Gujarat State Institute for Fire Safety Training (GSIFST)

Advance Course in Fire Prevention, Life Safety & Fire Protection Measures in Buildings

Category - Fire Safety Officer – Advance (FSO-A)

Participant's Workbook

Gujarat State Fire Prevention Services

Gandhinagar, Gujarat (India)

Advance Course in Fire Prevention, Life Safety & Fire Protection Measures in Buildings

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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 'Advance Course in Fire Prevention, Life Safety & Fire Protection Measures in Buildings' is one of the outcome documents.

The initiative is spearheaded by the Urban Development and Urban Housing Department with active support from Gujarat Institute of Disaster Management (GIDM), Directorate of Fire Prevention Services (DFPS), Gujarat State Institute for Fire Safety Training (GSIFST). The contribution of Chief Fire Offices and Regional Fire Offices across the state for the initiative is also very important.

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(V N Solanki)
Principal
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Contents

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 Industries 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.

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

1. Residential buildings (other than hotels and guest houses) having height more than 35 m but not exceeding 60 m in height.
2. Hotels upto 15 m in height (floor area more than 1000 m^2).
3. Hotels 15m and above but not exceeding 30 m in height.
4. Educational buildings having height more than 15 m but not exceeding 30 m in height.
5. Hospitals and Nursing Homes with beds having height less than 15 m with plot area more than 1000 m^2, or those having height above 15 m upto 24 m.
6. Custodial, Penal & mental institutions more than 10 m but not exceeding 24 m in height.
7. Assembly buildings less than 10 m in height having more than 300 persons, or above 15 m but not exceeding 24 m in height.
8. Business buildings above 24 m but not exceeding 30 m in height.
9. Mercantile occupancies above 15 m in height but not exceeding 30 m in height.
10. Moderate Hazard category Industrial buildings as per ANNEX-B of the NBC 2016 (Part 4) having covered area more than 1000 m^2.
11. Storage buildings below 15 m in height and covered areas more than 250 m^2, Ground floor or Ground plus more than one floor.
12. Mixed Use Occupancies having height more than 15 m upto 30 m.

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

(1) <u>Density:</u>

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.

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

If mass (m) is measured in kilograms (kg) and volume (V) in cubic meters (m3), the unit of density (ρ) will be kilograms per cubic meters (kg/m3). Similarly, if mass is in gram (g) and volume in cubic centimeters (cm3), the unit of density will be grams per cubic centimeters (g/cm3).

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

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

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.

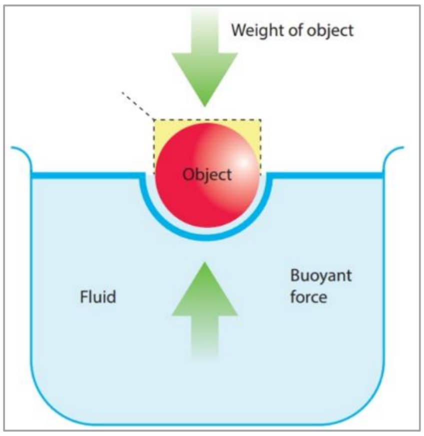
Gases and vapors have very low densities compared to liquids and solids and is measured as vapor density. At normal temperature and pressure (NTP), a cubic meter of water and air has mass of 1000 kg and 1.2kg, respectively. Because of this difference in mass at NTP, density of gas and vapor is given in relation to density of equal volume of hydrogen as H2 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^3 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°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_2; bromine, Br_2).

(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_2O (two atoms of hydrogen and one of oxygen) whereas propane is C_3H_8, where C stands for carbon. A formula may be written to indicate the arrangement of the atoms in the molecule. Thus, propane is $CH_3CH_2CH_3$.

(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

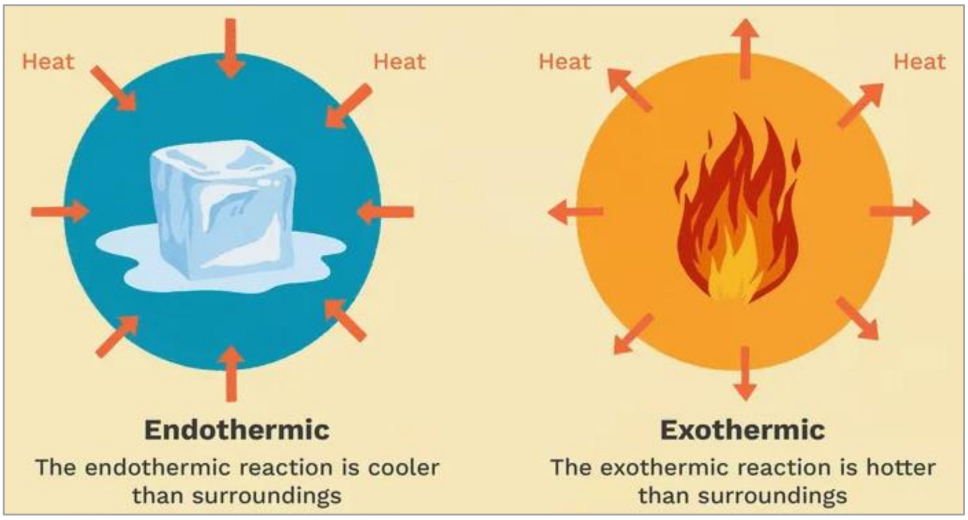
A mole of an element or compound is the amount that corresponds to the gram molecular weight. Thus, one mole of propane has a mass of 44 g. One mole of any element or compound contains 6.022 × 1023 molecules (see definition of atomic weight).

(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) <u>Ignition</u>

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-$C_{10}H_{22}$), 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.

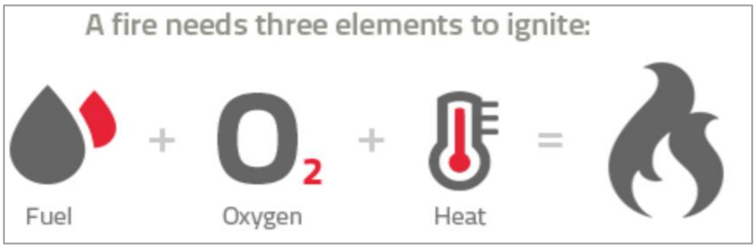
For most liquid fuels, this is simply a process of evaporation, but almost all solid fuels must undergo chemical decomposition (**pyrolysis**) before vapor is released.

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

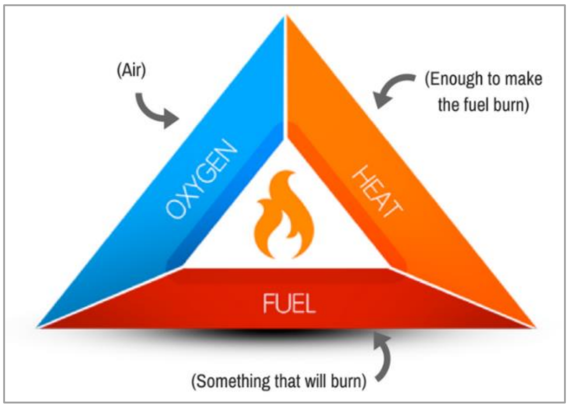
For combustion or burning to occur, oxygen, usually from air, must combine with a fuel.



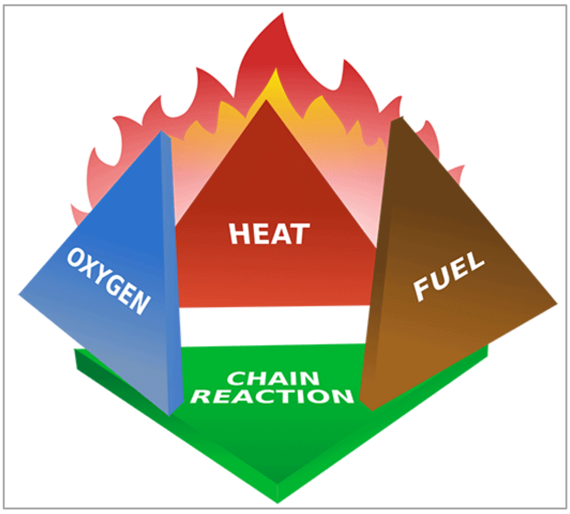
A fuel may be in any one of the three states initially but for flaming combustion to occur, a solid to liquid fuel must be converted to vapor, which then mixes with air and reacts with oxygen. Smoldering combustion on the other hand, involves a reaction between oxygen and surface of the fuel. A flame 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:

$$C_3H_8 + 5O_2 = 3CO_2 + 4H_2O$$

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:

$$C_3H_8 + H = C_3H_7 + H_2$$

$$C_3H_8 + OH = C_3H_7 + H_2O$$

$$C_3H_7 + O_2 = C_3H_6 + HO_2$$

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_3H_7):

$$H + O_2 = OH + O$$

$$C_3H_8 + O = C_3H_7 + OH$$

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

$$°C = 5/9 \times (°F-32)$$

$$°F = (9/5 \times °C) + 32$$

(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) 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°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 kJ/kg·K.

(iii) Fahrenheit

A Fahrenheit degree (°F) is 1/180th 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°C) is taken as 32°F; thus, 212°F is the boiling point of water (100°C).

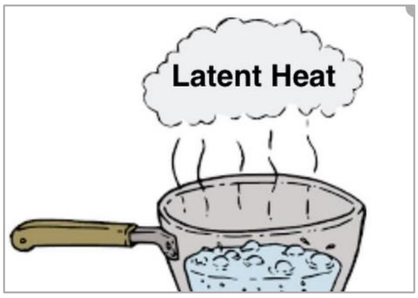
(iv) Rankine

A Rankine degree (°R) is the same size as the Fahrenheit degree, but on the Rankine scale, zero is –459.67°F (–273.15°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. <u>Latent heat and heat of gasification</u>

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 (J/kg). The latent heat of fusion of water (normal atmospheric pressure) at the freezing or melting point of ice (0°C) is 333.4 kJ/kg; the latent heat of vaporization of water at its boiling point (100°C) is 2257 kJ/kg.

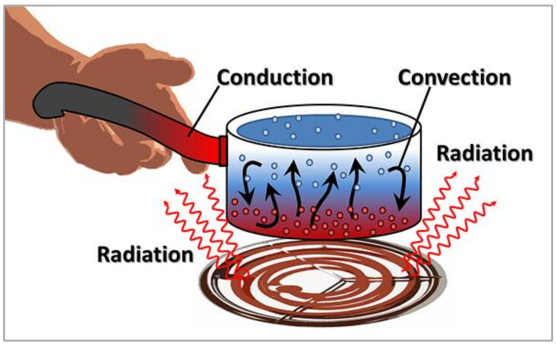
The large heat of vaporization of water is another reason for the effectiveness of water as an extinguishing agent. It requires 3 MJ to convert 1 kg of ice at 0°C to steam at 100°C. The latent heat of most other common substances are substantially less than that of water. Thus, the heat absorbed by water 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, convention 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

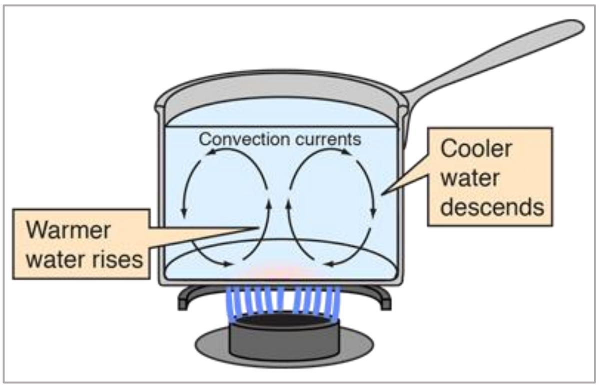
Heat transfer through a solid (e.g., from a heated surface to the interior of the solid) is the process called conduction. The rate at which heat (energy) is transferred through a body under steady state conditions is a function of the temperature difference and the conductance of the path involved.

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).

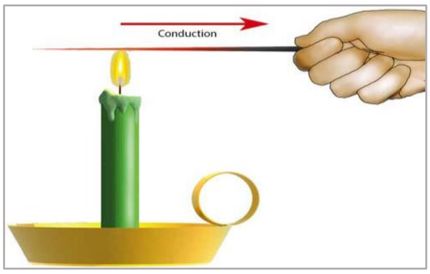
2. Convection



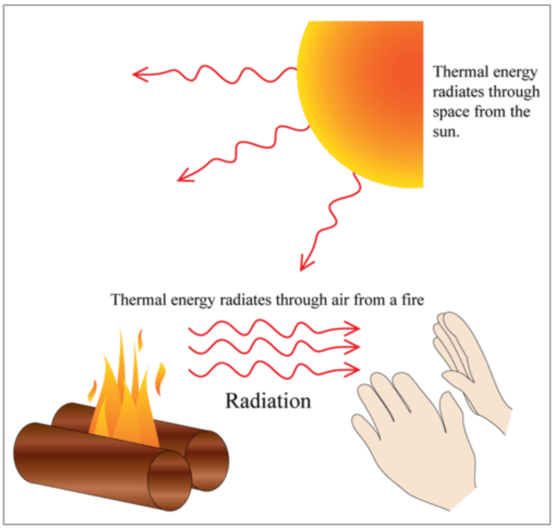
Convection involves transfer of heat by a circulating fluid— either gas or liquid. Thus, heat generated in a stove is distributed throughout a room by heating the air in contact with the stove (by conduction across the stationary boundary layer in contact with the hot surface).

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 life and service shafts, thereby spreading the fire to the upper parts of buildings.

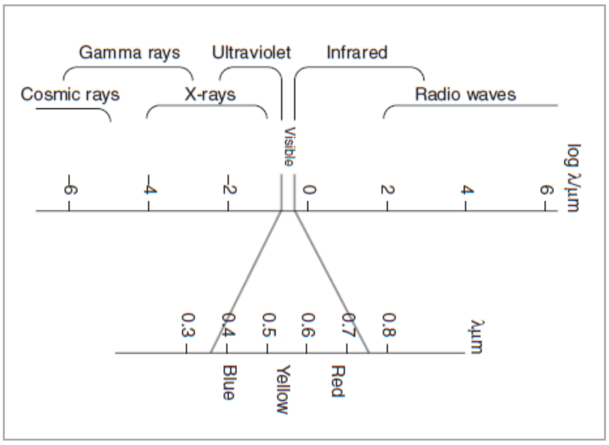


3. Radiation



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 (3×10^{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 0.4×10^{-6} to 0.7×10^{-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 × 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

Risk is the effect of uncertainty of on outcome. 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.

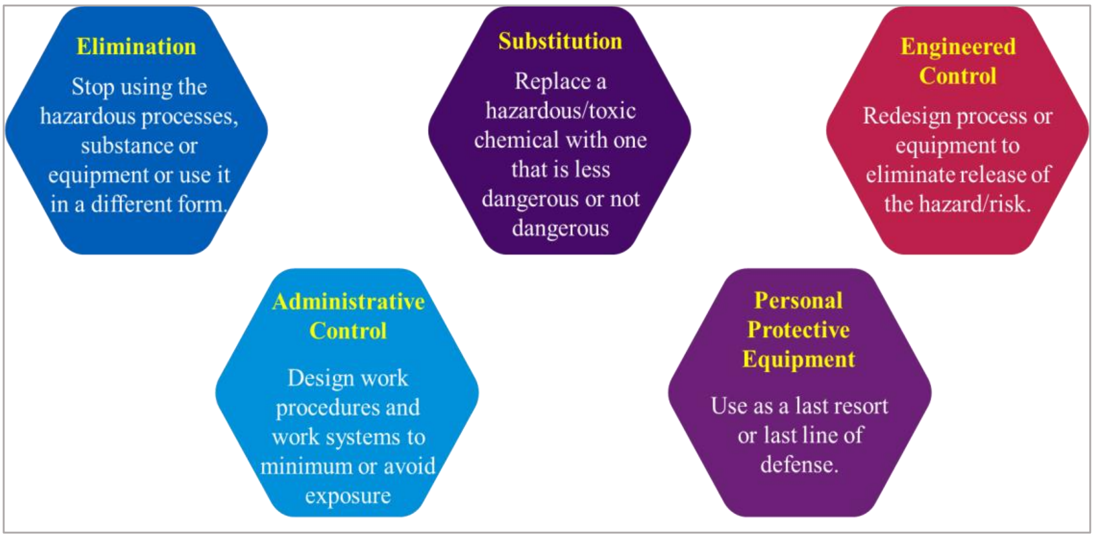
The process to manage risk is referred to as Risk Management. Risk Management comprises of culture, processes and structures that are directed towards realizing potential opportunities whilst managing the adverse effects/ outcomes.

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

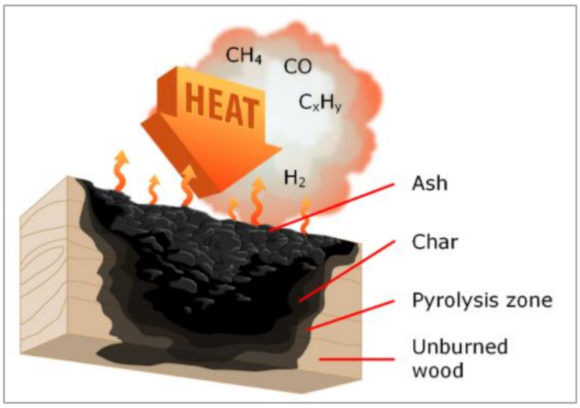
1.4.1. Combustion Process

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:

i. 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. **<u>Flaming combustion</u>**

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:

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 **vaporization** must take place, or in case of carbonaceous solids, **pyrolytic distillation** must take place, for enough molecules to be available to react with oxygen of the atmosphere.

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 **flammability limits.**

The mixture must be raised to a temperature where decomposition of molecules takes place **(Ignition temperature)** 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.

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.

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

i. Pre-combustion

ii. Smoldering combustion

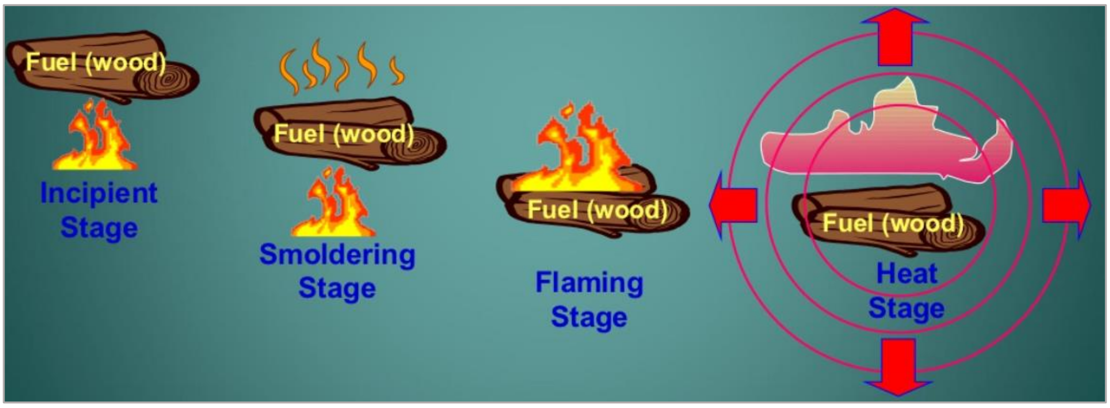
iii. Flaming combustion

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.

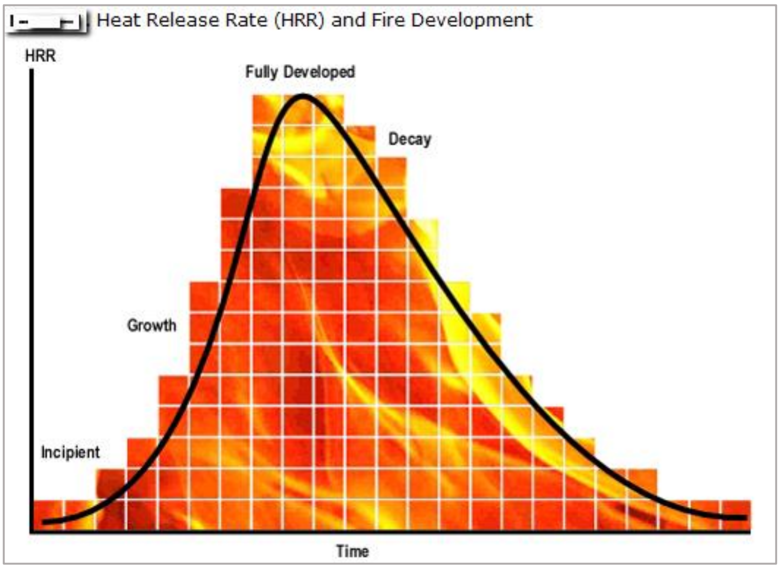
Flaming combustion - the production of sufficient energy and a fuel vapor mixture with air in a flammable range is the condition that underlies and supports the presence of flame.

<u>Fire growth can be either positive (increasing growth rate) or negative (decreasing growth rate).</u> 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[1].



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

[1] Source: https://journeytofirefighter.com/4-stages-of-a-fire/

1.5. Fire Extinguishment

1.5.1. Classification of fire

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

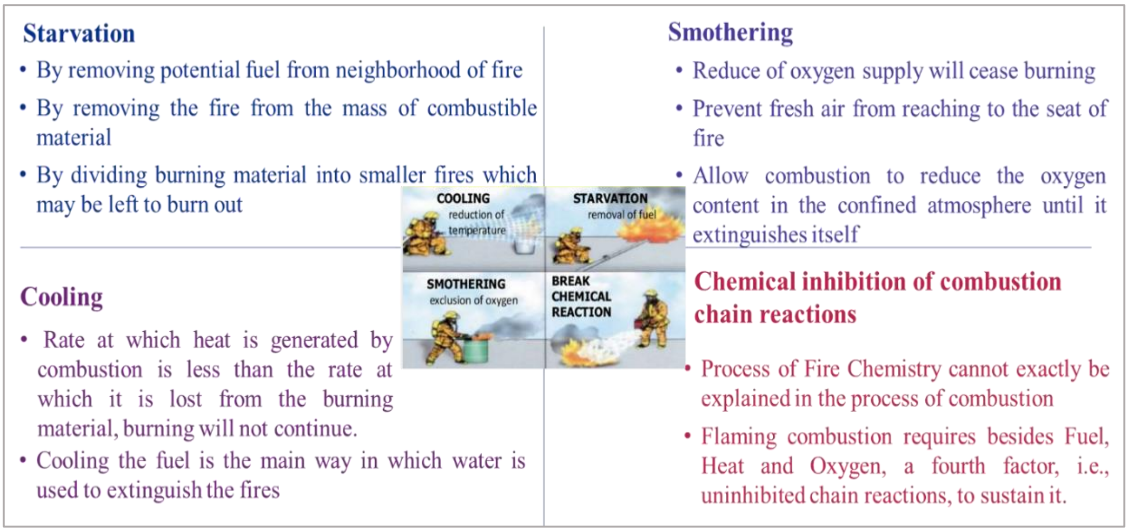
1. Class A
2. Class B
3. Class C
4. Class D
5. Class F

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:



Detailed explanation of each of these methods is presented below:

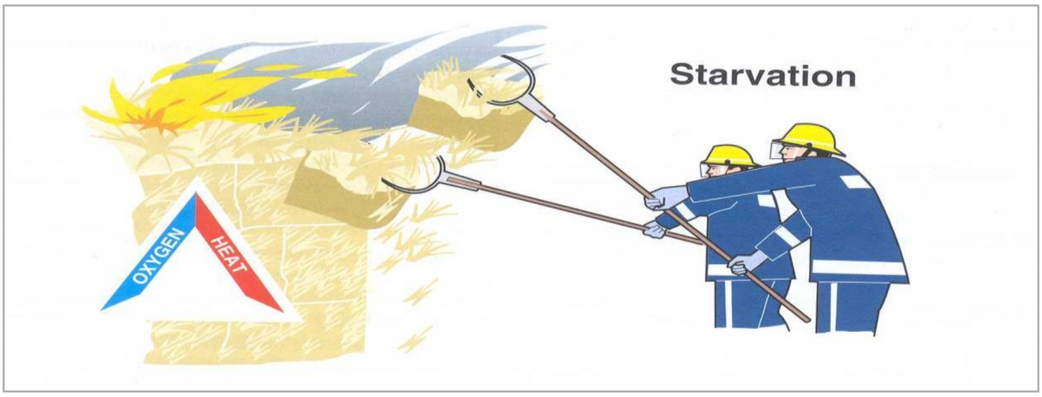
1. Starvation

Fire can be starved in three ways:

i. By removing potential fuel from neighborhood of fire. e.g. Draining out fuel from burning tank, counter burning in forest fire, etc.

ii. By removing the fire from the mass of combustible material for instance, pulling apart burning haystack.

iii. By dividing burning material into smaller fires which may be left to burn out or which can be extinguished more easily.



2. Smothering

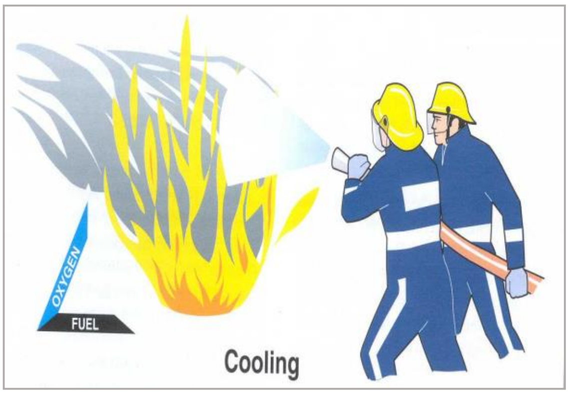
If the oxygen supply to the burning material can be sufficiently reduced, burning will cease.

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[2]. 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.

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

[2] It should be noted that Halons are being phased out worldwide, due to their adverse impact on the ozone layer

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[3]. 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

[3] 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[4]. 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 convicted 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

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

[4] This is why most storage tanks are painted with white or silver color paint externally

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_2)

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_2 concentration, and two times for 3% concentration. Though CO_2 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, it's 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 hours' 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 (NO2)

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 (C3H4O)**

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.

1.8. Combustion Process in Solid, Liquid & Gaseous Fuels

1.8.1. Combustion in Solids

Flammable solids can be divided into two classes –

- That which melt when heat is applied, like wax and thermoplastics. When sufficiently heated, the melted liquid then converts into vapor, and begins to burn. The liquid phase is clearly visible in such solids.
- Other solids like Paper, Wood, cloth, etc., do not melt on the application of heat.

Pyrolytic distillation in Solids

It is clear that combustion reactions occur in the vapor phase. What happens in the event of a piece of wood or paper burning ? Do gases get generated? Is there a liquid phase before the gases are generated? Unlike solid fuels which melt on application of heat, like wax, camphor, etc., carbonaceous solids, such as paper, cloth, wood, etc., consist of large, complex molecules. On being heated, the destruction of these molecules begin, and molecular fragments begin to distill off at different temperatures. On diffusing with the oxygen in the atmosphere, they will burn if sufficient heat is available. As the temperature rises, other molecular fragments will now attain their melting and boiling temperatures and get converted to vapor and take part in the combustion reaction. This process of breakdown of solids due to the rise of temperature is known as pyrolytic distillation or pyrolysis. The conversion of solids to gases does take place, and there is a liquid phase in between, but this occurs in such a small period that it is not normally visible.

Due to the fact that molecules have to be converted from a solid to a gas phase before combustion can begin, the amount of energy to initiate combustion in solids is quite high.

Smoldering in Fires

The fire risks of such substances include the fact that they are able to burn without flame, called ‘glow’ or smoldering fires.

Smoldering of coal

Most of the other types of molecules in such substances, besides carbon, distill off at various temperatures and take part in flaming combustion. Later, however, largely carbon molecules remain, which burn without a flame, in the form of glow. This glow has the ability to sustain for long periods of time and require specific attention. The reason why flaming combustion cannot take place with some fuels (such as coal) is that in the vicinity of the fuel surface, the number of fuel molecules are very high, as compared to the number of oxygen molecules. Due to this oxygen deficiency, only part of the fuel molecules are oxidized, while some of them form intermediate products, such as carbon monoxide (in the case of carbon). Thus, close to the fuel surface, there is always a layer consisting of fuel molecules, and intermediate products (such as carbon monoxide), which prevent the entry of the required amount of oxygen to the fuel molecules. Therefore, in a smoldering fire, there is always a deficiency of oxygen. If air is blown on such fires, the fire does not go out, but instead glows even more brightly, and in some cases, may even burst into flames. This is because by blowing air, the blocking layer close to the fuel surface is temporarily removed, and fresh oxygen is now available to the fuel for reacting. One should, therefore, be cautious in disturbing this blocking layer of smoldering fires.

In case of certain other solids, such as wax, rubber, etc., the application of heat results in melting of the substance and the liquid phase is clearly visible. If further heat is applied, the vapor phase appears, and combustion begins. The fire risks of such solids include the possibility of the melting liquid flowing to other and lower areas and further spreading the fire, and this needs to be taken into account while planning for fire prevention and firefighting.

1.8.2. Combustion in Liquids

While many industries aver that they do not handle flammable liquids, the fact is that it is impossible to think of an industry that does not use some or the other flammable or combustible liquid, in varying quantities. Most of these liquids are hydrocarbons, i.e. mainly consisting of hydrogen and carbon atoms, hence their fire risk is quite high (some inorganic liquids also pose fire risks but to a lesser extent). As a rough estimate, they account for almost a quarter of industrial fires. The reason is that most flammable (and some combustible) liquids will readily form a flammable mixture when exposed to atmosphere under normal conditions.

Most flammable and combustible liquids used in the industry are used either as fuels or for processing to obtain other/ newer products; on a smaller scale they are used for other purposes. As these liquids have a tendency to evaporate quickly, on being exposed to the atmosphere (actually, due to the heat in the atmosphere), vapours form on the liquid surface, which mix intimately with the oxygen in the atmosphere due to diffusion, and form a flammable mixture. As a flammable mixture is already present, the amount of energy required to initiate combustion (activation energy) is very small. Hence, as compared to solids, flammable liquids can be ignited by even small sources of ignition such as mechanical and electrical sparks, sparks from static electricity, etc.

Once ignited, the fire will quickly cover the entire exposed surface of the liquid. The heat from the flames feed back to the surface causing the temperature of the liquid to rise, till it reaches an equilibrium stage, and the heat output will become approximately constant.

Important ‘fire hazard’ properties of liquids

The most important property of flammable liquids with respect to their fire risk is their ability to form vapors, i.e., the more quickly it forms vapors, the higher its risk. Certain properties of the liquids, such as its flash point temperature are a measure of the liquid's tendency to form vapors. Amongst the other important properties of interest to the fire safety professional are the specific gravity (a measure of the liquid's density as compared to water), vapor density (a measure of its vapor density as compared to air), water miscibility, etc.

1.8.3. Combustion in Gases

It must be clear by now that a substance's ability to burn is influenced greatly by its ability to mix intimately with the air surrounding it. The molecules of a solid are in more or less fixed positions and are immobile, and hence a lot of energy is required to convert solids to the liquid state first, and then to vapours. Only then, can these vapours mix with atmospheric oxygen, and burn. In case of liquids, as the molecules are free to move about within the liquid, a small amount of energy is enough to cause these molecules to leave the liquid surface as vapours. Hence this energy is much lower as compared to solids, and varies from liquid to liquid, some of which can form sufficient vapours (to burn) in normal conditions while some liquids require small amount of energy before they can generate enough vapours to burn. In the case of gases, the molecules are in a free state, and once their confinement is removed, they easily mix up with the surrounding air due to diffusion. This means no extra energy is required to create a flammable mixture in case of flammable gases. Hence the energy required to initiate combustion is very small; so extreme caution has to be exercised in the event of a gas leakage, the smallest electrical or mechanical sparks can cause disaster.

If gaseous fuel under pressure leaks from a container and ignites in vicinity of the leak, it results in what is known as a 'jet fire'. There should not be attempts to extinguish such fires unless there is arrangement to shut off the gas supply. In fact, the normal response to such fires is to allow the fire to 'burn under control' till the supply of gas can be stopped or gets exhausted. Efforts are made to keep the container and surrounding materials cool by application of water spray.

However, if leaking gas from a container does not ignite immediately, it will form a mixture with the atmospheric air. These gases diffuse very easily with atmospheric oxygen and form large 'vapour clouds' which if ignited could result in explosions. Such 'vapour cloud explosions' have been recorded in numerous instances. Some of the worst industrial accidents such as Flixborough (1974), Mexico (1984), Nagothane (1990), Visakhapatnam (1997) can be attributed to this property of flammable gases. On a smaller scale, the large number of domestic LPG explosions, which occur after leakage of the gas are also due to this.

Important fire hazard properties with respect to gaseous fuels are its vapour density, flammability range, ignition temperature, flame velocity, etc.

1.9. Other Combustion Processes

1.9.1. Spontaneous Combustion

Oxidation is a process which involves oxygen, and since oxygen is available in sufficient quantity in the atmosphere, a number of oxidation reactions are normally taking place, at the surface of numerous materials. However, the reaction rates may differ in each case, for e.g. the rusting of iron is a slow oxidation process, while combustion is a much faster oxidation reaction. On being exposed to atmosphere, some materials (which include certain combustible and flammable substances) will automatically begin to react with the atmospheric oxygen. For e.g. paints contain solvents which after the application of paint, will oxidize with oxygen. This oxidation reaction gives out heat, but because it is dissipated to the surrounding material, and to the paint layer, it is not noticeable. If, however, the heat is not allowed to dissipate, the temperature will slowly begin to rise. If further oxidation takes place, the heat will continue to accumulate, and the ignition temperature of the solvent will be attained, resulting in flaming combustion.

Therefore, rags, cotton waste and clothes which have been used for wiping off oils, solvents, and some edible oils such as linseed, etc., are very dangerous if not properly disposed off. If they are carelessly thrown into a pile, the chances of spontaneous ignition are very high. Piles of certain agricultural products such as grains, hay, etc., can also oxidize and thus heat up, with the possibility of self-ignition. Spontaneous combustion , is thus, the property of certain materials to begin and maintain combustion without the need for external ignition.

Sodium is a metal, which spontaneously combines with oxygen of the atmosphere, giving out large amount of heat. It is thus, stored under a protective layer of kerosene. Coal is another substance, which is susceptible to spontaneous heating and combustion. The surface of coal begins to oxidize in open atmosphere but does not get noticed in normal course. If, however, the oxidation takes place in a large pile, the heat is not allowed to dissipate, and slowly the temperature rises, causing the coal to smolder. However, as there is oxygen deficiency near the coal surface, it continues to smolder, and flaming combustion in such cases is rare. Such instances normally occur in very large piles of coal.

1.10. Smoke Movement in Buildings

1.10.1. Spontaneous Combustion

As smoke is the leading cause of deaths in most indoor fires, much study has been undertaken on this subject, and continues to be done so. The development and movement of smoke can now be fairly accurately predicted in indoor fires with defined parameters. This smoke movement information results in the development of safer building designs, consequently lowering the risks to occupants from smoke.

The hazards of smoke and smoke movement

A large number of fires which have occurred in recent times have highlighted the deadly effect of smoke on humans. Amongst the worst in the country in recent times, was the tragic 'Uphaar cinema' fire of New Delhi. The fire, which started in a basement transformer, generated large amount of smoke, causing panic in the theatre and finally, asphyxiation of the trapped people. In the final analysis, 60 people had died, and it is believed that most of them were the victims of smoke.

Modern industries also use newer materials, which may give rise to deadly fire gases. The other important aspect of smoke hazards is that smoke generated in one area of a structure can easily spread to other areas, not affected by the fire. An example of this is the fire which occurred on 11th April, 1996, at Dusseldorf international airport, which was constructed in 1976, as per the practices then prevalent. The fire occurred on the outside of the airport, due to some welding work going on a suspended roadway, above the arrivals hall. The heat from the welding ignited some material in the ceiling void of the arrivals hall. This fire and resultant smoke spread rapidly through the ceiling void to other parts of the airport. The fire ultimately affected almost 2/3rd of the total area, and the use of PVC, and plastic materials for upholstery, gave rise to highly toxic gases. In spite of a seemingly efficient Fire service, the fire claimed 16 lives, and caused injury to 62 others. Almost all casualties were due to smoke, and this fire accident clearly highlighted the hazards of smoke and smoke movement.

Designs of most modern structures are adopted keeping in view smoke movement and venting, in the event of fires. The use of computers and simulation has resulted in very good models for smoke movement and personnel evacuation, and these are now being effectively utilized in many developed countries. The use of construction and other materials used within buildings is also being studied for their behavior in fire conditions and the smoke and fire gases generated from them. Selecting the right materials can greatly reduce the hazards of smoke to occupants of the building in the event of a fire.

While effects such as the 'stack effect' are very prominent in tall buildings, which affect smoke movement greatly, smoke movement is critical even for short buildings as it can affect people as also the firefighting operations. The use of smoke vents, smoke curtains/ partitions are now standard practices in most buildings and structures. A number of other systems such as smoke pressurization systems for stairwells, smoke extraction systems for floors/ basements, etc., are designed to reduce the effects of smoke and facilitate escape in the event of fire. This is achieved by following design requirements for smoke control and venting given in related standards or by using simulation and models to predict fire behavior and assess the effect of smoke control systems for keeping the protected area safe.

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

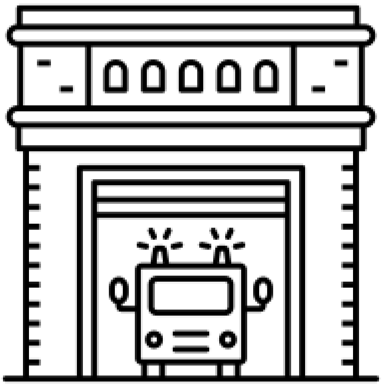
2.1. Introduction

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



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 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 Industry 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:

1) **Promote fire safety**
2) **To prepare for:**
   (i) Fighting fires and protecting people and property from fires;
   (ii) Rescuing people from road accidents(vehicle collision)
   (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

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.

Memnagar Fire Station, Ahmedabad

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.

Government	GIDC, Port Authorities, Airport authority of India, GEB, etc.

