take into consideration the following three important factors:



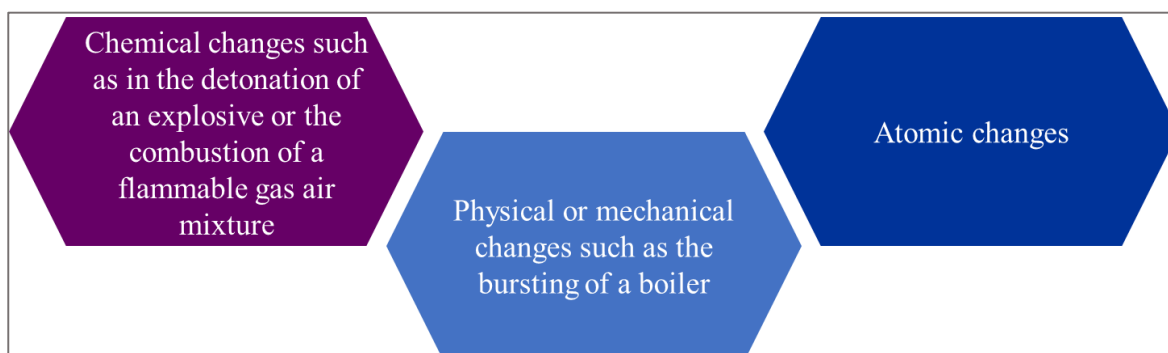
Depending upon the type of material involved (and hence, its fire class), it is easy to determine the type of extinguishing agent that will be applicable. However, a number of other factors are also considered, some of which are – the location of the hazard (i.e., whether indoors/ outdoors, clean environment, etc.), the effect of the extinguishing agent on surrounding material (can it cause unnecessary damage), storage consideration for the agent and environmental factors. The suitable extinguishing agent is selected based on these factors.

## 7.7. Explosion hazards in industries



Explosion generally occurs in situations where fuel and oxygen have been allowed to mix intimately before ignition. As a result, the combustion reaction proceeds very rapidly without being delayed by the need for bringing the fuel and oxidant together. Fires, in contrast, generally occur in situations where the mixing of fuel and oxidant is controlled by the combustion process itself. The burning rate per unit volume is much lower in fires and the rapid increase in pressure, characteristic of explosions is not encountered.

Therefore, in the widest sense, an explosion is an effect produced by the sudden violent expansion of gases. It is a process of rapid physical and/ or chemical transformation of a system into mechanical work, accompanied by a change of its potential energy and may also be accompanied by shock waves and/ or the disruption of enclosing materials or structures. An explosion may result from:



### 7.7.1. Types of explosions

#### 1) BLEVE

BLEVE stands for boiling liquid expanding vapor explosion. It is a type of explosion that occurs up on rupture of a vessel containing a liquid with vapor pressure well above atmospheric pressure like LPG, Propone, etc.

The effects of BLEVE of a vessel containing liquified gases are listed below:

Blast wave effects due to physical expansion of the gas above the liquid, flash evaporation of the liquid.
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A fireball will result if the escaping materials get ignited.
---

The tank shell tears, and a relatively small number of fragments are produced.
--

The fragments may be scattered over considerable distance by the energy that is released the expanding gas.
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#### 2) UVCE

UVCE stands for unconfined vapor cloud explosion. When some flammable material is released in the atmosphere, it gets mixed up with air and forms a mixture that is either totally within the flammability limits or the outer portion of it is within the flammability limits. If this mixture finds some source of ignition, it either results in a flash fire or in an explosion depending upon the quantity of material released and mixing of air in certain proportion. This type of explosion is termed as UVCE.

#### 3) Dust explosions<sup>17</sup>

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<sup>17</sup> Source of icon – The Noun Project



Often overlooked, and highly deadly, combustible dust is a major cause of fire in food manufacturing, woodworking, chemical manufacturing, metalworking, pharmaceuticals, among others. The reason is that food, dyes, chemicals, and metals – even materials that aren't fire risks in larger pieces – have the potential to be combustible in dust form.

And these explosions aren't easy to contain. In a typical incident, combustible material comes into contact with an ignition source causing a small fire. These small fires go unreported, but they don't come without consequences. Even small fires in industrial facilities cause loss of product, time and sometimes bodily injury.

The outcome, sometimes, can also be much worse. If there's dust in the area, the primary explosion will cause that dust to become airborne. Then, the dust cloud itself can ignite, causing a secondary explosion that can be many times the size and severity of the primary explosion. If enough dust has accumulated, these secondary explosions have the potential to bring down entire facilities, causing immense damage and fatalities. Most people recall the Imperial Sugar explosion as an example of a devastating loss due to combustible dust accumulation.

The key ingredient in combustible dust fires and explosions is the presence of dust itself. While dust cannot be eliminated entirely, you can make sure it doesn't accumulate to a dangerous level simply by following a regular housekeeping regimen.

## 7.8. Onsite/ off site emergency plan



This section covers the onsite/ offsite plan requirements, role and responsibility of occupier and other employees, etc.

### 7.8.1. About emergency





An occurrence or an accident of such magnitude which creates a situation, in which the normal patterns of life within a community, is suddenly disrupted and people are plunged into helplessness, life losses, property losses, miserable sufferings. As a result, there is urgent need of shelter, food, clothing, medical aid, mental support, protection, social care, other life standing and recopying requirement.