PSUs	ONGC, OPAL, other refineries, GoG companies, etc.
Private	It includes private industries which have their own fire department having 24x7 manned and vehicles

2.3.5. Details of region 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	• Chief Fire officer • Add. Chief Fire officer • Dy. Chief Fire officer • Divisional Fire officer • Fire officer/ Sub fire officer • Leading Fireman • Driver cum Pump operator • Fireman • Other
2	Surat	16	
3	Vadodara	08	
4	Rajkot	08	
5	Jamnagar	03	
6	Gandhinagar	01	
7	Bhavnagar	01	
8	Junagadh	01	
Total		**54**	

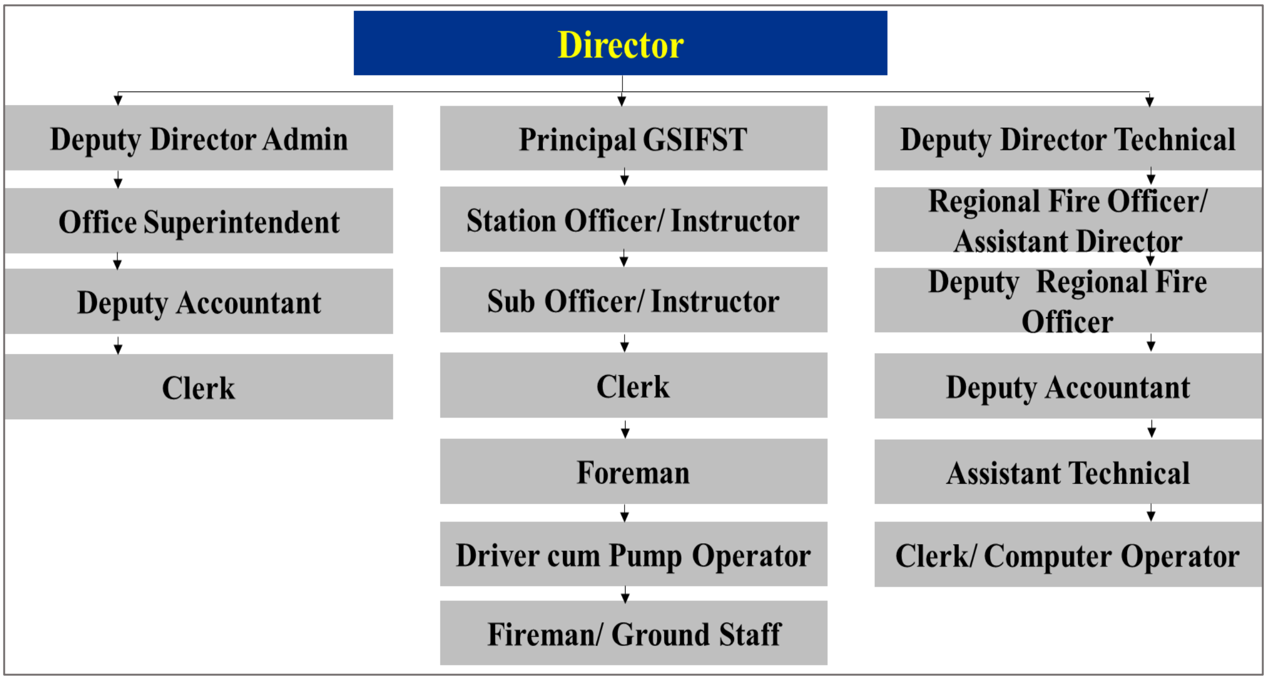
2.3.7. Details of Emergency Response Centers (ERCs)

SR. NO.	NAME OF THE ERC	MAINTAIN BY
1	Gandhinagar	Ahmedabad Municipal Corporation
2	Vadodara	Vadodara Municipal Corporation
3	Surat	Surat Municipal Corporation
4	Rajkot	Rajkot Municipal Corporation
5	Gandhidham	Collectorate, Bhuj

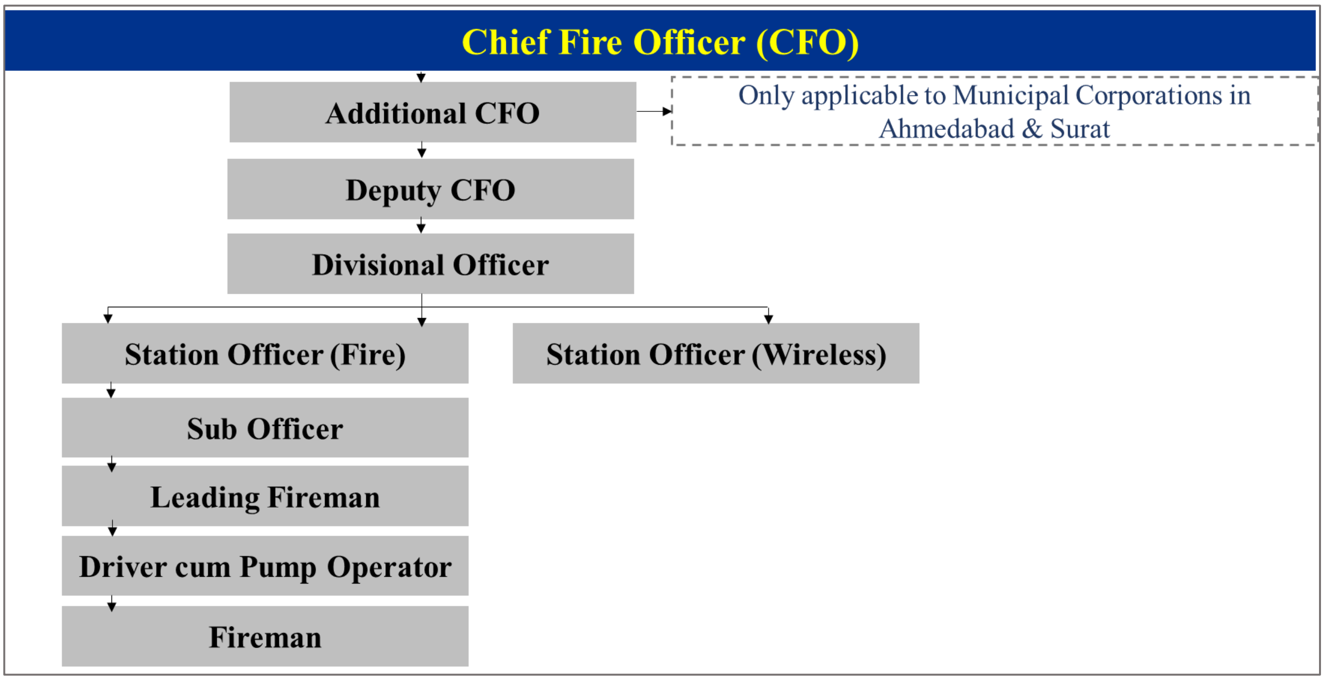
2.4. Understanding fire service hierarchy and ranks in other states and Gujarat

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

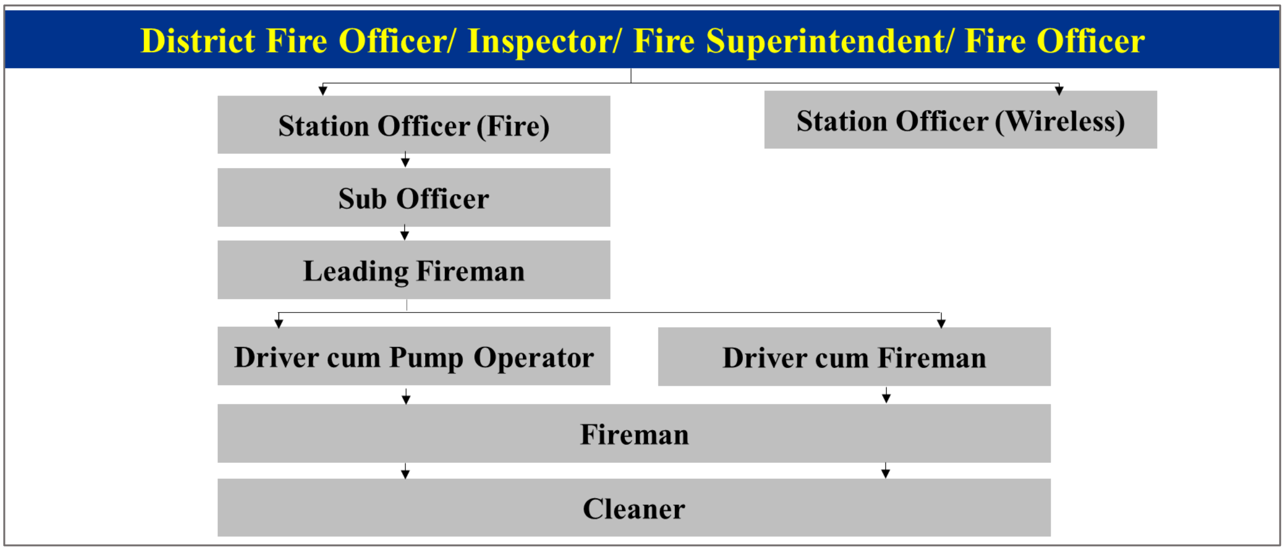
1) Organogram of Gujarat state fire prevention services



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 legislatives 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 of2 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;

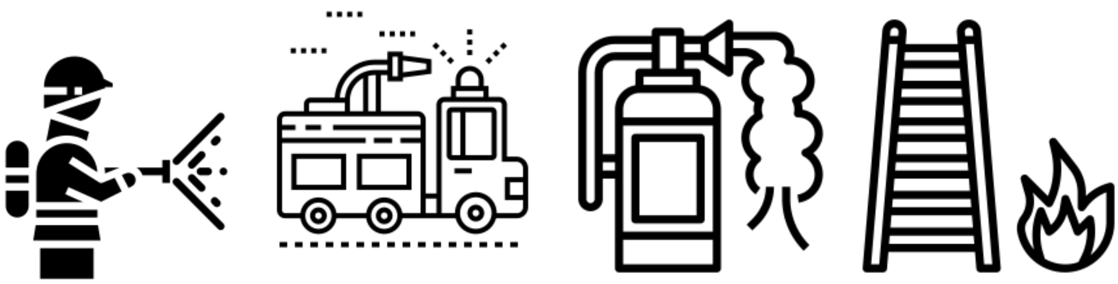
(7) To lead the turn-outs and to scheme and conduct the operations at the fire ground;

(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[5]



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 of life, and/or destruction of property. In fact, it 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.

[5] Source of icons – The Noun Project

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

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

Water tender

Hydraulic Elevated Platform

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

Delivery hose

Suction hose

Fire hook

Medical First Aid

Flood light

Thermal imaging camera

Portable ground monitor

Gas cutter

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

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 with efficiently.

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.

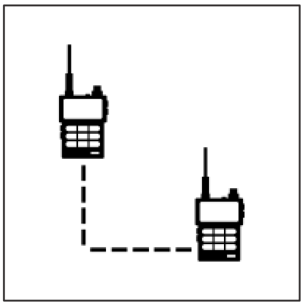
Different systems/ features provided in the building at the design stage itself are meant to help in fire and rescue efforts by Fire Service in event of an emergency. These features/ systems include:

1) Notification

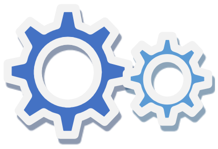
While fire alarm systems are primarily for early warning to building occupants about a fire incident, at the same time, if this information (i.e., the fire alarm) is also conveyed to the Fire service, it allows them to reach the incident site earlier and tackle the fire which has still not grown to a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

2) Internal communication[6]

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).

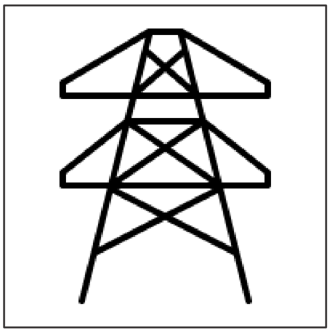
4) Fire tower, fire lifts, access stairs[7]

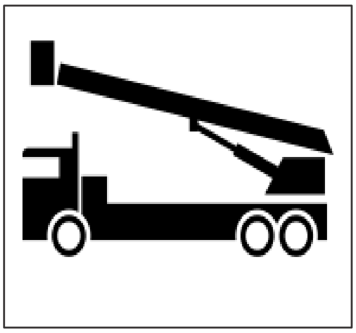
When a fire incident is underway in a building, firefighters are entering an environment where conditions are becoming more and more dangerous by the second (as the fire is pumping in more and more heat and effluents into the building space). While they will normally wear protective gear to protect themselves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

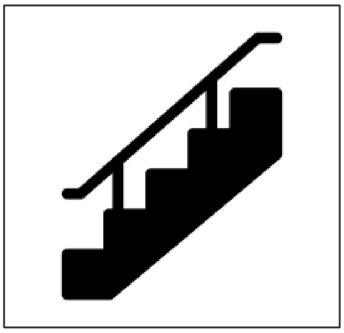
The concept of a ‘fire tower’ (in NBC Part 4) is an extension of this principle where the lift shaft, stair and the adjacent space is protected from the effects of a fire using rated

[6] Source of walkie talkie icon – The Noun Project
[7] Source of icons – The Noun Project

construction and smoke control systems, thus keeping this space free from the effects of fire.



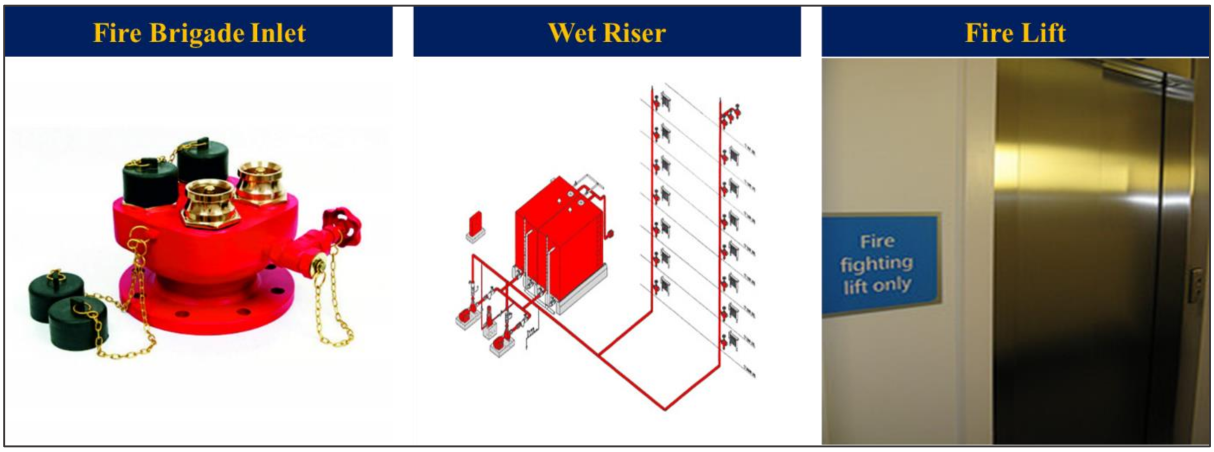




5) Fire command center

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

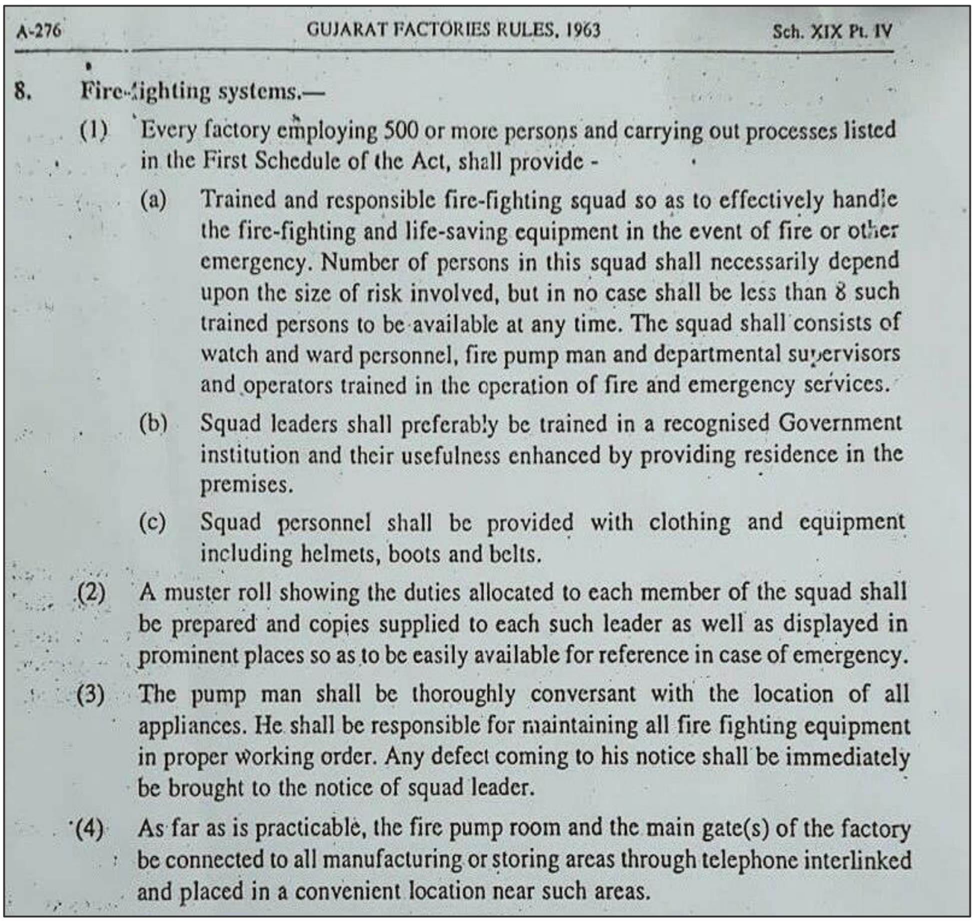
Squad leaders shall be trained by government recognized institution and their usefulness would be considerably enhanced, if they reside on the premises.

(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 inconvenient 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[8]

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.

[8] Source of icon – The Noun Project

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 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.

Chapter 3:

Fire Prevention & Life Safety in Buildings

3. Fire Protection Equipment & Systems

3.1. Introduction

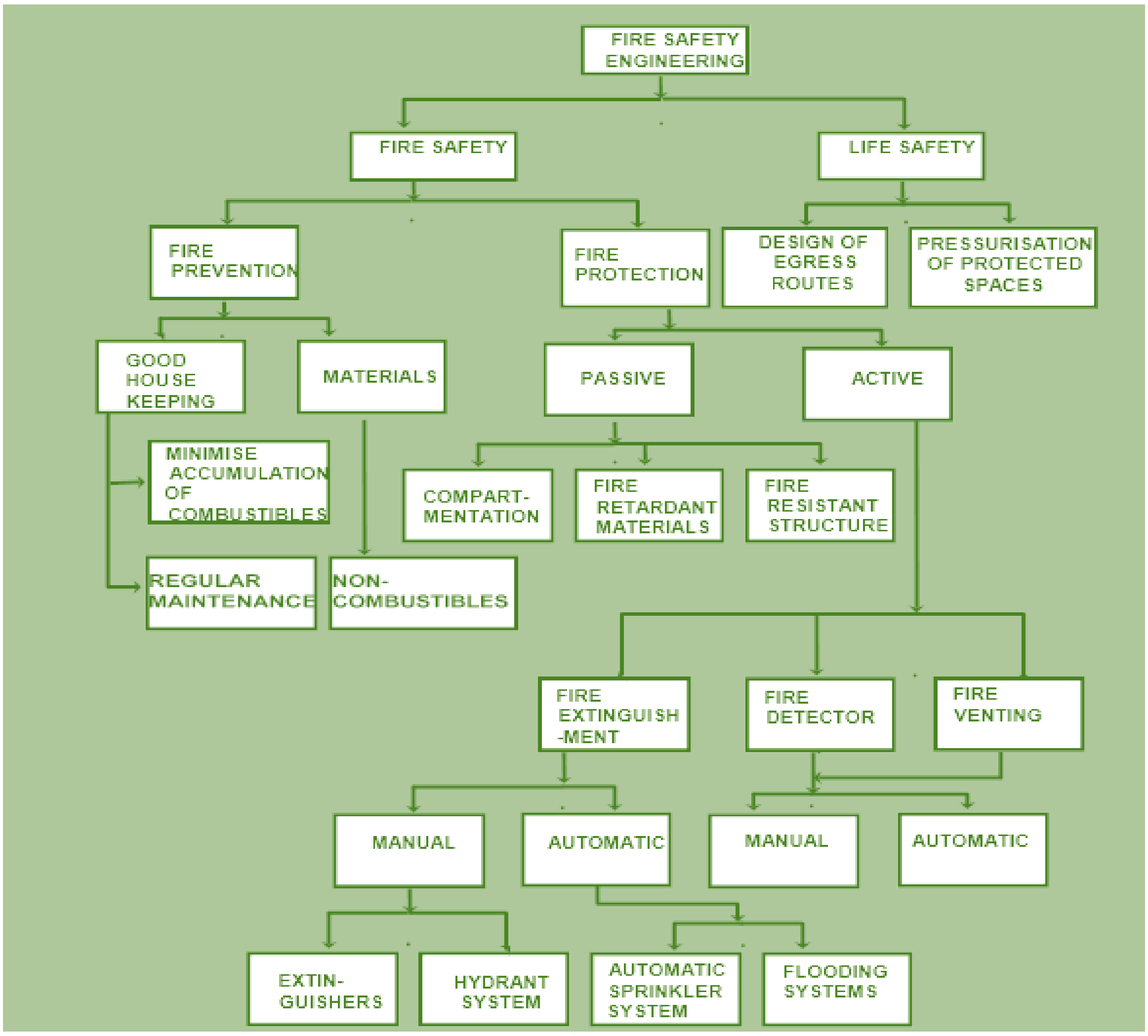
With technological advances on all fronts, not only the factor of susceptibility, but the complexity of fires, explosions and hazards to which buildings are exposed to, have also increased manifold. These hazards have been instrumental in causing heavy losses in lives and property throwing up fresh challenges 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 a 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 m2)
Subdivision F-2 Shops, stores, departmental stores, markets (with covered area > 500 m2)
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 rewireable 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

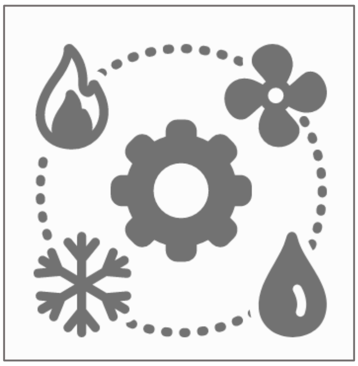
The process of transferring immediate discharge of electrical energy directly to earth by the help of low resistance wire is known as the electrical earthing. The electrical earthing is done by connecting the non-current carrying part of the equipment or neutral of supply system to the ground.

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.

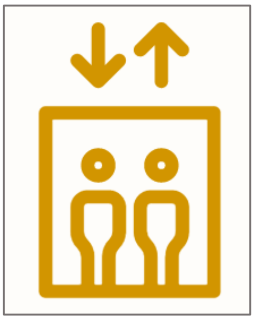
3.4.2. HVAC (Heating, Venting, and Air Conditioning)systems



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 <u>accumulation of waste in lift wells and in machine rooms are the main reasons why fires take place</u>. 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^2/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	Width per Person mm: Level Components and Ramps
(1)	(2)		(3)	(4)
i)	Residential	(Group A)	10	6.5
ii)	Educational	(Group B)		
iii)	Institutional	(Group C)	15	13
iv)	Assembly	(Group D)		
v)	Business	(Group E)		
vi)	Mercantile	(Group F)	10	6.5
vii)	Industrial	(Group G)		
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

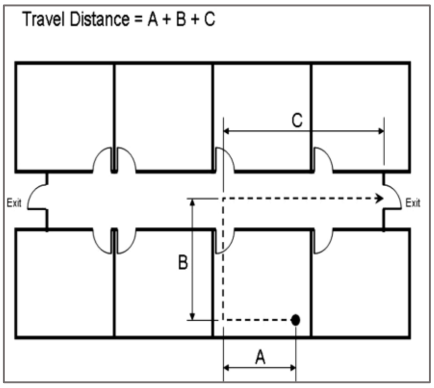


Figure on the right shows NBC Part 4 – Travel distances

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.

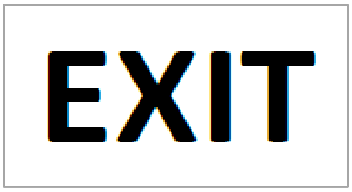
As there are openings such as doors in exit stairs, the chances of smoke entering the stair from a fire floor cannot be entirely ruled out. To keep occupants safe from smoke, there is a requirement to have natural or artificial venting arrangements in exit stairs, so that occupants are protected from 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.

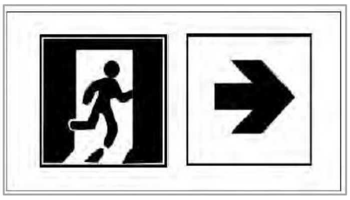
Illumination of Egress routes is another intervention.

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:





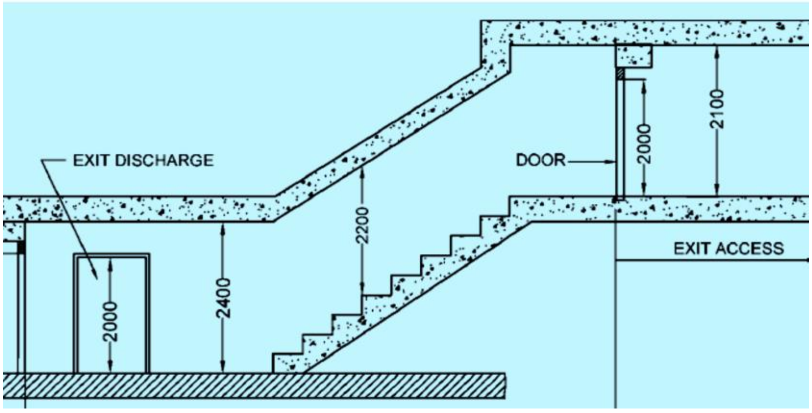
3.5.3. Egress components and life safety

During an emergency, it is important that occupants are able to use the exit without any problem. Therefore, exit components (doors, stairs, etc.) must meet design and installation requirements specified by the code. Minimum width and height for doors, stairs, etc., for different occupancies, are clearly specified by codes. Another fact is that during a fire incident, occupants can be under stress or display abnormal behavior and therefore, opening of locked or latched doors while egressing should not involve complex actions. There is a requirement to provide panic bars on exit doors because of this reason; an egressing occupant only needs to push the bar to open it.

A Fire exit door with panic bar

Doors using electric power or interfaced with other systems (e.g. fire alarm system) have to meet specific code requirements so that they can be safely used in a fire emergency.

Stairs should be of standard dimensions (tread/ height of risers, guard height, railing height and diameter, number of steps per flight, landing dimensions, etc.) to ensure that occupants experience no abnormality while using them and can exit confidently.



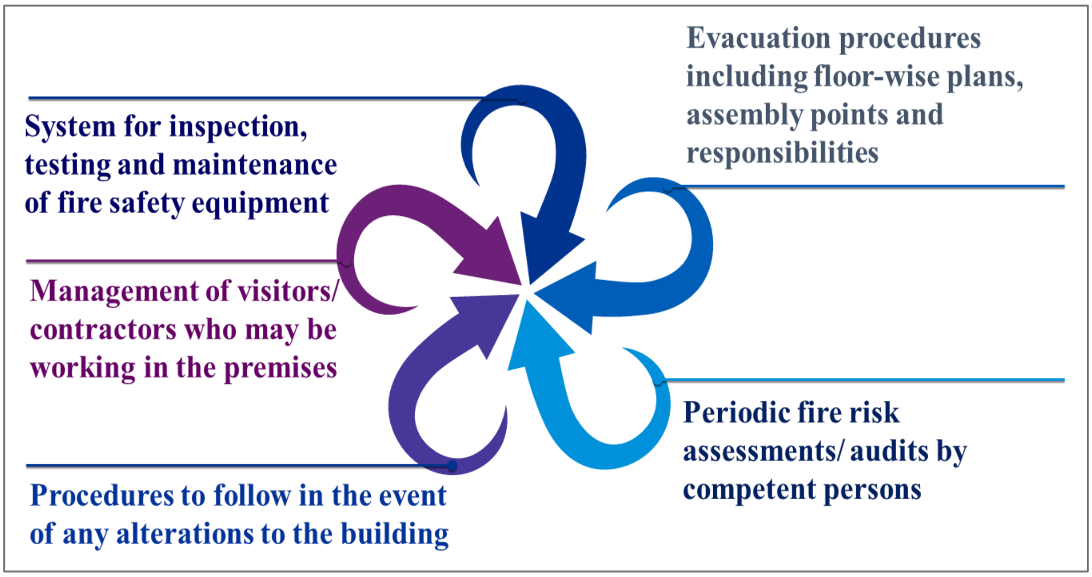
Sketch showing head room dimensions for different components within exit (from NBC Part 4)

As smoke can enter the stair shaft from the affected floor, 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 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. Codes will specify the type of smoke control system required for exit stairs and in some cases, exit access corridors. 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 the building.

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	5) Any processes/ appliances/ machines/ power supplies to be	6) The identity and duties of staff that have specific responsibilities in case of fire

particularly at risk, such as young persons, lone workers, and people with disabilities

isolates/stopped 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 contacted and who will be responsible for this
16) Contingency plans for when the life safety systems such as fire-detection, 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

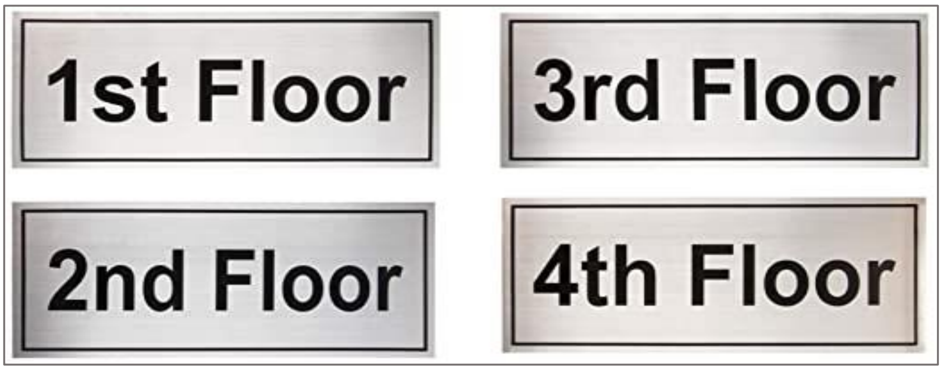
D-4.1: Signs at lift landings

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.

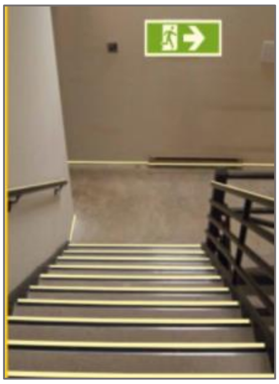
A sign shall read “IN CASE OF FIRE, USE STAIRS UNLESS INSTRUCTED OTHERWISE”. The lettering shall be at least 12.5 mm block letters in red and white background. Such lettering shall be properly spaced to provide good legibility. The sign shall be at least 250mm × 300 mm, where the diagram is also incorporated 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 an 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 in4.4.2.4.3.2(h)(9).

D-4.4: Stair Re-entry signs[9]

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-5.1: A format for the Fire Safety Plan shall be as given in D-9.10.

D-5.2: The applicable parts of the approved Fire Safety Plan shall be distributed to all tenants of the building by the building management when the Fire Safety Plan has been approved by the Fire Authority.

D-5.3: The applicable parts of the approved Fire Safety Plan shall then be distributed by the tenants to all their employees and by the building management to all their building employees.

D-5.4: In the event there are changes from conditions existing at the time the Fire Safety Plan for the building was approved, and the changes are such so as to require amending the Fire Safety Plan, within 30 days after such changes, an amended Fire Safety Plan shall be submitted to the fire brigade for approval.

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.

D-8 FIRE SAFETY PLAN FORMAT

It is critical to understand the Fire safety plan format as given in the Annexure D, NBC Part 4.

[9] Source of image - https://www.visibleinnovation.com/stair_id_signs.htm

Chapter 4:

Fire Protection Equipment & Systems

4. Fire Protection Equipment & Systems

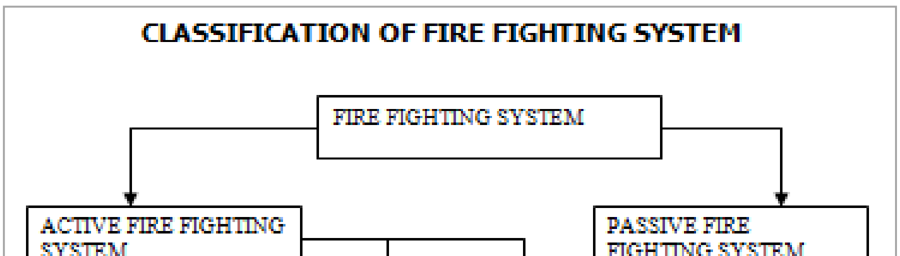
4.1. Introduction

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[10]

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.

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

[10] Source of icon – The Noun Project

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

<u>They can also be grouped into categories according to their method of operation.</u>

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 CO2) 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.

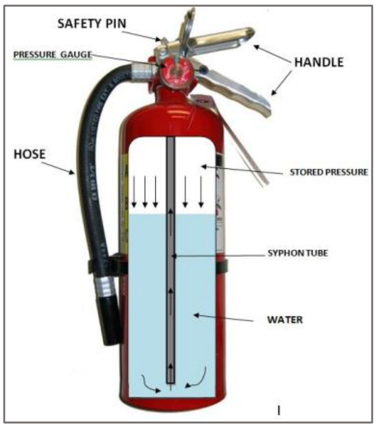
1) Water (gas cartridge) type extinguisher

- In this pressure is released from a cartridge which is stored inside the body of the extinguisher. The cartridge is pressurized with CO2 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 Than1.5
1 and 2	6	12	Not less Than4
5 and 10	15	25	Not less Than4

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_2 extinguisher

The main features of this extinguisher are:

- It consists of a high-pressure cylinder.
- CO_2 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 CO2 extinguishers:

- Although not itself toxic, CO_2 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_2 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
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

Sr. No.	Type of Extinguisher	Type of Fires				
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.

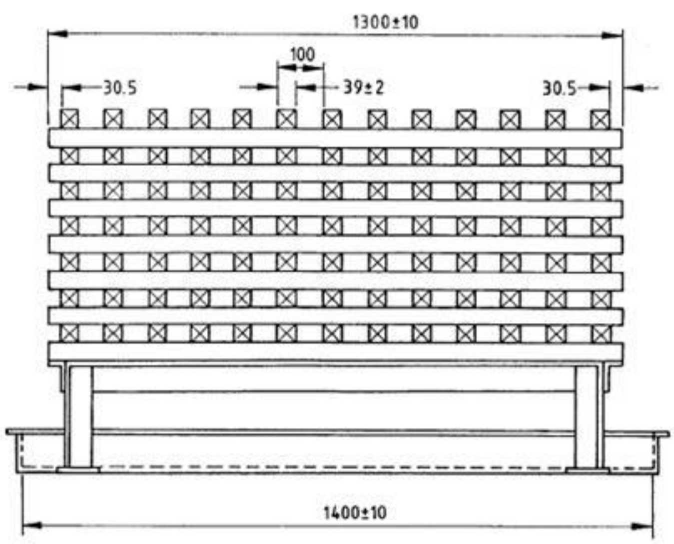
4.2.7. Fire extinguisher ratings explained

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.



Dimensions are in millimetres.

Figure 4. Class A test fire side view showing a 13A fire

Examples of available 13A rated extinguishers:

Water with Additive 3 liter	**Foam (AFFF) 3 liter**	**ABC Dry Powder 2kg** **(CO2 is unsuitable for this type of fire)**

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, CO2 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

ANNEX E

[*Clauses* 12.2.1 *and* 12.2.2 (g)]

SCHEDULE FOR HYDRAULIC PRESSURE TESTING OF FIRE EXTINGUISHERS

E-1 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.

E-2 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.

Sl No.	*Type of Extinguisher*	*Test Interval* Year	*Test Pressure* kg/cm^2	*Pressure Maintained for* min
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

ANNEX F

(*Clauses* 12.2.1)

LIFE OF FIRE EXTINGUISHERS

Sl No.	*Type of Extinguisher*	*Life Time,* Year
i)	Water type	10
ii)	Foam type	10
iii)	Powder type	10
iv)	Carbon dioxide	15
v)	Clean agent	10

4.2.10. Refiling schedule of extinguishers as per is 2190

ANNEX D

(*Clauses* 11.4.1 *and* 12.3)

REFILLING SCHEDULE FOR FIRE EXTINGUISHERS AND SCHEDULE FOR OPERATIONAL TEST ON FIRE EXTINGUISHERS

D-1 EXTINGUISHERS TO BE REFILLED/ OPERATED FOR PERFORANCE TEST IN ANNUALLY CYCLIC MANNER

D-1.1 Once in Two Years

a) Portable fire extinguisher, water type stored pressure.
b) Portable fire extinguisher, mechanical foam type stored pressure.
c) 135 litre fire engine, foam type.

D-1.2 Once in Three Years

BC and ABC powder extinguisher confirming to IS 4308 and IS 14609 respectively.

D-1.3 Once in Five Years

a) Portable fire extinguisher, water type 9 litre (gas cartridge).
b) Portable fire extinguisher, mechanical foam type 9 litre (cartridge type).
c) Portable fire extinguisher, water type 50 litre (gas cartridge).
d) Portable fire extinguisher, mechanical foam type 50 litre (cartridge type).
e) Fire extinguisher, carbon dioxide type (portable and trolley mounted).
f) Higher capacity dry powder fire extinguisher (trolley mounted).
g) Dry powder fire extinguisher for metal fires.
h) Clean agent fire extinguishers.

NOTES

1 In corrosive environments, it is desirable to have the discharge test carried out at half the frequency mentioned.

2 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_2 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

10 MARKING AND COLOUR

10.1 Colour

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:

Extinguishers	*Band Colour*
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:

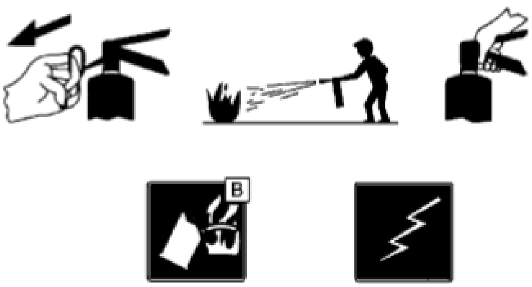
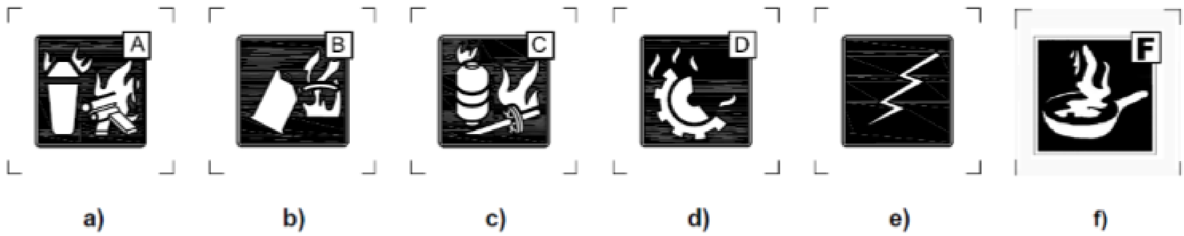
2 KG CARBON-DIOXIDE FIRE EXTINGUISHER **INSPECTION :** INSPECT MONTHLY CHECK THAT EXTINGUISHER IS CHARGED, UNDAMAGED AND SEAL IS INTACT. MAKE SURE HORN IS UNOBSTRUCTED. **MAINTENANCE :** EXAMINE CAREFULLY EVERY 12 MONTHS TO ENSURE EXTINGUISHER IS OPERABLE. RECHARGE IF MASS LOSS EXCEEDS 0.2KG. REPLACE ANY DAMAGED PARTS. CHECK HORN FOR OBSTRUCTIONS. HYDROSTATIC RETEST TO DOT/TC REQUIREMENTS EVERY 5 YEARS. **USE :** AFTER ANY USE RECHARGE IMMEDIATELY. **RECHARGE :** CO_2 CHARGES IS 2 KG. FULL MASS STAMPED ON VALUE BODY INCLUDES HORN ASSEMBLY. **RECORD :** RECORD MAINTENANCE AND RECHARGE DATES ON ATTACHED TAG. FOR INDUSTRIAL USE.	**INSTRUCTIONS** ① HOLD UPRIGHT PULL RING PIN ② START BACK 3 m AIM AT BASE OF FIRE ③ SQUEEZE LEVER SWEEP SIDE TO SIDE 	APPROVAL MARK CARBON-DIOXIDE FIRE EXTINGUISHER CLASSIFICATION 21B SERAIL NO. XX-XXXXX 2 KG CARBON DIOXIDE FIRE EXTINGUISHER SUITABLE FOR USE AT TEMPRATURES FROM -30°C TO 60°C PRESSURE TESTED TO 20 MPa MODEL 2018 MFG. NAME MFG. ADDRESS

FIG. 7 EXAMPLE OF LAYOUT MARKING FOR AN EXTINGUISHER

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



a) class A: Ordinary solid material fires
b) class B: Flammable liquid fires
c) class C: Gas and vapour fires
d) class D: Combustible metal fires
e) class E: Fires involving energized electrical conductors
f) class F: Cooking oil fires

FIG. 8 USE CODE SYMBOLS

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°C is referred to as specific heat capacity of the substance (J/kg per °C).

Specific heat capacities of some substances are given below:

Substance	Specific Heat Capacity(J/kg per °C)
Steel	460
Aluminum	900
Copper	400
Ice	2100
Methylated Spirit	2400
Water	4200 (4.2 kJ/kg/°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.

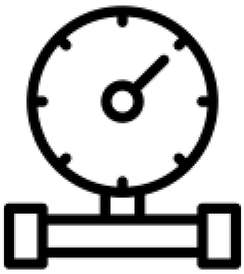
Specific heat capacity of water is unusually high, viz., 4200j/kg (4.2kJ/kg) per °C. This is one of the reasons why water is effective as an extinguishing agent.

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 (J/kg).

When a container with water is heated, the temperature of water goes on rising until it reaches 100oC, the BP of water. At this temperature, the water boils. However, the temperature remains constant at 100oC, 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. 2260kJ/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.l. unit of pressure is the newton per square meter (N/m2) 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 N/m2 or 105 N/m2

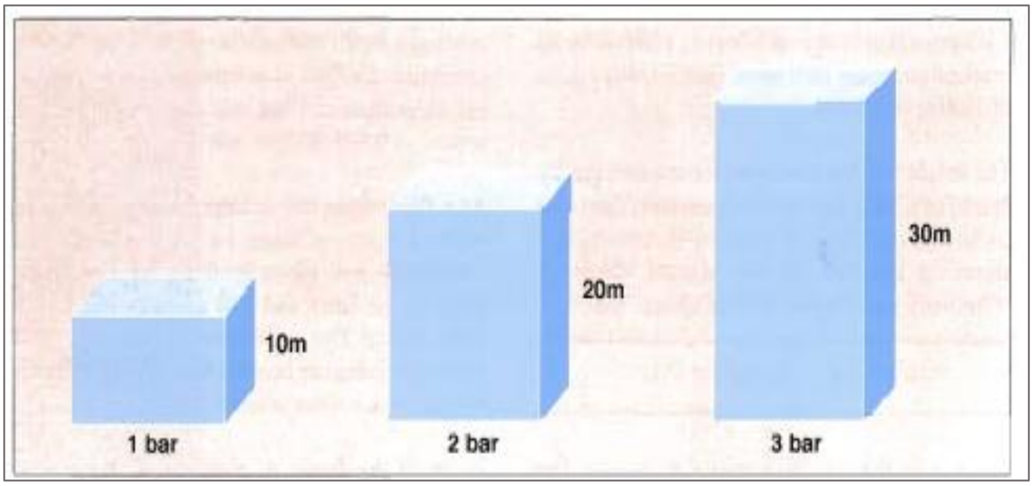
Normal atmospheric pressure = 1.013 bar

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.

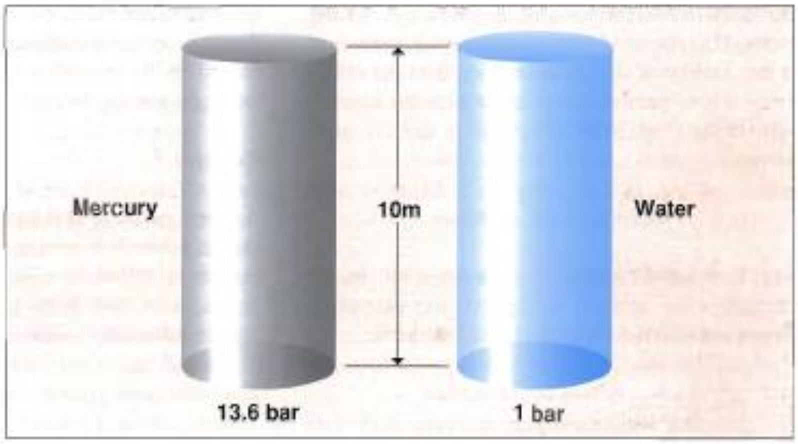
3) **Downward pressure of a fluid in an open vessel is proportional to its depth:**
Figure below shows three vertical containers, the depth of water in them is 10m, 20m and 30m. If pressure gauges were to be placed at the bottom of each container, they would show readings of approximately I bar, 2 bar 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.

Figure 1.2 (d) Downward pressure of a fluid in an open vessel is proportional to the density of the fluid



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:

External Hydrant System	Internal Hydrant System

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^3 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/cm2 (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/cm2 or bars (1atmosphere = 14.7psi or 101.325 kN/m2 or 1.013 bar) (1 bar = 100kN/m2), 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

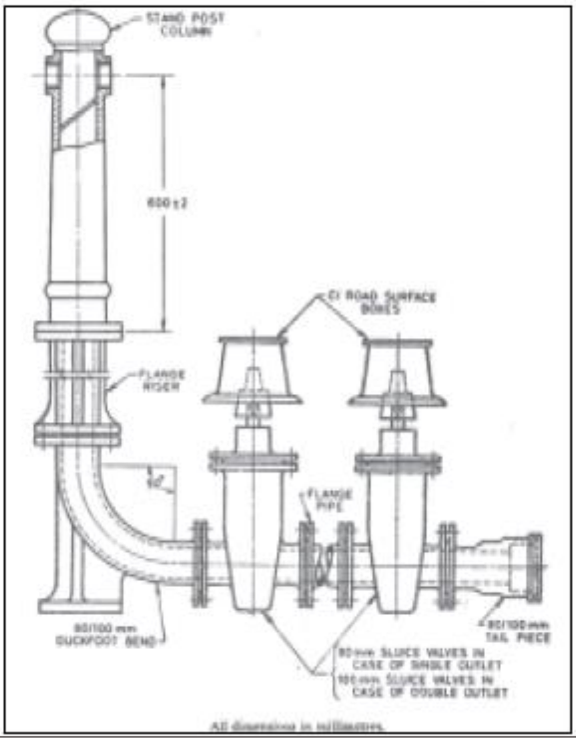
   i. Fire hydrants provide the means of drawing water from the water mains for firefighting. The water main is provided with a branch or T-piece to which the hydrant is attached either directly or with a short length of pipe.

ii. There are two types of hydrants - stand-post type, or underground type(sluice-valve type)

iii. Stand-post type hydrant - General requirements:

- Shall have one or two sluice-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.	M³/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[11]

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:
      - Dry riser system,
      - Wet riser system,
      - Wet riser cum down comer system, and
      - Down-comer-system

[11] Source of image - https://fireextinguishersindia.wordpress.com/2018/03/10/all-about-internal-fire-hydrant-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/cm2 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

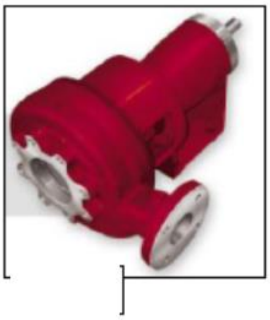
The functionality of a vertical split case pump is similar to that of a horizontal split case pump with the exception of the vertical orientation of the pump and motor. The vertical motor placement offers the advantages of less required floor space and the protection of the motor against potential flooding 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.

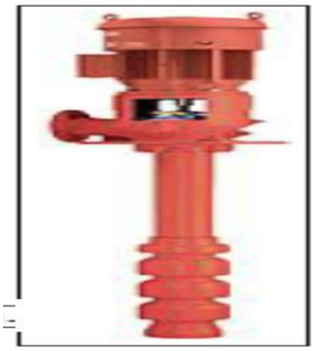
4.8.4. End suction



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

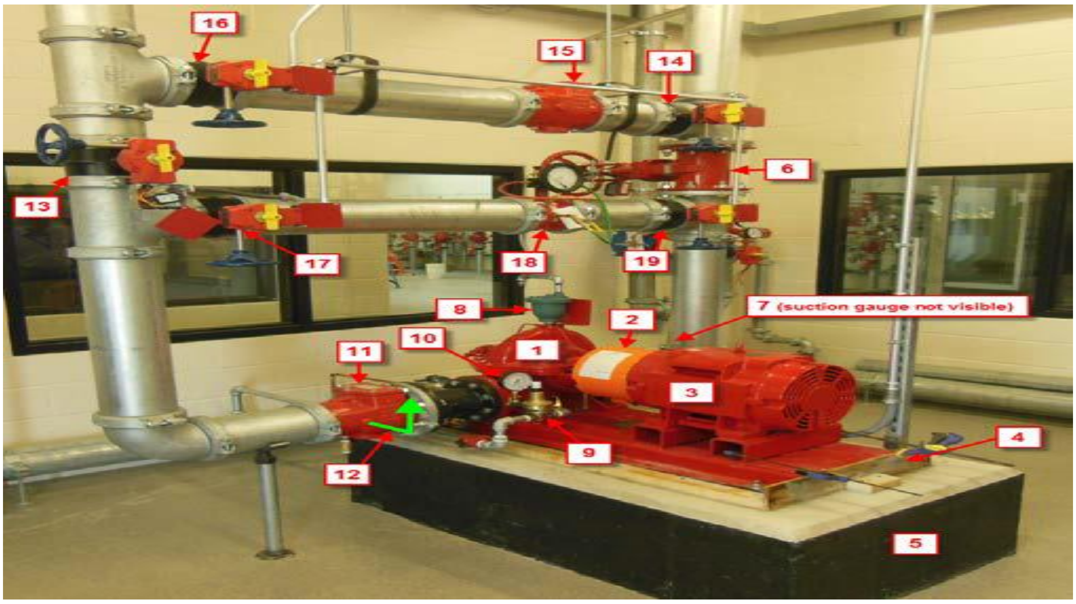
Unlike the previously discussed fire pumps, the vertical turbine pump does not require a water source that provides a positive suction pressure. As such, this type of pump is able to operate without priming. The typical supplies for these pumps are underground tanks or wells. When operating, these pumps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

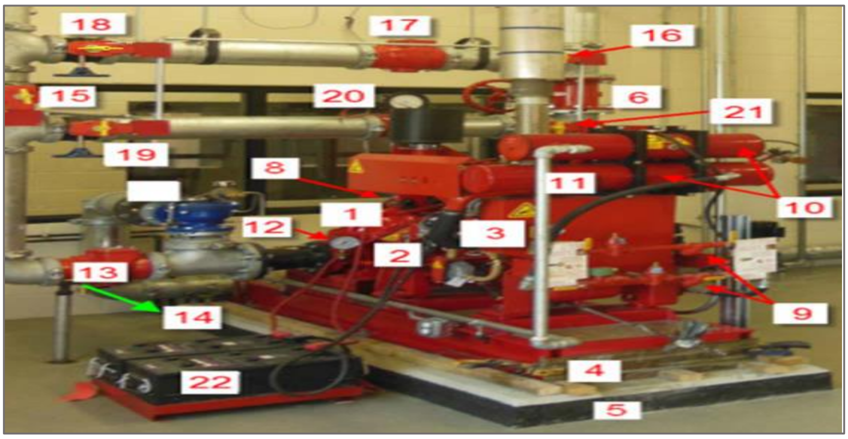
1. Fire pump	2. Coupling guard	3. Electric motor
4. Grouted base (wood forms still in place to retain curing grout)	5. Plinth or housekeeping pad	6. Fire pump suction valve (gate type valve)
7. Fire pump suction gauge (not visible)	8. Automatic air release	9. Circulation relief valve
10. Fire pump discharge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

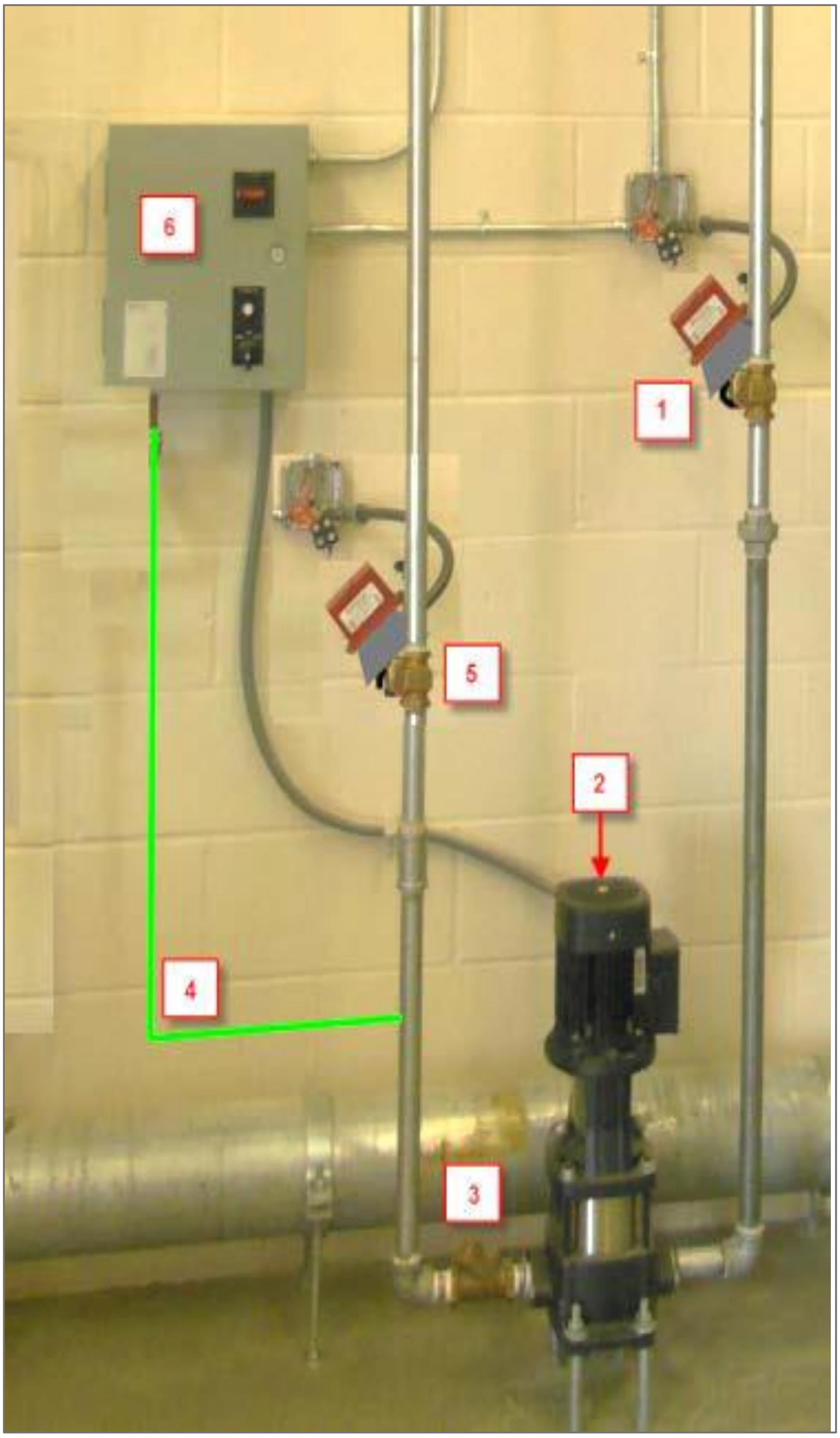
Example of a diesel fuel tank (Photo source: Rich Gallagher, Zurich) is mentioned below:

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

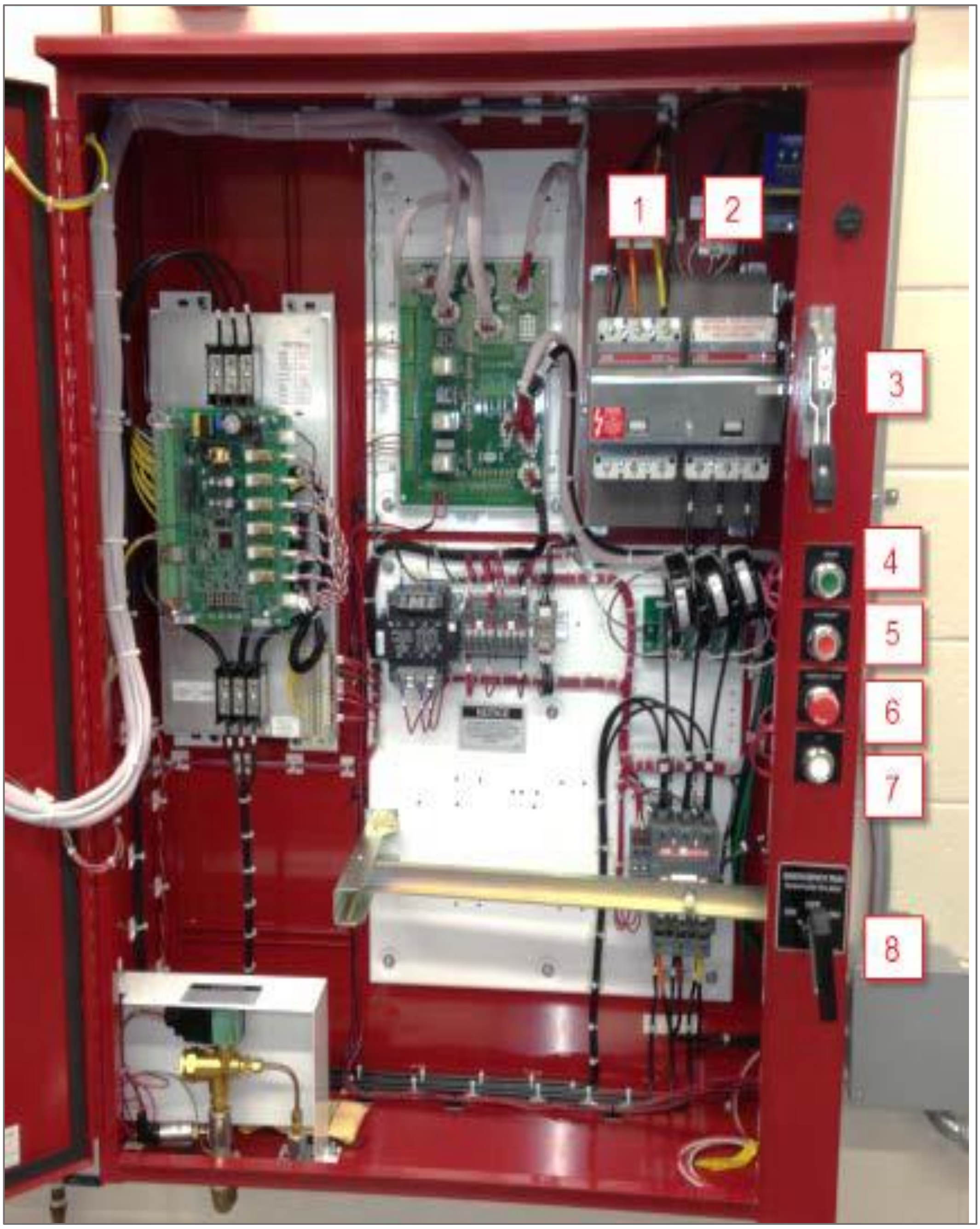
Jockey pump installation (Photo source: Rich Gallagher, Zurich)

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)

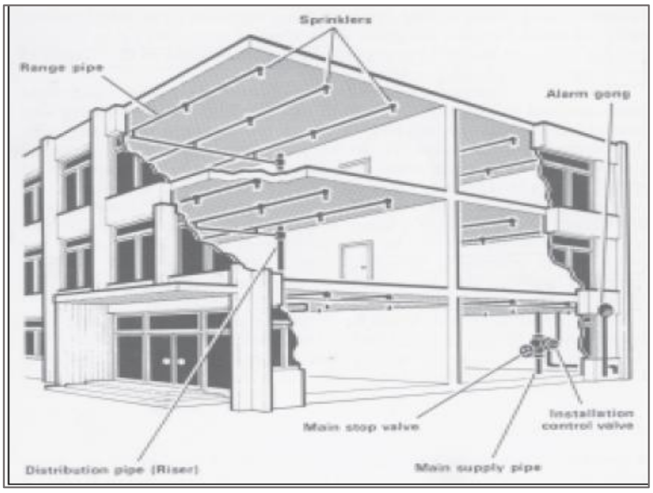
4.9. Water based fire extinguishing system

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

Wet - The pipes are permanently charged with water and used for all locations except where freezing temperatures are likely to occur, or special conditions exist.	**Dry -** The pipes are normally charged with air under pressure.
Alternate - Can be arranged to be either wet or dry depending upon ambient temperature conditions.	**Pre-action -** 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^2	84m^2
Moderate Hazard System (MH)	5.0 lpm/m^2	360m^2
High Hazard System(HH)		
(a) Process risks	7.5/12.5 lpm/m^2	260m^2
(b) High piled storage risks	7.5/30 lpm/m^2	260/300 m^2

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:

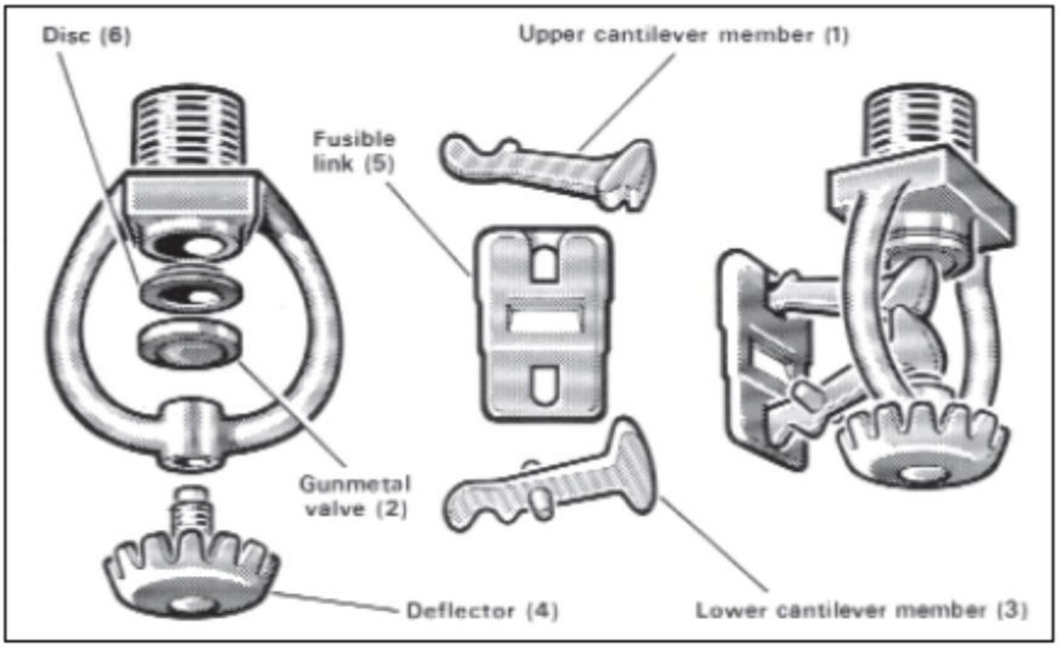
- town mains
- elevated private reservoirs
- gravity tanks
- automatic pump supply
- pressure tanks

Sprinkler heads

Their operation can be divided into two main types:

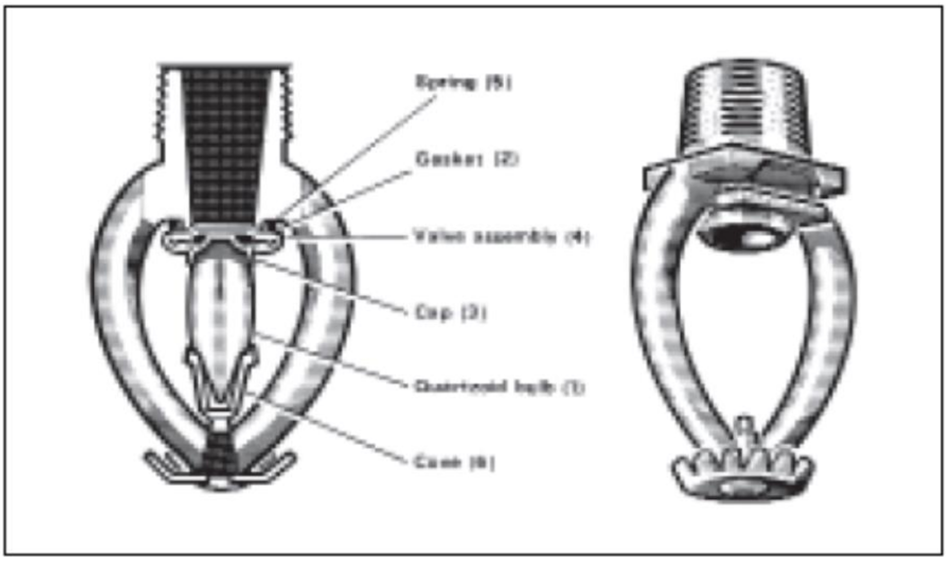
(i) Those in which the operating medium is fusible solder
(ii) Those in which the operating medium is a glass bulb (quartzoid bulb).

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

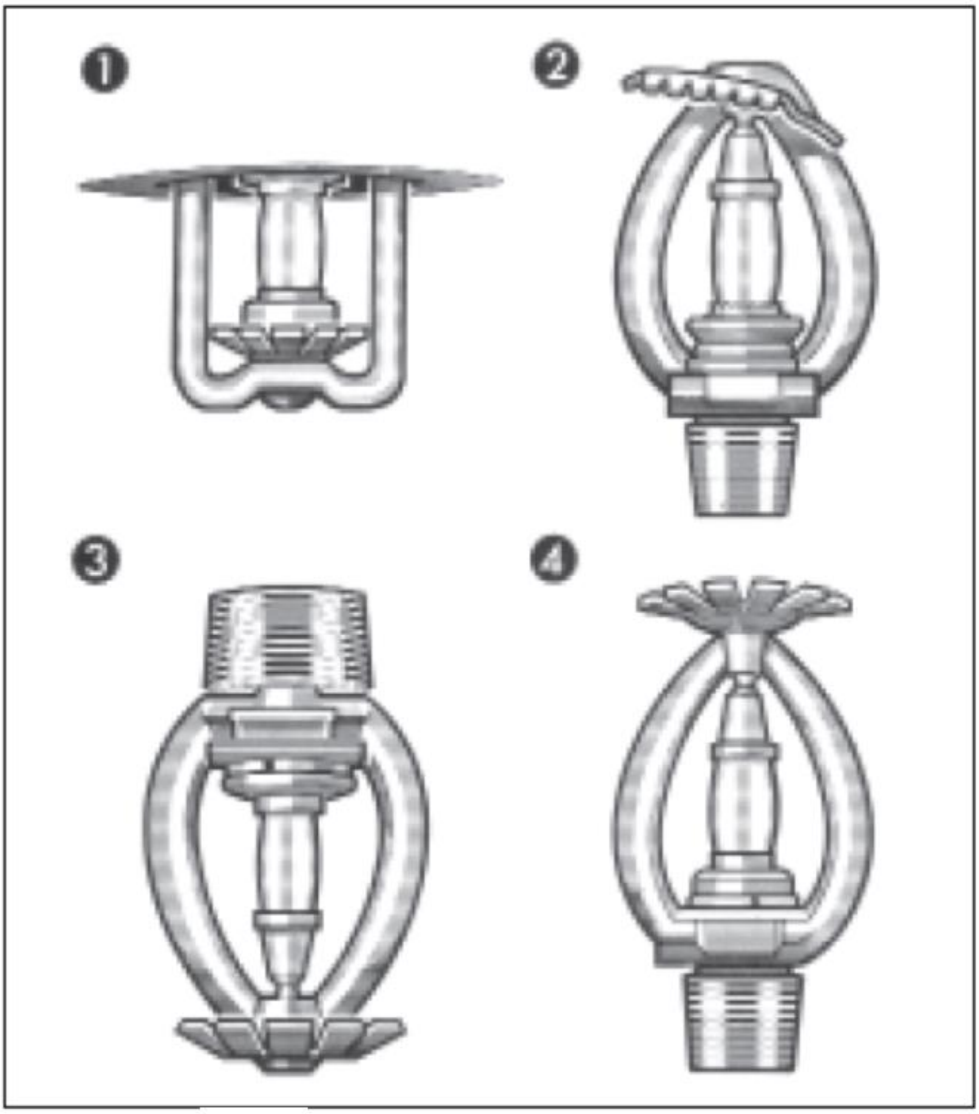
The heads are installed with the base flush to the ceiling, and heat sensitive elements facing downwards. The pipe work remains concealed above the ceiling.

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

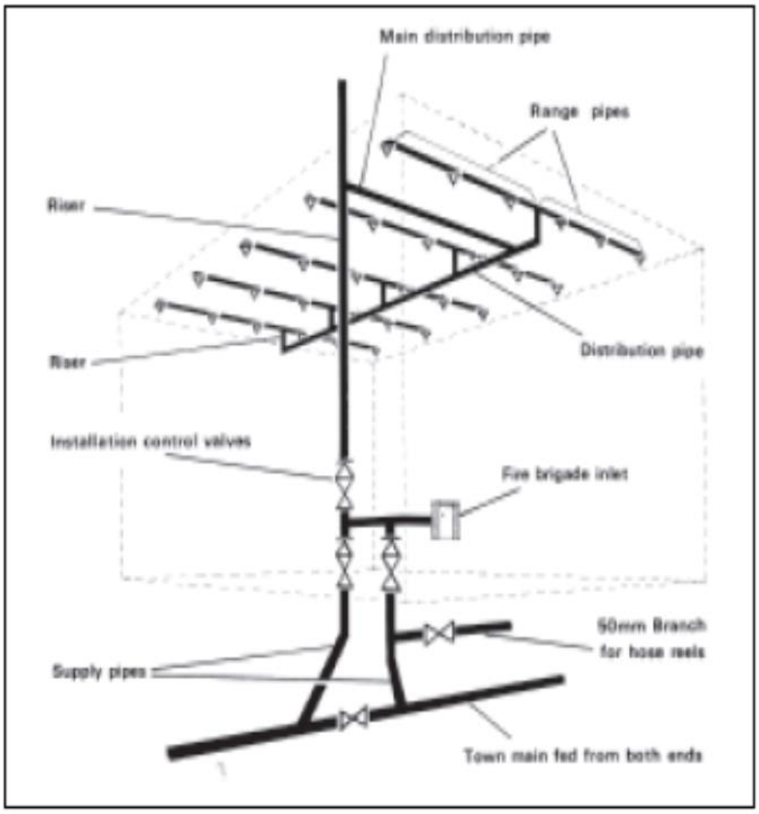
These are the same as pendent type sprin



Types of sprinklers (bulb type)

(1) Ceiling flush pattern (2) Sidewall pattern

(3) Pendent type (4) Dry upright type



Diagramatic 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^2	9 m^2
Ordinary hazard	12 m^2	9m^2
Extra high hazard	9m^2	7.5 to 10 m^2

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 $36m^2$.

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^2;

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 $125m^2$ 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^2.

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^2.

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.

Sprinkler systems for storage:

Automatic sprinkler protection supplemented by manual firefighting operations and sound storage and housekeeping practices is the most effective and practical means of fire protection. Properly designed, installed, and maintained systems will perform their intended tasks. However, a fire protection plan incorporating an inadequate, impaired, or partial sprinkler system cannot be expected to produce good results.

Recent advances in sprinkler technology provide three basic approaches for sprinkler protection of storage operations. These include the use of

(1) Control-mode density-area sprinklers,

(2) Control-mode specific-application sprinklers, and

(3) Suppression-mode (ESFR) sprinklers.

Each of the three approaches is associated with varying sprinkler types, sizes, and installation arrangements, thus providing a number of possible alternatives for sprinkler system design for most storage situations. There is no single “best” method for protecting a given storage arrangement, as each design must take into consideration the overall effectiveness, flexibility, and cost in relation to the design goals.

Control-Mode Density-Area Sprinklers:

Control-mode density-area sprinklers are the oldest technology used to protect current storage methods. One key indicator of a control-mode density-area sprinkler is the description of the design area by a density. Control-mode density-area sprinklers are the only sprinklers that can change their minimum operating pressure by changing the spacing. The area of protection for each sprinkler dictates the minimum operating pressure, unlike control-mode specific-application and ESFR sprinklers that have a minimum operating pressure regardless of sprinkler spacing. The performance of these sprinklers in the protection of storage is characterized by the fact that the first sprinklers that operate work to contain or rather control the fire. Through a combination of pre wetting of combustibles surrounding the initial fire area and cooling at roof/ceiling level, the fire is confined to a relatively small area until it is manually extinguished or burns itself out.

Control-Mode Specific-Application Sprinklers:

Control-mode specific-application sprinklers are control-mode sprinklers whose performance characteristics have been enhanced through the use of orifice/deflector designs that produce larger water droplets that better penetrate a fire plume. This enhanced performance provides certain advantages over traditional control-mode density-area sprinklers. The discharge criterion for this type of sprinkler is specified as a number of sprinklers operating at a minimum pressure rather than a minimum density and design area. The first control-mode specific-application sprinkler was the large-drop sprinkler. More recently, control-mode specific application sprinklers with larger K-factors have been developed. The design requirements and applications of various types of control-mode specific-application sprinklers can differ and are based on fire testing. It cannot be assumed that, because one type of control-mode specific-application sprinkler is permitted by standards for protection of a type of storage, other types of control-mode specific-application sprinklers may be used.

Suppression-Mode Sprinklers:

Suppression-mode, or ESFR, sprinklers are a radical departure from control-mode sprinkler technology and come with their own unique set of strengths and limitations. The fundamental premise of suppression-mode sprinkler protection is that a sensitive sprinkler capable of producing an optimized high- volume, high-momentum discharge can actually suppress (rather than simply control) a fire in storage. The primary advantage of suppression-mode sprinklers is their ability to protect many rack storage arrangements without the need for in-rack sprinklers. Although they are much more effective in protecting such storage than ceiling-only control-mode sprinklers, they are no more effective than a ceiling/in-rack sprinkler design using control mode sprinklers. They also have their own quite complex and sensitive installation rules.

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.

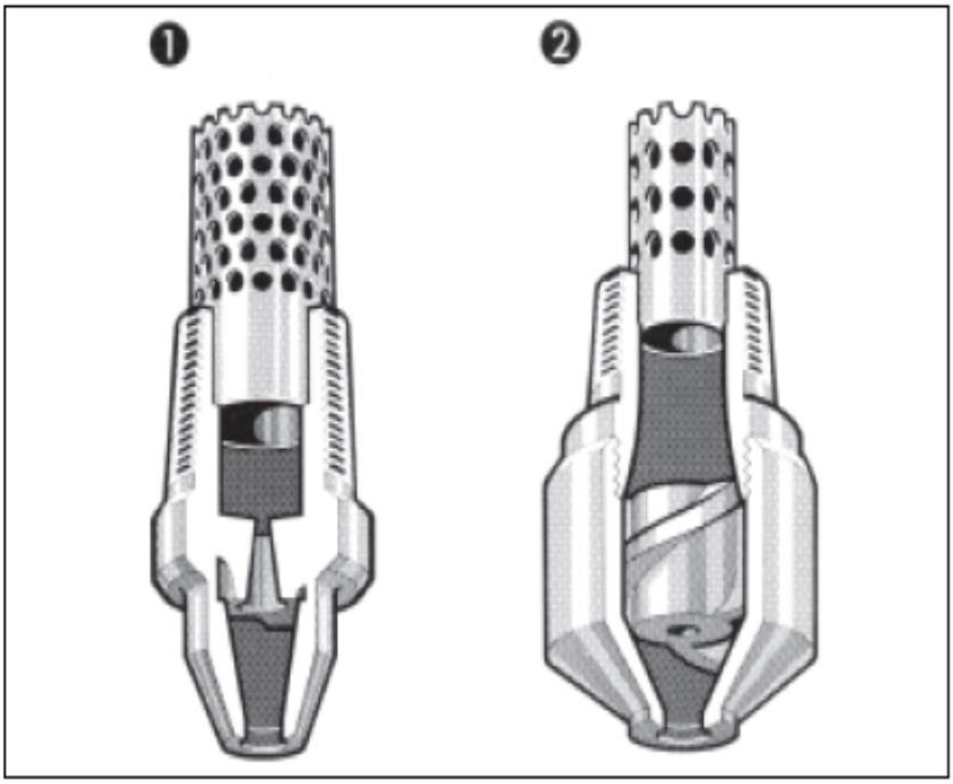
Types of water spray systems

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.