### 7.8.2. Types of hazards

The emergencies arises due to two types hazards as highlighted below:

#### 1) Natural hazards<sup>18</sup>




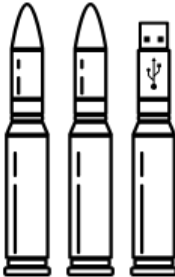
	<b>Wind related</b> – Cyclone, tornado
	<b>Water related</b> – Flood, cloudburst, excessive rains, draught
	<b>Earth related</b> – Earthquake, tsunami, landslides, volcanic eruption, soil erosion
	<b>Due to natural reasons</b> – Forest fire, epidemic

#### 2) Manmade hazards<sup>19</sup>

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<sup>18</sup> Source of icons – The Noun Project

<sup>19</sup> Source of icons – The Noun Project

	<p><b>Accidents:</b> Road, Rail, Air, Sea, building collapse</p>
  	<p><b>Industrial mishaps:</b> There are three sub-divisions of industrial mishaps</p> <ol style="list-style-type: none"> <li>1) <b>Un-intentional:</b> Poor maintenance, Low quality of work, Human error.</li> <li>2) <b>Willful or intentional:</b> Revenge, Riots, Enemy Attack.</li> <li>3) <b>Industrial and technological (mostly system/ process mal function)</b> such as nuclear radiation, Gas leak, Explosion, Fire <ul style="list-style-type: none"> <li>• <b>Fire:</b> Building, Coal, Oil, Gas, Electrical etc.</li> <li>• <b>Forest fire</b></li> <li>• <b>Contamination/ poisoning:</b> Food, Water, Epidemic.</li> <li>• <b>Terrorist activity</b></li> <li>• <b>Ecological:</b> Pollution (air, water, noise), global warming, toxic wastes</li> <li>• <b>Warfare:</b> Chemical, Nuclear</li> </ul> </li> </ol>

### 7.8.3. Classification of emergencies for factory

#### 1) **On-site emergency**

Effects remains limited to plants/ industry boundary

#### 2) **Off-site emergency**

Effects spread to neighboring industries or population



#### 7.8.4. Categorization of emergencies

Categorization	Intensity	Category	Potential Incidents	Level of Command	Communication
Level 1	Effect to particular plant only	<b>Minor incident:</b> Part site emergency services required	Fire, small explosion, medium spill, gas release.	Incident Controller	No siren / Only local FAS hooter/PA
Level 2	Effect on entire company premises	<b>Serious incident:</b> Full Site emergency services required	Serious fire, explosion, significant spill/ gas release/ marine pollution	Site Main Controller	Emergency siren
Level 3: Offsite emergency	Effect to entire company premises and nearby community resident	<b>Major:</b> Full site emergency services plus mutual aid required	Major fire, explosion, major spill, major gas release	Site Main Controller and District Collector	Emergency siren

#### 7.8.5. Why emergency planning is required?

Many disasters like Bhopal gas tragedy, Chernobyl nuclear disaster, etc. occurred at different places across the world, caused heavy loss of life and property. Emergency situation arises all of a sudden and creates havoc and damage to person, property, production and environment.

Such situations and risks should be thought in advance and it should be planned before hand to tackle them immediately and control them within the shortest time possible.

#### 7.8.6. Objective of emergency plan

- To control and contain the incident/ accident and if possible, eliminate.
- To minimize the effects of the incident on employees, company assets, environment and nearby community.
- Ensure the continuity of company supply chain business impact on market.



- Protect the company's brand image.
- To inform employees, the general public and the authority about the hazards / risks assessed, safeguard provided, residual risk if any and the role to be played by them in the event of emergency.
- Mock exercise according to the plan enhance the confidence to prevent or mitigate the emergency and persons made fully prepared to fight against any incident in the plant.

#### 7.8.7. Statutory requirement

##### 1) **The Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989**

###### Rule 13. Preparation of on-site emergency plan by the occupier.

(1) An occupier shall prepare and keep up-to-date [an on-site emergency plan containing details specified in Schedule 11 and detailing] how major accidents will be dealt with on the site on which the industrial activity is carried on and that plan shall include the name of the person who is responsible for safety on the site and the names of those who are authorized to take action in accordance with the plan in case of an emergency.

##### 2) **Factories Act - 1948, Gujarat Factories Rules, 1963**

###### Rule (12.) Preparation of on-site emergency plan by the occupier.

(1) An occupier who has control of an industrial activity to which this sub rule applies shall prepare in consultation with the Chief Inspector, keep up-to date and furnish to the Chief Inspector, and the Inspector an on-site emergency plan detailing how major accidents shall be dealt with on the site on which the industrial activity is carried on and that plant shall include the name of the person who is responsible for safety on the site and the names of those who are authorized to take action in accordance with the plan in case of an emergency.

##### 3) **Factory Act, 1948**

Under Section 41(B)(4) - Every occupier is to prepare On-site Emergency Plan and detailed disaster control measures for his factory. Again under provision of Rule 13 of the Manufacture, Storage and Import of Hazardous Chemicals Rules 1989, the occupier shall prepare and keep up to date On-site Emergency plan containing details how major accidents will be dealt with on the site on which the industrial activity is carried on and that plan shall include the name of the person who is responsible for safety on the site and names of those who are authorized to take action in accordance with the plan in case of emergency.



## Chapter 8: Annexures





## **8. Annexures**

Refer the Gujarat State Fire Act, Rules and Regulations and recent amendments for various forms and checklists.

## Chapter 9: References





## 9. References

# **Chapter 10:**

## **List of Various Acts, Rules, Regulations and Standards**





## 10. List Of Various Acts, Rules, Regulations And Standards

The following list records those standards which are acceptable as good practice and accepted standards in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code. In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part.