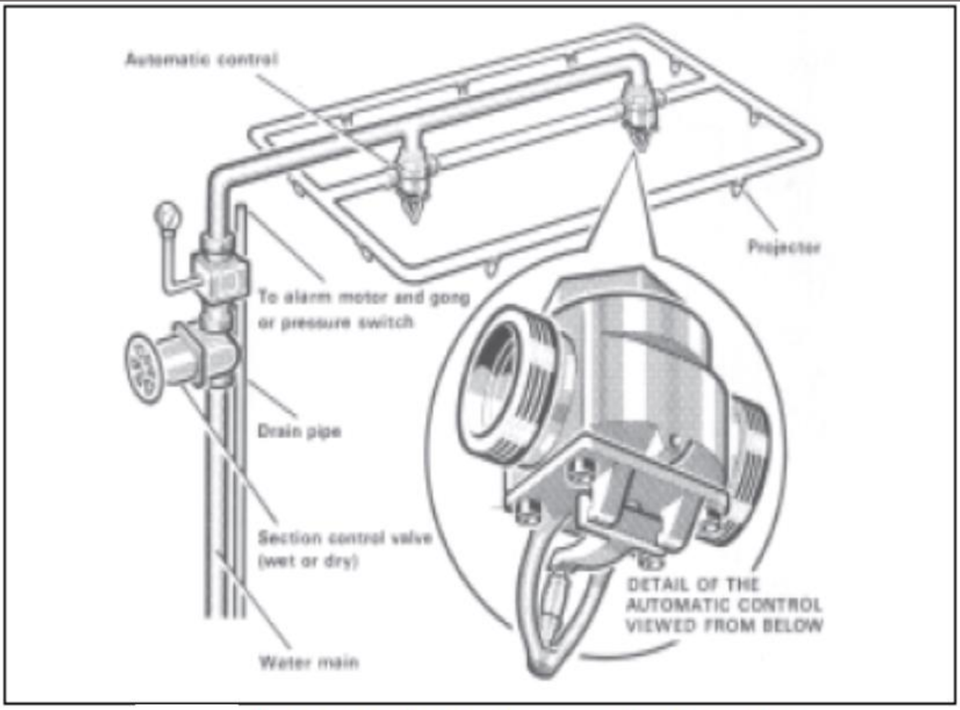


Two types of High Velocity
Water Spray projectors

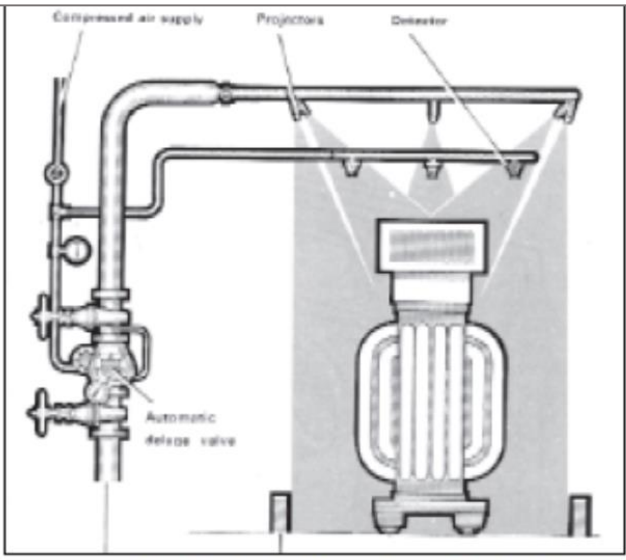
The high velocity spray system for transformers should be well designed to have adequate coverage of the entire transformer unit including the conservation tanks, the bushings and the bottom area.

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^2 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.



Automatic Water Spray projector system



High Velocity Water Spray System for Transformer Protection

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/m2 of protected surface.
- For fire control -- not less than 20.4 lpm / m2 (for protection of pumps, glands other critical areas)
- For exposure protection (for cooling) -- not less than 10.2 lpm/m2

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:

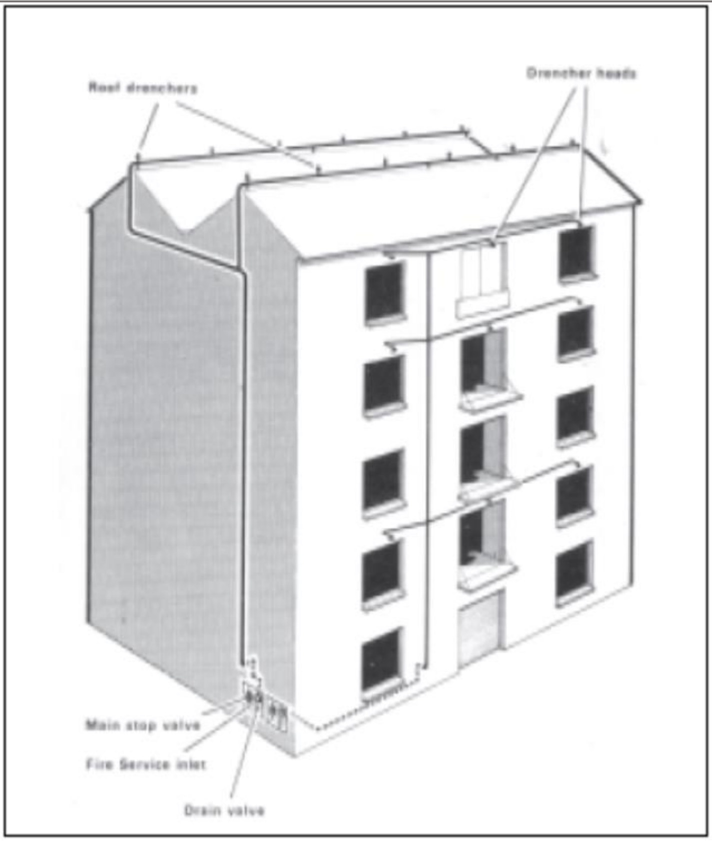
(a) Roof drenchers - From the roof edge they throw a curtain of water upwards which then runs down the roof

(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.



A typical drencher system

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

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

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:

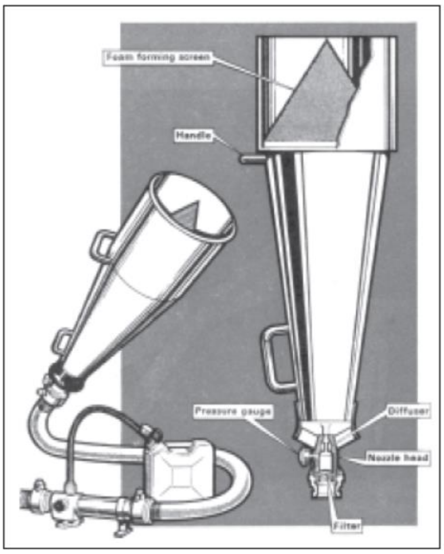
i. This type of foam is an aggregation of bubbles resulting from mechanical expansion of a foam solution by air or by other gases, with expansion ratios in the range of 50:1 to 1000:1

ii. There are 3 type of systems:

- l total flooding
- l 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.



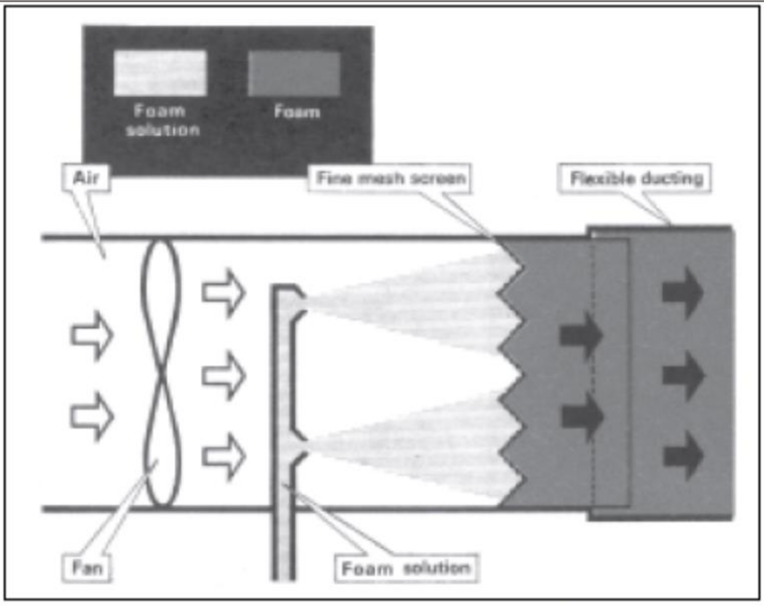
A typical medium expansion foam generator

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.

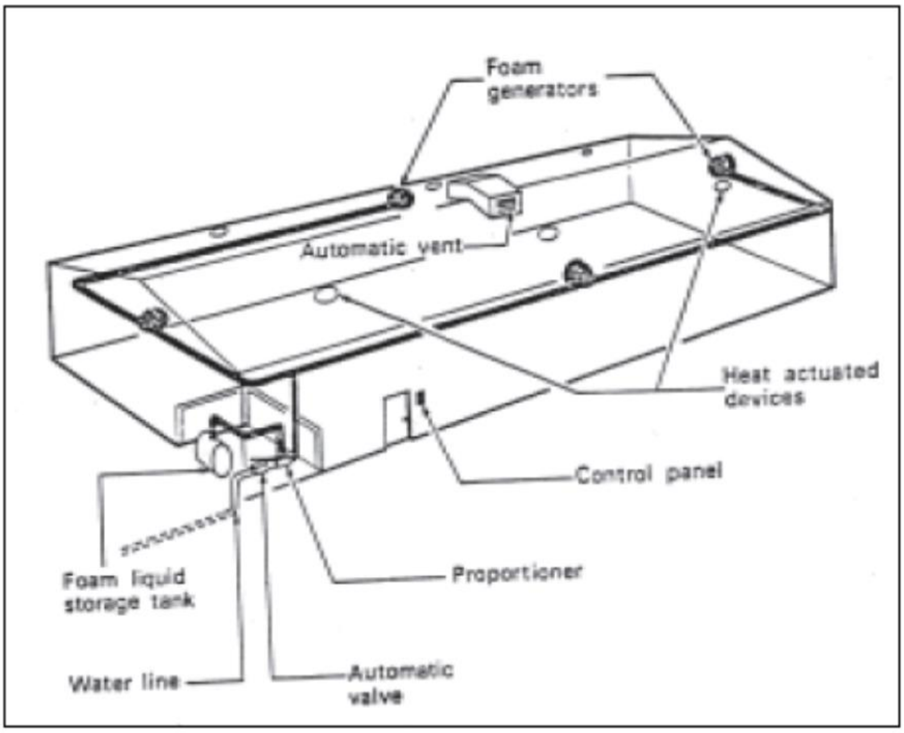


Principles of operation of a high expansion foam generator

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^3 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.



Typical High Expansion Foam System for Warehouse-

Currently, are high expansion foam system are used for protection of warehouses, aircraft hangars, Dip tanks of combustible liquids, and basements within buildings. Due to large volume of foam generated, they fill up the hazard space quickly and are able to access hard-to-reach locations, preventing air from reaching the combustion zone. Smaller amount of water in the foam also allows conversion to steam when exposed to the fire, and water absorbed into adjacent material helps in cooling and preventing spread. The main design features of such systems include a specified expansion ratio for the foam generated, the submergence height (i.e. the minimum height upto which the foam must fill up a given volume) and the submergence time (the maximum time in which the submergence height must be achieved). The system operation duration will depend on the type of fire hazard protected.

The components for these systems will be largely similar to low expansion foam systems, as the proportioning (mixing of water with foam concentrate) system will be similar (note that depending on manufacturer, high expansion foam concentrates may have slightly different proportioning rates as compared to low expansion foam concentrates). The piping arrangements for delivery of foam solution will also be similar to low expansion systems. The main difference is in the discharge devices, which are called high expansion foam generators. Due to the higher expansion ratios required, these equipment are specifically designed to blow a large amount of air on a screen on which the foam solution is applied. This results in large volume of foam being generated. As the generators require fresh air for generating foam, it's location in the hazard area is important, as products of combustion reaching the generator can adversely affects its performance/output. These systems too are normally interfaced with suitable detection systems. In some cases, protected hazards may also have sprinkler systems installed alongwith these systems; simultaneous operation of both systems is possible.

High expansion foam system operation in a warehouse

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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 CO2 or N).

The commonly used dry chemical agents are listed below:

Chemical Name	Formula	Other Name(s)
Sodium bicarbonate	NaHCO3	Baking soda
Sodium chloride	NaCl	Common salt
Potassium bicarbonate .	KHCO3	Purple K.
Potassium chloride.	KCl	Super K.

Chemical Name	Formula	Other Name(s)
Potassium sulphide	K2SO4	-
Monoammonium (NH4). phosphate Powder	H2PO4	ABC. or Multipurpose
Urea + potassium. bicarbonate +	NH2CONH2 KHCO3	Monnex. (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)
Hydrochloroflurocarbons (HCFC)	Perfluorocarbons (FC or PFC)
Fluoroiodocarbons (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 N2 52%, Argon(A) 40% and CO2 8%
- Argonite - IG - 55 (mixture of N2 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-I New Technology Halon Alternatives

Table-2 - Physical Properties

Total Flooding Gaseous Alternatives	
Halocarbons	**Composition**
HCFC: HFC: PFC: FIC:	HCFC Blend A, HCFC 124 HFC-23, HFC-125, HFC-227ea, HFC-236fa FC-3-1-10, FC-2-1-8 FIC-1311
Inert Gases	
Nitogen: Argon: Nitrogen/argon blend: Nitrogen/argon/CO2 blend:	IG-10 IG-01 IG-55 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: HFC: PFC:	HCFC Blend B, HCFC Blend E, HCFC-124 HFC: HFC-227ea, HFC-236fa 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-13I1	Triodide	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. CO2 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 1bf/in) at about 15^{o}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 CO2 required for various types of fuels vary from approx. 30% to 62% depending upon the fuel.

Minimum CO2 concentration required for extinguishment of various materials

Materials	Minimum extinguishing concentration required
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

Materials	Minimum extinguishing concentration required
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
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, CO2 is substantially more effective than N. However, on weight basis, both have nearly equal effectiveness as CO2 is 1.57 times heavier than N.
- It is actually the depletion of the O2 level in the air which is responsible for extinguishment in the case of inert gases. A reduction of the O2% in the air from 21% to 10% by volume would make fires and explosions impossible, except for a few special gases like H, C2H2, or CS2 which would require greater dilution.

CO2 extinguishing systems/ installations

1) General

i. CO2 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. CO2 is not suitable for fires involving the following:

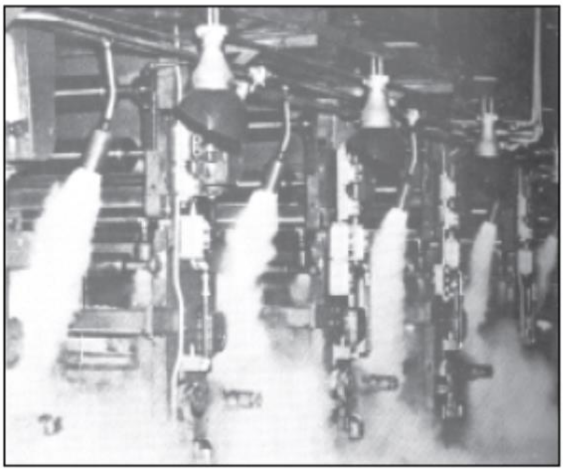
- Chemicals containing their own supply of oxygen such as cellulose nitrate, chlorates etc.
- Reactive metals such as sodium, potassium, magnesium, titanium and zirconium, and their halides.

2) Methods of application

There are two basic methods of applying CO2 in the fire extinguishing systems:

i. Total flooding:

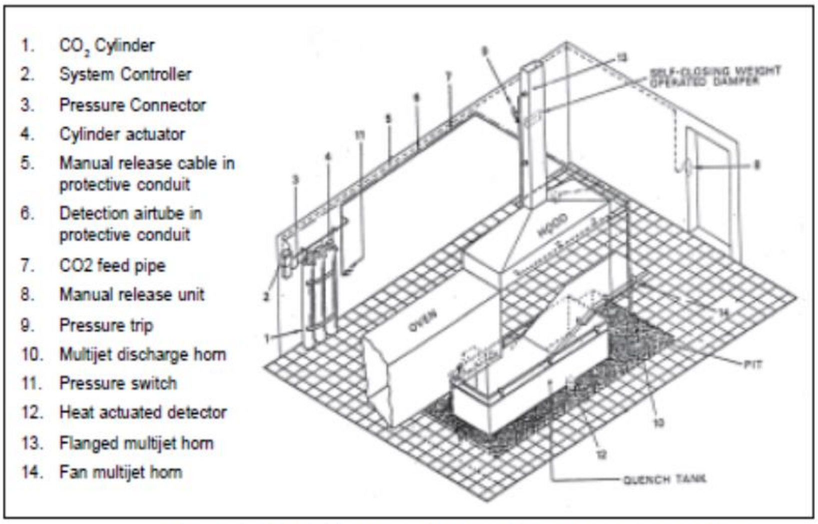
- In these systems, CO2 is applied through nozzles to develop a uniform concentration of CO2 in the protected enclosure. The minimum concentration used in the total flooding system is 34% CO2 by volume for surface-burning materials. 50% concentration will be required for electrical machines; bulk paper requires 65%, and for storage vaults and dust collectors 75%.



A CO_2 Extinguishing System that has been activated

ii. Local application:

- In this system CO2 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



CO_2 Local Application System protecting quench tank

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.)

Powdered Aerosols

Powdered aerosols are relatively new to the fire protection industry, and though they were used earlier in the aircraft and space industry, their application for normal fire risks has only recently begun. This is a unique technology, which employs aerospace propellant chemistry, whereby an oxidizer and a reducer combined with various additives produce in a chemical reaction, a finely dispersed dry powder aerosol that has outstanding extinguishing characteristics. This Halon alternatives extremely effective, in fact even more efficient than Halon 1301 on a weight basis. Additionally, it features minimal environmental effects, i.e. zero Ozone Depletion Potential (ODP) and does not contribute to the Global Warming effect.

Powdered aerosols are produced by the reaction of an oxidizing agent and a solid fuel, which, when ignited, produces a fine solid particulate aerosol (powdered aerosol) providing extinguishment similar to that provided by dry chemical agents. The small particle size appears to increase efficiency, decrease deposits, and increases the space filling capability (multidimensionality) relative to normal dry chemical agents. This technology has been termed as "pyrotechnically generated aerosol", or "pyrogenic aerosol", which some feel is more appropriate.

The powdered aerosol agents are produced in an oxidation-reduction combustion process that takes place in a combustion chamber specifically designed to contain varied amounts of solid casted material. The combustion chamber is introduced in modular units (generators) that include cooling means (chemical and physical) as well as discharge outlets that direct the aerosol flow towards the protected volume. The agents provide an air-suspended dry chemical aerosol with micron size particles that give total flooding capabilities.

As particle size decreases, the particulate surface on which heterogeneous recombination of combustion chain propagators can occur increases. Thus, in addition to improving dispersion, the small particle sizes inherent in particulate aerosols give these materials greater weight effectiveness than standard dry chemical agents; consequently smaller amount of agent is required, lessening the problems of residue.

Considering its effectiveness and growing application, there are design & installation standards published by NFPA, ISO and other bodies such as UL. Within the country, there is an effort by Bureau of Indian Standards (BIS) to set up a committee to study and develop a suitable standard for this extinguishing agent.

Powdered Aerosols – application and operational uses

These agents are casted in the solid form and are contained in modular units (generators) of various sizes containing from 100 grams up to 5 kilograms. They can be used as stand-alone units or grouped together for protection of larger risks. Typical system configuration include several modular units connected in a loop to a control box/display panel, activated electrically by a signal from a separate detection system or by a self-contained detection element incorporated in the modular unit.

These fire suppression systems eliminate the need for pressurized containers and pipes, thus reducing the system's size, weight and maintenance requirements. Due to these facts, and the possible weight/volume costs benefits of this technology, it is being considered particularly suitable for aircraft fire protection, and further research and evaluation is being done in this area, as also in other military, industrial and commercial applications. In the U.S., powdered aerosol in total flooding systems have presently been listed as acceptable in normally unoccupied areas.

Wet Chemical Systems

Commercial cooking operations have undergone major changes in recent years in two areas that have produced an increased challenge to chemical fire extinguishing systems. First, there has been a change in the cooking medium from animal fats to vegetable oils. These newer cooking oils change their makeup after ignition. This change results in an ignition temperature that is considerably lower (50°F, or 28°C) than that of the original oil. Therefore, to prevent reflash of the oil, the entire volume of the oil must be cooled below the autoignition temperature. Vegetable oils also have less fatty acids than do animal fats. It is the fatty acids that interact with the alkaline solution of the chemical agent that produces the saponification

Wet chemical fire extinguishing agents consist of organic or inorganic salts mixed with water to form an alkaline solution that is capable of being discharged through piping or tubing when

under expellant gas pressure. They are extremely effective and are currently the only agents used for suppression of fires in commercial cooking equipment, such as deepfat fryers, range tops, and broilers, because of their ability to retain the separation of the oil from air for a sufficient time to allow complete cooling.

Wet chemical extinguishing agents are typically a proprietary mixture consisting of potassium carbonate, potassium acetate, potassium citrate, or a combination, mixed in water and other additives such as phenolphthalein, phosphoric acid, and/or dyes. As they are already liquid in character, wet chemical agents do not require additives to enhance flow. Wet chemicals range in other physical properties depending on the mixture used.

Wet Chemical – application and operational uses

When wet chemical extinguishing agents are sprayed on a grease fire, they interact immediately with the grease and saponify, forming a blanket of foam over the surface on which they are sprayed. This blanket extinguishes the fire by a combination of two primary methods: smothering and cooling.

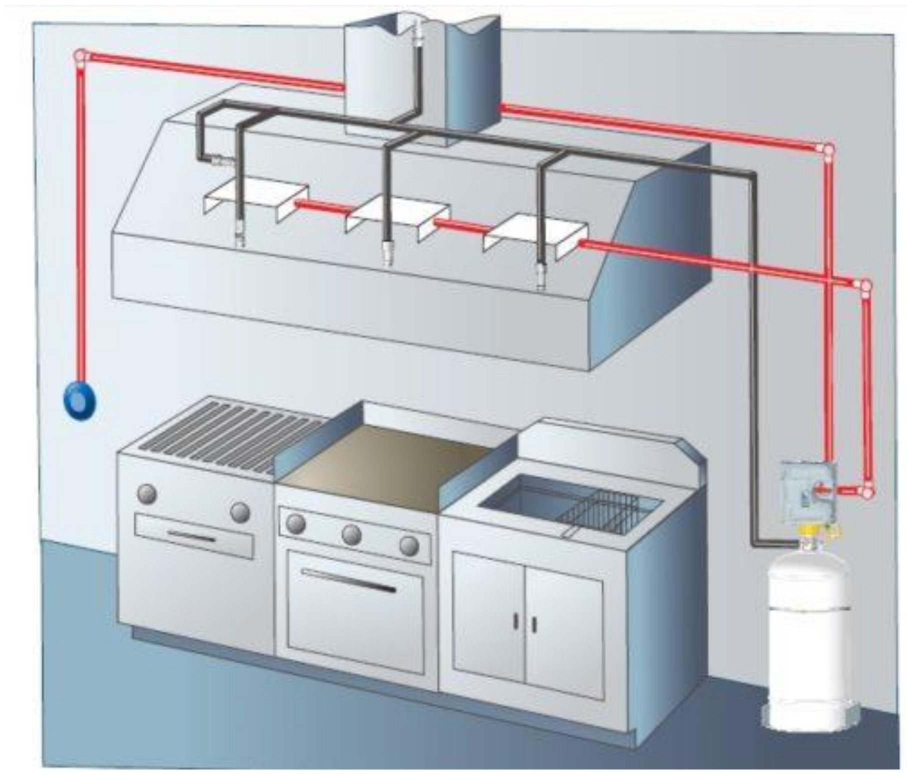
Smothering Action. When wet chemical agent is applied to flammable liquid surfaces, the result is a rapid knockdown of flame and a spreading of foam on the fuel surface. This vapor suppressing foam barrier extinguishes the flame by separating the liquid fuel and oxygen. The result is the inability of the flammable vapors from the fuel source to escape the surface and ignite. Because the primary use of wet chemical systems is for protection of commercial cooking equipment and this is a very localized protection area, it is critical that the fire be contained within the equipment involved. To achieve this end, wet chemical systems are specifically tested to determine that during the discharge process they do not splash burning grease.

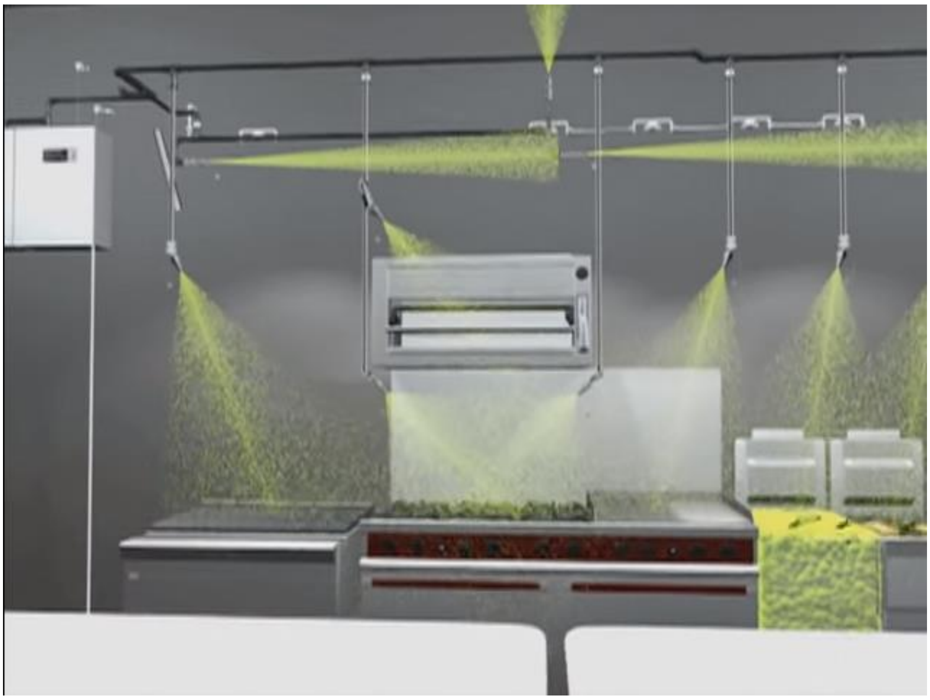
Cooling Action. The effect of water vaporization by wet agents provides a cooling effect on the fuel. Furthermore, the application of the wet chemical solution and the resulting formation of foam on the surface of the fuel also provides a cooling effect, lowering the temperature of the flammable fuel, further decreasing flammable vapor release. Some wet chemical systems are designed to continue with an application of water through the nozzles after the wet chemical has been completely discharged. This serves to further cool the surrounding surfaces, thereby preventing reflash.

The hardware components are similar to dry chemical systems insofar as there is an agent supply and expellant gas and an actuating method. The agent is delivered through piping to specially designed nozzles that atomize the solution and distribute the agent over the hazard area. Wet chemical systems are local application systems. Local application systems are practical in those situations where the hazard can be isolated from other hazards so that fire will not spread beyond the area protected, and where the entire hazard can be protected. In this type of system, the nozzles are arranged to discharge directly onto the fire or burning surface such as deep-fat fryers, and stoves. It is especially critical in commercial cooking operations that the cooking equipment not be rearranged after the installation of the extinguishing system.

Most wet chemical systems apply the agent through nozzles that are specifically designed to protect the equipment under them. It is therefore critical to note that any rearrangement of the

cooking equipment after installation of the extinguishing system could result in unprotected surfaces.





Current standards for Wet chemical suppression systems are NFPA 17A (standard for wet chemical extinguishing systems) and NFPA 96 (Standard for Ventilation Control and Fire Protection for Commercial Cooking Operations).

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

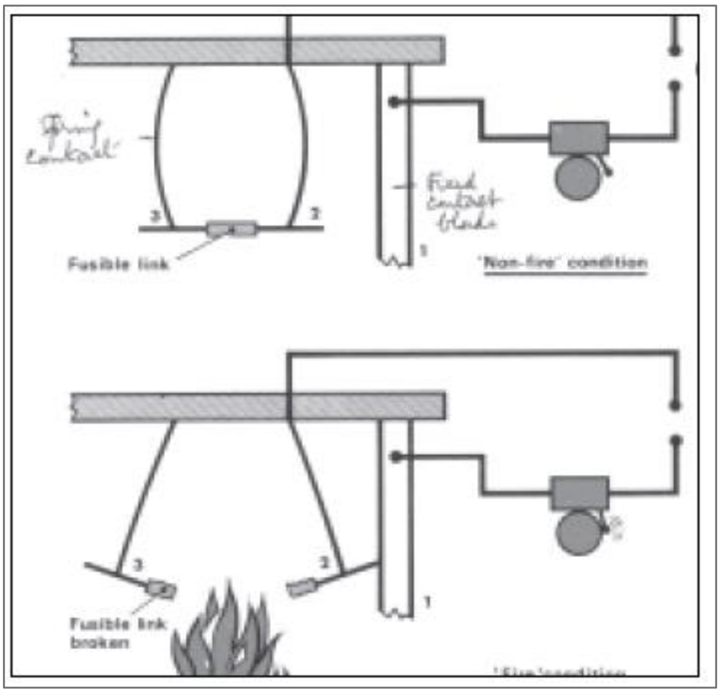
   (ii) Line detectors, which have a linear sensing device usually protecting a larger area.

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^{o}C to 180^{o}C, inclusive if the rate of rise of the temperature is less than 1^{o}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:

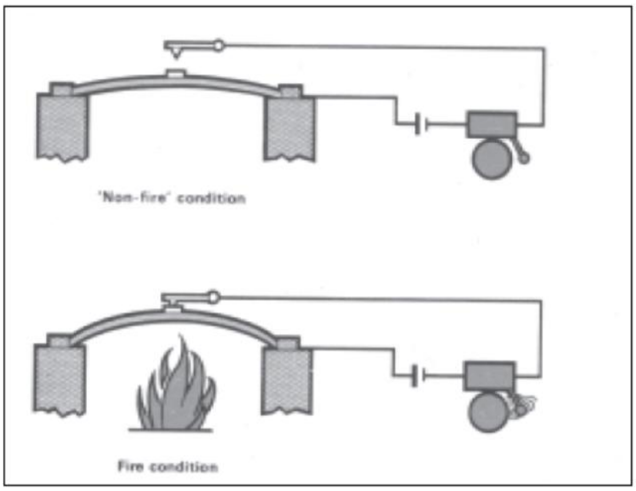


ii. **Heat sensitive covering in cable assembly (thermostatic cables)**

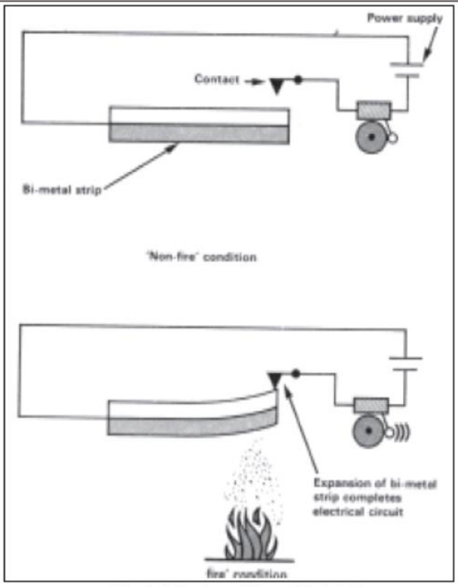
In this, two conductors are insulated from each other by a heat sensitive covering. At the rated temperature, the covering melts and the two conductors come into contact initiating an alarm.

iii. **Expansion of metals**

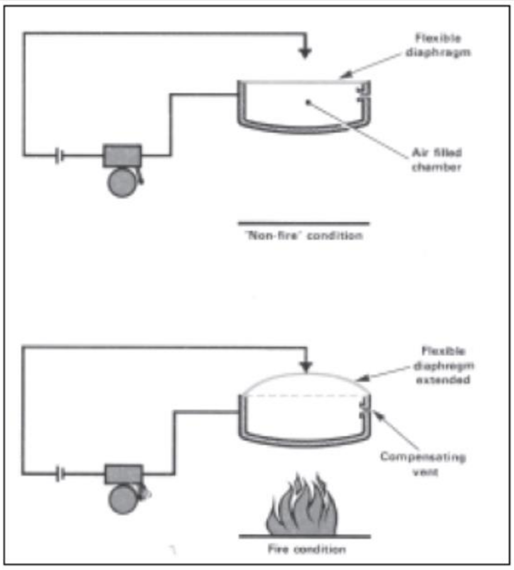
The movements created by expanding metals or bi-metal strips are used to make or break electrical circuits. Figures depicting these principles are given below:



Heat detector using expansion of metal strip principle



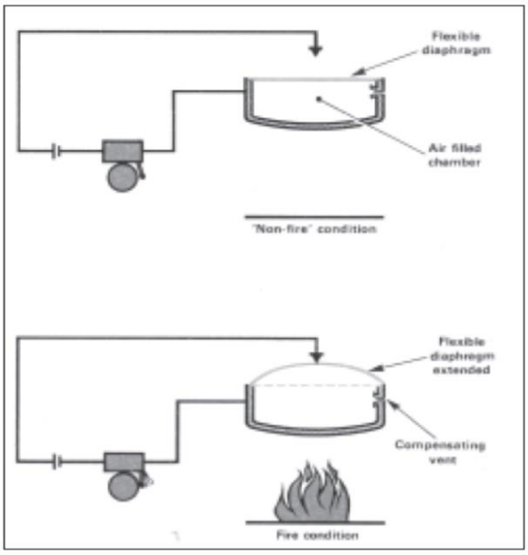
Heat detector - Bi-metal strip type



Heat detector - Rate-of-rise principle

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:



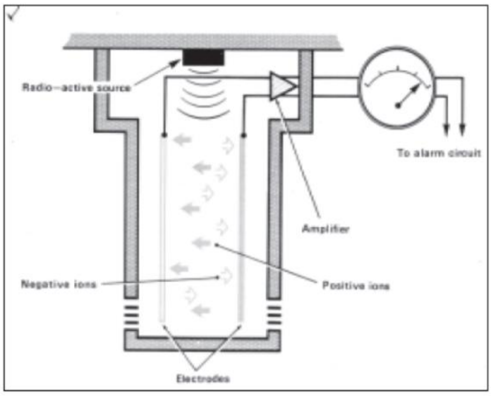
Heat detector - Using principle of expansion of air (pneumatic detector)

4.12.3. Smoke detectors

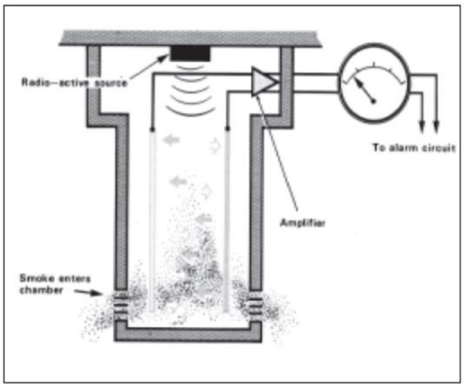
There are two types:

Ionization detector

Figures depicting Ionization type of smoke detector under non-fire condition as well as fire condition are shown below:



Ionisation Detector - Non-fire condition



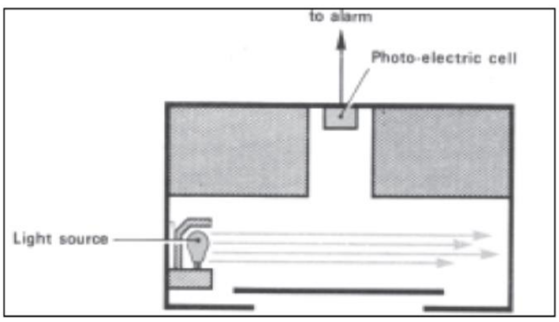
Ionisation Detector -fire condition

The basic principle involved in Ionization detector are as follows:

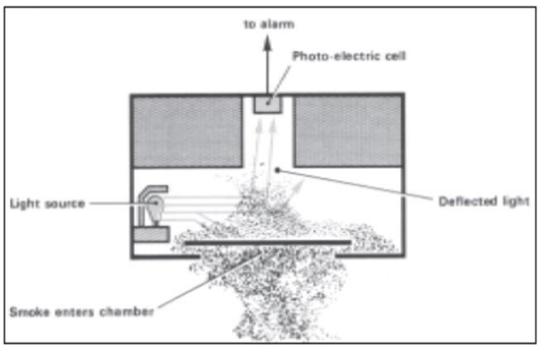
- The detector head consists of one (or two) Ionization chamber(s) connected to form a balanced electrical circuit. The Ionization chamber contains two electrodes, across which a potential difference is maintained, and a radioactive source (usually an alpha-particle source - usually Americium 236) ionizes 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

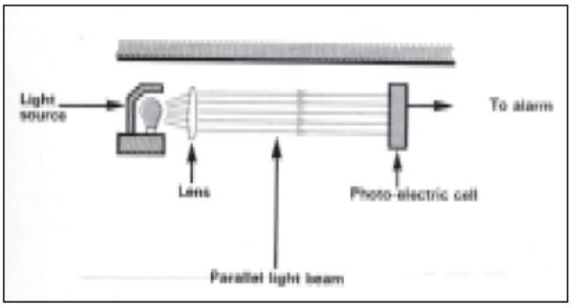
While the Ionization detector responds to the invisible products of combustion including, small particles of smoke, the optical detector, as its name implies, reacts to the visible products of combustion. An optical detector has two important components, a light source and a photo-electric cell. The 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:



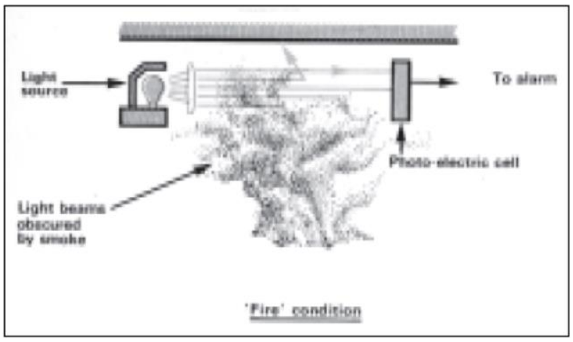
Optical Detector - Light scatter type(Non fire condition)



Optical Detector - Light scatter type(fire condition)



Optical Detector - Obscuration Type-Non-fire condition

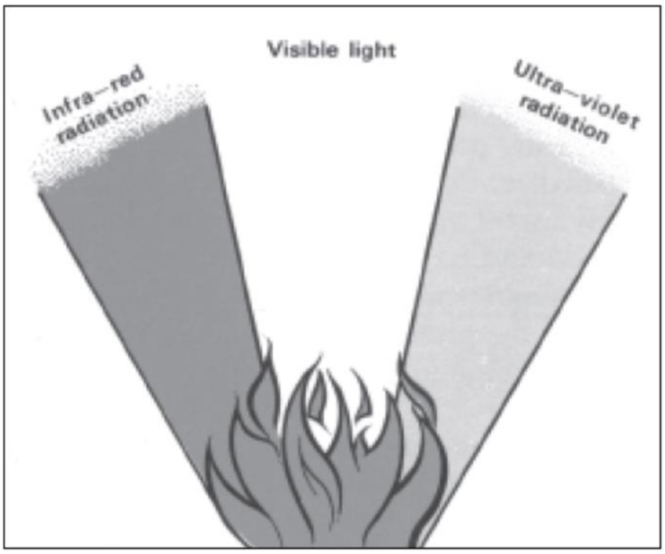


Optical Detector - Obscuration Type-fire condition

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



Forms of radiant energy produced in a fire

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:

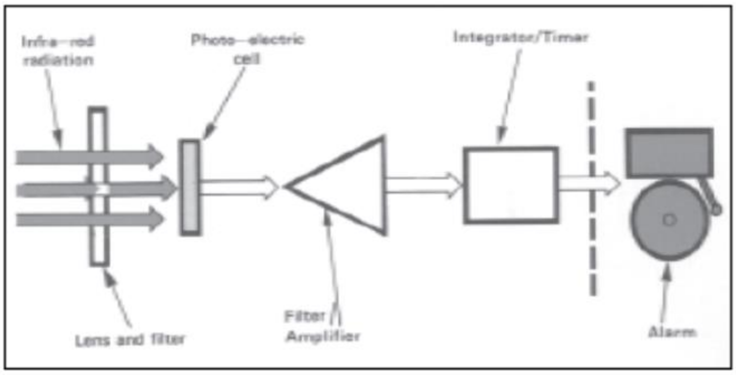
(i) Infra-red radiation

(ii) Ultra-violet radiation

(iii)Combination of IR/UV radiation

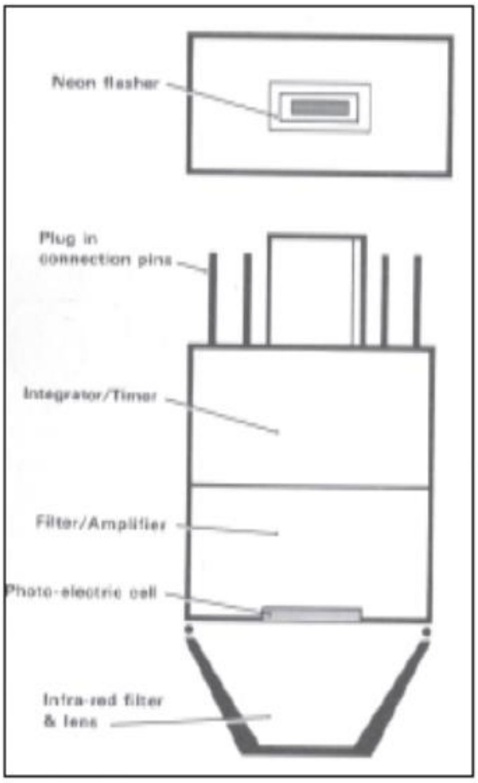
Infra-red detector

- The figure below illustrates the basic components of this detector:



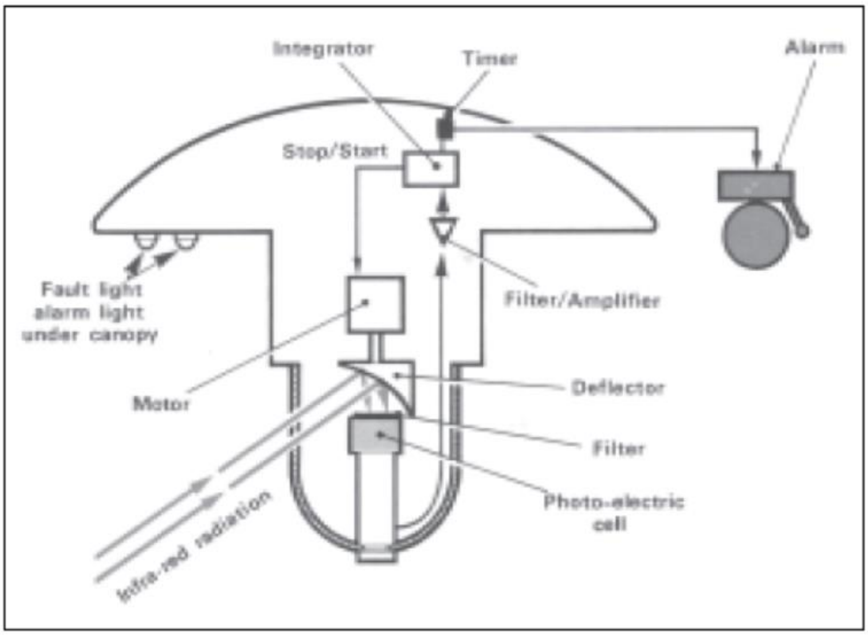
Components of an Infra-red Detector

- 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.



A typical Infra-red Detector

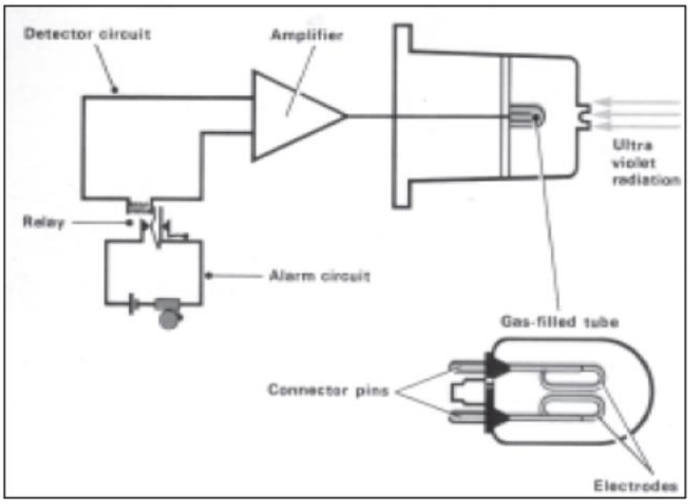
- Infra-scan radiation detector - The conventional Infra-red detector is designed to protect small areas. For larger areas with a more open plan, infra-scan radiation detectors are provided. In this, the detector monitors 360 degrees in the horizontal plane and a wide angle on the vertical plane. The 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:



A typical Infra-scan Detector

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:



Components of an Ultra-violet Detector

- 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) Main Components & types of fire detection and alarm systems.

Depending on the type and complexity of building protected, and the functions required, the fire detection & alarm system components will vary, however most systems will have the components described below.

Control & Indicating Equipment: Commonly referred to as the Fire Alarm Control Panel (FACP), it is the main control centre of the system to which the various devices are connected and which houses the hardware (and software) to carry out its various functions. The initiating (detection) and notification (alarm) devices are connected to the FACP, which receives and transmits signals to and from these devices based on the logic and hardware incorporated.

FACPs will be located at a continuously manned location, and should be easily accessible to the occupants/Emergency responders; typically they are located near main entrance/reception area or as per NBC Part 4, they should be located in the Fire Command Centre.

Power Supply (Main & Standby): The system works on DC power, however the main supply is from an AC source, typically 230 V AC, which is then converted to DC within the Panel. The system is supposed to be operational 24x7, and so it is imperative that even if the main (AC) power supply fails due to any reason, the system should continue to function and so standby power in the form of Battery back-up is provided.

Detectors: They provide the means to detect fire automatically and have been discussed in detail earlier.

Manual Call Points: These are provided to allow manual intervention using the Fire alarm system. Note that normal humans are capable of detecting the presence of fire through their various senses, and it is quite possible that people present in the area will smell the products of combustion or see some signs indicating the presence of fire, much before a detector can detect it. To allow people present to give an alarm using the Fire alarm system, manual call points (also called manual pill boxes) are provided at various locations.

Alarm Notification Device (Audio & Visual alarms): Once a fire is detected, it is important to alert occupants about the same. This is done through alarm notification devices, which can have audio, video or both type of signals. Audio devices consist of hooters or sounders which give out sounds of suitable frequency and decibel levels to draw occupants' attention. Visual devices are used where high noise levels are present, and audio signals may not be clearly audible; flashing (strobe) lights of appropriate lux levels are used to draw people's attention.

Cables & Wiring: The fire alarm system is an electronic system and the various components are connected using cables. Cables are used for providing power to the various devices as well as for communication between the devices and the FACP, and therefore need to be reliable and suited to performance requirements. An important property is that there should not be undue power loss due to resistance (in long lengths of cable), and hence minimum cross-sectional area for cables are specified by standards.

Interfaces with Building Systems: Fire alarm systems interact with different building systems and equipment such as the HVAC system, Smoke Control systems, Access control systems, Lifts, etc, with the purpose of improving survivability of occupants, aiding their egress and reducing property damage.

Depending on use, complexity and configuration of system, most fire alarm systems are divided into two basic types – conventional and addressable.

Conventional Systems: These are the older of the two, and are normally utilized for small buildings/ areas, where minimal functions from the system are specified. The protected building area is divided into zones and there is a limit to the number of devices connected in a zone. The zone cable runs from the Control panel to the protected area, and detectors are installed on this cable.

Addressable Systems: Conventional systems have limitations in terms of the output and information, hence more sophisticated systems were developed in form of addressable systems. In this, each individual detector can be identified from the Panel instead of the zone (in case of conventional panel). Instead of zones, addressable systems are configured in loops i.e. both ends of the cable are terminated at the Control panel; even in the event of a break in the cable, the detectors can continue to function, which results in higher reliability and is an important advantage over conventional systems. Each loop can connect from 100 to 200 devices based on the technology used.

3) 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. 16m2 - 20m2.
- 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 ease 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.

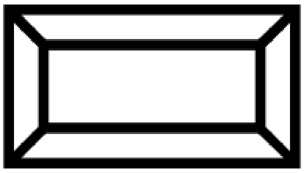
- However, panels with the following core materials are also in use: Expanded Polystyrene, Extruded Polystyrene, Foam Glass, Polyurethane, Polyisocyanurate, Mineral Fiber, Modified Phenolic.

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.

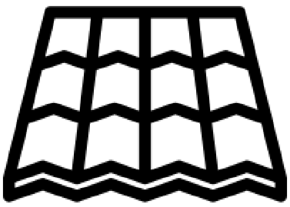
2) Columns

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,

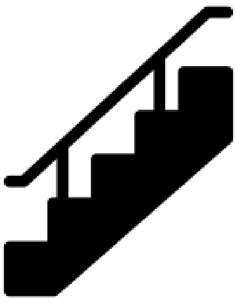


glass, plastics, tubing, cables etc., and which are suspended, cantilevered, sometimes geodetic, frequently braced and, occasionally, inflated is problematical.

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.

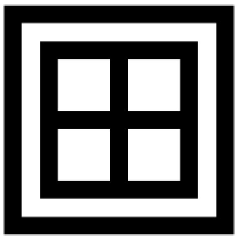
ii. Non-loadbearing partition walls

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".

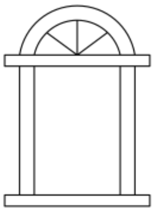
7) Doors, door sets and shutters

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.

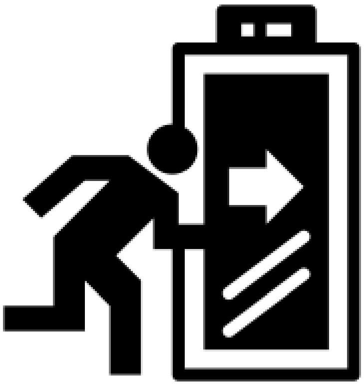
A fire door may be defined as:



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. 1S 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 grated 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^2 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^2
- 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/m2 to 550,000 K cal/m2
- Equivalent Severity of Fire - 2hours

High fire load occupancy

- Fire load between 5500,000 K cal/m2 to 11,00,00 K cal/m2.
- 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)

Sl 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 probabiolity 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^2 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 sublimes. 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., ⅓, ¾, 1, 1½, 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.

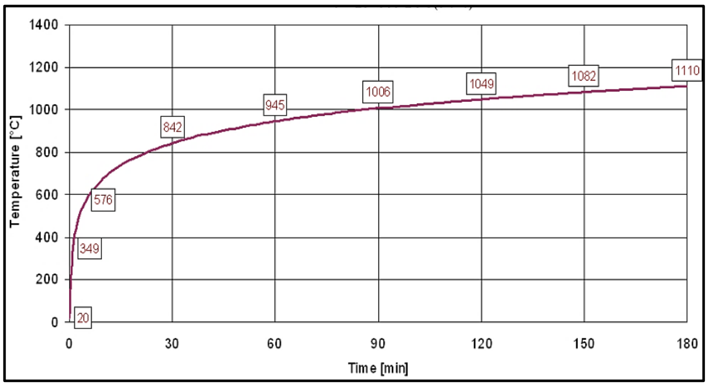
5.5. Fire resistance – concepts & testing

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°C. At this temperature, it begins to soften. It starts losing strength at about 400°C but these effects are reversible on cooling. However, once the temperature exceeds 500°C, permanent loss of strength occurs (at a temperature of about 540 °C, the yield strength of steel will drop to approximately 50% of its original, and at 650°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).

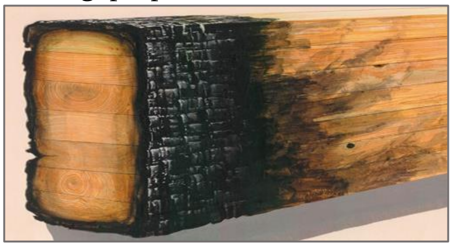
Wood

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, it's 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

With reference to the loss behavior of steel members, the main properties considered are its yield strength, ultimate strength, modulus of elasticity, coefficient of thermal expansion, density, specific heat and thermal conductivity. A lot of testing and research has been carried out by researchers and manufacturers on these steel properties and it is clear that all properties, except for density, are strongly influenced by temperature. From the designer's point of view, yield strength and the modulus of elasticity decreases with increasing temperatures and the yield stress of steel is the significant parameter in establishing load-carrying capacity. The temperature at which failure of a member is likely to occur is the temperature at which the yield stress is reduced to a point where it is approximately equal to the stress the member was designed to have applied to it, at or near its full design load, i.e., when the safety factor utilized in the structural design has been reduced to unity due to the reduction in strength. It has now been established that this temperature range is between 1000 to 1100ºF (538 to 593ºC). This variation in the critical temperature arises from the fact that other related factors such as the load and support conditions, dimensions and geometry of the structural member, also play a part in its behavior and failure.

It should be noted that to limit the increase in temperature, all that is required is to provide thermal protection to the member in form of some insulating material. Concrete became a preferred material for such applications, especially where weight was not an important consideration; it began to be used extensively for industrial applications. However, where weight was an important factor, it became necessary to use materials which could provide the required insulation but not unduly increase the weight. In some applications, there were also aesthetic issues related to the protection provided. Therefore, some desirable properties with respect to such materials are:

- Insulation – the ability to prevent heat transfer to the protected member
- Non-combustibility and non-generation of smoke or toxic gases when subjected to elevated temperatures
- Consistency and uniform performance
- Availability in a form that permits efficient and uniform application
- Bonding to protected material, strength and durability to prevent either dislodgement or surface damage during normal construction operations
- Resistance to weather and erosion

Different types of steel protective methods shown below -

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 2000ºF (1100ºC). 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.

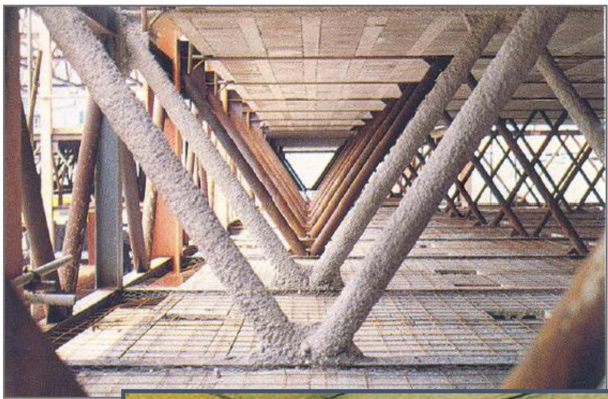
Spray-applied materials

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 –



Other techniques

Membranes, such as suspended ceilings are commonly used to protect members above; the material for ceiling tiles are frequently board materials Flame shields are metallic barriers, used to protect portions of a structure from flame impingement and where exposure is mainly due to localized fires or flames from windows, and not to full-grown (post flashover) fires. The purpose is to prevent heat absorption by providing a barrier between the fire and the element.

Heat sink is a technique where a hollow element is filled with water or concrete, which acts to absorb the heat from an exposing fire, thus preventing temperature rise in the member itself. It should be noted that many building codes will allow in reduction in fire resistance for structural members where sprinklers are installed. Sprinklers do not directly offer any protection to the steel member; however, they are effective in controlling and reducing the size of fire to which members will be exposed. It is in recognition of the high reliability and effectiveness of sprinklers that this reduction in fire resistance is granted.

Improving inherent fire resistance of steel

For improvement of the inherent fire resistance properties of steel structures, a good amount of work has been done and a number of fire resistant steels with different strength levels have been developed. These steels are superior to the conventional steels with regards to the elevated temperature yield strength. This improvement is possible due to the addition of elements such as niobium and molybdenum, which have shown to increase the elevated temperature strength by stabilizing the microstructure at elevated temperature through solute and precipitation effects. Other elements such as W, V, Cr, Ti, etc., are also relevant to heat-resistant steels. The yield strength of such fire resistant steels at 600ºC is usually set at the minimum of two thirds of the specified room temperature yield strength while maintaining low yield ratio, good weldability and other properties.

Early research was initiated by countries such as Japan, Korea & USA, though these are now offered within the country as well; economic feasibility, vis-à-vis, current practices and reduction in labour involved in fire protection practices are relevant factors to be considered.

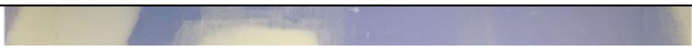
5.8. Fire barrier integrity and fire stopping

When fire compartments are breached by various building service elements such as pipes and conduits, their fire-rating and ability to resist smoke migration is compromised. Firestopping, thus, is the process of installing third-party tested and listed materials into openings in fire-rated barriers to restore fire-resistance ratings. A through-penetration occurs when a service element breaches a fire-rated barrier. If the opening around the conduit is unprotected the fire has a path to propagate quickly into the adjoining space. Similarly, in modern buildings, it is common to see the use of facades for the purpose of aesthetics and faster construction. The gap between the curtain wall (façade) and the floor slab is an open path which will allow heat and smoke from a fire to easily travel between floors. This gap has to be filled with suitable fire resisting material to ensure that the integrity of the compartment is maintained.

Therefore, there are two major applications as stated above, i.e., penetrations and construction gaps/ joints. Each of the two has its own critical consideration when designing the firestopping systems.

For penetration firestopping applications, the most critical consideration is the combustibility of the penetration items. Combustible materials, such as plastic pipes, insulation layers (for hot/ chilled water pipe, condensation pipe and refrigerant pipe) and cable PVC jacket, would be burnt out under fire, leading to fire and hot gases passing through the resulted through-opening. Intumescent materials, which swell and expand multiple times under high temperature, are able to timely close up the burnt-out holes of the combustible materials in preventing fire and smoke from passing through. Among the combustible penetration, cables penetrations firestopping is a challenging area due to various cable sizes and varied installation details. In short, cable penetrations happen in the following systems: cable tray, cable trunking and cable bundle. Firestopping system selected for cable penetration should take into account cable size, number of cables, overall opening size and ratios of cable cross-section area to sealing system, etc. In addition to intumescent firestopping technology, firestop coating is another well-approved technology for cable penetration.

Curtain wall perimeter gap firestopping material being installed



Through penetration barriers around pipe penetrations

Construction joint, referring to the linear gap between two fire barriers, such as wall-to-wall, slab-to-wall and floor-to-floor, usually requires certain amount of movement capability due to varied reasons such as thermal differentials, seismicity and movement induced by wind load. The effects of movement within the supporting construction on the fire performance of linear joint seals, which are easily overlooked, shall be tested in accordance to the current test standards. If materials with zero movement capacity, such as non-shrink cement grout, is used in firestop for a linear joint with movement design, it is highly likely that fire and smoke may leak through the movement induced gap.

Firestopping materials with suitable movement capacity should be selected to cater to the movement tolerance design. Typical examples of joint applications with movement requirements are top of wall joint in tunnel, curtain wall joint and precast facade joint in spandrel zone.

Firestopping performance are characterized by FRR (Fire Resistance Rating), which typically means the duration for which a passive fire protection system can withstand a standard fire resistance test (carried out in standard furnaces). Proper installation of firestopping material by trained personnel is critical, however newer products today are being made so that they can be relied upon to be installed properly with minimal training. Preformed products, such as cast-in firestop device for combustible penetrations with preinstalled intumescent wrap and smoke-seal strip, is a state of-the-art firestopping solution aimed to abolish the possibility of wrong firestopping design by contractors. From the design and approval perspective, engineers can utilize online tools, such as firestop product selector, to ensure the products submitted were designed for the specific applications.

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 t© 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 be 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 is Annex B of NBC Part 4 is shown below:

ANNEX B

(*Clause* 3.1.8)

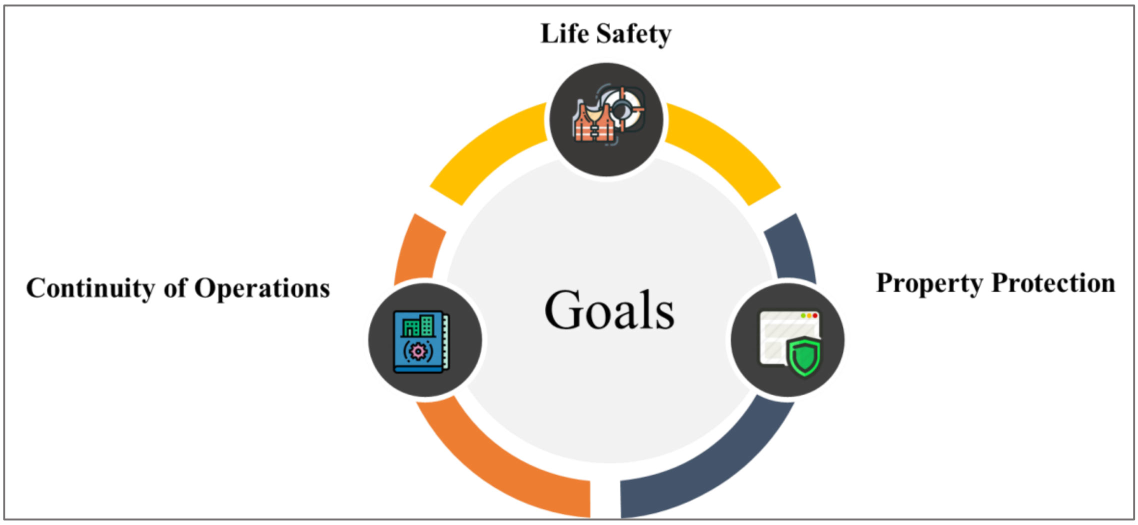
BROAD CLASSIFICATION OF INDUSTRIAL OCCUPANCIES INTO DIFFERENT DEGREE OF HAZARD

Light Hazard	Moderate Hazard	High Hazard
Abrasive Manufacturing Premises	Aluminium Factories	**SUB-CATEGORY (A)**
Aerated Water Factories	*Atta* and Cereal Grinding	Aircraft Hangers
Agarbatti Manufacturing	Bakeries and Biscuit Factories	Aluminium/Magnesium Powder Plants
Areca Nut Slicing and/or Betel nut Factories	*Beedi* Factories	Bituminised Paper and/or Hessian Cloth/Tar Felt Manufacturing
Analytical and/or Quality Control Laboratories	Bobbin Factories	Cotton Waste Factories
	Bookbinders, Envelopes and Paper Bag Manufacturing	

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:

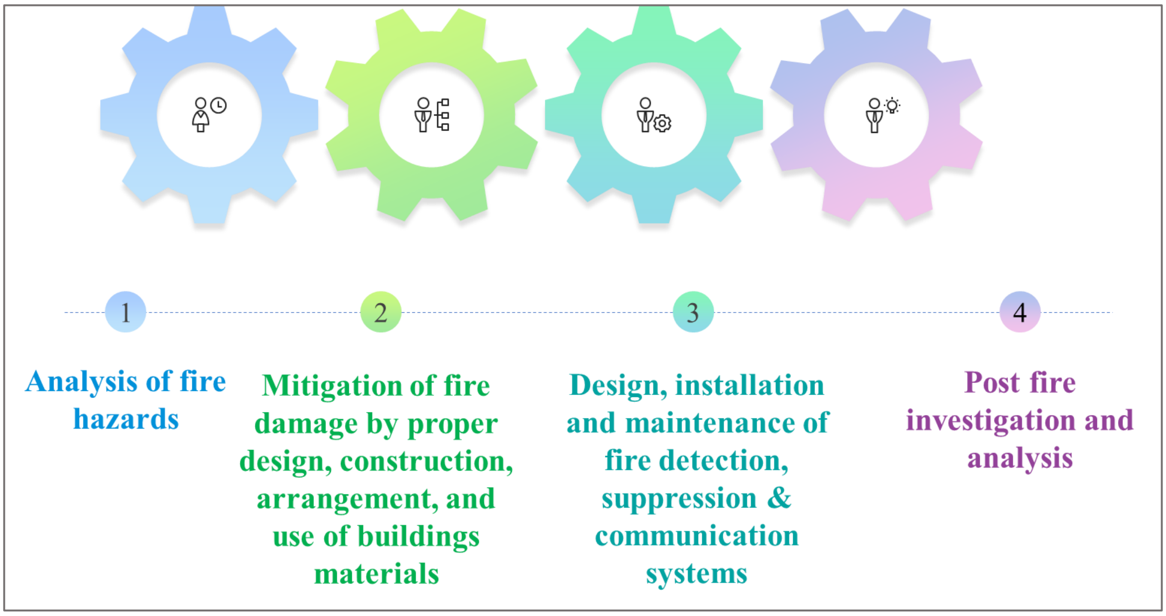


While life safety is the primary objective, property protection and business continuity are also critical due to heavy investment, especially in large industries. Note that for large industries, losses resulting from downtime can be enormous.

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.

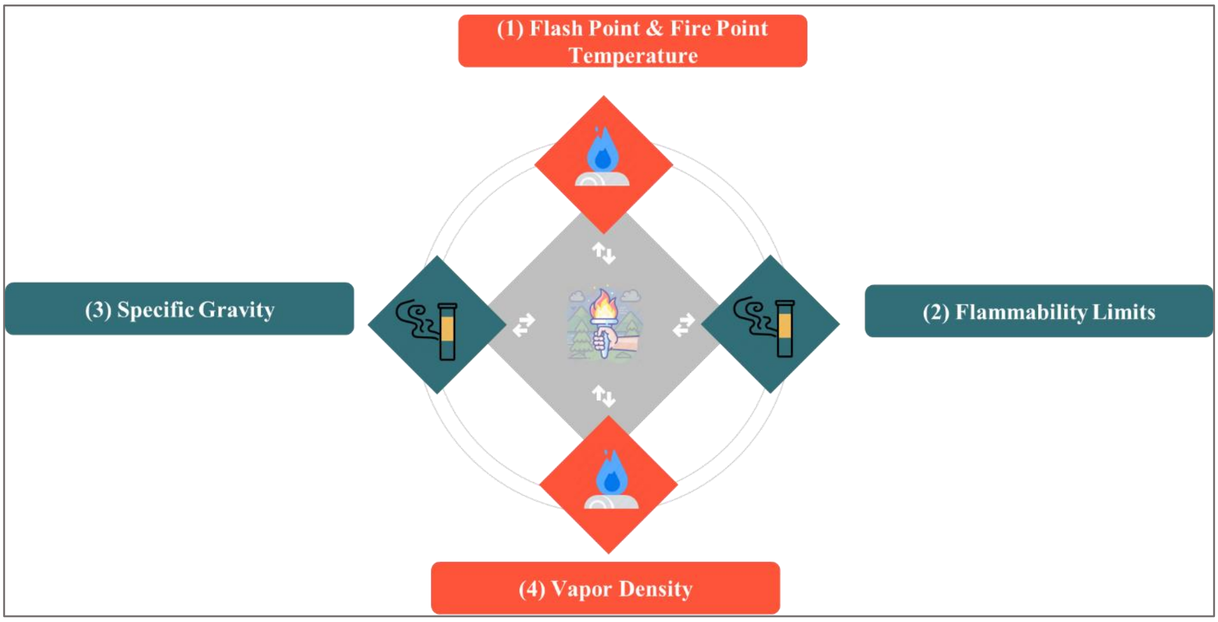
While code requirements can be prescribed for small industrial sheds and buildings, this is not possible for large industries, especially those handling combustible/ flammable materials or other hazardous process. The industry, therefore, follows an engineering approach for industrial fire protection. 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.

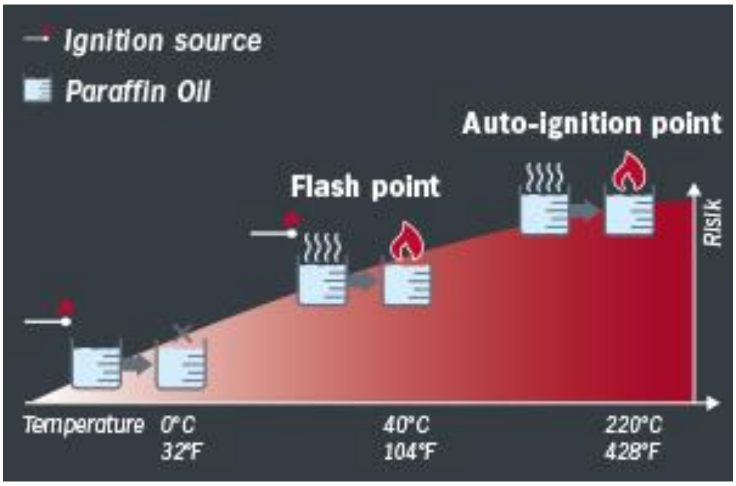
The ignitions repeat as the liquid temperature continues to rise. The observed temperature when the burning becomes continuous is the Fire Point.

Note the following with respect to flash point temperature:

- The flash Point temperature value of a liquid can vary with slight variations in its constituents, as well as the testing methods adopted. In the event of both Open Cup (OC) and Closed Cup (CC) values being given, it is safer to take the CC value, as this is lower. In general, for storage, operation and handling, it is wise to keep a safety margin, and take a value about 5/ 10 ºC lower than value given.
- While low flash point liquids are more dangerous as compared to high flash point liquids, even high flash point liquids become equally dangerous when they are sufficiently heated to temperatures above their flash point temperatures.
- High flash point liquids can ignite, or even explode at temperatures much lower than their flash point temperatures, if they are in the form of fine spray or mist.
- Another important fact is that even at low pressures (below atmospheric) the vapor-air mixture can be ignited below its flash point, obviously because as the pressure above the liquid reduces, vaporization begins to increase (at the same temperature).
- Contamination of a high flash point liquid by even a small quantity of low flash point liquid can lower the flash point temperature of the mixture considerably.

2) Autoignition temperature & piloted ignition temperature

Simply put, it is defined as the lowest temperature at which a material will begin to burn in air by itself. The autoignition temperature is the lowest temperature at which a volatile material will be vaporized into a gas which ignites without the help of any external flame or ignition source. As a result, the autoignition temperature is much higher than the flash point. The autoignition temperature (also referred to as the spontaneous ignition temperature) is normally measured by injecting a measured quantity of the fuel in a conical flask (of volume from 200 to 500 ml) whose temperature is then raised and maintained at a set value, for a specific period (normally five minutes). If no flame is observed, the temperature is then raised. The test is continued till the flame is observed. The autoignition temperature values obtained by such tests can vary greatly as different results are obtained for different volumes of the flask, different ratios of fuel and air, for different exposure times, and even for different heating surfaces. Hence the above test is repeated for different fuel/ air ratios, and the minimum autoignition temperature observed is taken into consideration.



An important property in case of solid fuels is the piloted ignition temperature, this is also normally mentioned in the MSDS. Although experts feel that this value cannot be very accurately measured, it is still probably the most important property considered when assessing a solid combustible material's fire hazard. This is the minimum temperature at which sustained combustion will occur on the application of a flame or spark. It must be remembered that an external heat source will be applied to the material which is giving off sufficient vapors to ignite.

It must be noted that as bonds between the atoms of a molecule weaken, less energy is required to break the bonds and the autoignition temperature value starts to decrease. With a number of hydrocarbons, it is seen that as the carbon chain length increases, the bonds between the atoms become comparatively weaker, and hence the autoignition temperature reduces. Thus, the autoignition temperature of methane is the highest (in this series) and progressively reduces as the carbon chain length increases.

3) 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.

- If the vapors are at a high temperature, it means that they now require very little amount of energy to cause combustion. This means that there is now excess energy available, and hence more fuel or air molecules can be accommodated within the combustion reaction limits. Therefore, at elevated temperatures, the flammability range of a substance widens. This also means that even negligible amounts of gases are flammable at higher temperatures.
- If higher concentration of oxygen (more than normal, i.e., 21%) is available, the extra fuel molecules present (which otherwise would not have taken part in the reaction) now have oxygen molecules to react with. This means that more energy is generated because of these 'extra' reactions. Hence, as the level of oxygen in or around the combustion zone increases, the upper limit of flammability increases, and consequently, the flammability range widens.
- While a flammable vapor/ air mixture above the UFL, is too 'rich' to burn, this is also a very dangerous situation because the mixture can be diluted by mixing with air, at any point, and can thus come within the limits of flammability. Such situations should always be handled with great caution. Once ignited, even mixtures having concentration above the UFL, can burn, as turbulence of the fire causes further diluting/ mixing with air.

4) Vapor density

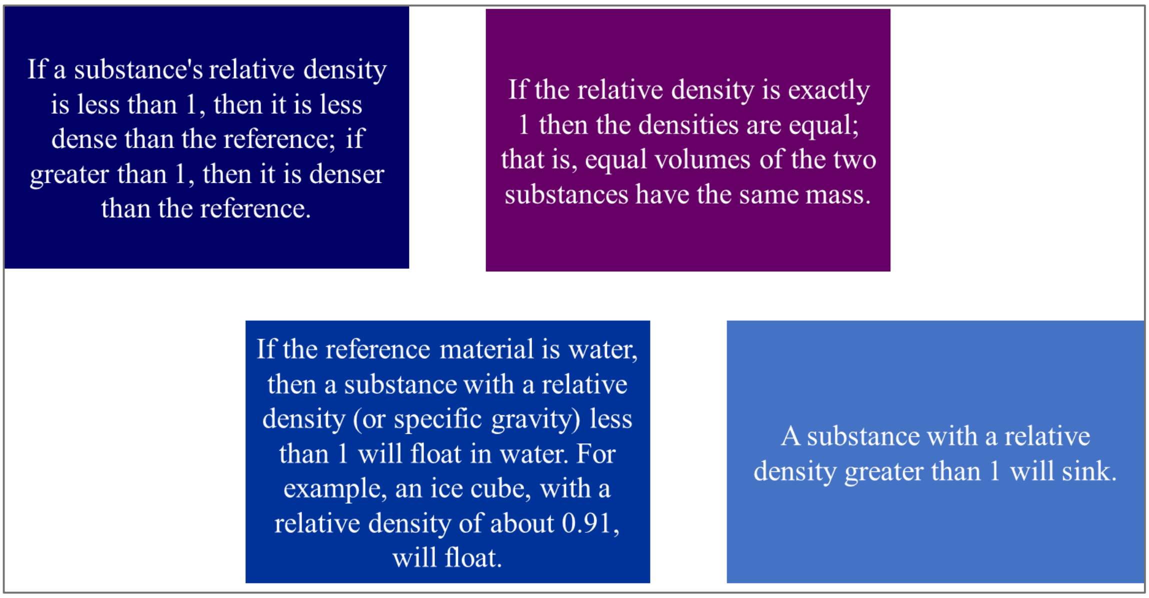
The weight of a vapor or gas compared to the weight of an equal volume of air; an expression of the density of the vapor or gas. Materials lighter than air have vapor densities less than 1.0 (example: acetylene, methane, hydrogen). Materials heavier than air (examples: propane, hydrogen sulfide, ethane, butane, chlorine, sulfur dioxide) have vapor densities greater than 1.0.

Heavy gases/ vapors can thus travel over long distances, without getting sufficiently diluted, and in the event of encountering a source of ignition, can flash back to the source. Accumulation (pocketing) of such gases in pits, below road culverts, etc., can result in strong explosions in the event of vapors getting ignited. It will be observed that most flammable hydrocarbon vapors/ gases are heavier than air. If such gases/ vapors leak and accumulate in large quantities, and then ignite, there is a strong possibility of a vapor cloud explosion occurring, which has tremendous damaging effects. Most major industrial accidents in the country can be attributed at least in part, to this property of flammable vapors/ gases.

Gases/ vapors which are lighter than air, if enclosed, tend to accumulate at the ceiling, and this is also a dangerous situation, if adequate ventilation is not provided (very few industrial gases fall in this category, amongst the commonly used gases in the industry are hydrogen, methane and ammonia). But, in general, lighter gases do not pose as much of a threat as heavier gases. Detection and ventilation arrangements for vapors lighter than air, will naturally be provided near the ceiling in enclosed areas, while those for vapors/ gases heavier than air are located at ground level.

5) 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)



Obviously, a flammable liquid with specific gravity less than 1.0 poses a special threat, as it floats on water. This means, if released into any body of water, a river, pond, or even a drain, it will float on top of the water, and if having low flash points, will continue to emit large quantity of vapors. On encountering a source of ignition these vapors will ignite, and the fire will continue even on the body of water, as long as the fuel remains. Most flammable liquids, used commonly in industry and in the home, are lighter than water.

Lighter flammable liquids also pose a problem in firefighting, as water is ineffective, and will sink below the liquid. It is for this specific reason, that development of firefighting Foam took place, and even today, Foam remains the most effective medium for fighting fires in liquids having specific gravity less than 1.0. Similarly, for covering large spills involving such liquids, the application of firefighting foam is necessary.