- National Building code, 2016, PART 4 - Fire and Life Safety
- Gujarat Fire Prevention and Life safety measure act 2013
- Gujarat Fire prevention and Life Safety measure rule 2014
- Gujarat Fire Prevention and Life Safety Regulations 2016
- Indian Factory Act 1947 AND Gujarat Factory Rule 1963
- National Disaster Management Act, 2005.
- IS 3808 : 1979 Method of test for non-combustibility of building materials (first revision)
- IS/ISO 834-1:1999 : Fire resistance tests Elements of building construction Part 1 General requirements
- IS/ISO 834-4:2000 : Fire resistance tests - Elements of building construction: Part 4 Specific requirements for load bearing vertical separating elements
- IS/ISO 834-5 : Fire resistance tests - Elements 2000 of building construction: Part 5 Specific requirements for load bearing horizontal separating elements
- IS/ISO 834-6:2000 : Fire resistance test - Elements of building constructions: Part 6 Specific requirements for beams
- IS/ISO 834-7:2000 : Fire resistance tests - Elements of building construction: Part 7 Specific requirements for columns
- IS/ISO 834-8: 2003 : Fire resistance tests - Elements of building construction: Part 8 Specific requirements for non-load bearing vertical separating elements
- IS/ISO 834-9: 2003 : Fire resistance tests - Elements of building construction: Part 9 Specific requirements for non-load bearing ceiling elements



- IS 8757 : 1999 Glossary of terms associated with fire safety (first revision) 7673 : 2004 Glossary of terms for firefighting equipment (first revision)
- IS 8758 : 2013 Code of practice for fire precautionary measures in construction of temporary structures and pandals (second revision)
- IS 9668 : 1990 Code of practice for provision and maintenance of water supplies and fire fighting
- IS 3844 : 1989 Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (first revision)
- IS 1646 : 2015 Code of practice for fire safety of buildings (general) : Electrical installations (third revision)
- IS 9457 : 2005 Code of practice for safety colours and safety signs (first revision)
- IS 12349 : 1988 Fire protection - Safety sign
- IS 12407 : 1988 Graphic symbols for fire protection plans
- IS 11360 : 1985 Specification for smoke detectors for use in automatic electrical fire alarm system
- IS 655 : 2006 Specification for air ducts
- IS 1649 : 1962 Code of practice for design and construction of flues and chimneys for domestic heating appliances (first revision)
- IS 1642 : 2013 Code of practice for safety of buildings (general): Details of construction (second revision)
- IS 12777 : 1989 Method for classification of flame spread of products
- IS 1642 : 2013 Code of practice for safety of buildings (general): Details of construction (second revision)
- IS 16246 : 2015: Elastomer insulated cables with limited circuit Integrity when affected by fire - Specification
- IS 6044 (Part 1):2013 : Liquefied petroleum gas storage installations - Code of Practice : Part 1 Residential commercial and industrial cylinder installations
- IS 6044 (Part 2):2001 : Code of Practice for liquefied petroleum gas storage Installations: Part 2 Commercial, industrial and domestic bulk storage installations





- IS 2175 : 1988: Specification for heat sensitive fire detectors for use in automatic fire alarm system (second revision)
- IS/ISO 7240-5: 2003 :Fire detection and alarm systems: Part 5 Point-type heat detectors
- IS/ISO 7240-7: 2011 :Fire detection and alarm systems: Part 7 Point-type smoke detectors using scattered light, transmitted light or ionization
- IS/ISO 7240-11: 2011: Fire detection and alarm systems: Part 11 Manual call points
- IS/ISO 7240-15: 2004 :Fire detection and alarm systems: Part 15 Point-type fire detectors using scattered light, transmitted light or ionization sensor in combination with a heat sensor
- IS 11360 : 1985 Specification for smoke detectors for use in automatic electrical fire alarm system
- IS 2189 : 2008 Code of practice for selection, installation and maintenance of automatic fire detection and alarm system (second revision)
- IS 636 : 1988 Specification for non-percolating flexible fire fighting delivery hose (third revision)
- IS 884 : 1985 Specification for first-aid hose reel for firefighting(first revision)
- IS 901 : 1988 Specification for couplings, double male and double female instantaneous pattern for firefighting (third revision)
- IS 902 : 1992 Specification for suction hose couplings for firefighting purposes (third revision)
- IS 903 : 1993 Specification for fire hose delivery couplings, branch pipe, nozzles and nozzle spanner (fourth revision)
- IS 904 : 1983 Specification for two-way and three-way suction collecting heads for firefighting purposes (second revision)
- IS 905 : 1980 Specification for delivery breechings, dividing and collecting, instantaneous pattern for firefighting purposes (second revision)
- IS 906 : 1988 Specification for revolving branch pipe for firefighting (third revision)
- IS 907 : 1984 Specification for suction strainers, cylindrical type for firefighting purpose (second revision)
- IS 908 : 1975 Specification for fire hydrant, stand post type (second revision)



- IS 909 : 1992 Specification for underground fire hydrant : Sluice valve type (third revision)
- IS 910 : 1980 Specification for combined key for hydrant, hydrant cover and lower valve (second revision)
- IS 926 : 1985 Specification for fireman's axe (second revision)
- IS 927 : 1981 Specification for fire hooks (second revision)
- IS 928 : 1984 Specification for fire bells (second revision)
- IS 937 : 1981 Specification for washers for water fittings for firefighting purposes (second revision)
- IS 939 : 1977 Specification for snatch block for use with fibre rope for fire brigade use (first revision)
- IS 941 : 1985 Specification for blowers and exhausters for firefighting (second revision)
- IS 942 : 1982 Functional requirements for 275 l/min portable pump set for firefighting (second revision)
- IS 943 : 1979 Functional requirement for 680 l/min trailer pump for fire brigade use (second revision)
- IS 944 : 1979 Functional requirement for 1800 l/min trailer pump for fire brigade use (second revision)
- IS 947 : 1985 Functional requirement for towing tender for trailer fire pump for fire brigade use (first revision)
- IS 948 : 1983 Functional requirement for water tender, Type A, for fire brigade use (second revision)
- IS 949 : 2012 Functional requirement for emergency (rescue) tender (third revision)
- IS 950 : 2012 Functional requirements for water tender, Type B for fire brigade use (third revision)
- IS 952 : 1986 Specification for fog nozzle for fire brigade use (second revision)
- IS 955 : 1980 Functional requirements for dry power tender for fire-brigade use (150 kg capacity) (first revision)
- IS 957 : 1967 Specification for control van for fire brigade