7.4. Plant siting and layout fire protection siting considerations

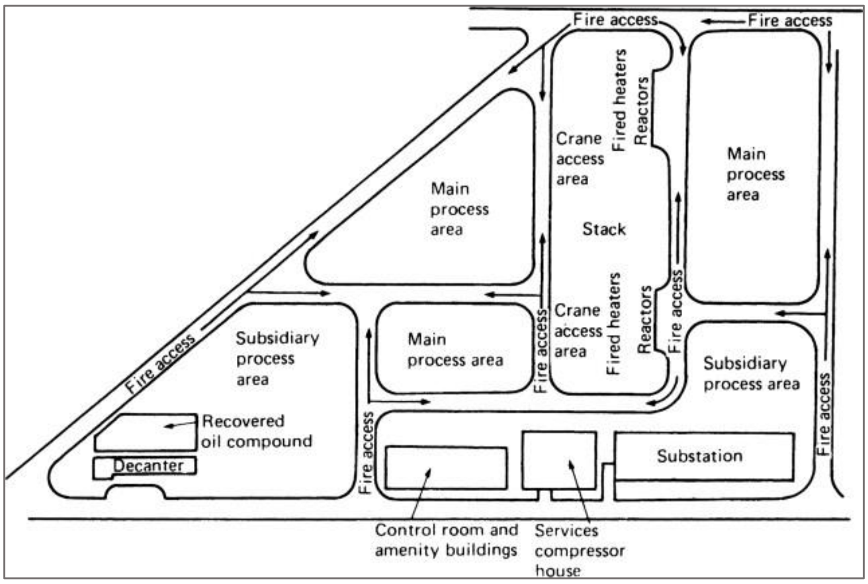
7.4.1. General principles for plant siting and layout

Plant layout is often a compromise between a number of factors such as:

1. The need to keep distances for transfer of materials between plant/storage units to a minimum to reduce costs and risks.
2. The geographical limitations of the site.
3. Interaction with existing or planned facilities on site such as existing roadways, drainage and utilities routings.
4. Interaction with other plants on site.
5. The need for plant operability and maintainability.
6. Need to locate hazardous materials facilities as far as possible from site boundaries and people living in the local neighbor hood.
7. The need to prevent confinement where release of flammable substances may occur.
8. The need to provide access for emergency services.
9. The need to provide emergency escape routes for on-site personnel.
10. 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:

1. Prevent, limit and/or mitigate escalation of adjacent events
2. Ensure safety within on-site occupied buildings
3. Control access of unauthorized personnel
4. Facilitate access for emergency services



7.4.2. Plant layout philosophy

Following philosophy should be adopted in layout of an installation;

a) 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 sub-divided into blocks.

b) All process units and dyked enclosures of storage tanks shall be planned in separate blocks with roads all around for access and safety.

c) Primary traffic roads in the installation should be outside hazardous areas. Roads separating the blocks shall act as firebreaks.

d) Pedestrian pathways should be provided / marked alongside the primary traffic roads.

e) Alternative access shall be provided for each facility so that it can be approached for firefighting in the event of blockage on one route.

f) 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.

g) 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.

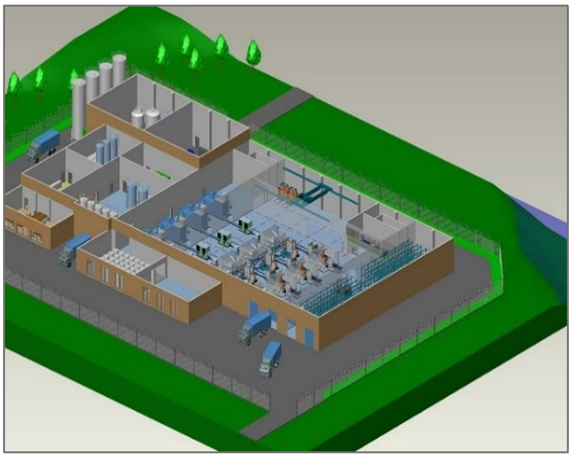
As far as layout of the industry is concerned, there is always an attempt to reduce costs, especially in terms of equipment and piping, by locating interconnected units as close as possible. This is especially true for developing countries, where resources are limited. However, this can lead to a situation where many units and equipment are close together, and hence are at risk in case of an accident (for instance, at a refinery, a vapor cloud explosion affected the fire pump house and fire station, totally impairing the firefighting operations). It is therefore important to have proper segregation and spacing between units to ensure that an accident in a unit remains limited and does not spread to adjacent areas.

Fire can spread through various means, i.e., direct flame contact, conduction, convection and radiation. However, for industrial sites, radiation is considered especially important, because for most chemical fires, almost 30 to 40% of the energy is given out in the form of radiation. The important fact with respect to radiation is that it is not physically evident to personnel who are at a distance from the actual affected area, and hence causes the spread of fire in a silent, unnoticed manner. Approximate calculations are possible to find out the radiation values from a fire of large sizes, such as spill fires and those expected in industrial units. The distance of adjoining units can then be decided, so that they shall not be affected due to the radiation in case of a fire.

The other factor that is taken into consideration while siting of units is the leakage of flammable liquids or gases from plant equipment, and how far the vapors/ gases can travel before getting sufficiently diluted. The various units will thus be located at minimum distances from other units (depending upon the quantity of leakage that is expected) so that leak in one unit is unlikely to affect adjacent units. Based on data available from such study and past accidents, various design codes have been developed, and are normally referred to when deciding the siting of units. In most countries, insurance related bodies and industry specific organizations have developed such codes.

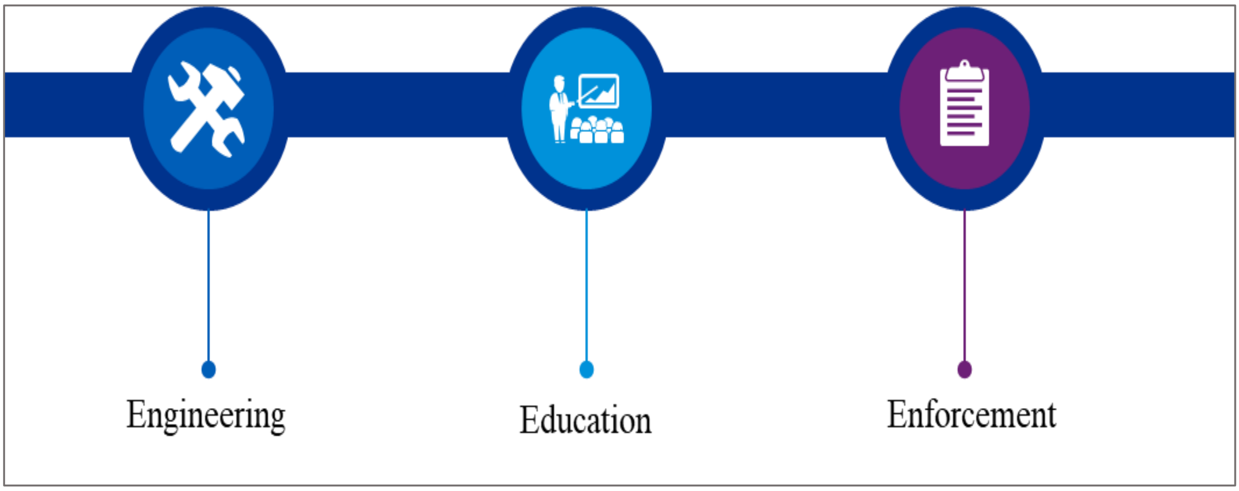
Areas/ units where hazardous materials are handled and where the presence of flammable vapors/ dusts is likely will have to be designated as hazardous areas. Such areas/ units shall be required to have specific construction and design features, as well as the need to eliminate all ignition sources. These areas are normally located downwind and well clear of open fired equipment such as furnaces, heaters, flares, etc. Since normal electrical equipment generates electrical sparks, it is necessary to install inherently safe or explosion proof electrical apparatus in such areas. Most industrial plants will follow certain guidelines for the use of such electrical equipment depending upon the type of material used and the likelihood of flammable mixtures.

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.

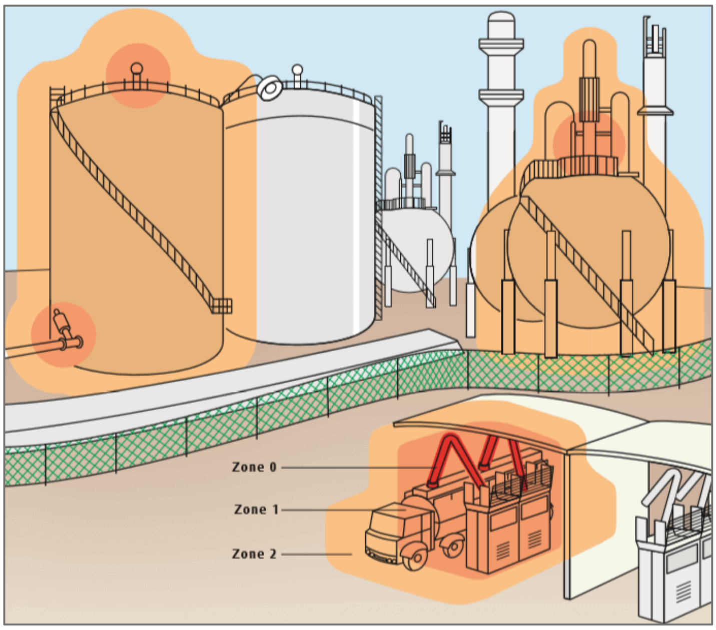
Zone 0:- An area place in which an explosive atmosphere is present continuously or for long periods or frequently.
Zone I :- An area in which an explosive atmosphere is likely to occur in normal operation occasionally.
Zone 2 :- An area in which an explosive atmosphere is not likely to occur in normal 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.

Separation of Process and Storage areas

With production capacities of industries going up, the inventories of raw and finished materials have also gone up considerably. In many industries, the amount of raw material and products under storage is far in excess of what is in the process. If the material is flammable or explosive, the fire risks in storage are thus, far greater than in the process. It is, therefore, standard practice to locate storage areas away from the process areas. The reason for this is that since most human activity takes place in the process areas, the chances of accident are always higher. Storage areas, are however, extremely dangerous if involved in a fire incident due to the huge quantities of flammable materials present. Many past accidents, such as the Flixborough disaster, vizag disaster highlighted this fact, where storage tank fires continued unabated for long periods after the plant fires had been put out, further escalating and complicating the situation. It has therefore, now become standard practice to separate chemical storage areas away from process areas.

Similarly, in many industries the finished products are in the form of liquid or gas, and loaded through rail or road tankers. In such cases, the loading areas are normally located at a safe distance away from process as well as storage areas, due to the presence of a large number of outsiders in these areas.

7.4.5. Fire & explosion resistant construction[12]

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, 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

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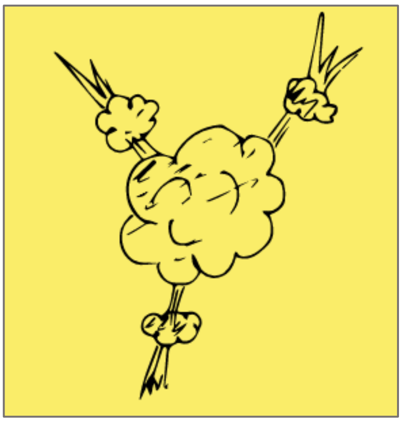
[12] Source of icon – The Noun Project

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.[13] 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.
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.

Dust Explosions

A phenomenon similar to vapour cloud explosions occurs, when fine particles or 'dust' of solid fuel gets intimately mixed up in the atmosphere and get ignited. These dust particles being very small in size (typically between 5 to 200 microns) are comparable to vapours, and if present in a minimum concentration, will allow the propagation of flame through the dust cloud. As with vapour cloud explosions, this reaction also causes an overpressure, which then propagates as a blast wave. As with most vapour cloud explosions, dust explosions too are deflagrations.

[13] Source of icon – The Noun Project

Many solid fuels are prone to dust explosions, and a list of some such materials are given later in the chapter. However, the important factor for the dust to be explosive is its size and the minimum concentration (termed the minimum explosive concentration 'MEC'). An important difference between vapour cloud explosions and dust explosions is that the accumulation of dust as required for dust explosions can normally occur only within some sort of partial or full confinement, as normal outdoor conditions are unlikely to favour buildup of large dust clouds. Due to this, there are limitations to the dust cloud size. However, as most dust explosions will take place in partial or full confinement, they are, in fact, quite damaging.

Another important feature of dust explosions occurs where the fuel is likely to be present in large quantities, such as product stores. In case of a dust explosion occurring in such area, it causes further agitation and dispersal of the solid particles (dust) into the atmosphere, creating the environment for another explosion. If the ignition source is still present, it can ignite the dust cloud, causing another explosion. This, in turn, can trigger another, and a series of explosions is likely to result. Unfortunately, it has been experienced in such cases that the intensity of explosions keeps on increasing, with the last one being the most powerful.

7.5. Storage of combustible & flammable liquids[14]

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.

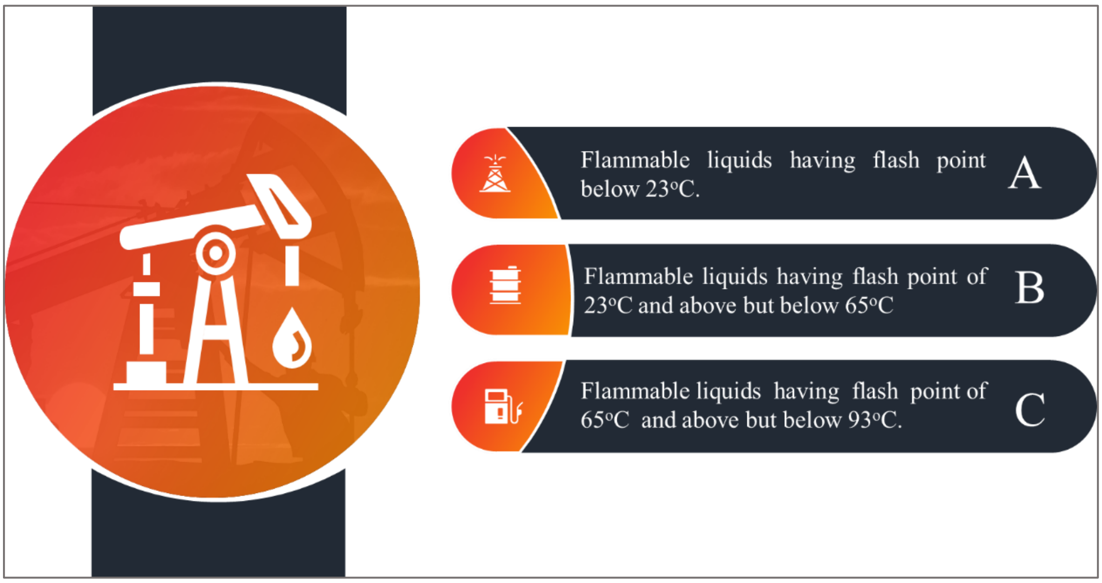
- **Modern Oil and Liquid fuel storage tanks** included in lifeline system vary from 12 to 76 m in diameter with height that are nearly always less than the diameter.
- **Ground supported, circular cylindrical tanks** are more frequent than any other types because they are simply in design, efficient in resisting primary hydrostatic pressure and can be easily constructed.

[14] Source of icon – The Noun Project

7.5.1. Classification of petroleum

Petroleum products are divided into three classes based on their flash points as follows:

(Note: Liquids having flash point of 93°C and above are excluded)

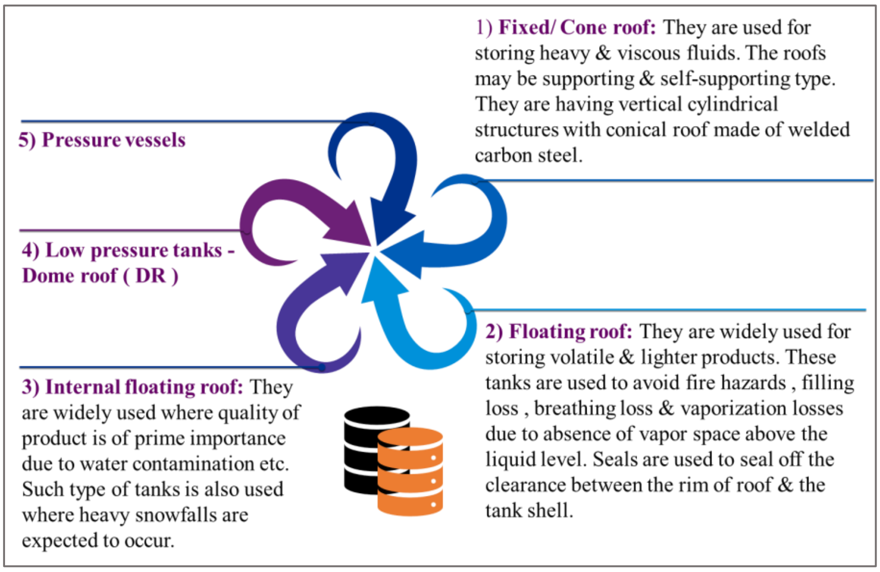


7.5.2. Types of storage tanks and their suitability

Modern oil and liquid fuel storage tanks included in lifeline system vary from 12 to 96 m in diameter with a height that is nearly always less than the diameter.

Ground supported, circular cylindrical tanks are more frequently used than any other types because they are simple in design, efficient in resisting primary hydrostatic pressure and can be easily constructed.

Types of storage tanks are elaborated below



(1) Fixed/ cone roof

They are used for storing heavy & viscous fluids. The roofs may be of supporting & self -supporting types. They have vertical cylindrical structures with conical roof made of welded carbon steel.

(2) Floating roof

They are widely used for storing volatile & lighter products .These tanks are used to avoid fire hazards, filling loss, breathing loss & vaporization losses due to absence of vapor space above the liquid level. Seals are used to ensure clearance between the rim of roof & the tank shell .

(3) Internal floating roof

They are widely used where quality of product is of prime importance due to water contamination, etc. Such type of tanks are also used where heavy snowfalls are expected to occur.

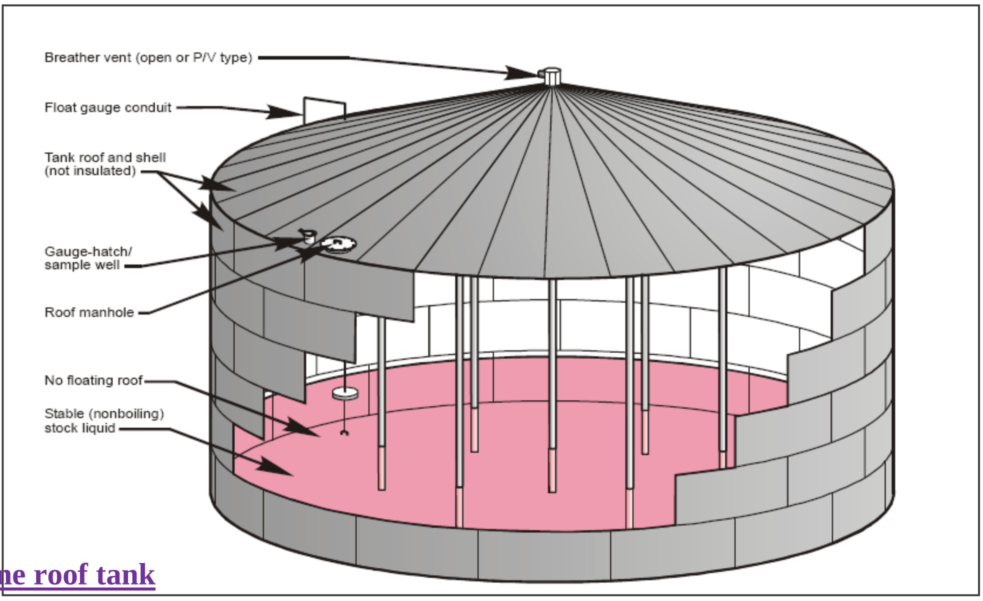
Selection criteria for tanks

Basic parameters for selection of type of storage tanks are vapor pressure & purity requirement of fluid to be stored. Vapor pressure limits vis-a-vis type of storage tank selected in the complex are as follows.

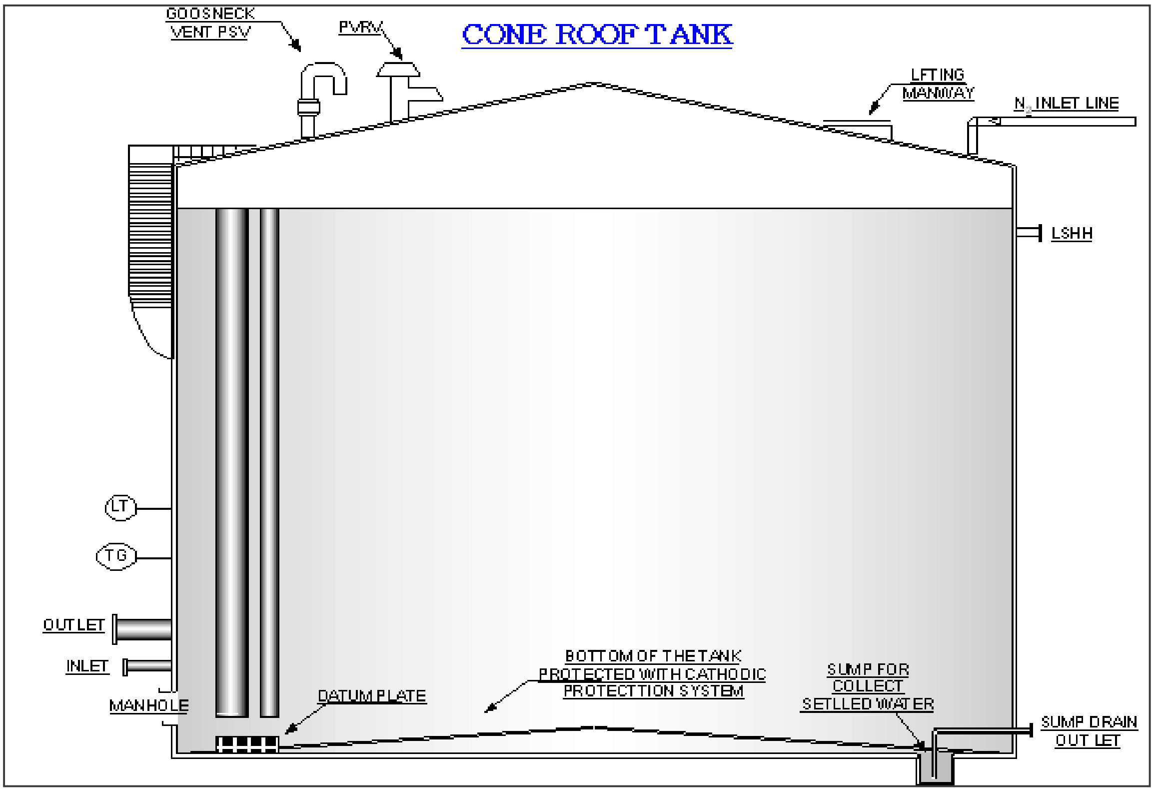
Vapor pressure	Type of tank
Less than 0.05 Kg/cm2 (a)	Cone Roof
Between 0.05 Kg/cm2 (a) & 0.85 Kg/cm2 (a)	Floating Roof
Between 0.85 Kg/cm2 (a) & 1.25 Kg/cm2 (a)	Dome Roof
More than 1.25 Kg/cm2 (a)	Pressure Vessel

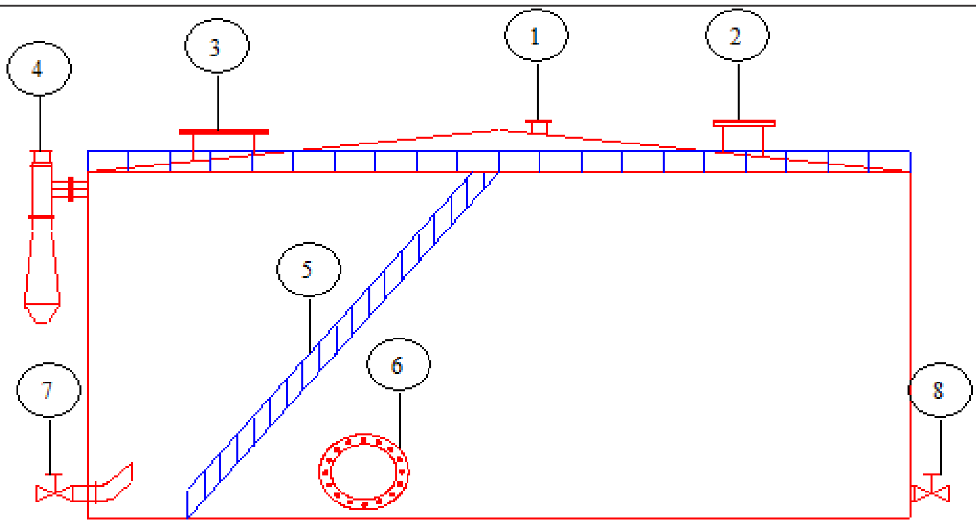
For petroleum products where purity is very high & even traces of impurity are not tolerable, internal floating roof tanks are being provided.

Fixed roof tank



Cone roof tank





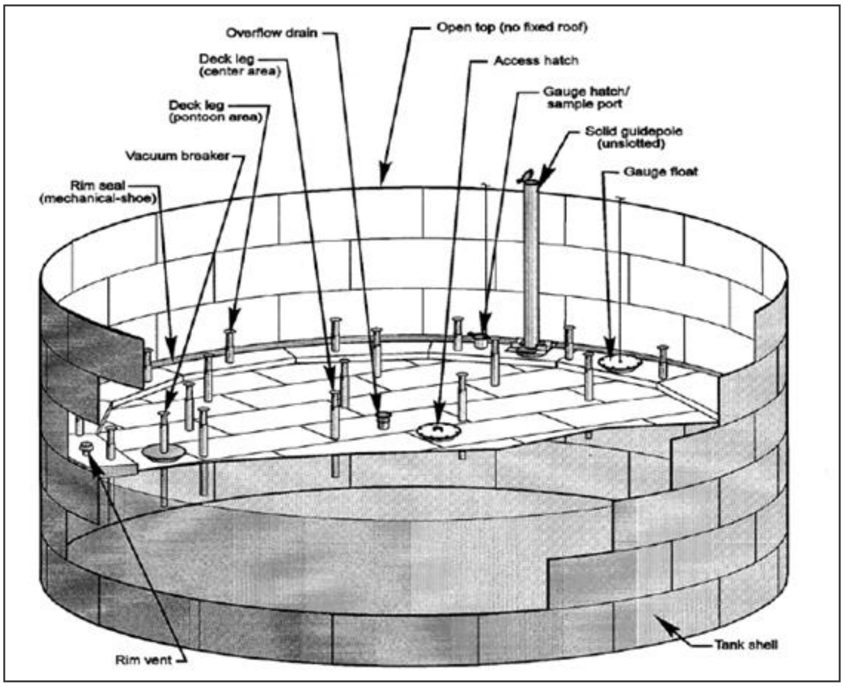
1. Pressure Vacuum Relief Valves
2. Emergency Vents
3. Roof Manhole
4. Foam Chamber
5 Spiral Stairway
6. Shell Manhole
7. Jet Mixing Nozzle
8 . Inlet Nozzle

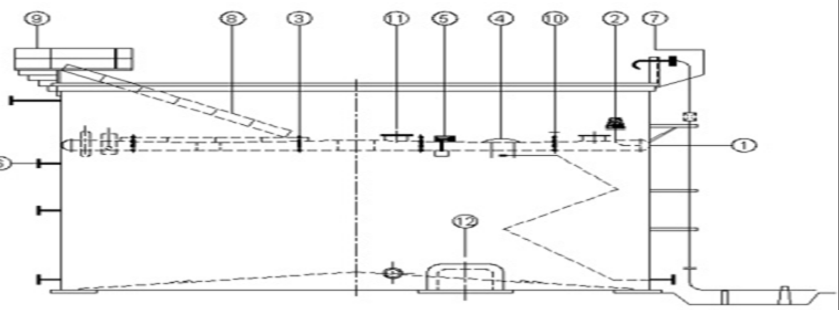
Floating – roof tanks

External floating – roof tanks

- Pontoon-type and double-deck-type external floating roof tanks.
- External floating roof tanks - the roof rises and falls with the liquid level in the tank.
- External floating decks are equipped with a rim seal system, which is attached to the deck perimeter and contacts the tank wall.

- The purpose of the floating roof and rim seal system is to reduce evaporative loss of the stored liquid.
- Some annular space remains between the seal system and the tank wall. The seal system slides against the tank wall as the roof is raised and lowered.
- The floating deck is also equipped with fittings that penetrate the deck and serve operational functions.
- The external floating roof design is such that evaporative losses from the stored liquid are limited to losses from the rim seal system and deck fittings (standing storage loss) and any exposed liquid on the tank walls (withdrawal loss).

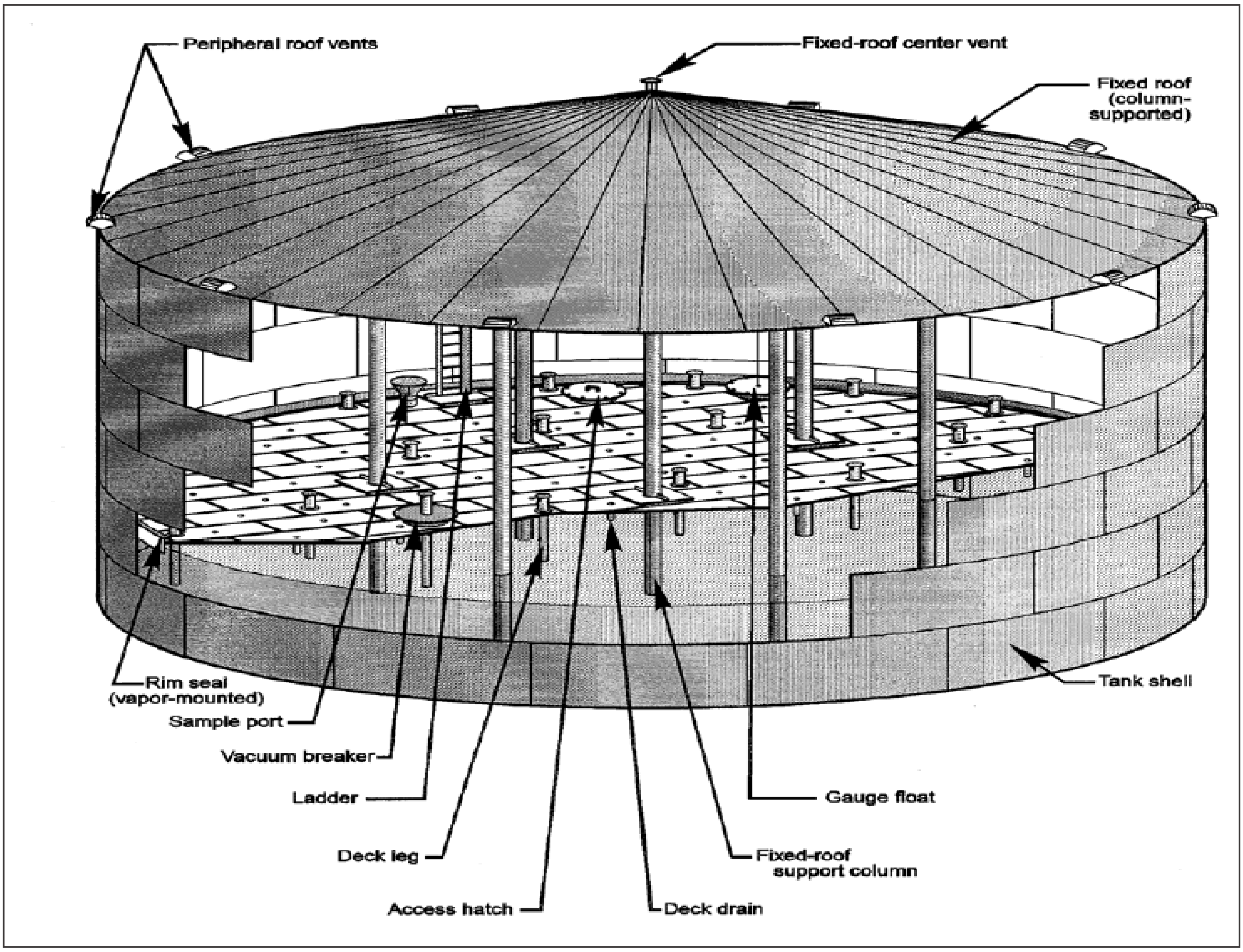




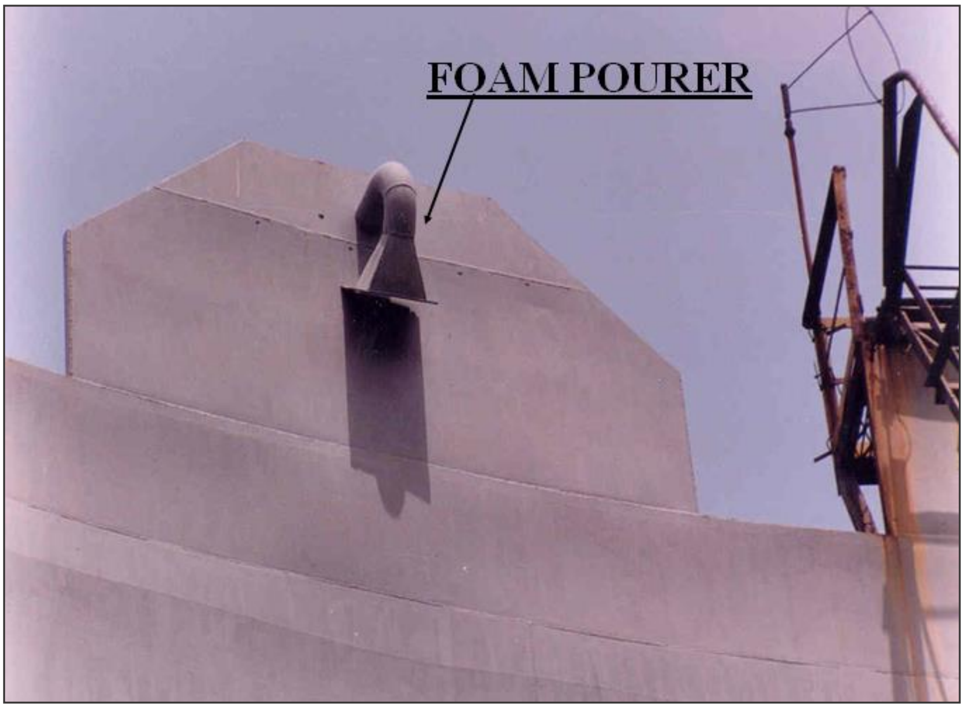
2. Rim vent
3. Roof Support
4.Roof Drains
5.Emergency Drain
6.Wind Grider
8.Rolling Ladder
9.Spiral Stairway
10. Breather Valve
11. Manhole
12. Clean Out Door

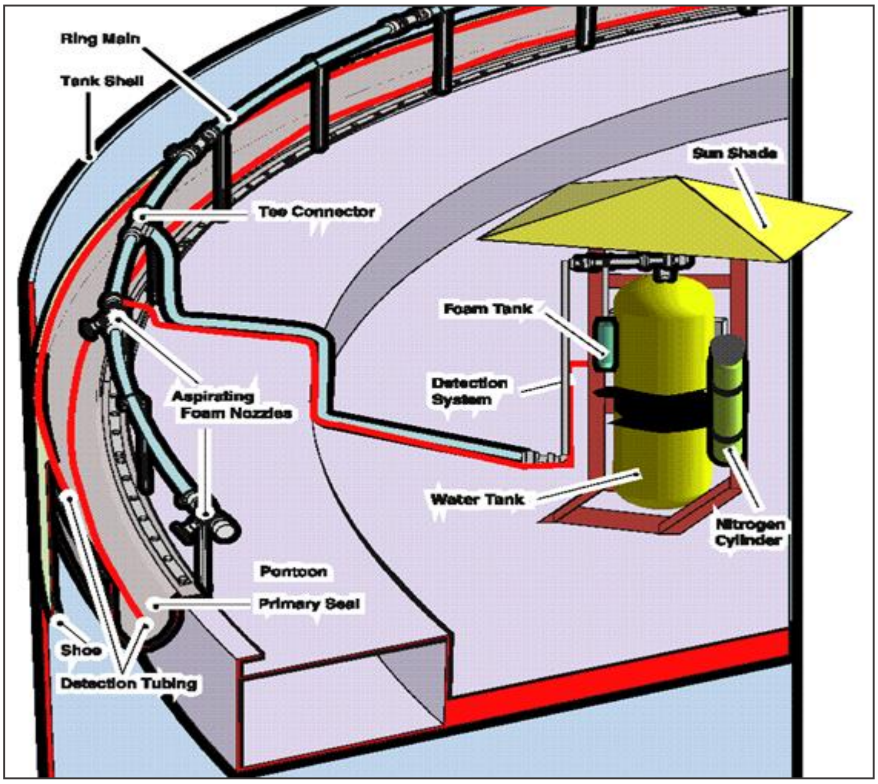
Internal floating roof tank

- An internal floating roof tank (IFRT) has both a permanent fixed roof and a floating roof inside.
- There are two basic types of internal floating roof tanks:
  - tanks in which the fixed roof is supported by vertical columns within the tank,
  - tanks with a self-supporting fixed roof and no internal support columns.
- Evaporative losses from floating roofs may come from deck fittings, non-welded deck seams, and the annular space between the deck and tank wall.
- In addition, these tanks are freely vented by circulation vents at the top of the fixed roof. The vents minimize the possibility of organic vapor accumulation in the tank vapor space in concentrations approaching the flammable range.
- An internal floating roof tank not freely vented is considered a pressure tank.



7.5.3. Fire protection systems for tanks



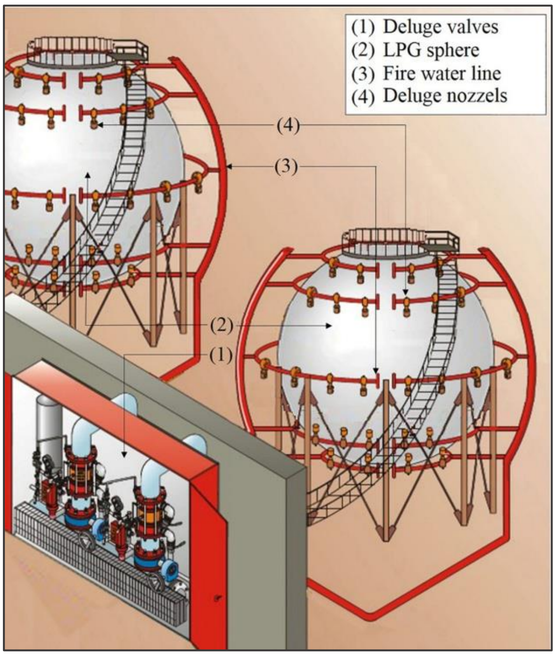


LPG sphere

Lay out

- Grading of the ground underneath should be levelled by stones/ concreted

- Kerb wall shall be provided around sites of the storage vessel. Kerb wall's height shall be minimum 30 cm but shall not exceed 60 cm otherwise evaporation of spilled LPG may get affected.
- A slope of 1:100 (min.) to be maintained to direct spillage from the fourth side to a shallow sump away from the storage vessel
- Spillage collection shallow sump shall be located at a distance where the flames from sump fire will not impinge on the vessel.
- Well ventilated area, Fenced as CCOE/ PESO norms
- Fireproof supports is must



Mounded storage

A sand mounded storage system created around the LPG storage vessels, placed above the ground level, provides the following advantages:

- LPG stored in the form of mounded storage eliminates the possibility of BLEVE
- The sand cover of 1 metre, which provides natural insulation from external heating, is adequate to outlast any fire in the surrounding areas.
- In addition, the mounding material provides good protection against most of the external influences like flying objects and pressure waves from explosions.
- A well-engineered and well-executed mounded storage is the safest and the most economical solution for bulk LPG storage. Other safety features of the above ground LPG storage vessels, viz., hydrant network all around with monitors and hydrants, heat detectors and gas detectors etc., are provided to mounded storage facilities also.