- IS 1941 (Part 1): 1976 : Functional requirements for electric motor sirens :Part 1 AC, 3-Phase, 50 Hz, 415 volts type (second revision)
- IS 2097 : 2012 Specification for foam making branch pipe and foam inductor (second revision)
- IS 2175 : 1988 Specification for heat sensitive fire detectors for use in automatic detectors for use in automatic fire alarm system (second revision)
- IS 2546 : 1974 Specification for galvanized mild steel fire bucket (first revision)
- IS 2696 : 1974 Functional requirements for 1125 l/min light fire engine (first revision)
- IS 2745 : 1983 Specification for non-metal helmet for firemen and civil defense personnel (second revision)
- IS 2871 : 2012 Specification for branch pipe, universal for firefighting purposes (second revision)
- IS 2878 : 2004 Specification for fire extinguisher, carbon-dioxide type (portable and trolley mounted) (third revision)
- IS 2930 : 1980 Functional requirements for hose laying tender for fire brigade use (first revision)
- IS 3582 : 1984 Specification for basket strainers for firefighting purposes (cylindrical type) (first revision)
- IS 4308 : 2003 Specification for dry chemical powder for firefighting B and C class fires (second revision)
- IS 4571 : 1977 Specification for aluminum extension ladders for fire brigade use (first revision)
- IS 4643 : 1984 Specification for suction wrenches for fire brigade use (first revision)
- IS 4861 : 1984 Specification for dry powder for fighting fires in burning metals (first revision)
- IS 4927 : 1992 Specification for unlined flax canvas hose for firefighting (first revision)
- IS 4928 : 1986 Specification for delivery valve for centrifugal pump outlets (first revision)
- IS 4947 : 2006 Specification for gas cartridges for use in fire extinguishers (third revision)



- IS 4989 : 2006 Foam concentrate for producing mechanical foam for firefighting - Specification (third revision)
- IS 4989 (Part 4) 2003 : Specification for multipurpose aqueous film forming foam liquid concentrate for extinguishing hydrocarbon and polar solvent fires
- IS 5131 : 2002 Specification for dividing breeching with control, for fire brigade use (second revision)
- IS 5290 : 1993 Specification for landing valve (third revision)
- IS 5486 : 1985 Specification for quick release knife (first revision)
- IS 5505 : 1985 Specification for multi-edged rescue axe (non-wedging) (first revision)
- IS 5612 Specification for hose-clamps and hose-bandages for fire brigade use (Part 1) : 1977: Hose clamps (first revision) (Part 2) : 1977 Hose bandages (first revision)
- IS 5714 : 1981 Specification for hydrant, standpipe for firefighting (first revision)
- IS 6026 : 1985 Specification for hand operated sirens (first revision)
- IS 6067 : 1983 Functional requirements for water tender, Type 'X' for fire brigade use (first revision)
- IS/ISO 7240-5:2003 :Fire detection and alarm systems - Part 5: Point-type heat detectors
- IS/ISO 7240-7 :Fire detection and alarm 2011 systems - Part 7: Point-type smoke detectors using scattered light, transmitted light or ionization
- IS/ISO 7240-11:Fire detection and alarm systems - 2011 Part 11 Manual call points
- IS 8090 : 1992 Specification for couplings, branch pipe, nozzle, used in hose reel tubing for firefighting (first revision)
- IS 8096 : 1992 Specification for fire beaters (first revision)
- IS 8149 : 1994 Functional requirements for twin CO2 fire extinguishers (trolley mounted) (first revision)
- IS 8423 : 1994 Specification for controlled percolating hose for firefighting (first revision)
- IS 8442 : 2008 Specification for stand post type water and foam monitor for firefighting (first revision)



- IS 9972 : 2002 Specification for automatic sprinkler heads (first revision)
- IS 10460 : 1983 Functional requirements for small foam tender for fire brigade use
- IS 10658 : 1999 Specification for higher capacity dry powder fire extinguisher (trolley mounted) (first revision)
- IS 10993 : 1984 Functional requirements for 2 000 kg dry powder tender for fire brigade use
- IS 11101 : 1984 Specification for extended branch pipe for fire brigade use
- IS 11108 : 1984 Specification for portable fire extinguisher halon-1211 type
- IS 11833 : 1986 Specification for dry powder fire extinguisher for metal fires
- IS 12717 : 1989 Functional requirements of firefighting equipment - High capacity portable pump set (1 100-1 600 l/min)
- IS 12796 : 1989 Specification for fire rake
- IS 13039 : 1991 Code of practice for provision and maintenance of external hydrant system
- IS 13385 : 1992 Specification for fire extinguisher 50 capacity wheel mounted water type (Gas cartridge)
- IS 13386 : 1992 Specification for 50 litre capacity fire extinguisher, mechanical foam type
- IS 14609 : 1999 Specification for ABC dry powder for firefighting
- IS 14933 : 2001 Specification for high pressure fire fighting hose
- IS 14951 : 2001 Specification for fire extinguisher, 135 litre capacity mechanical foam type
- IS 15051 : 2002 Specification for high pressure fire hose delivery couplings
- IS 15105 : 2002/ ISO 6182-1 : Design and installation of fixed automatic sprinkler fire extinguishing system
- IS 15220 : 2002/ ISO 7201-1 : Specification for halon 1211 and halon 1301 - fire extinguishing media for fire protection
- IS 15683 : 2006/ ISO 7165 : 2009: Portable fire extinguishers - Performance and construction — Specification