7.5.3.1. Fire emergency in tanks

- Over filling
- Over pressurizing
- Collapse due to vacuum
- Water in hot oil tanks
- Roof sinking
- Tank fire mechanical work
- Lighting & static charge
- Lack of attention
- Error in level indications
- Wrong setting of valves
- Change of service
- Gravity filling

7.6. Industrial fire detection & protection systems[15]

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
Combustion Gas detection	Emissions monitoring	Video smoke and flame detection

Various other complementary 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

[15] Source of icon – The Noun Project

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.

Gas detectors used most commonly in the oil & gas industry are primarily of two types –

(1) Flammable gas detectors

These are sub divided into 2 categories:

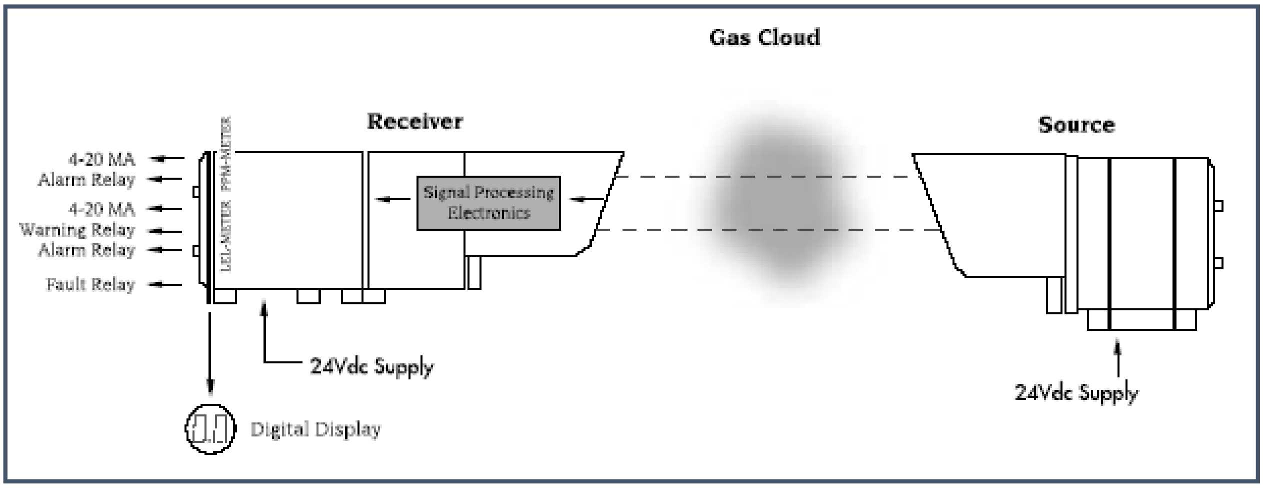
- Catalytic type
- Infrared type

Electrocatalytic or "catalytic" detectors have been around for over 30 years and are widely used in a variety of industries as single-point detectors for combustible gases.

They function on the relatively simple and reliable principle that a combustible gas can be oxidized to produce heat. The resulting temperature change can be converted, via a standard Wheatstone Bridge, to a sensor signal.

Infrared gas detection is based on the ability of some gases to absorb IR radiation.

It is well known that almost all hydrocarbons (HC) absorb IR at approximately 3.4 µm and in this region H2O and CO2 are not absorbed, making the system immune to humidity and atmospheric changes. Shown below is a line of sight (LOS) Infrared Flammable Gas Detector.



(2) Toxic gas detectors

These are sub divided into 2 categories:

- Electrochemical type
- Semiconductor type

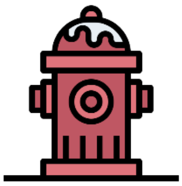
Currently, electrochemical detection is preferred to the semi-conductor type. Both sensing mechanisms have strengths and weaknesses, but the electrochemical sensor has proved to be more reliable in wet and humid atmospheres. It is based on an electrochemical cell, developed to react exclusively to H2S. An electric potential is applied between the measuring and reference electrode.

The semi-conductor type is based on the adsorption of H_2S molecules on the surface of a solid-state semi-conductor crystal, which causes a change in resistance of the electrical circuit of which the semi-conductor forms part. The change in resistance is proportional to the H_2S concentration in the sample gas. However, their life is adversely affected when exposed to poisonous contaminants (e.g. paint solvents) or to humid atmospheres

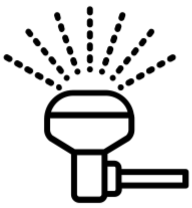
7.7. Fire protection

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.

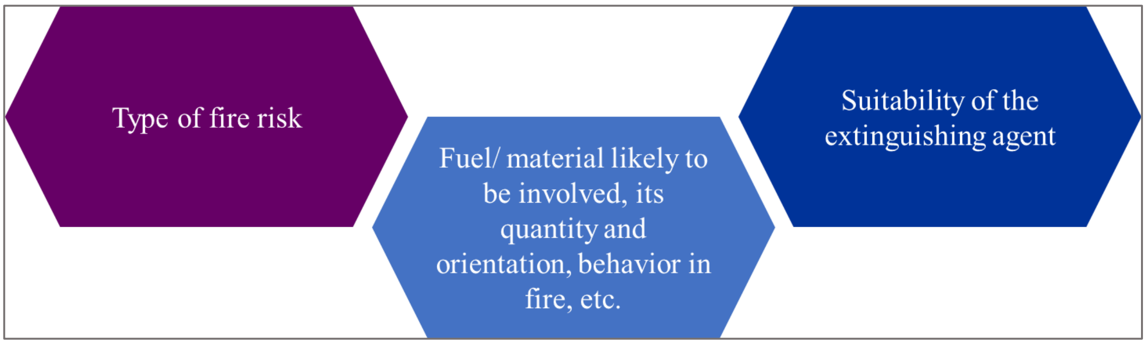
The pumping arrangements should be sufficient to provide the required amount of water at requisite pressure, to the fire site which has the greatest demand. As far as possible, these pumps should be solely dedicated for firefighting. It is advisable to have multiple pumps instead of a single large pump, 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:

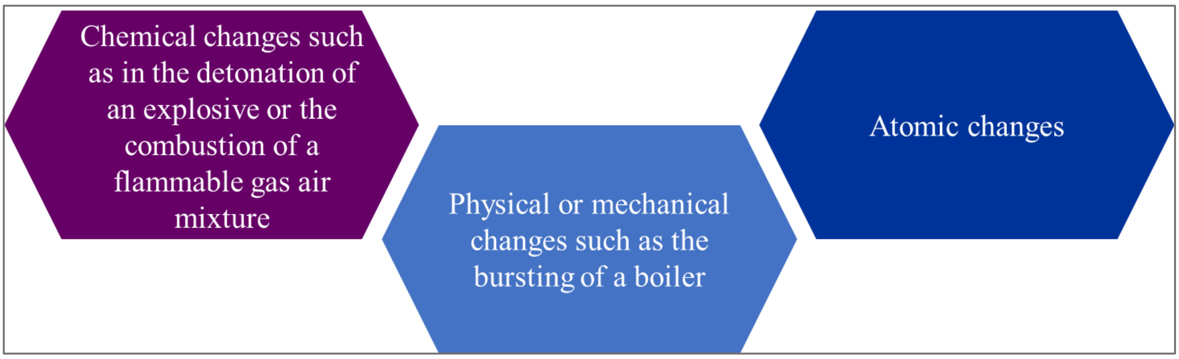


Depending upon the type of material involved (and hence, its fire class), it is easy to determine the type of extinguishing agent that will be applicable. However, a number of other factors are also considered, some of which are – the location of the hazard (i.e., whether indoors/ outdoors, clean environment, 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.

7.8. 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 accompanies by shock waves and/ or the disruption of enclosing materials or structures. An explosion may result from:



7.8.1. 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.

Considering the large amount of liquefied gases which are in use both in the industry and society, the risk of BLEVEs is high, as is also evident from the large number of instances of BLEVEs, both within and outside the industrial premises. Amongst the most dangerous of such explosions are the rupture of liquefied gas containers such as large Horton spheres, bullets (both fixed and mobile), smaller cylinders, etc. If such a container is engulfed in fire, its metal is heated, and it loses its mechanical strength. If the flames are in contact with the shell of the container, above the liquid level, the vessel can rupture violently. Below the liquid level, the liquid conducts the heat away from the shell, thus helping to maintain its integrity. However, above the liquid level, the vapor is unable to conduct away heat from the shell, causing its temperature to rise. The critical temperature for most steels is around 450^{o} C, and once this temperature is exceeded, the shell starts to lose its strength and begins to bulge outward. The metal thins at this area and the bulging will accelerate till rupture occurs.

This failure can occur in as little a time as 10 to 30 minutes of direct flame exposure, depending on the thickness of the metal and the intensity of heating.

When a pressure vessel, such as the one mentioned above, ruptures, the vaporization of the superheated liquid produces a large volume of vapor. As residual fires are already present, this vapor ignites almost instantly, and begins to burn at the outer periphery of the vapor cloud where the vapor-air mixture is flammable. This fire heats and expands the inner core, which is fuel rich, and hence cannot burn. The fire, therefore, remains limited to the outer envelope, where a flammable mixture forms because of diffusion of atmospheric oxygen. As the shape of the vapor cloud is approximately spherical, the term 'fireball' is used to describe it.

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.
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.

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.

The important point to remember regarding vapor cloud explosions is that the confinement need not necessarily be from physical structures such as rooms or vessels. The atmosphere consists of gases, which has an inertia of its own and hence confines a fuel-oxygen vapor cloud, due to which a pressure wave gets generated on ignition. This is also the reason why the term VCE is used instead of UVCE in many journals/ publications.

Since these explosions take place in open atmosphere, it is logical to assume that the pressure buildup would not be high, and hence damages can be expected to be minimal. However, pressure of the order of 1 psi is enough to cause damage to many manmade structures, hence losses have been substantial whenever such explosions occurred on industrial premises. While the vapor cloud is in open atmosphere, partial confinement of the vapors occur due to physical structures, such as plants, vessels, walls, etc., as commonly seen in industrial plants, giving rise to much higher pressures.

The incidents of vapor cloud explosions are fairly high in the industry and some of the major industrial incidents have been due to this phenomenon. Fuels which vaporize quickly and have high burning velocities are most likely to be involved in vapor cloud explosions. These include liquefied gases like butane, propane, propylene, butadiene, etc., liquids like naphtha, petrol, cyclohexane, and similar fuels. It should be noted that even relatively high flash point liquids like diesel and kerosene, when in a heated condition or when released under pressure can form vapor clouds and explode. Unfortunately for us, not only are most of these fuels commonly used in the industry, but are also routinely transported through rail, road and sea.

Therefore, knowledge of the properties of such products is very important for responders to manage incidents of leakage, as there is a likelihood of explosion.
Besides the blast wave, the other risk of vapor cloud explosions is the heat wave which travels along with the flame front and can cause heat shock to those exposed (which is usually fatal).

3) Dust explosions[16]

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.

[16] Source of icon – The Noun Project

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.

7.8.2. Processes/ industries prone to explosions

Certain industrial activities carry the inherent risk of explosions due to the nature of the chemicals they handle and the processes that are carried out on them. Such industries are those in which the environment is likely to have flammable vapors and dusts. The activities of conveying and handling of combustible solid and liquid materials and powders are amongst such activities, and certain equipment/ systems such as bucket elevators, pneumatic ducts, screw conveyors, separators, vapor control systems are more susceptible to explosion risks. Similarly, storage arrangements for such materials such as bins, flammable liquid storage areas, hoppers, tanks, etc., also are prone to these risks.

Processing activities prone to explosions include the high hazard hydrocarbon processing industry, especially those areas/ systems handling low flash point liquids and liquefied gases. Other such activities include blenders, dust collectors, fluid bed dryers, hydrocarbon mixing and fill rooms, ink toning, mixers, powder paint booths, pipe coating, spray dryers, etc.

7.9. Onsite/ off site emergency plan

This section covers the onsite/ offsite plan requirements, role and responsibility of occupier and other employees, etc.

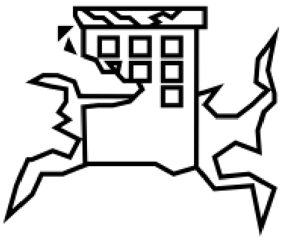
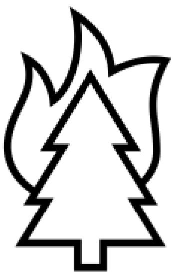
7.9.1. About emergency

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.

7.9.2. Types of hazards

The emergencies arises due to two types hazards as highlighted below:

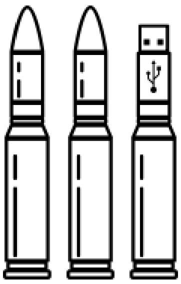
1) Natural hazards[17]

	**Wind related –** Cyclone, tornado
	**Water related** – Flood, cloudburst, excessive rains, draught
	**Earth related** – Earthquake, tsunami, landslides, volcanic eruption, soil erosion
	**Due to natural reasons** – Forest fire, epidemic

2) Manmade hazards[18]

	**Accidents:** Road, Rail, Air, Sea, building collapse

[17] Source of icons – The Noun Project
[18] Source of icons – The Noun Project



Industrial mishaps: There are three sub-divisions of industrial mishaps

1) **Un-intentional**: Poor maintenance, Low quality of work, Human error.
2) **Willful or intentional:** Revenge, Riots, Enemy Attack.
3) **Industrial and technological (mostly system/ process mal function)** such as nuclear radiation, Gas leak, Explosion, Fire
   - **Fire**: Building, Coal, Oil, Gas, Electrical etc.
   - **Forest fire**
   - **Contamination/ poisoning**: Food, Water, Epidemic.
   - **Terrorist activity**
   - **Ecological:** Pollution (air, water, noise), global warning, toxic wastes
   - **Warfare**: Chemical, Nuclear

7.9.3. 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

7.9.4. Categorization of emergencies

Categorization	Intensity	Category	Potential Incidents	Level of Command	Communication
Level 1	Effect to particular plant only	**Minor incident:** 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	**Serious incident**: 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	**Major:** Full site emergency services plus mutual aid required	Major fire, explosion, major spill, major gas release	Site Main Controller and District Collector	Emergency siren

7.9.5. 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.

7.9.6. 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.

7.9.7. 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:

Fire Hazard & Risk Assessment

8. Fire Hazard & Risk Assessment

8.1. Important Terms & Definitions

As Low As Reasonably Practicable (ALARP): where all reasonable measures will be taken in respect of risks which lie in the tolerable zone to reduce them further until the cost of further risk reduction is grossly disproportionate to the benefit

Assessment: undertaking of an investigation in order to arrive at a judgement based on evidence

Availability: ability of a system to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided

Common mode failure: failure that is the result of event(s) that, because of dependencies, cause(s) a coincidence of failure states of components in two or more separate channels of a redundancy system, leading to the defined system failing to perform its required function

Conditional probability: probability of an event given the occurrence of a preceding event

Consequences: severity of the outcome of an event

Deterministic: based on physical relationships derived from scientific theories and empirical results that, for a given set of initial conditions, will always produce the same outcome

Event: something happening or that has happened that can be made up of several but mutually exclusive occurrences

Extreme value: statistical methodology dealing with the probability distributions of large and small values

Failure cause: circumstances during design, manufacture or use which have led to failure

Failure mode: predicted or observed results of a failure cause on a stated item in relation to the operating conditions at the time of the failure

Fire hazard: physical situation with a potential for harm to life or limb, or damage to property, or both, from the effect of fire

Frequency: probability that an event will happen over a period of time

Hazard: situation with a potential for human injury

Individual risk: frequency at which an individual can be expected to sustain a given level of harm from the realization of
specified hazards

Initiating event: event that leads to other events and one or more outcomes

Maintenance: combination of all technical and administrative actions including supervision actions intended to retain a product in, or restore it to, a state in which it can perform a required function

Mean time between failures (MTBF): total cumulative functioning time of a population divided by the number of failures

Outcome: result of a chain of events

Probabilistic model: methodology to determine statistically the probability and outcome of events

Scenario: set of circumstances and/or an order of events in a fire incident that are feasible and reasonably foreseeable

Redundancy: provision of more than one means of achieving a function

Reliability: ability of an item to perform a required function under stated conditions for a stated period of time

Risk: probability of occurrence of a hazard causing harm and the degree of the severity of the harm

Risk to life and health: expected extent of injury or loss of life from a fire, defined in terms of probability as the product of:
— frequency of occurrence of an undesirable event to be expected in a given technical operation or
state; and
— hazard to life and health

Societal risk: relationship between frequency of occurrence and the number of people in a given population suffering from a specified level of harm from the realization of specified hazards

Stochastic model: methodology for evaluating, in probabilistic terms, the outcome of events as function of time

Tolerable risk: maximum level of risk of a building that is acceptable to the approval body.

8.2. Introduction

Hazards are present in every aspect of our lives. There are hazards in the air we breathe, the food we eat, the places we live in, through to the most hazardous sport, occupation or location we can think of. This is true from fire safety point of view as well. There are fire hazards in every building and associated with most activities that we do day in and day out. We try to identify these hazards and try to assess the risk involved and evaluate if it is acceptable to us. We are continuously carrying out a process of hazard identification, risk assessment, risk control, and review. This process is collectively referred to as the risk management process.

To understand this better, we could look at the simple process of crossing the road. The rule is 'Look right, look left, look right again, and if the road is clear move quickly across'. This rule is extremely simple (although not always observed) and understood by even quite small children. Unless a study is made of the subject, what is not always understood is the process by which this simple rule was arrived at. In applying risk management to the task of crossing a road we first identify that a hazard exists in the form of vehicles which could strike and injure us. When assessing the risk, in terms of the speed, current location of approaching vehicles and our own location and mobility, we recognize that the consequences and likelihood of an accident occurring are too great to ignore. We therefore develop a procedure of looking, to ensure that we only cross the road at a time when the likelihood of an accident is removed. There is little doubt that hazards result in accidents.

When we apply this process to fire safety, we are trying to identify and assess the fire hazards in a given facility, calculate the likelihood that it will cause harm, put barriers in terms of fire prevention and fire protection systems and features, and then evaluate if the residual risk is acceptable to us as a society or an organization. Note that what is acceptable differs from country to country, from one organization to another, and from person to person. Traditionally, what is acceptable is defined through legislation.

8.3. Fire Hazard & Risk Concepts

If the above process restricts itself to identifying and assessing fire hazards, it is termed a fire hazard assessment. If the process also includes assessment and evaluation of the likelihood of a given hazard causing harm, it is termed a fire risk assessment. Note that fire and life safety requirements stated in building codes are hazard based, not risk based i.e. for a given building occupancy of a specified height and area (assuming a specific fire load density), the codes will specify different fire and life safety components. The codes assume that a fire will occur during the lifetime of the given building and affect people or property. It does not differentiate between a building owner known to keep his buildings very well operated and systems well maintained and another whose buildings are shoddily run and in which fire prevention measures are not maintained or neglected; both will have to provide the requirements as per the relevant legislation.

A fire risk assessment, however, also considers the likelihood that a fire will occur and cause harm. Therefore, it involves mathematical calculations involving probability, the use of past data and tools for evaluating consequences. Where would a fire risk assessment be applied? As buildings become older, systems deteriorate, fire loads change and changes /modifications may occur. Whether fire and life safety requirements installed based on an earlier assumption are still valid would be questionable? It would need a fire risk assessment to provide answers to these problems. Similarly, performance-based designs assess the performance of different fire and life systems proposed against different fire scenarios, which involve calculation of probabilities.

Note that both Fire Hazard and Fire Risk analyses can be applied in very simple to highly complex forms, depending on the type and level of application. A very simple form of fire hazard analysis is to calculate the fire load density for a given facility; a more complex hazard analysis would involve determining the type of fire which would occur in the same facility using other factors besides the fire load density such as ventilation, building configuration, compartment lining, etc. Similarly, fire risk analyses could be qualitative giving simple values to the risk such as ‘low’ or ‘high’, to quantitative risk calculations giving numerical values of fatality rates or monetary loss. A simple fire risk assessment checklist used for simple buildings/ facilities is given as Annexure 1. Subsequent sections will deal with the different techniques and methods applied for these.

8.4. Fire Hazard Assessment

8.4.1. Fire Hazard Identification:

As seen earlier a hazard is anything which may cause harm, injury, or ill health to a person. Fire hazards are required to be identified at the first step. To ensure accuracy and completeness, the process of hazard identification should be carried out as a dedicated task and people with a thorough knowledge of the area, process or machine should carry out a hazard identification survey.

A typical hazard in a fire risk assessment is an ignition source (i.e., an ignition source which ignites the first item in a postulated fire scenario). Another example of a hazard is the intervening (or secondary, i.e., second item ignited) combustible. Clearly, the ignition source has the potential of triggering a chain of events resulting in a fire scenario. Fuel packages in a given compartment also constitute hazards. It is likely that there are many types of ignition sources and fuel packages in a given application. All such ignition sources and fuel packages will be required to be identified. In summary, the identification and characterization of hazards and barriers is the first step in identifying fire scenarios. This process is done primarily by engineering walkdowns and review of events records.

Since each hazard represents a potential loss, it is important to identify them. In most cases fire hazards are identified on the basis of intuition and experience. At best, the experience of several persons would be combined to assess a given situation in order to fully identify all the potential hazards. Some fire hazard identification processes given below -

Fire Safety Checklist. The most common approach to hazard identification is some form of checklist. A traditional fire safety checklist is a list of specific items used to identify known types of hazards, design deficiencies, and potential fires associated with specific buildings, equipment, and operations. Usually, the identified items are compared to appropriate NFPA standards. Using checklists requires three simple steps: (1) identify or develop an appropriate checklist, (2) conduct a survey of the premises, and (3) document the results. Only people with a thorough knowledge of the area, process or machine under review should carry out a hazard identification survey, but they should use the many different sources of information available to help identify hazards.

To be sure that all hazards are found:

- Look at all aspects of the work and include non-routine activities such as maintenance, repair, or cleaning.
- Look at the physical work environment, equipment, materials, products, etc. that are used.
- Look at injury and incident records.
- Talk to the occupants, they know their job and its hazards best.
- Include all shifts, and people who work off site either at home, on other job sites, drivers, teleworkers, with clients, etc.
- Look at foreseeable unusual conditions (for example: possible impact on hazard control procedures that may be unavailable in an emergency situation, power outage, etc.).
- Determine whether a product, machine or equipment can be intentionally or unintentionally changed (e.g., a safety guard that could be removed).
- Examine risks to visitors or the public.
- Consider the groups of people that may have a different level of risk such as young or old people, inexperienced workers, persons with disabilities, or new or expectant mothers.

Also review the history of the area under review. Any accidents or near misses should be carefully investigated. Sources for this information would include accident records. At this stage it is worth sorting all the past accidents and near miss information into a number of categories.

8.4.2. Design Fire Scenarios

Fire hazards will result in a fire scenario. A very simple result from the hazard identification would be to obtain the fire load density, thus providing the categorization into a low, medium or high fire load occupancy, which would lead to different types of fires, assumed to be in increasing order. The goal of a more detailed fire hazards analysis is to determine the expected outcome of a specific set of conditions, involving the hazards identified, ventilation, configuration, etc, called a fire scenario. The scenario includes details of the room dimensions, contents, and materials of construction; arrangement of rooms in the building; sources of combustion air; position of doors; numbers, locations, and characteristics of occupants; and any other details that have an effect on the outcome of interest. This outcome determination can be made by expert judgment, by probabilistic methods using data from past incidents, or by deterministic means such as fire models. “Fire models” include empirical correlations, computer programs, full-scale and reduced-scale models, and other physical models. The trend today is to use models whenever possible, supplemented if necessary by expert judgment. Typically, when the potential impact of fire is estimated, a hazard basis is used. When probabilities or frequencies are considered, it is usually in the context of determining whether or not a scenario is sufficiently likely to warrant further analysis.

8.4.3. Fire Hazard Analysis

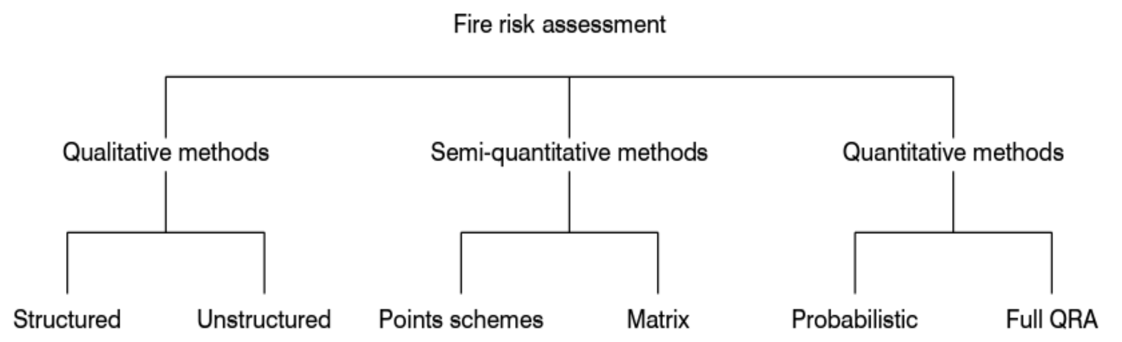
Fire is a dynamic process of interacting physics and chemistry, so predicting what is likely to happen under a given set of circumstances can be difficult and complex. The simplest predictive methods are algebraic equations. Computer models are used to automate fire hazard calculations and are particularly useful where many repeated calculations must be performed. Simple Fire Hazard Calculations Once the design fire curve has been developed, it is then possible to predict the hazards that would result. The types of hazards that might be of interest include the following- radiant heat flux, which affects the potential for ignition of materials or thermal injury to people, smoke production, which dictates the volume of smoke produced fire plume and ceiling jet temperatures and velocities, which could cause weakening of exposed structural elements, species production, which affects the rate at which an untenable environment could be created, depth of upper layer, which can be used as a surrogate for an untenable environment. As was the case with the stages of design fire curves, it is not always necessary to quantify all of the hazards that result from a design fire scenario. The hazards that are quantified are a function of the goals of the analysis. For example, if the purpose of the analysis is to determine whether a thermally activated detection or suppression system activates, only the plume and ceiling jet temperatures and velocities might be determined. For analysis of a smoke control system, only the smoke production rate might be determined. A structural analysis might only require calculation of the heat transfer to the structure. An evacuation analysis might require quantification of all of the hazards listed.

8.5. Fire Risk Assessment Concepts

Fire risk assessment can be used to support any decisions about fire prevention or fire protection of new or existing built environments, such as buildings, where probabilistic aspects, such as fire ignition or the reliability of fire precautions, are important. Fire risk assessment can also be used to establish safety equivalent to a code, to assess the balance between the cost and the risk reduction benefit of a proposal, or to examine acceptable risk specifically for severe events. Fire risk assessment can also be used to provide general guidance or to support choices in the selection of scenarios and other elements of a deterministic analysis. While fire risk assessment methods can vary from simple, qualitative approach to highly complex, quantitative risk assessments, the basic approach/

steps to be undertaken remain largely similar. In this connection, the general concept and steps can be outlined as follows :

1. Identification of fire hazards:
    - Sources of ignition;
    - Sources of Fuel;
    - Sources of Oxygen.
2. Identify the consequences and probabilities of the fire hazards:
    - Identify the type of classification and use of the building/area;
    - Review the proposed layout and internal arrangement of the building/area;
    - Ascertain relevant statistics influencing building/area (e.g. area of fire origin, fatalities etc.)
3. Identify hazard control options:
    - Determine the base building passive and active fire safety measures;
    - Ascertain Management in use procedures or Regulatory Requirements.
4. Quantify the effects of the options on the risks of the hazards;
    - Evaluate the identified design parameters with consideration of occupants, fire brigade and property protection (where applicable).
5. Select appropriate protection:
    - Depending on the effects identified, adopt appropriate fire safety measures with consideration of the cost implications in the event of a fire.



A simple explanation of different approaches to Fire Risk assessments

The Fire hazard analysis described above is actually a component of risk analysis. Once the design fire scenarios are determined, it is required to calculate the probability of such scenarios so that risk can be calculated. That is, a risk analysis is a set of hazard analyses that have been weighted by their likelihood of occurrence. The total risk is then the sum of all of the weighted hazard values. In the insurance and industrial sectors, risk assessments generally target monetary losses, since these dictate insurance rates or provide the incentive for expenditures on protection. Fatality rates are also calculated for hazardous industries, based on which decision to give permissions can be taken by Authorities. It is also important

All fire safety decisions involve uncertainty. Probabilities are the mathematical representation of uncertainty, and risk assessment is the form of fire safety analysis that most extensively uses probabilities and so most extensively addresses all types of uncertainty. It is important for fire safety practitioners to understand these concepts, especially fire safety engineers; authorities having jurisdiction, fire service personnel, code enforcers, code developers, insurers and risk managers.

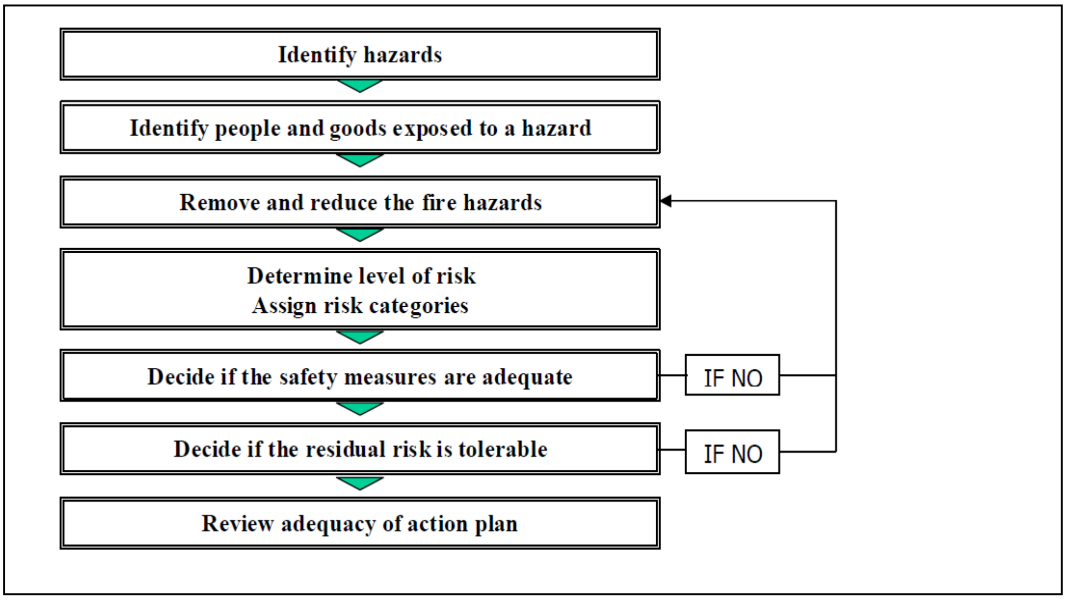
Risk assessment process have two basic prerequisites: one, the establishment of a context, including the fire safety objectives to be met, the subjects of the fire risk assessment to be performed, and related facts or assumptions; and two, identification of the various hazards to be assessed. A "hazard" is something with the potential to cause harm. The fire hazard identification and assessment has already been covered in the preceding section.

8.6. Qualitative Risk Assessment

The use of qualitative fire risk assessment for assessing the fire safety in different categories of buildings is already being done in several countries. In the UK, it is mandatory for owners/ occupiers to carry out fire risk assessment based on provided format/ procedure and report periodically to the authorities. The regulations also allow the owner/occupier to use the services of certified fire risk assessors to carry out the fire risk assessment. The format for carrying out this assessment has been published by bodies such as the HSE (Health & Safety Executive), UK. A similar guide has been brought out by the CFPA-E (European) Guideline No 4:2010 F, which cover the basic

1) Hazard Identification

Understanding of the character and intrinsic properties of the materials or equipment that have been identified, or the methodologies in which they are used, is important as this leads to an understanding of the ways in which they could contribute to the initiation of a fire. Proper understanding of the fire dangers, like the presence of dangerous substances (combustible, flammable, etc.) and possible sources of ignition, allows a determination of the probability of a fire occurring.



2) Identify people and property exposed to a hazard

The people exposed may be staff, contractors, visitors or members of the public. Consideration should be given to the numbers of people visiting or working in each area, to ensure that the means of escape are adequate. Particular note should be made where:

- sleeping accommodation is provided
- large numbers of the public may be present
- people may be unfamiliar with the layout of the building and the location of the exit routes
- staff are working in areas where there is a specific risk, such as spray painting
- people may have lengthy or tortuous escape routes
- contractors are working up ladders or on scaffolding

Consideration must also be given to the weak points of the structure and to its contents.

3) Eliminating or Reducing the fire hazards

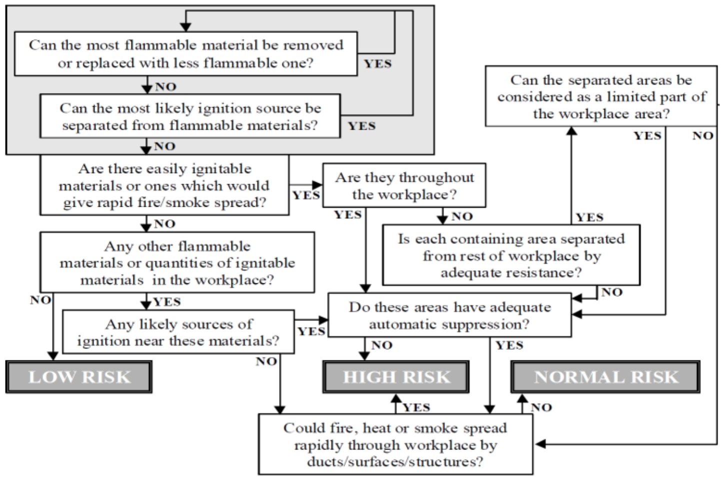
For each of the hazards that have been identified in step 6.1, consider whether it could be removed, reduced, replaced, separated, protected, repaired or cleaned and if people in workplaces can be better informed or trained. Be careful! Don't insert a hazard of a different kind trying to reduce the level of the previous hazard.

References to determine whether the residual risk is acceptable or not should be:

- national laws and regulations,
- accepted European/International technical standards (e.g. Eurocodes for structural fire design)
- accepted fire protection principles (both national and European/International)

<u>Determine level of risk /Assign risk categories</u>

This activity requires some expertise/ knowledge to determine the level of risk. Different types of algorithms can be used to guide assesors based on the type of hazards and the people/ property exposed to the hazard. A simple example for flammable chemicals shown here. The assigning of risk levels should also be based on certain guidelines as suggested below -



A schematic representation for assigning risk levels to a process

No Risk: No action is required and no documentary records need to be kept.

Low Risk: Where there is hardly any risk from fire, few combustible materials, no highly flammable substances and virtually no sources of heat

Normal Risk: Where there are sufficient quantities of combustible materials and sources of heat to be of greater than low fire risk but where a fire would be likely to remain confined or to spread but slowly

High Risk: Where there is a serious risk to life from fire, there are substantial quantities of combustible materials, there are any highly flammable substances or there exists the likelihood of the rapid spread of fire, heat or smoke. High fire risk place are considered those where, apart from the presence of flammable substances and the probability for fire to spread, overcrowding of places, their condition and motor restrictions on people make the evacuation difficult in case of fire.

RISK
f (Hazard x Exposure)

Exposure (E) = 1, 2 or 3
Hazard (H) = 0 or 1

H = 0; E = 1/2/3 No risk
H = 1; E = 1 Low risk
H = 1; E = 2 Normal risk
H = 1; E = 3 High risk

J	Hazard	See points D - E - F - G HAZARD 0: no combustible materials or in very poor amount, no sources of ignition, no hot works HAZARD 1: presence of combustible materials, presence of sources of ignition regardless of preventive measures adopted
	Exposure level	See points H – I Exposure level 1: damages to goods are possible; people not exposed Exposure level 2: accidents to people and damages to goods are possible; Exposure level 3: deaths are possible; accidents to people and damages to goods
	Risk level	LOW/NORMAL/HIGH Risk 1: Low Risk 2: Normal Risk 3: High

Decide if the measures of risk reduction are reliable

The risk analysis demands the total appraisal of the reliability of all the present measures for the management of the risk. This is important because a failure of any measure will result in exposure to the risk, and thus increase the risk level.

To decide if the measures of risk reduction are reliable, the different aspects which could affect the presence, reliability and functioning of fire prevention and fire protection measures provided, should be assessed. This includes presence of trained people (both during working and non-working hours), reliability of Fire alarm systems (during normal power and loss of power), fire protection systems.

Decide if the residual risk is tolerable

To this point of the analysis, by estimating the outcomes which have been assessed, it is possible to estimate the acceptability of the residual risk and verify if the stated safety objectives being are met. Objectives could include -

- the generation and spread of fire and smoke within the works are limited
- occupants can leave the works or be rescued by other means

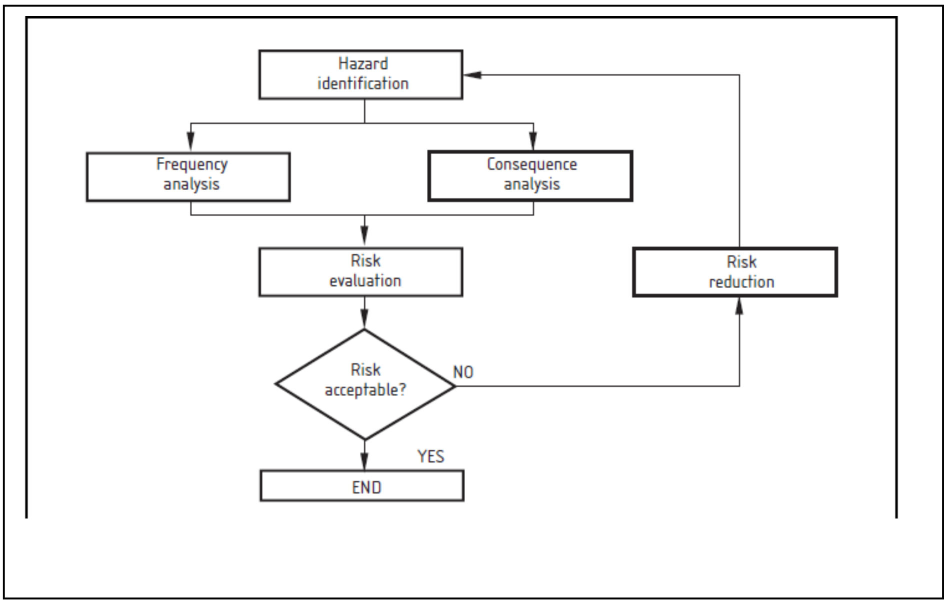
- the load bearing capacity of the building for a specific period of time
- the safety of the fire & emergency rescue teams is taken into consideration

Where the primary safety (i.e. human life) can be considered adequate and the residual risk is tolerable, decide if it is more convenient to improve cost/effective measures and/or transfer the risk for goods to an insurance company. Possible improvements would include such steps as:

- The reduction of evacuation times/escape route lengths
- The provision of additional escape routes
- The installation of more fire alarm call points
- The provision of more fire safety signs
- The installation of a sprinkler system
- The institution of better programmes of fire safety training
- The appointment of fire wardens, etc

8.7. Semi-Quantitative Risk Assessment

Semi-quantitative risk analysis seeks to categorise risks by comparative scores rather than by explicit probability and financial or other measurable consequences. It is thus more rigorous than a purely qualitative approach but falls short of a full comprehensive quantitative risk analysis. But rather like deterministic methods, it can complement a full stochastic risk analysis by inserting a reality check. Semi-quantitative methods can be used to illustrate comparative risk and consequences in an accessible way to users of the information. Indeed, some output from complex stochastic models may be presented in forms similar to that used in semi-quantitative risk analysis, e.g., risk matrices



A risk matrix is a means to communicate a semi-quantitative risk assessment: a combination of two dimensions of risk, severity and likelihood, which allows a simple visual comparison of different risks. Severity can be considered for any unwanted consequence such as fire, explosion, toxic release, impact of natural hazards (e.g. floods and tsunamis) with their effects on workers and the community, environmental damage, property damage or asset loss. A severity scale from minor to catastrophic can be estimated or calculated, perhaps informed by some form of model. Normal risk matrices usually have between four and six levels of severity covering this range with a similar number of probability scales. There is no universally adopted set of descriptions for these levels, so stakeholders can make a logical selection based on the purpose of the risk assessment being carried out. To make the risk matrix more meaningful, it would be logical to assign values to the levels which are logical and based on past data and experience. For e.g. the likelihood and consequence levels (four) for a medium scale plant handling combustible liquids could be –

Likelihood levels:

1 – Unlikely to occur during lifetime of the Plant (i.e. 25 years)

2 – Likely to occur once during lifetime of the Plant (i.e once in 25 years)

3 – Likely to occur once in 5 years

4 – Quite likely to occur (once in an Year)

Consequence levels:

1 – Negligible damage

2 – Minor damage (upto Rs. 500000)

3 – Significant damage (upto Rs. 10000000)

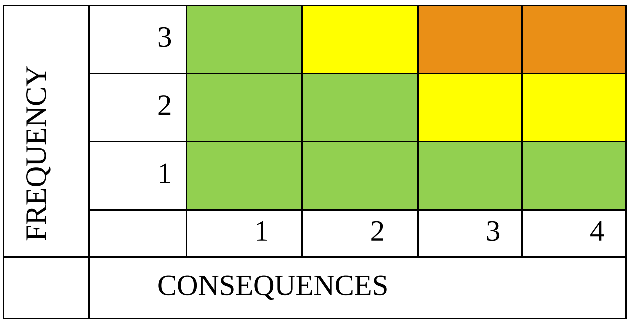
4 – Extreme damage (>Rs. 10000000)

Note that in the above case, the consequences are considered both in terms of property loss and/or fatalities. This could be based on the objective of the FRA i.e. whether human fatality or property loss or any other factor.

Based on the above, the risk level (Frequency x Consequence) will vary from 1 to 16. Using the frequency of fire accidents and the losses likely to occur due to these, a possible categorization of fire risk levels can be done as given below. The representative risk matrix shall be as seen below:

- Low risk: 1 to 4 (highly unlikely to occur or will result in negligible damage (less than Rs. 100,000)
- Medium risk: 5 to 8 (may occur in 5 – 25 years and will result in minor or significant property loss (upto Rs. 500000)
- High risk – 9 to 12 (likely to occur in 5 years and will result in significant damage (upto Rs. 10000000)
- Extreme risk – 13 to 16 (quite likely to occur in an year and result in extreme damage (> Rs. 10000000)

	4				



Risk Evaluation Methodology

Based on the risk value obtained for different scenarios, philosophy for risk evaluation and proposed actions for different risk levels are given below. Suitable recommendations, if required for reduction/control of risk, shall be proposed, especially if risk values are found to be high or in unacceptable range.

- **Low risk**: Value $\leq$ 4. These risks can be ignored i.e. the risk is quite low
- **Medium risk**: Value between 5 & 8. No immediate action will be required for these risks, but it is important to ensure that risks do not change over the lifetime of the project due to factors such as aging of equipment/machines, changes in design/use, etc.
- **High risk**: Value between 9 & 12. Immediate action/s required to reduce risk to acceptable level i.e. 8 or lower. Risk reduction measures could be preventive and/or mitigative.
- **Extreme risk**: Value between 13 & 16. Such risks are unacceptable and it should be seen if these hazards can be eliminated altogether by removal/ relocation or other means. If not, suitable reduction/ control measures must be applied immediately.

Assigning Risk Values to Fire scenarios Identified:

The next step is to identify different fire scenarios most likely to occur in the facility and assess the Fire Scenarios for their risk levels, keeping in mind the different barriers provided (in terms of fire prevention, life safety and fire protection measures provided, training, emergency response capability, etc). The loss occurred due to each scenario can thus be calculated per year. Based on this, the risk levels for the different scenarios can be calculated (an example shown below)

Fire Scenario #	Area affected	Fire Scenario Description	Calculated Loss (Rs/Year)	Risk Level
1	Storage tanks	Fire in Diesel spill	800000	6 (Medium Risk)
2	Blending Kettles	Fire in oil spill	160000	6 (Medium Risk)

3	Filling Area	Electrical fire in Filling Machine	100000	4 (Low Risk)
4	Packing Area	Fire in packing material	100000	4 (Low Risk)
5	Storage	Fire in stored goods	1200000	6 (Medium Risk)
6	Office	Fire in office equipment	100000	4 (Low Risk)

The above scenarios can be represented for clarity on the Risk Matrix as show below.

FREQUENCY					
	4				
	3				
	2		(3), (4), (6)	(1), (2), (5)	
	1				
		1	2	3	4
	CONSEQUENCES				

Risk Reduction & Treatment

- From the above, we can see that scenarios 3, 4 & 6 are low risk scenarios, and do not require any further action. These are fire scenarios associated with Filling Area, Packaging Area & Offices. In these areas, due to presence of people, fire growth is unlikely as manual intervention will be quick. The fire detection and fire protection systems provided will ensure that consequences will be limited.
- Scenarios 1, 2 & 5 pose medium fire risk. These are scenarios associated with the Storage, Blending Kettles and Storage area. Fires in Storage area (involving Diesel) can affect other tanks adjacent to it if not controlled quickly, and can result in higher consequences. As adequate fire detection and protection measures are already provided in these areas, the above risks do not require further risk reduction measures. However they should be continuously monitored over the lifetime of the facility to ensure that risks do not increase due to factors such as deterioration of machine/equipment integrity, change in design, increase in combustible loading, laxity in procedures, etc.

8.8. Quantitative Fire Risk Assessment

How the fire develops and interacts with the building structure and occupants is subjected to more detailed analysis to take into account the specific nature of individual buildings or scenarios. This approach is more flexible than the qualitative approach. However, the typical "deterministic" fire engineering study will still make certain (generally conservative) assumptions about how the fire scenarios will develop. Quantitative assessment can take fire safety engineering studies beyond the deterministic models, where a certain set of assumptions are always taken to be true, by assessing the effects of fire not only in terms of the consequences, but also taking into account the likelihood that a given set of consequences will occur. The objective of this is to try to model real buildings and real fires in greater detail.

Quantitative FRAs allows deterministic fire safety engineering techniques to be enhanced by taking account of uncertainties and adding in the additional factor of probability to the assessment. This allows a number of useful extensions to fire safety engineering to be made. The principal example of this is the study of diverse systems which are designed to achieve the same objective (e.g. a mechanical and natural smoke extract system, both designed to vent smoke from a fire compartment). In a purely deterministic model, it would be assumed that the system operated and, assuming that the systems were designed correctly, the model would show that the same smoke layer conditions would result in either the mechanical or natural ventilation case.

A quantitative FRA could look deeper into the differences between the two systems and generate "failure data" for the two systems. Hence, whilst both systems might provide identical conditions in the event of a fire if they work correctly, one system might be found to be better than the other because it is more reliable. This sort of study is known as a comparative study and is well accepted, perhaps because it is a natural extension of more subjective approaches.

<u>Identifying and selecting fire scenarios</u>

Fire safety design traditionally consists of identifying important parameters of a building design (e.g. purpose group and height above ground) and identifying a set of fire precautions to achieve an acceptable solution. For deterministic fire safety engineering, there is a need to identify the set of circumstances that are appropriate for analysis [the scenario(s)]. A scenario considers aspects like the design fire (size and rate of growth), number of people and which fire precautions are assumed to work and which are assumed, for the purposes of analysis, to have failed. The objective is to assess a reasonably severe scenario to assess whether the solution is acceptable. HAZard and OPerability (HAZOP) methods are an example of this from the process industry.

<u>Using Input Data for the Analysis</u>:

The application of accurate data for calculations has a very critical role in FRA and greatly affects its relevance and usefulness. Wherever possible, the data used should be directly applicable to the case under consideration. For example, many shopping malls and airports collate data on the time it takes to evacuate the building when the fire alarm goes off. Such data are unlikely to be released into the public domain, but might be available when a study on the development in question is carried out.

Manufacturers often have data on the failure of their systems or the components that make up their systems. Service companies for fire alarms and sprinklers might keep maintenance records that can be interrogated. Again, such data might be confidentially sensitive and difficult to obtain. A lot of useful data can be obtained from fire incident reports and may be made available in a raw data format. In our country, however, it is very difficult data which can be directly applied to FRA calculations and we will have to depend on external data, which may need to be tailored to our requirements.

For e.g. reliability for a sprinkler data in the UK is given below After taking into the above variations in data, the following values for the probability that a sprinkler system will operate successfully on demand are as follows.

— Maximum: 95 % (applicable to new systems in areas where statutory enforcement is in place).

— Typical: 90 % (new life safety systems) or 80 % (new property protection systems).

— Minimum: 75 % (older systems).

As the maintenance and testing in our country is not as robust as it is in developed countries, we may need to modify the above values to be more representative of the situation in our country.

Similarly data on fire statistics, fire growth, heat release rates, smoke and species generation, human response, system component reliability and other aspects related to life safety and fire protection will be required to support the quantitative assessment of FRA.

Year	Number of house fires in US*	Number of house units**
2000	379,500	116,295,167
2001	396,500	117,868,605
2002	401,000	119,381,715
2003	402,000	120,969,394
2004	410,500	122,676,668
2005	396,000	124,521,886

*Source: USFA statistics posted in http://www.usfa.dhs.gov/statistics/national/residential.shtm

**Data from US Census Bureau posted in http://www.census.gov/popest/housing/HU-EST2005.html

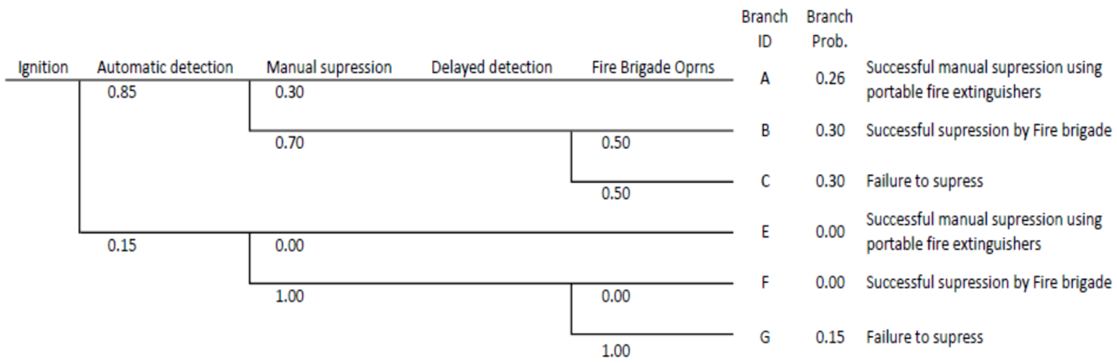
An example of fire statistics from the USA

<u>Use of Event Trees & Fault Trees in FRA</u>

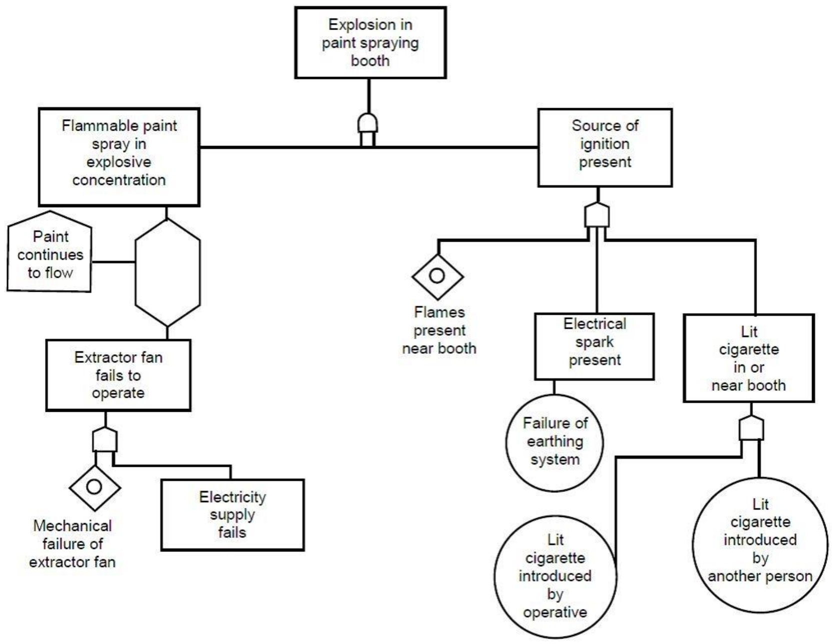
An event tree is a visual representation of all the events that can occur in a system. As the number of events increases, the picture fans out like the branches of a tree. All the events stem from the initiating event, which starts the sequence of events. Event trees can be used to analyze systems in which components involve sequential operations or transitions. In fire safety, event tree analysis is one way to build up a reasonable picture of the likelihood of fire scenarios using our knowledge of the mechanisms by which fire occurs, spreads, and is controlled. The goal of an event tree is to determine the probability of a scenario based on the outcomes of each event in the chronological sequence of events leading up to the scenario.

A fault tree analysis is a deductive top-down methodology used to analyze the design or performance of a system or component. Similar to the event tree, it begins with a top event to analyze, followed by identifying all of the associated events in the system leading to the top event. Fault trees provide a convenient graphic representation of the combination of events resulting in the occurrence of the top event. Fault tree analyses are generally performed graphically using a logical structure of AND and OR gates. It can also be viewed as a framework that guides you to a systematic transformation of available information into a concrete plan of action. This process provides the analyzer with a logical sequence that helps you discover the exact root causes of the event in question.

Both ETA & FTA are used in Quantitative FRAs to arrive at failure frequencies based on which further calculations can be carried out.



An example of ETA for a large educational facility



An example of FTA for a paint booth explosion

<u>Risk Presentation</u>

The most common risk assessment and presentation method is to multiply the frequency of fire incidents with the consequences and then sum these products for all scenarios considered in the risk assessment project. The aggregated results can be presented in terms of average exposure values; however, a better approach is to present the results as a range defined by upper and lower uncertainty bandwidths (confidence limits) that contain best estimates that can be made.

The objectives of risk presentation are threefold:

1. Provide presentation of estimated risk results in terms of a graphical risk profile or risk contour plot to aid management's understanding of the existing risk to the targets of interest as stated in the risk assessment objectives and acceptable risk limits.

2. Provide a graphical presentation of the differences in risk afforded by various risk reduction strategies to allow further cost–benefit assessment study, which may be a requirement of the specific risk assessment project.

3. Provide an uncertainty bandwidth (i.e., degree of confidence limits) associated with the above two items to allow stakeholders the opportunity to evaluate alternative risk management techniques (i.e., risk transfer by insurance). This is especially important for large consequence potentials which may be quantitatively classified as rare events that may also have a high degree of uncertainty in terms of the likelihood of occurrence.

Life Safety criteria

Acceptance criteria for life safety can fall into two categories – individual and societal.

Individual risk is the frequency at which an individual is expected to sustain a given level of harm from the realization of specified hazards This is usually related to a specific pattern of life. For fire safety, this might be the individual risk of someone who works in an industrial or office building or of a shopper who visits a retail market once a week.

Individual risk exposure is presented in many risk assessment studies in terms of a risk contour plot. Individual risk contours show the geographical distribution of individual risk. The risk contours show the expected frequency of fires or explosions capable of causing a specified level of harm to an individual at a specified location, regardless of whether or not anyone is present at that location to suffer that harm.

Societal risk is the relationship between frequency of occurrence and the number of people in a given population suffering from a specified level of harm from the realization of specified hazards. This may be expressed as the frequency with which ten or more people will die from fires in a facility/ location. This is normally significantly lower than he individual level of risk. Societal risk is often presented in the form of F-N curves, which are plots of the cumulative frequency (F) of multiple fatalities versus the number (N) of fatalities. F-N-type curves can provide useful insight into the degree of risks from fire incidents in a building to employees likely to be exposed to the event.

In addition, societal risks can be expressed in the form of various risk indices, which generally provide a summation of risks from each accident and an annual predicted fatality rate. Risk indices usually provide an easily understood, single-value number to present the acute risk and are sometimes quite useful in comparing various engineering design and protection options.

Financial criteria

From financial viewpoint, an organization or facility can decide whether it can tolerate certain levels of loss or interruption with certain return periods. These are usually expressed in terms of a financial loss per year It is possible to estimate the risk of damage that result from a fire. This can then be used to estimate potential monetary losses and enable cost-benefit analysis to be undertaken for establishing the relative value of installing additional or alternative fire protection measures.

8.9. Annexure 1: Fire Risk Assessment Checklist Template

Fire Risk Assessment (FRA) Checklist

Assessed by:		Date Document Downloaded:	
Job Title:		Date of Assessment:	
Department/Location:		Duty Holder Name:	

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
1. MANAGEMENT, PLANNING & PROCEDURES					
1.1	Do you have an up-to-date Fire Safety Policy?	☐ Yes ☐ No ☐ N/A			
1.2	Have you established and documented your procedures in the event of a fire or fire drill/practice?	☐ Yes ☐ No ☐ N/A			
1.3	Are fire safety risk assessments and resultant fire safety action plans reviewed regularly?	☐ Yes ☐ No ☐ N/A			
1.4	Are fire safety drills/practices carried out regularly?	☐ Yes ☐ No ☐ N/A			
1.5	Are fire safety drills/practices reviewed for successes and failures, and subsequent action taken?	☐ Yes ☐ No ☐ N/A			
1.6	Are any findings from risk assessment and fire drills/practices reported to your staff or their representatives?	☐ Yes ☐ No ☐ N/A			

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FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
1.7	If you share the workplace with others do you inform them of the risks you have identified?	☐ Yes ☐ No ☐ N/A			
1.8	If you do not have direct control of the premises have you made your findings known to the landlord, owner or agent?	☐ Yes ☐ No ☐ N/A			
1.9	Has an emergency plan been drawn up in case of a major fire?	☐ Yes ☐ No ☐ N/A			
1.10	Has an assembly point been identified and informed to staff?	☐ Yes ☐ No ☐ N/A			
1.11	Do you have sufficient Fire Marshals, and are they properly trained (and such training recorded)?	☐ Yes ☐ No ☐ N/A			
1.12	Has provision been made for contacting the emergency service both during and out of working hours?	☐ Yes ☐ No ☐ N/A			
1.13		☐ Yes ☐ No ☐ N/A			
1.14		☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.

2. STAFF AWARENESS AND TRAINING

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
2.1	Are all new employees informed of and provided with the company's Fire Safety Policy and Procedures? *(See Induction Feedback Form)*	☐ Yes ☐ No ☐ N/A			
2.2	Are any staff provided with fire fighting training and, if so, is this properly recorded?	☐ Yes ☐ No ☐ N/A			
2.3	Are all staff informed of and trained following risk assessment and related significant findings?	☐ Yes ☐ No ☐ N/A			
2.4	Are all staff aware of the fire prevention measures as detailed in sections 8 to 12 of this checklist?	☐ Yes ☐ No ☐ N/A			
2.5	Are all fire routes and exits in the premises known to staff?	☐ Yes ☐ No ☐ N/A			
2.6	Have all staff been informed of the location of the fire extinguishers [and other fire fighting equipment]?	☐ Yes ☐ No ☐ N/A			
2.7	Is the assembly point(s) in the event of fire known to all staff?	☐ Yes ☐ No ☐ N/A			
2.8		☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
2.9		☐ Yes ☐ No ☐ N/A			

3. VISITORS, CONTRACTORS & DISABLED

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
3.1	Have provisions been made to inform visitors/contractors of the location of the fire safety assembly point(s)?	☐ Yes ☐ No ☐ N/A			
3.2	Are visitors/contractors informed as to the procedures on discovering a fire or hearing the fire alarm?	☐ Yes ☐ No ☐ N/A			
3.3	Are controls in place in respect of contractors' use of potentially hazardous equipment? E.g. blowlamps, cutting and welding equipment.	☐ Yes ☐ No ☐ N/A			
3.4	Has provision been made for the safe evacuation of visiting disabled persons?	☐ Yes ☐ No ☐ N/A			
3.5	Do escape routes provide adequately for the needs of the disabled? See Section 4 below.	☐ Yes ☐ No ☐ N/A			
3.6	Have staff been instructed on know to assist visitors, the disabled [and members of the public] in evacuation of the workplace?	☐ Yes ☐ No ☐ N/A			
3.7	Are Contractors asked to complete Hot Work Permits?	☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
3.8		☐ Yes ☐ No ☐ N/A			
3.9		☐ Yes ☐ No ☐ N/A			

4. FIRE EXITS, ESCAPE ROUTES & EMERGENCY LIGHTING

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
4.1	Are there sufficient exits of suitable width for the people likely to be present?	☐ Yes ☐ No ☐ N/A	*If only one exit is available complete 4.5 below. If more than 1 exit complete 4.6 below.*		
4.2	Is this escape route fire resistant (protected)?	☐ Yes ☐ No ☐ N/A	<<If no, recommend you install an automatic fire-detection system>>		
4.3	Are escape routes clearly signed?	☐ Yes ☐ No ☐ N/A			
4.4	What is the level of risk in (this part of) the premises of a fire starting or spreading quickly?	☐ High ☐ Med ☐ Low			
4.5	What distance do people need to go to reach the exit? (single exit)	☐ 12m ☐ 18m ☐ 25m	<<12, 18 and 25m are required respectively for high, normal/medium and low risk areas>>		
4.6	What distance do people need to go to reach the exit? (more than one exit)	☐ 25m ☐ 45m ☐ 60m	<<25, 45 and 60m are required respectively for high, normal/medium and low risk areas>>		

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
4.7	Are all exits/routes clearly indicated by the "Green Running Man" on a white background, together with an arrow pointing in the direction of escape? ("Final Exit" signs do not require an accompanying arrow)	☐ Yes ☐ No ☐ N/A			
4.8	Are all fire exit routes and the points of exit (inc. stairways and corridors) from the building clear of obstructions?	☐ Yes ☐ No ☐ N/A			
4.9	Are all floor surfaces and stairs on escape routes free from tripping and slipping hazards?	☐ Yes ☐ No ☐ N/A			
4.10	Are all fire-resisting self-closing doors on escape routes correctly labeled, closing fully, in good state of repair and not wedged open?	☐ Yes ☐ No ☐ N/A			
4.11	Are escape routes adequately lit and is all lighting (normal and where provided emergency) on escape routes fully operational?	☐ Yes ☐ No ☐ N/A	<<Emergency lighting is required in underground and windowless parts of premises, in core stairways or those serving storeys more than 30 m above ground level, internal corridors more than 30m and in open plan office areas of more than 60m²>>		
4.12	Is the emergency lighting tested regularly and the tests recorded?	☐ Yes ☐ No ☐ N/A			
4.13	Do all exits lead to a place of safety?	☐ Yes ☐ No ☐ N/A			
4.14	Are steps and stairs in a good state of repair?	☐ Yes ☐ No ☐ N/A			

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FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
4.15	Does the workforce know not to use lifts in the event of a fire?	☐ Yes ☐ No ☐ N/A			
4.16	Are "Fire Action" notices clearly displayed throughout the premises?	☐ Yes ☐ No ☐ N/A			
4.18		☐ Yes ☐ No ☐ N/A			
4.19		☐ Yes ☐ No ☐ N/A			

5. FIRE DOORS, EXIT DOORS & COMPARTMENTATION

5.1	Are final exit routes always unlocked when the premises are in use?	☐ Yes ☐ No ☐ N/A			
5.2	Are devices securing final exits capable of being opened immediately and easily without a key?	☐ Yes ☐ No ☐ N/A	<<ideal fastening for fire exit door is bar across the width of the door that releases the lock/latch>>		
5.3	Are internal doors labeled as such and normally kept closed?	☐ Yes ☐ No ☐ N/A			
5.4	Are self-closers on fire doors operating correctly?	☐ Yes ☐ No ☐ N/A			

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FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
5.5	Do the doors on escape routes open in the direction of travel?	☐ Yes ☐ No ☐ N/A	<<must do so if more than 50 people may be required to escape from the relevant area, or leads from a high risk area>>		
5.6	Have other measures been taken to ensure that smoke and flames cannot spread from one part of the premises to another part?	☐ Yes ☐ No ☐ N/A	<<spaces between ducting and services through holes in fire walls should be filled with fire resistant stopping>>		
5.7		☐ Yes ☐ No ☐ N/A			
5.8		☐ Yes ☐ No ☐ N/A			

6. FIRE FIGHTING EQUIPMENT

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
6.1	Do you have sufficient fire-fighting appliances throughout your premises?	☐ Yes ☐ No ☐ N/A	<<e.g. a 9 litre water extinguisher will be required for every 200m² of floor area for Class A fires - combustible solids - paper, wood, cloth & plastics + 1 per floor		
6.2	Are your fire extinguishers and blankets positioned properly and located near to sites of higher fire risk?	☐ Yes ☐ No ☐ N/A	<<e.g mounted on walls and within 30m of a potential fire>>		
6.3	Are portable extinguishers of the correct type for the fire risk and properly colour coded?	☐ Yes ☐ No ☐ N/A	<<e.g. powder for electrical and liquid (not metals): foam for liquid (not electrical or metal): water for wood, paper & textiles (not liquid, electrical or metal)		
6.4	Are all fire-fighting appliances certified for quality? And is the last date of inspection displayed on the extinguisher?	☐ Yes ☐ No ☐ N/A			
6.5	Are all fire extinguishers, hose reels and sprinkler systems etc. regularly tested by competent persons [and the results recorded]?	☐ Yes ☐ No ☐ N/A	See maintenance and Testing of Fire Equipment Guidance Notes		

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
6.6	Have employees been instructed on when to use equipment?	☐ Yes ☐ No ☐ N/A			
6.7	Has every member of staff been trained in the correct use of fire fighting equipment?	☐ Yes ☐ No ☐ N/A			
6.8		☐ Yes ☐ No ☐ N/A			
6.9		☐ Yes ☐ No ☐ N/A			

7. FIRE ALARM SYSTEMS

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
7.1	Do the premises require an electrical or automatic fire alarm?	☐ Yes ☐ No ☐ N/A	<<depends on size and nature of workplace and number of employees: manual system for small open offices, electrical system where a shouted warning or bell cannot be heard by everyone: and automatic systems where a fire might start & grow undetected>>		
7.2	Can the alarm be heard throughout the premises?	☐ Yes ☐ No ☐ N/A			
7.3	Is the fire alarm system tested regularly and in good working order, and tests recorded?	☐ Yes ☐ No ☐ N/A	See Maintenance and Testing of Fire Equipment Guidance Notes		
7.4	Is the fire alarm maintained on a regular basis?	☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
7.5	Can the fire alarm be raised without placing anyone in danger?	☐ Yes ☐ No ☐ N/A			
7.7	Are the fire alarm points clearly visible and unobstructed?	☐ Yes ☐ No ☐ N/A			
7.8	Is the fire alarm connected to a monitoring station that contacts the fire brigade?	☐ Yes ☐ No ☐ N/A			
7.9	Have all members of staff been trained in how to operate the fire alarm system(s)?	☐ Yes ☐ No ☐ N/A			
7.10		☐ Yes ☐ No ☐ N/A			
7.11		☐ Yes ☐ No ☐ N/A			

8. FIRE PREVENTION: NEATNESS, TIDINESS & HEATERS

8.1	Have all employees been instructed to keep their workplace(s) tidy?	☐ Yes ☐ No ☐ N/A			
8.2	Is there a waste control system, and is it working effectively to keep the workplace clear of combustible waste and rubbish?	☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
8.3	Is waste put in a safe, secure place awaiting collection?	☐ Yes ☐ No ☐ N/A			
8.4	Is burning of rubbish on the site prohibited?	☐ Yes ☐ No ☐ N/A			
8.5	Are production areas kept clear of dust and rubbish?	☐ Yes ☐ No ☐ N/A			
8.6	Is there a system for controlling the amounts of combustible materials, flammable liquids and gases in the workplace?	☐ Yes ☐ No ☐ N/A	<<only such quatities as required for the day's production should be taken from storage>>		
8.7	Are all ducts, pipes, beams and trusses and kept clean?	☐ Yes ☐ No ☐ N/A			
8.8	Are all areas outside the premises kept clear of waste and combustible material?	☐ Yes ☐ No ☐ N/A			
8.9	Is the upholstery of furniture in good condition?	☐ Yes ☐ No ☐ N/A			
8.10	Are all heaters fitted with suitable guards and fixed in position away from combustible materials?	☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
8.11		☐ Yes ☐ No ☐ N/A			
8.12		☐ Yes ☐ No ☐ N/A			

9. FIRE PREVENTION: STORAGE & FLAMMABLES

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
9.1	Are flammable products used on the premises?	☐ Yes ☐ No ☐ N/A			
9.2	If so, are they kept away from potential sources of ignition?	☐ Yes ☐ No ☐ N/A			
9.3	Is sufficient storage available for combustible materials and flammable liquids and gases?	☐ Yes ☐ No ☐ N/A	<<small quantities should be kept in flameproof metal cabinents. Large quantities in a dedicated flameproof store>>		
9.4	Are the quantities of flammable products used in the workplace kept to a minimum and, when not needed, returned to safe storage?	☐ Yes ☐ No ☐ N/A			
9.5	Are the storage areas secure and with proper signs and restricted access? *No smoking should be on all stores.*	☐ Yes ☐ No ☐ N/A	<<e.g. Flammable Liquid>>		
9.6	Do fire-resistant walls and doors provide storage areas?	☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
9.7	Are adequate gangways provided between shelving and stacks of stored material?	☐ Yes ☐ No ☐ N/A			
9.8	Are sprinkler heads and fire detectors free from obstruction from stacks and shelves?	☐ Yes ☐ No ☐ N/A			
9.9	Are stacks and shelves clear of light fittings and hot service pipes?	☐ Yes ☐ No ☐ N/A			
9.10		☐ Yes ☐ No ☐ N/A			
9.11		☐ Yes ☐ No ☐ N/A			

10. FIRE PREVENTION: ELECTRICAL INSTALLATION & EQUIPMENT

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
10.1	Within last 5 years has the electrical installation been subject to an insulation test by a qualified electrician in accordance with IEE Regulations?	☐ Yes ☐ No ☐ N/A			
10.2	Are all items of electrical equipment working properly, inspected regularly and fitted with correctly rated fuses?	☐ Yes ☐ No ☐ N/A			
10.3	Is the use of electrical extension leads and multipoint adaptors kept to a minimum?	☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
10.4	Are cables and leads run in safe places to prevent tripping hazards and damage to the cables and leads?	☐ Yes ☐ No ☐ N/A			
10.5	Are isolators and mains electricity switches clearly signed?	☐ Yes ☐ No ☐ N/A			
10.6		☐ Yes ☐ No ☐ N/A			
10.7		☐ Yes ☐ No ☐ N/A			

11. FIRE PREVENTION: SMOKING

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
11.1	Have all enclosed and partially enclosed smoking facilities been removed?	☐ Yes ☐ No ☐ N/A			
11.2	Are all company vehicles (those used by more than one person) now smoke free?	☐ Yes ☐ No ☐ N/A			
11.3	Are no-smoking signs displayed in a prominent position at every public entrance with a minimum size of A5 (210mm by 148mm) in area with the international no-smoking symbol and the words "No Smoking: It is against the law to smoke in these premises"?	☐ Yes ☐ No ☐ N/A			
11.4	In workplaces only used by members of staff, or workplaces that are part of larger smoke free premises, are no-smoking signs of at least 70mm in diameter displayed consisting of the international no-smoking symbol?	☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
11.5	Do company vehicles (used by more than one person and not used primarily for private use) display the international symbol as described in 11.4?	☐ Yes ☐ No ☐ N/A			
11.6	Does the company maintain an up-to-date No-Smoking Policy?	☐ Yes ☐ No ☐ N/A			
11.7		☐ Yes ☐ No ☐ N/A			
11.8		☐ Yes ☐ No ☐ N/A			

12. FIRE PREVENTION: ARSON

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
12.1	Have suitable measures been taken to secure building against intruders?	☐ Yes ☐ No ☐ N/A			
12.2	Are all doors and windows locked when the premises are unlocked?	☐ Yes ☐ No ☐ N/A			
12.3	Are all visitors to the building signed in, provided with badges and accompanied by their host or staff at all times?	☐ Yes ☐ No ☐ N/A			
12.4	Are all members of staff trained to challenge or report suspicious persons and behaviour?	☐ Yes ☐ No ☐ N/A			

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
12.5		☐ Yes ☐ No ☐ N/A			
12.6		☐ Yes ☐ No ☐ N/A			

13. BUSINESS CONTINUITY

FRA Ref No.	Description	Yes/No	Comments	Action Required	FHRA No.
13.1	Are duplicate copies of contingency plans, records, back-up discs and documents kept safely in another building or on a different server?	☐ Yes ☐ No ☐ N/A			
13.3	Are the insurance policies up-to-date and adequate to cover all requirements?	☐ Yes ☐ No ☐ N/A			
13.4		☐ Yes ☐ No ☐ N/A			

Assessor Name: Signature: Date:		Duty Holder Name: Signature: Date:	

Chapter 9:

Annexures

9. Annexures

Refer the Gujarat State Fire Act, Rules and Regulations and recent amendments for various forms and checklists.

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 exhauster 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 delintering) 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
14	OISD-STD-159	LPG Tank Trucks - Requirements of Safety on Design/Fabrication & Fittings	Oct, 2018

Sr. No.	OISD Standard /GDN /RP No	Standard Name	Current Edition In Vogue
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
NFPA 1	Fire Code
NFPA 2	Hydrogen Technologies Code
NFPA 3	Standard for Commissioning of Fire Protection and Life Safety Systems
NFPA 4	Standard for Integrated Fire Protection and Life Safety System Testing
NFPA 10	Standard for Portable Fire Extinguishers
NFPA 11	Standard for Low-, Medium-, and High-Expansion Foam
NFPA 11A	Standard for Medium- and High-Expansion Foam Systems
NFPA 11C	Standard for Mobile Foam Apparatus
NFPA 12	Standard on Carbon Dioxide Extinguishing Systems
NFPA 12A	Standard on Halon 1301 Fire Extinguishing Systems
NFPA 13	Standard for the Installation of Sprinkler Systems
NFPA 13D	Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes
NFPA 13E	Recommended Practice for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems
NFPA 13R	Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies
NFPA 14	Standard for the Installation of Standpipe and Hose Systems
NFPA 15	Standard for Water Spray Fixed Systems for Fire Protection
NFPA 16	Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems
NFPA 17	Standard for Dry Chemical Extinguishing Systems
NFPA 17A	Standard for Wet Chemical Extinguishing Systems
NFPA 18	Standard on Wetting Agents
NFPA 18A	Standard on Water Additives for Fire Control and Vapor Mitigation
NFPA 20	Standard for the Installation of Stationary Pumps for Fire Protection
NFPA 22	Standard for Water Tanks for Private Fire Protection
NFPA 24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances
NFPA 25	Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems

NFPA Code	Description
NFPA 30	Flammable and Combustible Liquids Code
NFPA 30A	Code for Motor Fuel Dispensing Facilities and Repair Garages
NFPA 30B	Code for the Manufacture and Storage of Aerosol Products
NFPA 31	Standard for the Installation of Oil-Burning Equipment
NFPA 32	Standard for Dry-cleaning Facilities
NFPA 33	Standard for Spray Application Using Flammable or Combustible Materials
NFPA 34	Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids
NFPA 35	Standard for the Manufacture of Organic Coatings
NFPA 36	Standard for Solvent Extraction Plants
NFPA 37	Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
NFPA 40	Standard for the Storage and Handling of Cellulose Nitrate Film
NFPA 42	Code for the Storage of Pyroxylin Plastic
NFPA 45	Standard on Fire Protection for Laboratories Using Chemicals
NFPA 46	Recommended Safe Practice for Storage of Forest Products
NFPA 50	Standard for Bulk Oxygen Systems at Consumer Sites
NFPA 50A	Standard for Gaseous Hydrogen Systems at Consumer Sites
NFPA 50B	Standard for Liquefied Hydrogen Systems at Consumer Sites
NFPA 51	Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes
NFPA 51A	Standard for Acetylene Cylinder Charging Plants
NFPA 51B	Standard for Fire Prevention During Welding, Cutting, and Other Hot Work
NFPA 52	Vehicular Natural Gas Fuel Systems Code
NFPA 53	Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres
NFPA 54	National Fuel Gas Code
NFPA 55	Compressed Gases and Cryogenic Fluids Code
NFPA 56	Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems

NFPA Code	Description
NFPA 57	Liquefied Natural Gas (LNG) Vehicular Fuel Systems Code
NFPA 58	Liquefied Petroleum Gas Code
NFPA 59	Utility LP-Gas Plant Code
NFPA 59A	Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)
NFPA 61	Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
NFPA 67	Guide on Explosion Protection for Gaseous Mixtures in Pipe Systems
NFPA 68	Standard on Explosion Protection by Deflagration Venting
NFPA 69	Standard on Explosion Prevention Systems
NFPA 70®	National Electrical Code®
NFPA 70A	National Electrical Code® Requirements for One- and Two-Family Dwellings
NFPA 70B	Recommended Practice for Electrical Equipment Maintenance
NFPA 70E®	Standard for Electrical Safety in the Workplace®
NFPA 72®	National Fire Alarm and Signaling Code®
NFPA 73	Standard for Electrical Inspections for Existing Dwellings
NFPA 75	Standard for the Fire Protection of Information Technology Equipment
NFPA 76	Standard for the Fire Protection of Telecommunications Facilities
NFPA 77	Recommended Practice on Static Electricity
NFPA 78	Guide on Electrical Inspections
NFPA 79	Electrical Standard for Industrial Machinery
NFPA 80	Standard for Fire Doors and Other Opening Protective
NFPA 80A	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!