- IS 11360 : 1985 Specification for smoke detectors for use in automatic electrical fire alarm system
- IS 15493 : 2004/ ISO 14520-1 : Gaseous fire extinguishing systems : General requirements
- IS 15505 : 2004/ ISO 14520-6 : Gaseous fire extinguishing systems: HCFC Blend A extinguishing systems
- IS 15506 : 2004/ ISO 14520-14: Gaseous fire extinguishing systems - IG 55 extinguishing systems
- IS 15525 : 2004/ ISO 14520-13 : Gaseous fire extinguishing systems - IG 100 extinguishing systems
- IS 15501 : 2004/ ISO 14520-15: Gaseous fire extinguishing systems - IG 541 extinguishing systems
- IS 15497 : 2004/ ISO 14520-12 : Gaseous fire extinguishing systems - IG 01 extinguishing systems
- IS 15519 : 2004 Code of practice for water mist fire protection systems - System design, installation and commissioning
- IS 15517 : 2004/ ISO 14520-9 : Gaseous fire extinguishing systems - Carbon dioxide, total flooding and local application including in cabinet subfloors systems
- IS 15517 : 2004/ ISO 14520-9 : Gaseous fire extinguishing systems - HFC 227ea (Hepta Fluoro Propane) extinguishing system
- IS 2190 : 2010 Code of practice for selection, installation and maintenance of portable first-aid fire extinguishers (fourth revision)
- IS 884 : 1985 Specification for first aid hose reel for firefighting (first revision)
- IS 15105 : 2002 Design and installation of fixed automatic sprinkler fire extinguishing system
- IS 15325 : 2003 Design and installation of fixed automatic high and medium velocity water spray system — Code of practice
- IS 12835 (Part 1) : 1989 : Design and installation of fixed foam fire extinguishing system - Code of practice: Part 1 Low expansion foam



- IS 15528 : 2004 Gaseous fire extinguishing systems - Carbon dioxide, total flooding and local application (sub-floor and in-cabinet), high and low floor pressure (refrigerated) systems
- IS 15519 : 2004 Water mist fire protection systems - System design, installation and commissioning — Code of Practice
- IS 15493 : 2004 Gaseous fire extinguishing Systems - General requirements
- IS 15497 : 2004 Gaseous fire extinguishing systems - IG 01 extinguishing systems
- IS 15501 : 2004 Gaseous fire extinguishing systems - IG 541 extinguishing systems
- IS 15505 : 2004 Gaseous fire extinguishing systems - HCFC Blend A
- IS 15506 : 2004 Gaseous fire extinguishing systems - IG 55 extinguishing systems
- IS 15517 : 2004 Gaseous fire extinguishing systems - HFC 227 ea (Hepta fluoro propane) extinguishing systems
- IS 15525 : 2004 Gaseous fire extinguishing systems - IG 100 extinguishing systems
- IS 2189 : 2008 Code of practice for selection, installation and maintenance of automatic fire detection and alarm system (fourth revision)
- IS 2190 : 2010 Code of practice for selection, installation and maintenance of portable first-aid fire extinguishers (fourth revision)
- IS 3844 : 1989 Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (first revision)
- IS 9668 : 1990 Code of practice for provision and maintenance of water supplies for firefighting
- IS 13039 : 1991 Code of practice for provision and maintenance of external hydrant system
- IS 13039 : 2014 External hydrant systems - Provision and maintenance Code of practice
- IS 4878 : 1986 Byelaws for construction of cinema buildings (first revision)
- IS 2726 : 1988 Code of practice for fire safety of industrial buildings : Cotton ginning and pressing (including cotton seed delinting) factories (first revision)
- IS 3034 : 1993 Code of practice for fire safety of industrial buildings : Electrical generating and distributing stations (second revision)





- IS 3058 : 1990 Code of practice for fire safety of industrial buildings : Viscose rayon yarn and/or staple fibre plants (first revision)
- IS 3079 : 1990 Code of practice for fire safety of industrial buildings : Cotton textile mills (first revision)
- IS 3594 : 1991 Code of practice for fire safety of industrial buildings : General storage and warehousing including cold storage (first revision)
- IS 3595 : 1984 Code of practice for fire safety of industrial buildings : Coal pulverizers and associated equipment (first revision)
- IS 3836 : 2000 Code of practice for fire safety of industrial buildings : Jute mills (second revision)
- IS 4209 : 2013 Code of safety for chemical laboratories (second revision)
- IS 4226 : 1988 Code of practice for fire safety of industrial buildings : Aluminium/ Magnesium powder factories (first revision)
- IS 4886 : 1991 Code of practice for fire safety of industrial buildings : Tea factories (first revision)
- IS 6329 : 2000 Code of practice for fire safety of industrial buildings : Saw mills and wood works (first revision)
- IS 9109 : 2000 Code of practice for fire safety of industrial buildings : Paint and Varnish factories
- IS 11457 (Part 1): 1985 : Code of practice for fire safety of chemical industries: Part 1 Rubber and plastic
- IS 13039 : 2014 External hydrant systems Provision and maintenance Code of practice

# **Chapter 11:**

## **List of Various National/ International Standards and Organizations**





## **11. List of Various National/ International Standards and Organizations**

### **11.1. Bureau of Indian Standards (BIS)**

The Bureau of Indian Standards (BIS) is the national Standards Body of India working under the aegis of Ministry of Consumer Affairs, Food & Public Distribution, Government of India. It is established by the Bureau of Indian Standards Act, 1986 which came into effect on 23 December 1986. The Minister in charge of the Ministry or Department having administrative control of the BIS is the ex-officio President of the BIS. It has been providing traceability and tangibility benefits to the national economy in a number of ways – providing safe reliable quality goods; minimizing health hazards to consumers; promoting exports and imports substitute; control over proliferation of varieties etc. through standardization, certification and testing.

A new Bureau of Indian standards (BIS) Act 2016 which was notified on 22 March 2016, has been brought into force with effect from 12 October 2017. The Act establishes the Bureau of Indian Standards (BIS) as the National Standards Body of India.

As a corporate body, it has 25 members drawn from Central or State Governments, industry, scientific and research institutions, and consumer organizations. Its headquarters are in New Delhi, with regional offices in Eastern Region at Kolkata, southern Region at Chennai, Western Region at Mumbai, Northern Region at Chandigarh and Central Region at Delhi and 20 branch offices.

Fire Fighting Sectional Committee, CED 22 of BIS is engaged in formulation of Indian Standards on Fire Fighting equipment/extinguishers using water, carbon dioxide, foam, dry powder and halon as extinguishing agents. In view of the phasing out of halons as per Montreal Protocol, BIS has recently published various standards on halon alternatives. These are intended for use by the Fire brigades and other organizations.

BIS has formulated more than 100 standards on firefighting including standards on various type of fire tenders, fire engines, trailer pumps, high capacity portable pump sets etc.

Safety of the occupants of the buildings is the fundamental requirement that the owner and the professionals involved endeavor to achieve. Fire Safety Sectional Committee, CED 36 of BIS has formulated a series of Indian Standards pertaining to General requirements and specific to various buildings & industries. Some of the important standards formulated by this Committee are as mentioned in earlier chapter.



National Building Code (Part 4) – Fire Protection: As a major development, BIS has published NBC (Part 4) Fire Protection which includes comprehensive recommendation of minimum standards of fire protection. It specifies the demarcation of fire zones, restrictions on construction of buildings in each fire zone, classification of buildings based on occupancy, types of building construction according to fire resistance of the structural and nonstructural components and other restrictions and requirements necessary to minimize danger to life from fire, smoke, fumes or panic before the building can be evacuated. The Code recognizes that safety of life is more than a matter of means of exits and accordingly deals with various matters which are considered essential to the safety of life.

Click here for more information: <https://bis.gov.in>

## 11.2. Oil Industries Safety Directorate (OISD), India

OISD (Oil Industry Safety Directorate) is a technical directorate under the Ministry of Petroleum and Natural Gas that formulates and coordinates the implementation of a series of self-regulatory measures aimed at enhancing the safety in the Oil & Gas industry in India.

The following few OISD standards are related to Fire and Safety.

Sr. No.	OISD Standard /GDN /RP No	Standard Name	Current Edition In Vogue
1	OISD-STD-105	Work Permit System	Sep, 2004
2	OISD-RP-110	Recommended Practices on Static Electricity	Oct, 2018
3	OISD-STD-113	Classification of Area for Electrical Installations at Hydrocarbon Processing & Handling Facilities	Oct, 2013
4	OISD-STD-114	Safe Handling of Hazardous Chemicals	Oct, 2010
5	OISD-GDN-115	Guidelines on Fire Fighting Equipment and Appliances in Petroleum Industry	Jul, 2000
6	OISD-STD-116	Fire Protection Facilities for Petroleum Refineries and Oil/Gas Processing Plants	Oct, 2017
7	OISD-STD-117	Fire Protection Facilities for Petroleum Depots, Terminals, Pipeline Installations & Lube oil installations	Oct, 2017
8	OISD-STD-142	Inspection of firefighting equipment and systems	Feb, 1996
9	OISD-STD-144	Liquefied Petroleum Gas (LPG) Installations	Oct, 2017
10	OISD-GDN-145	Guidelines on Internal Safety Audits (Procedures and Checklist)	Sep, 2001
11	OISD-RP-149	Design aspects for safety in electrical systems	Oct, 2013
12	OISD-STD-156	Fire Protection Facilities for Ports Handling Hydrocarbons	Oct, 2017
13	OISD-RP-157	Safety in Transportation of Bulk Petroleum Products (Rail and Road)	Aug, 2019



Sr. No.	OISD Standard /GDN /RP No	Standard Name	Current Edition In Vogue
14	OISD-STD-159	LPG Tank Trucks - Requirements of Safety on Design/Fabrication & Fittings	Oct, 2018
15	OISD-GDN-161	LPG Tank Truck Incidents Rescue & Relief Operations	Oct, 2018
16	OISD-STD-163	Process Control Room Safety	Sep, 2004
17	OISD-STD-173	Fire Prevention and Protection System for Electrical Installations	Oct, 2017
18	OISD-GDN-180	Lightning Protection	Oct, 2018
19	OISD-STD-191	Oil Field Explosive Safety	Oct, 2017
20	OISD-GDN-192	Safety Practices during Construction	Apr, 2016

### 11.3. National Fire Protection Association (NFPA), USA

The National Fire Protection Association (NFPA) is a global self-funded nonprofit organization, established in 1896, devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards.

**NFPA vision:** We are the leading global advocate for the elimination of death, injury, property, and economic loss due to fire, electrical and related hazards.

**NFPA mission:** To help save lives and reduce loss with information, knowledge, and passion.

NFPA delivers information and knowledge through more than **300 consensus** codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering our mission. NFPA membership totals more than 50,000 individuals around the world.

Click here to learn more – <https://www.nfpa.org/>

#### List of Few NFPA standards:

NFPA Code	Description
<b>NFPA 1</b>	Fire Code
<b>NFPA 2</b>	Hydrogen Technologies Code
<b>NFPA 3</b>	Standard for Commissioning of Fire Protection and Life Safety Systems
<b>NFPA 4</b>	Standard for Integrated Fire Protection and Life Safety System Testing
<b>NFPA 10</b>	Standard for Portable Fire Extinguishers



NFPA Code	Description
<b>NFPA 11</b>	Standard for Low-, Medium-, and High-Expansion Foam
<b>NFPA 11A</b>	Standard for Medium- and High-Expansion Foam Systems
<b>NFPA 11C</b>	Standard for Mobile Foam Apparatus
<b>NFPA 12</b>	Standard on Carbon Dioxide Extinguishing Systems
<b>NFPA 12A</b>	Standard on Halon 1301 Fire Extinguishing Systems
<b>NFPA 13</b>	Standard for the Installation of Sprinkler Systems
<b>NFPA 13D</b>	Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes
<b>NFPA 13E</b>	Recommended Practice for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems
<b>NFPA 13R</b>	Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies
<b>NFPA 14</b>	Standard for the Installation of Standpipe and Hose Systems
<b>NFPA 15</b>	Standard for Water Spray Fixed Systems for Fire Protection
<b>NFPA 16</b>	Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems
<b>NFPA 17</b>	Standard for Dry Chemical Extinguishing Systems
<b>NFPA 17A</b>	Standard for Wet Chemical Extinguishing Systems
<b>NFPA 18</b>	Standard on Wetting Agents
<b>NFPA 18A</b>	Standard on Water Additives for Fire Control and Vapor Mitigation
<b>NFPA 20</b>	Standard for the Installation of Stationary Pumps for Fire Protection
<b>NFPA 22</b>	Standard for Water Tanks for Private Fire Protection
<b>NFPA 24</b>	Standard for the Installation of Private Fire Service Mains and Their Appurtenances
<b>NFPA 25</b>	Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems
<b>NFPA 30</b>	Flammable and Combustible Liquids Code
<b>NFPA 30A</b>	Code for Motor Fuel Dispensing Facilities and Repair Garages
<b>NFPA 30B</b>	Code for the Manufacture and Storage of Aerosol Products
<b>NFPA 31</b>	Standard for the Installation of Oil-Burning Equipment
<b>NFPA 32</b>	Standard for Dry-cleaning Facilities
<b>NFPA 33</b>	Standard for Spray Application Using Flammable or Combustible Materials
<b>NFPA 34</b>	Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids
<b>NFPA 35</b>	Standard for the Manufacture of Organic Coatings
<b>NFPA 36</b>	Standard for Solvent Extraction Plants
<b>NFPA 37</b>	Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
<b>NFPA 40</b>	Standard for the Storage and Handling of Cellulose Nitrate Film
<b>NFPA 42</b>	Code for the Storage of Pyroxylin Plastic
<b>NFPA 45</b>	Standard on Fire Protection for Laboratories Using Chemicals
<b>NFPA 46</b>	Recommended Safe Practice for Storage of Forest Products
<b>NFPA 50</b>	Standard for Bulk Oxygen Systems at Consumer Sites
<b>NFPA 50A</b>	Standard for Gaseous Hydrogen Systems at Consumer Sites
<b>NFPA 50B</b>	Standard for Liquefied Hydrogen Systems at Consumer Sites
<b>NFPA 51</b>	Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes
<b>NFPA 51A</b>	Standard for Acetylene Cylinder Charging Plants



NFPA Code	Description
<b>NFPA 51B</b>	Standard for Fire Prevention During Welding, Cutting, and Other Hot Work
<b>NFPA 52</b>	Vehicular Natural Gas Fuel Systems Code
<b>NFPA 53</b>	Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres
<b>NFPA 54</b>	National Fuel Gas Code
<b>NFPA 55</b>	Compressed Gases and Cryogenic Fluids Code
<b>NFPA 56</b>	Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems
<b>NFPA 57</b>	Liquefied Natural Gas (LNG) Vehicular Fuel Systems Code
<b>NFPA 58</b>	Liquefied Petroleum Gas Code
<b>NFPA 59</b>	Utility LP-Gas Plant Code
<b>NFPA 59A</b>	Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)
<b>NFPA 61</b>	Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
<b>NFPA 67</b>	Guide on Explosion Protection for Gaseous Mixtures in Pipe Systems
<b>NFPA 68</b>	Standard on Explosion Protection by Deflagration Venting
<b>NFPA 69</b>	Standard on Explosion Prevention Systems
<b>NFPA 70®</b>	National Electrical Code®
<b>NFPA 70A</b>	National Electrical Code® Requirements for One- and Two-Family Dwellings
<b>NFPA 70B</b>	Recommended Practice for Electrical Equipment Maintenance
<b>NFPA 70E®</b>	Standard for Electrical Safety in the Workplace®
<b>NFPA 72®</b>	National Fire Alarm and Signaling Code®
<b>NFPA 73</b>	Standard for Electrical Inspections for Existing Dwellings
<b>NFPA 75</b>	Standard for the Fire Protection of Information Technology Equipment
<b>NFPA 76</b>	Standard for the Fire Protection of Telecommunications Facilities
<b>NFPA 77</b>	Recommended Practice on Static Electricity
<b>NFPA 78</b>	Guide on Electrical Inspections
<b>NFPA 79</b>	Electrical Standard for Industrial Machinery
<b>NFPA 80</b>	Standard for Fire Doors and Other Opening Protective
<b>NFPA 80A</b>	Recommended Practice for Protection of Buildings from Exterior Fire Exposures

#### 11.4. Underwriter Laboratories (UL), USA

UL LLC is a global safety certification company headquartered in Northbrook, Illinois. It maintains offices in 46 countries. Established in 1894 as the Underwriters' Electrical Bureau (a bureau of the National Board of Fire Underwriters), it was known throughout the 20th century as Underwriters Laboratories and participated in the safety analysis of many of that century's new technologies. UL is one of several companies approved to perform safety testing by the U.S. federal agency, the Occupational Safety and Health





Administration (OSHA). OSHA maintains a list of approved testing laboratories, which are known as Nationally Recognized Testing Laboratories.

Click here to learn more - <https://www.ul.com/about>

### 11.5. FM Global, USA

FM Global is an American mutual insurance company based in Johnston, Rhode Island, United States, with offices worldwide, that specializes in loss prevention services primarily to large corporations throughout the world in the Highly Protected Risk (HPR) property insurance market sector. "FM Global" is the communicative name of the company, whereas the legal name is "Factory Mutual Insurance Company". FM Global has been named the "Best Property Insurer in the World" by Euromoney Magazine.

The company employs a non-traditional business model whereby risk and premiums are determined by engineering analysis as opposed to historically based actuarial calculations. This business approach is centered on the belief that property losses can be prevented or mitigated. FM Global engineering personnel regularly visit insured locations to evaluate hazards and recommend improvements to their property or work practices to reduce physical and financial risks if a loss occurs.

Click here to learn more: <https://www.fmglobal.com/about-us>

### 11.6. Institutions of Fire Engineers (IFE), UK

The Institution of Fire Engineers (IFE) is a worldwide body that provides research, training, conferences and professional qualifications for firefighters and civilians who work in fields related to firefighting, the science of firefighting and prevention, and related technology.[1] The IFE was established in 1918 and upholds professional standards within all public and private fire sectors by offering assessment of knowledge, experience and development and engages with major stakeholders to offer international conferences, identify and promote good practice and enhance technical networks worldwide. The IFE is also an equal recognized Awarding Organization.



Members are involved in a number of areas such as: fire dynamics including ignition, chemistry and toxicology; consultations with government in the drafting and implementation of fire safety legislation and regulations; structural fire protection of buildings; fire insurance and arson investigation; behavior pattern of persons faced with emergencies; fire detection and alarm systems, fire appliances and automatic fire fighting systems Specialist interest groups include Fire modelling, heritage buildings, transport, fire investigation and research.

Grades of membership: Affiliate, Student, Technician (TIFireE), Graduate (GIFireE), Associate (AIFireE), Member (MIFireE), Fellow (FIFireE).

The mission of the Institution is to encourage and improve the science and practice of fire extinction, fire prevention and fire engineering and all operations and expedients connected therewith, and to give an impulse to ideas likely to be useful in connection with or in relation to such science and practice to the members of the Institution and to the community at large.

The IFE has c. 10,000 members with 19 UK branches and 22 International branches.

The IFE has been a licensed member of the Engineering Council since 2007 and can register those members that meet the necessary criteria as Chartered Engineers (CEng), Incorporated Engineers (IEng) or Engineering Technicians (EngTech). Number of professionally registered members in 2011 were; • 173 EngTech • 32 IEng • 238 CEng

The Institution also manages a Register of Fire Risk Assessors and Auditors.

The IFE head office moved to Stratford upon Avon, Warwickshire in 2011 from its former home at the Fire Service College at Moreton in Marsh.

Click here for more information: <https://www.ife.org.uk/>

## **11.7. Petroleum of Explosive Safety Organization (PESO), Mumbai**

The Petroleum and Explosives Safety Organization (PESO), formerly known as Department of Explosives, since its inception on 05/09/1898, has been serving the nation



as a nodal agency for regulating safety of hazardous substances such as explosives, compressed gas and petroleum.

The organization has earned rare distinction as an institution of excellence in matters related to safety in manufacturing/refining, storage, transportation, handling and use of hazardous substances for over a century. Apart from the normal functions of enforcement of statutory safety regulations to safeguard public safety, life, property and environment, the organization has rendered meritorious voluntary services in examination and disposal of explosives, improvised explosives devices till late eighties of the last century, some of which were of national importance encountered during freedom struggle of the country, terrorist activities in different regions in the country. Till early nineties of the last century, the officers of the organization were carrying out anti-sabotage checks and duties related to VVIP security, Airport Security etc.

Click here for more information: <https://peso.gov.in/>

## **11.8. National Disaster Management Authority**

The National Disaster Management Authority (NDMA), headed by the Prime Minister of India, is the apex body for Disaster Management in India. Setting up of NDMA and the creation of an enabling environment for institutional mechanisms at the State and District levels is mandated by the Disaster Management Act, 2005. NDMA is mandated to lay down the policies, plans and guidelines for Disaster Management. India envisions the development of an ethos of Prevention, Mitigation, Preparedness and Response.

Click here for more information: <https://ndma.gov.in/>

## **11.9. Gujarat State Disaster Management Authority**

The Government of Gujarat established the GSMA in February 2001 to co-ordinate the comprehensive earthquake recovery program. Its vision is to go beyond reconstruction and make Gujarat agriculturally and industrially competitive with improved standards of living and with a capacity to mitigate and manage future disasters.

Click here for more information: <http://www.gsdma.org/>

**Save yourself, save others**  
**Be prepared and stay alert!**